Annex K

Report of the Standing Working Group on Environmental Concerns

Members: Rowles (co-Chair), Parsons (co-Chair), Baulch, Bell, Bickham, Bjørge, Brockington, Brownell, Burkhardt, Charrassin, Cipriano, Collins, Cosentino, Cozzi, Currey, Diallo, Donovan, Double, Fortuna, Fossi, Frey, Fujise, Gallego, Galletti-Vernazzani, Genov, George, Gerber, Greig, Gulland, Hall, Haug, Herr, Hielscher, Holm, Hrabkovsky, Iñíguez, Jimenez, Kelkar, Kitakado, Lacy, Lauriano, Leaper, Lee, Lundquist, Mallette, Marsili, Mattila, Mazzariol, Moore, New, Øien, Palka, Paniego, Panigada, Parsons, Podesta, Porter, R. Reeves, S. Reeves, Rendell, Reyes, Ridoux, Ritter, Rodriguez-Fonseca, Rojas-Bracho, Rose, Rosenbaum, Rowles, Ryeng, Santos, Scheidat, Simmonds, Širović, Slooten, C. Smith, S. Smith, Stachowitsch, Stimmelmayr, Suydam, Tamura, Thomas, Ulloa, Urbán, Víkingsson, Vlckova, Williams, Wimmer, Woo Kim, Yasokawa, Yasunaga, Ylitalo, Zerbini.

1. CONVENORS' OPENING REMARKS

Rowles and Parsons welcomed the participants to the Standing Working Group on Environmental Concerns (SWG).

2. ELECTION OF CHAIRS

Rowles and Parsons were elected as co-Chairs.

3. APPOINTMENT OF RAPPORTEURS

Greig and Ylitalo were appointed as rapporteurs, with Rose assisting with the final report.

4. ADOPTION OF AGENDA

The adopted agenda is given as Appendix 1.

5. REVIEW OF AVAILABLE DOCUMENTS

The documents available to the SWG were identified as SC/66b/E01, SC/66b/E02rev1, SC/66b/E03-E13; SC/66b/Rep09; SC/66b/Rep10; SC/66b/BRG02; SC/66b/BRG03rev1; SC/66b/BRG06; SC/66b/BRG10; SC/66b/BRG14; SC/66b/BRG25; SC/66b/SM04; Centelleghe *et al.* (2016); Di Guardo and Mazzariol (2016); Fossi *et al.* (2016a; 2016b); Leaper *et al.* (2015); Lefebvre *et al.* (2016); Maglio *et al.* (2016); Maron *et al.* (2015); Mazzariol *et al.* (2016); McAloose *et al.* (2016); Murphy *et al.* (2015); Jepson *et al.* (2016); Smith *et al.* (2016) and Wilson *et al.* (2016).

6. STATE OF THE CETACEAN ENVIRONMENT REPORT - SOCER

Several resolutions of the International Whaling Commission, including Resolutions 1997-7 (IWC, 1998) and 1998-5 (IWC, 1999), directed the Scientific Committee to provide regular updates on environmental matters that affect cetaceans. Resolution 2000-7 (IWC, 2001) welcomed the concept of the State of the Cetacean Environment Report (SOCER) and requested the annual submission of this report to the Commission. The first full SOCER (Stachowitsch *et al.*, 2003) was submitted in 2003 and subsequent editions initiated and continued a cycle of focusing on the following regions: Mediterranean and Black Seas, Atlantic Ocean, Pacific Ocean, Arctic and Antarctic Oceans, Indian Ocean. Each SOCER also includes a Global section addressing the newest information that applies generally to the cetacean environment. The 2016 SOCER focuses on the polar oceans (Arctic and Antarctic), summarising key papers and articles published from *ca* 2014 through 2016 to date (SC/66b/E02rev1; see Appendix 3).

The ongoing and predicted developments in polar seas are so severe that the UN First Global Integrative Marine Assessment considers the Antarctic to be subject to one of the largest ecosystem changes on the planet. This includes ice retreat, decline and replacement of key cetacean prey (krill/salps), and temperature-induced invasions of benthic predators (king crabs) that would dramatically alter ecosystem functioning. In the Arctic, warming is proceeding at twice the global rate and sea ice loss is accelerating and may be irreversible. This will expose cetaceans to increased exploration by the oil and gas industry and to more vessel traffic, i.e. increased noise and greater risk of ship strikes. Moreover, the technology to deal with industry wastewater is limited in harsh environments like polar seas, and polar seas are also more vulnerable to such pollution. The ecosystem changes will be evident on all levels, beginning with higher biological production and altered algal blooms, including toxic algal blooms: the respective toxins, domoic acid and saxitoxin, were detected in all 13 species of marine mammals investigated, with highest prevalence in baleen whales. For the Arctic, the UN report predicts invasions of new species, hosts, harmful microorganisms and diseases. The ongoing shifts in prey species and therefore in their cetacean predators are already evident in several Arctic areas. This is combined with more subtle changes, such as in the body condition of cetaceans and other marine mammals as well as in their fish prey. This has triggered a broad call for more holistic approaches and improved multi-species models to better understand and predict changes in polar habitats. One such effort predicts a 'new normal' Pacific Arctic marine ecosystem. Importantly, cetaceans are increasingly being recognised as determinants rather than mere victims of environmental changes. They play a key role in ecosystem function and ecosystem services by acting as buffering and stabilising elements, furthermore as sentinel species, as food and cultural keystones, and as icons.

As mentioned above, accelerating warming and ice loss in polar regions will have global ramifications for marine ecosystems and cetaceans. Other global level issues arising over the past year include an international review of fisheries that determined that only a third are 'healthy'. It has also been suggested that some collapses in fish stocks were the result of a failure to adapt management advice in the face of climate change. There has been increasing attention on the important role cetaceans play as ecosystem engineers, aiding nutrient recycling and carbon storage, and buffering the marine environment from certain stressors, such as climate change.

Some interesting modelling studies have been able to translate disturbance into population level effects, e.g. it was predicted that just a 4% energetic loss, or 10 days of disturbed foraging, could cause a pregnant gray whale to lose her calf. In terms of entanglement in fishing gears, studies have investigated how changing breaking strengths of ropes could decrease entanglement and how factors such as rope length and float attachment can increase the impacts on entangled whales.

The use of plastics has increased twenty fold over the past fifty years and is predicted to double again in the next 20 years, and much of this enters the oceans. It is estimated that by 2025 there will be one tonne of plastic to every three tonnes of fish in the marine environment and that by 2050 the mass of plastics will exceed the mass of fish. In particular, concerns about marine microplastics, and their impacts, have been rapidly been increasing, including studies investigating the issue of unique microbial communities associated with the surface of plastics (called the plastisphere). Marine plastics have now been described in almost all marine organisms from planktonic species to large whales.

Ship strikes continue to be a cause for concern with studies showing that, e.g. blue whales may be particularly prone to ship strikes as their diving behaviour in shipping lanes may increase their risk of collisions; prototype alarms to warn whales of boat presence have found to be ineffective; and warming oceans may increase the risk of ship strikes as layers of warm surface water may reduce the ability of whales to detect fast approaching vessels. But there is some optimism with regards to the issue of ship strikes, in that mariners are open to receiving alerts about whale presences, decreasing shipping speeds and their activities being monitored by researchers.

New research on environmental contaminants have provided more evidence of immune system suppression caused by polychlorinated biphenyls (PCBs) and heavy metals, with one study showing, e.g. that heavy metals may increase the prevalence of fungal infections in the skin of cetaceans. Contamination from other pollutants, such as flame retardants, continue to be a cause for concern, and even radioactive contamination has been highlighted, with radioactive contamination being found in stranded small cetaceans and whales on the Hokkaido coast of Japan, and the meat of whales caught in the JARPN programme.

Finally, with respect to the impacts of noise, there have been several major reviews of the issue, and several studies that have increased our knowledge in areas that were previously data gaps, e.g. findings that show harbour porpoises may be more sensitive to certain sounds than predicted, including seal scarers and 'pingers' used as a bycatch mitigation device. Low Frequency Active Sonar, a type of military sonar that has been little studied (in comparison to mid-frequency active sonar), was found to cause a decrease in sperm whale foraging, providing evidence that this is an additional concern. Several studies have been conducted on seismic survey impacts, and whilst some studies showed minimal effects of seismic surveys in the Arctic on some populations of whales, it has also been highlighted that many mitigation guidelines to reduce the impacts of seismic surveys on cetaceans, have been found to be wanting and there are concerns that some guidelines are not adequately protecting adjacent cetaceans.

In discussion, it was noted that there is an increase in papers that report using cetaceans as indicators of the environment and as functioning components of the total ecosystem. The SWG congratulated the SOCER editors for compiling this year's report. Next year the focus of the SOCER will be on the Indian Ocean.

7. CHEMICAL POLLUTION

7.1 Pollution 2020

The Pollution 2020 working group has continued to refine the individual-based population model developed under the Pollution 2020 initiative (Hall *et al.*, 2015). For example, the SWG received information on the results of a study of PCB gestational transfer in stranded harbour porpoise that reported that a high proportion (93%, 95% CI 87%-99%) of the concentration in the female's blubber was found in the foetus by late term. On a congener specific basis, the percentage varied by the level of chlorination with higher chlorinated compounds being transferred to a slightly less degree than lower chlorinated compounds. These results will allow the uncertainty in the *in utero* transfer parameter to be captured in the model in future.

The SWG thanked Hall for her continued work on the development of individual-based population models and encouraged continued development of tools to help understand the potential effects of single or multiple pollutants and cumulative impacts on individual cetaceans and populations. In addition, the SWG recommended that additional contaminants, possibly polybrominated diphenyl ethers (PBDEs), be added to the model for evaluation of single and multiple effects and cumulative effects.

7.2 Data integration and mapping of POPs and trends

Progress was presented on the contaminant mapping work that has been advancing under the Pollution 2020 initiative. An online contaminant visualisation and mapping portal is being developed to allow users to explore a database of trends in contaminants (e.g. blubber concentrations of PCBs, dichlorodiphenyltrichloroethane [DDTs] and PBDEs) in different cetacean species across the world. An example of the webpage is shown in Fig. 1.

The SWG thanked Hall for her continued efforts on contaminant mapping for cetaceans. The SWG **agreed** that this contaminant mapping tool was a useful way to visualise and explore temporal and spatial trends but emphasised the need to determine a mechanism for collating relevant data, keeping it up to date and ensuring that the data are standardised and quality-assured. The SOCER editorial team agreed to send any relevant papers to the convenor of the Pollution 2020 working group each year. In addition, the SWG noted the importance of inclusion of critically endangered species, such as Southeast Asian river and estuarine dolphins, or populations with low reproductive rates, in the mapping tool when information is available. In discussion, the SWG also noted that the ability to overlap ranges of the cetacean for each study would be beneficial. The SWG **recommended** this contaminant mapping work continue and that Hall work with the Secretariat for further modifications of the mapping tool.

7.3 Other chemical pollution

Additional information on chemical pollutants, including PCBs, heavy metals and plastics, was presented to the SWG.

SC/66b/E08 was a revised version of Yasunaga and Fujise (2016c) presented to the JARPN II final review meeting in February 2016, which responded to some recommendations for further analyses from the Review Panel. Multiple robust linear regression analyses were carried out, including adjustment for confounders, years, longitude, latitude, date, body length, blubber thickness and main prey item. Total mercury concentrations in common minke whales (*Balaenoptera acutorostrata*) from sub-areas 7 and 9 during 1994-2014 were significantly conditioned with sampling year and main prey item. Main prey items

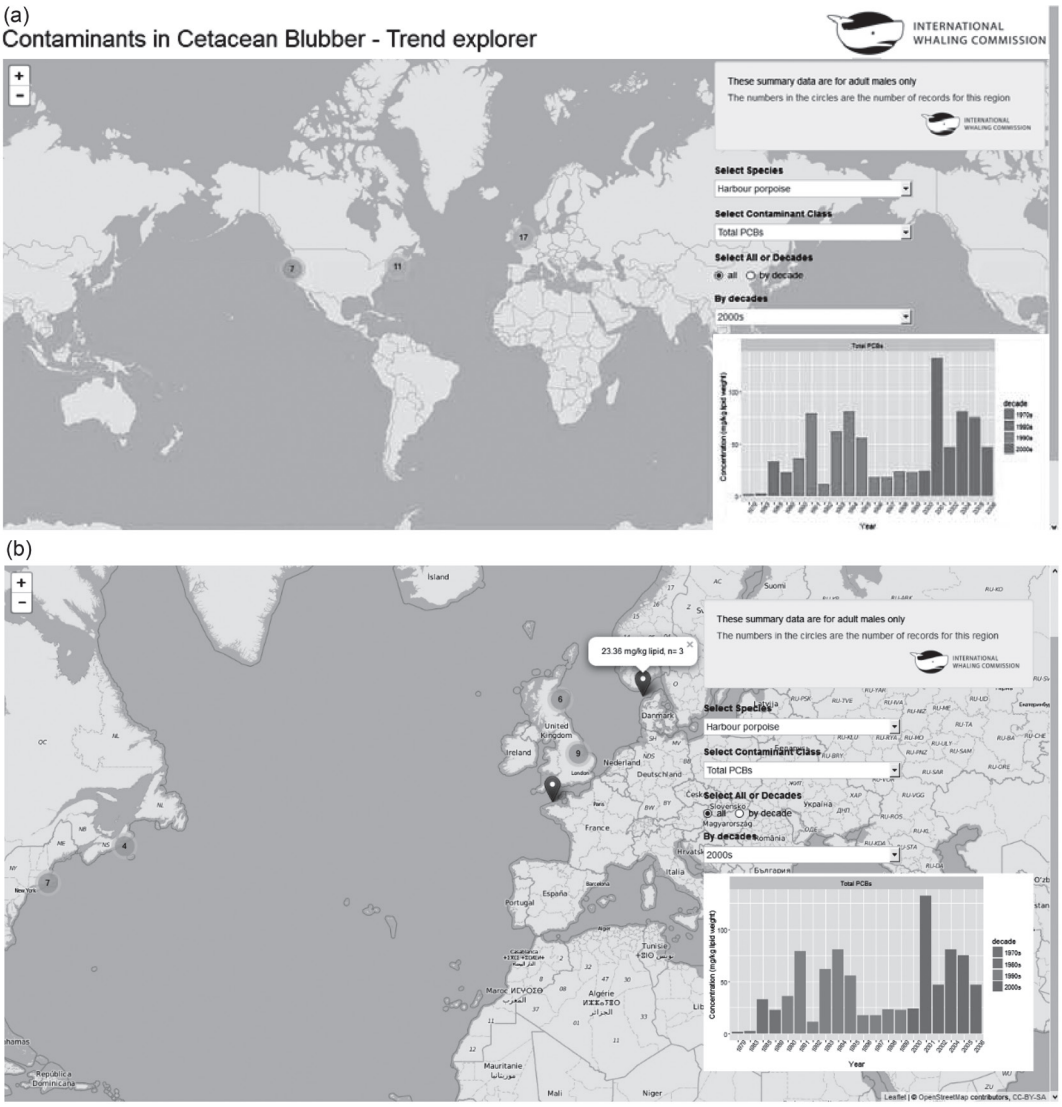

Fig. 1. (a) The circles show the locations representing where the data for the selected species were collected (on the website, <10 records=green, 11-99 records=orange, >100 records=red). The plot shows the overall trend in the selected blubber contaminant concentrations, colour coded by decade. The data shown are for illustrative purposes only and do not necessarily represent actual data. (b) Zoomed in, the circles disaggregate and when only one set of data for a given location is available, a marker is shown. On click, the geometric mean concentration is shown for that location with the number of individuals represented. Future versions will include the ability to select the data to display by region as well as species, decade and contaminant class.

had an effect on total mercury concentrations in the common minke whales from those sub-areas. These findings suggest that yearly changes of total mercury in common minke whales from the western North Pacific could be affected by changes of their prey items. Results of Generalised Additive Models (GAM) indicated no effect of flexion point in the yearly changes of total mercury. Furthermore, total mercury levels of common minke whales, sei whales (*Balaenoptera borealis*) and Bryde's whales (*Balaenoptera edeni*) from the western North Pacific were much lower than total mercury toxicological threshold of terrestrial wildlife mammals and striped dolphins.

SC/66b/E07 was a revised version of Yasunaga and Fujise (2016b) presented to the JARPN II final review meeting in February 2016, which responded to some recommendations for further analyses from the Review Panel. Multiple robust linear regression analyses adjusted for confounders, year, longitude, latitude, date, body length, blubber thickness and main prey item found no significant yearly changes of PCBs in common minke whales from the western North Pacific during 2002-14. These results were consistent with those in the original document. Results of GAM indicated no effect of flexion point in the yearly changes of PCB concentrations. Furthermore, PCB levels of common minke whales in each sub area were much lower than PCB toxicological threshold of marine mammals, e.g. 17 ppm lipid weight reported by Kannan *et al.* (2000).

During discussion, the authors noted that mercury concentrations in muscle tissue were measured in minke whales from various areas in the western North Pacific, as this tissue has higher turnover rate than liver, and because the aim was to investigate interannual differences. It was noted by some members that there was very low variability in the levels of mercury reported, and it was also noted that concentrations of mercury in the North Atlantic whales were more variable than those reported in the North Pacific minke whales in SC/66b/E08. The authors noted that only adult males were measured to mitigate any confounding effects associated with age and sex. It was further noted by the authors that the mercury levels of the western North Pacific minke whales were similar, regardless of sampling area. When asked about levels of other organochlorine contaminants, the authors noted that concentrations of additional persistent organic pollutants were also measured in the western North Pacific minke whales, and the levels found are reported in Yasunaga and Fujise (2016a).

SC/66b/BRG06 reported the results of methods development for mercury and steroid hormone analyses for future application to western gray whale (*Eschrichtius robustus)* skin and blubber biopsies. Tissue samples from stranded eastern gray whales were used as surrogates for western gray whale biopsies. Epidermis was sectioned and four layers including the stratum corneum and three layers within the stratum spinosum were analysed for total mercury. It was found that the methods used could be applied to the small amounts of skin available from the biopsies of western gray whales. It was found that levels of total mercury were low and at levels expected from previous studies of cetacean skin. However, significant differences were found among the different epidermal layers for both water and total mercury. The stratum corneum had significantly lower concentration of water and had the highest total mercury by wet weight. By dry weight, the stratum corneum, and the deepest layer of the stratum spinosum, had significantly lower mercury levels than the outermost layer of the stratum spinosum. Concentrations of total mercury (dry weight) ranged from 30 to 99 ppb. Thus, studies that report skin mercury from gray whales should specify at what levels of the epidermis the samples were analysed.

Information on concentrations of heavy metals in gray whales and walruses (*Odobenus rosmarus*) from the western Bering Sea was presented in SC/66b/BRG10. In coastal waters of the Chukchi Peninsula (the Mechigmenskiy Bay, Western Bering Sea, Russia) tissues and organs of gray whales and Pacific walruses were necropsied and collected by TINRO-Center and ChukotTINRO scientists after their aboriginal harvest and landing by Chukotka Natives. Necropsy samples included muscle, kidney, liver, blubber (100g samples) and blood (100ml samples). The biologically active components of iron, zinc and copper had the highest concentrations, but cadmium and mercury had the lowest levels in the tested animal organs. The levels of iron, zinc, copper, arsenic and mercury were significantly higher in the liver of animals. Chukotka Natives consume intestines and meat of whales and walruses. The Russian State Sanitary, Epidemiological and Hygienic Requirements are regulating the level of toxic elements of arsenic, cadmium and mercury in the marine mammal meat. The maximum permissible levels are 5ppm for arsenic, 0.2ppm for cadmium and 0.5ppm for mercury (wet weight). The concentrations of toxic elements in the studied muscle samples of gray whales and walrus did not exceed the maximum permitted levels of these metals.

In further discussion, it was noted that, in gray whales from the western Bering Sea, levels of toxic elements (e.g. mercury, arsenic, cadmium) are higher in liver than other tissues but it is not known what the Russian advisory levels for these elements are for this tissue. However, contaminated liver may not pose a risk to aboriginal hunters as other organs, such as heart and kidney, are more routinely consumed. It was also noted that gray whales feed primarily on benthic invertebrates and thus may be exposed to higher levels of contaminants associated with sediments such as metals and organochlorines than would be expected, based on their trophic position. Information on concentrations of toxic elements, including mercury, measured in organs of subsistence harvested and stranded eastern gray whales have been published previously (Tilbury *et al.*, 2002; Varanasi *et al.*, 1994) and could be compared to those determined in tissues of more recently collected samples of western gray whales. The SWG also noted that the analyses of the western gray whale biopsy samples could be expanded to include other contaminants such as organochlorines and metals associated with petroleum (e.g. vanadium, nickel) and that these analyses would be useful health measures and for identifying differences between foraging areas.

Murphy *et al.* (2015) reported the results of a study investigating reproductive failure and PCB concentrations in harbour porpoises from the North Sea. Resting mature females had significantly higher mean level of total PCBs than both lactating and pregnant females. Furthermore, a lower pregnancy rate of 50% was estimated for 'healthy' females that died of traumatic causes of death, compared to other populations. Whether or not PCBs are part of an underlying mechanism, individual PCB burdens were given as further evidence of reproductive failure in the northeast Atlantic harbour porpoise population. A recent paper by Jepson *et al.* (2016) also reported that three species of cetaceans (striped dolphins, *Stenella coeruleoalba*, common bottlenose dolphins, *Tursiops truncatus* and killer whales, *Orcinus orca*) from Europe had mean PCB levels that exceeded all known marine mammal PCB toxicity thresholds, including those associated with reproductive dysfunction.

Genov presented data on organochlorines in common bottlenose dolphins from Slovenia, northern Adriatic Sea. Between 2011 and 2014, biopsy samples were obtained from 22 free-ranging adults, both males (n=15) and females (n=7). Biopsied animals were photo-identified and are part of a well-known population of about 150 individuals monitored since 2002 (Genov *et al.*, 2008). Skin and blubber tissue samples were collected using a crossbow and bolt dart with 25mm sampling tips. A total of 25 PCB congeners plus hexachlorobenzene and *p,p'*-DDE were determined in the samples. Lipid content of the biopsy blubber samples varied from 3.4 to 33.8%. The sum of the 25 PCB congeners ($\sum_{25}$PCB) ranged from 3.34 to 293mg/kg lipid weight, with a mean of 66.3 and a geometric mean of 43.8. Males (geometric mean=69.2mg/kg lipid weight) had higher organochlorine concentrations than females (geometric mean=16.1mg/kg lipid weight), suggesting offloading of organochlorines from reproducing females to their offspring. Overall, the vast majority of animals contained concentrations believed to be high enough to cause physiological effects in marine mammals (Jepson *et al.*, 2016; Kannan *et al.*, 2000). The potential population-level effects of organochlorine burdens are of concern, particularly in combination with other known or suspected threats to this population.

In discussion it was noted that stranding efforts on the common bottlenose dolphins from the northern Adriatic Sea are coordinated between Slovenia and Italy, with a peer-reviewed paper reporting a dolphin observed off Slovenia, and subsequently stranding in Italy (Genov *et al.*, 2016). The SWG noted the importance of transboundary collaboration in understanding the health of these populations in the Adriatic Sea. There is some indication of low survival of first-born calves in this population but this is based on limited observational data. Data have been collected on stranded dolphins from this population and full necropsies carried out, but limited inferences are possible due to decomposition of most carcasses. The SWG expressed concern with regard to the high concentrations of persistent organic pollutants measured in this dolphin population and recommended long-term monitoring of this dolphin population through continued regional collaborations follow reproductive history and survivorship of known individuals, and identify the causes or lesions in any mortalities. The SWG noted that concern about continued high PCB levels in cetacean populations was discussed at SC/66a.

Fossi *et al.* (2016b) presented the results of the 'Plastic Pelagos Pilot Project', supported by the Italian Ministry of Environment, which focuses on investigating overlap between microplastics and fin whale (*Balaenoptera physalus)* feeding grounds in convergence areas (gyres) of the Specially Protected Area of Mediterranean Importance (SPAMI) Pelagos Sanctuary in the northwestern Mediterranean Sea. During a sampling cruise in September 2014, surface microplastic samples and fin whale biopsies were collected, as well as information on macrodebris counts and cetacean sightings in the Sanctuary. Two operational models of ocean circulation and fin whale potential habitat were used to identify possible convergence areas of marine litter and probable presence of foraging fin whales, respectively. A multi-layer approach was used to investigate the possible overlap between microplastics convergence areas and fin whale feeding ground. The three layers of field data, microplastics (items-micro/m^2) and macroplastics (items-macro/km^2) abundance and cetacean presence, were compared with the maps of ocean circulation and fin whale potential feeding habitat. High occurrence of microplastics in the investigated surface neustonic/planktonic samples was found, showing a significant overlap with the areas with high macroplastic density. In conclusion, the ocean circulation model and experimental data set suggest that there is an overlap between areas with high levels of microplastic pollution and the potential feeding grounds of fin whales in the Mediterranean Sea, indicating that fin whales are likely to be exposed to microplastic, during feeding in the areas of Pelagos Sanctuary. Further ecotoxicological analyses for phthalates and biomarker responses of the fin whale skin biopsies are currently being conducted to support this hypothesis. Finally, future studies on the impact of microplastics on biota of the Mediterranean Sea (one of the most affected areas in the world), in conjunction with mitigation efforts, are mandatory under the auspices of the European Marine Strategy Framework Directive and the Marine Litter Action Plan of the Barcelona Convention.

Fossi *et al.* (2016a) reported on the interaction between fin whales and microplastics, focusing on the Mediterranean Sea and the Sea of Cortez regions. The impact that microplastics have on baleen whales is a question that remains largely unexplored. This study examined for the first time the interaction between free-ranging fin whales and microplastics by comparing populations living in two semi-enclosed basins, the Mediterranean Sea and the Sea of Cortez (Gulf of California, Mexico). The results indicate that a considerable abundance of microplastics and plastic additives exists in the neustonic samples from Pelagos Sanctuary of the Mediterranean Sea, and that pelagic areas containing high densities of microplastics overlap with whale feeding grounds, suggesting that whales are exposed to microplastics during foraging; this was confirmed by the observation of a temporal increase in toxicological stress in whales. Given the abundance of microplastics in the Mediterranean environment, along with the high concentrations of persistent bioaccumulative and toxic chemicals, plastic additives and biomarker responses detected in the biopsies of Mediterranean whales were compared to those in whales inhabiting the Sea of Cortez. It appears that direct ingestion and consumption of microplastic-contaminated prey of fin whales from the Mediterranean Sea may pose an additional major threat to these cetaceans.

During discussion, it was noted that analyses of bisphenol A, and other metabolites associated with plastics, are being conducted on the fin whale biopsy samples. It was also noted that studies of plastics could be extended to other species of cetaceans such as right whales and gray whales. It was further noted that standardised reporting of and quality assurance of contaminant data are needed in order to compare data among various studies.

The SWG commended all of the presenters for providing updated information on pollutants in cetaceans and **emphasised** the need for standardised and quality-assured contaminant data in order to compare data among various studies that examine temporal and geographical trends of pollutants.

8. OIL SPILL IMPACTS

8.1 Review progress of the intersessional working group

Ylitalo presented potential options for an oil spill workshop as proposed at SC/66a. Options for one- or two-day workshops were provided. Concern was expressed about the lack of knowledge or consideration of cetaceans when the oil spill response communities are developing response plans and making response decisions. Discussion focused on the best ways to enhance communication between the oil spill community (response organisations and industry/managers/responders) and the marine mammal community (scientists and managers). The SWG suggested that more thought be given to the most effective mechanism (e.g. workshops, information packets, guidelines) and most appropriate audience to inform the oil spill response communities, such that they consider cetaceans in oil spill prevention, preparedness, response and assessments. The SWG suggested that the intersessional working group discuss this further and provide additional guidance to the SWG next year.

8.2 Oil spill impact updates

In SC/66b/E04, the IWC Pollution 2020 individual-based model, SPoC (Hall *et al.*, 2015) was modified to incorporate additional effects of petroleum-associated chemical exposure following an oil spill on a simulated population of bottlenose dolphins. The magnitude and duration of reductions in vital rates were estimated following the *Deepwater Horizon* oil spill in the Gulf of Mexico (Deepwater Horizon Natural Resource Damage Assessment Trustees, 2016). These estimates were then used to investigate the effect of both PCBs and an oil spill on potential population growth rates (λ). The advantage of this approach is that it allows for cumulative effects of pollutants to be considered.

Rowles presented a summary of the findings in the Programmatic Damage Assessment and Restoration Plan[1] for the *Deepwater Horizon* oil spill in which millions of gallons of oil spilled into the Gulf of Mexico over several months in 2010. The Natural Resource Damage Assessment (NRDA) was designed to investigate the potential impacts of the *Deepwater Horizon* oil spill on free-ranging cetaceans in deep water, on the continental shelf, and in coastal bottlenose dolphins, including observation studies (aerial and vessel surveys), tagging, biopsy studies, stranded animal studies, and comprehensive health assessments in bottlenose dolphins. Specifically, comprehensive health assessment studies and stranding investigations were conducted on dolphins occupying oiled bays (Barataria Bay [BB], Louisiana, and Mississippi Sound [MS], Mississippi and Alabama] and a reference bay (Sarasota Bay [SB], Florida, for health assessments) or other coastal areas

[1] *http://www.gulfspillrestoration.noaa.gov/restoration-planning/gulf-plan/.*

(Texas, South Carolina and the west coast of Florida for strandings) with no evidence of *Deepwater Horizon* oil spill contamination. Multiple health issues were detected in BB dolphins during the initial post-spill study period (2011), including poor body condition, an impaired stress response, moderate to severe lung disease, and haematological/serum chemistry indicators of inflammation, hypoglycaemia, and abnormal iron levels. Nearly half of the dolphins evaluated were considered unhealthy, indicated by a 'guarded' or worse prognosis, and 17% of dolphins were given a 'poor' or 'grave' prognosis, meaning they were not expected to survive. During follow-on assessments in BB during 2013 and 2014, moderate-severe lung disease remained elevated and dolphins continued to release low levels of cortisol in the face of capture stress. Prevalence of moderate-severe lung disease among BB dolphins decreased slightly with time since the spill, but was still elevated relative to expected prevalence based on the SB reference site. Health assessments performed in MS in 2013 showed similar findings to BB. Specifically, MS dolphins had low serum cortisol levels and a high prevalence of moderate-severe lung disease. Concurrent studies focused on dead dolphin retrieval, necropsy, and histopathology in northern Gulf of Mexico dolphins recovered within the oil spill footprint had similar findings. Histopathology results showed an increase in potentially lethal changes to dolphin adrenal glands and primary bacterial pneumonia, consistent with the findings of impaired stress responses and moderate-severe lung disease in live-sampled dolphins. Reproductive impacts were also studied in both live and dead dolphins in the northern Gulf of Mexico, with a focus on the heaviest oiled coastal regions. Study of live dolphins showed low reproductive success from heavily oiled estuaries when compared with other populations, and stranded animal studies confirmed a high rate of perinatal loss within the oil spill footprint. The evidence to date supports that the *Deepwater Horizon* oil spill is a causal factor for poor dolphin health, increased mortality and reproductive failure.

The injury assessments described above were then used in models to quantify the injuries to specific stocks of cetaceans as lost dolphin years, maximum population reduction, and years to recovery within 95% of the baseline population (Fig. 2).

In conclusion, BB dolphins had a maximum reduction in population of 51% and will require 40-50 years for recovery without active, effective restoration. Nearly all the cetacean stocks within the oil spill footprint had quantifiable injuries and continued monitoring is essential to understand the long-term health effects and success of restoration. On 4 April 2016, the NRDA legal process was finalised, with a decision on allocation of funds by location and taxa or type with monitoring and adaptive management for the next 15-20 years.

The SWG congratulated the team on an impressive piece of science. The SWG **agreed** that, based on the studies presented to the SWG, there is compelling evidence that oil and dispersants have substantive long-term health impact on cetaceans.

In discussion, the SWG noted injury quantification is useful for assessing damages, but determining costs for restoration efforts is more challenging. In order to ensure a clear path from injury to recovery, scientists and managers need to identify actions that will reduce impacts on populations, improve survivorship and fecundity, and enhance recovery. For example, the evaluation of ocean noise reduction on cetacean populations may be informed by the work identified in item 11 of the Report of the Workshop on Acoustic Masking and Whale Population Dynamics, June 2016 (SC/66b/Rep10). The SWG encouraged additional work to evaluate the effectiveness of restoration activities for cetaceans affected in this spill.

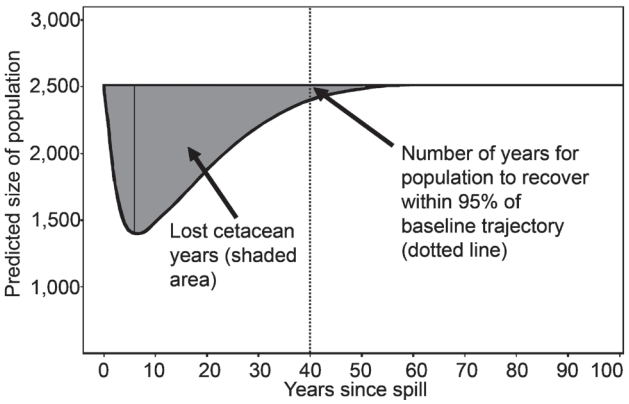

Fig. 2. Population model outputs. Shaded area represents the difference between the baseline and DWH-injured population size, summer over all years (lost cetacean years). The dashed line represents the number of years post-spill until the injured population trajectory reaches 95% of the baseline population trajectory. From: DWH MMIQT (2015).

In discussion, the SWG also noted that restoration activities may be very similar to recovery actions that are commonly evaluated for cetacean populations.

The SWG also emphasised the importance of baseline information for damage assessment and recovery monitoring and **recommended** collection of quality baseline data before oil/gas exploration begins or expands, or shipping lanes/ports are developed or increased. Also, the SWG **agreed** that an adaptive management framework is essential to provide feedback on the impacts of all of the restoration activities, especially on nearshore dolphin populations.

The SWG thanked Rowles for the annual updates during the NRDA process.

In summary, given the tremendous amount of information obtained on the impacts of the *Deepwater Horizon* oil spill on cetaceans and the lack of consideration of cetaceans in oil spill response planning, preparedness and response in many regions, the SWG **recommended** that an intersessional working group evaluate tools and mechanisms to integrate and inform oil spill response organisations and national and international response plans of the need for response actions and the assessment of the impact of spills and spill response activities related to cetaceans. Given the increased attention to disaster preparedness through Arctic Council's Emergency Prevention, Preparedness and Response (EPPR) working group, the SWG **recommended** that member Arctic states on the EPPR working group consider cetaceans in planning and preparedness.

Further, the SWG **recommended** the following.

(1) That the Scientific Committee develop an information resource on risks of oil spills to cetaceans such that: (i) response organisations can make environmental trade-off decisions based on sound science evaluating the risks and benefits of certain cleanup operations to cetaceans; and (ii) guidance can be provided for potential response actions for cetaceans during spill responses. This information resource may be used by IWC member countries and international response organisations working with cetacean experts to develop 'best management practises' to reduce impacts of cleanup operations on cetaceans and identify mitigation actions for cetaceans.

(2) That IWC Member States obtain and share information on exposure of and impacts to cetaceans when medium to large spills occur in their waters to enhance global understanding of risks and impacts to cetacean populations.
(3) That IWC Member States and industry:
  (a) increase efforts on prevention of spills; and
  (b) focus research to improve tools to detect exposure and evaluate impacts of oil spills to cetaceans.
(4) The Scientific Committee continue to encourage the collection of baseline data on location, health status and other measures in areas of higher risks of impacts to cetaceans.

There was discussion about identifying the best path forward for planning, preparedness and response with regard to cetaceans and oil spills. It was noted that the SWG could work with IWC Member States that may have national response plans and organisations already in place. In discussion, it was noted that guidance from the Secretariat is needed on how to engage international organisations (e.g. Arctic Council - EPPR Working Group) with regard to oil spill planning and preparedness related to cetaceans.

8.3 Review national, international or regional work on oil spill impacts on cetaceans

Rowles updated national oil spill impact work underway in the USA. NOAA has developed National Oil Spill Response Guidelines for Marine Mammals[2] and is developing guidelines for natural resource damage assessments of pinnipeds and cetaceans. The Arctic Council EPPR Working Group has developed an agreement on Marine Oil Pollution Preparedness and Response in the Arctic and has been holding oil spill response drills. As discussed at SC/66a (IWC, 2016b), the Global Oiled Wildlife Response System project funded by IPIECA, the global oil and gas industry association for environmental and social issues, should be completed in late 2016.

9. CETACEAN DISEASES OF CONCERN

9.1 Update on website

An update and a demonstration of the Cetacean Diseases of Concern (CDoC) beta website was provided. In 2012, at SC/64, the Cetacean Emerging and Resurging Diseases (CERD) working group proposed to develop a website that provides information on infectious diseases (e.g. viral, bacterial, fungal, parasitic) and non-infectious diseases (e.g. nutritional disorders, environmental conditions, biotoxins). Since SC/66a, the following progress has been made on the database: all changes identified by the intersessional working group have been completed and all permissible pictures have been uploaded, however the infectious disease list has not been uploaded. The website content has been standardised and clarified for each of the sections and a discussion board has been created that will be responsive to allow for consultations and review. Additional work is needed, such as continuing to compile information, uploading the infectious disease reference list and populating the visual health assessment section. The intersessional working group encourages members of the Committee to submit additional information for the website, evaluate the site for utility and clarity and provide photographs where needed.

After discussion, the SWG agreed that the next steps for the CDoC website are to work with the Secretariat to design and reformat the site using the Secretariat's requirements and determine how a mapping effort might be best accomplished, consistent with other mapping efforts (such as those for Pollution 2020). It was noted that adding an interactive mapping function would be a useful addition that could link other information on harmful algal blooms, pollution and ocean observing system into the website structure. The decision whether to move forward with a static map or an interactive one will be decided by the Secretariat as it maintains the website.

The SWG recognised the value of the CDoC website and **recommended** that the CDoC intersessional working group continue the work associated with refining the website and making it operational as soon as possible.

9.2 Other health issues in cetaceans

The Strait of Gibraltar includes shipping lanes, commercial and big game fishing, and is a 'hotspot' of PCB contamination. A database with more than 32,000 photos collected on platforms of opportunity over 15 years was analysed for cetaceans with externally visible anomalies (SC/66b/E13). A total of 500 cetaceans with skin anomalies, injuries, diseases, emaciation and deformations were recorded. Fishing gear and ship strikes were likely reasons for most of the injuries and scars observed in 245 whales and dolphins. In six cases, injuries due to transmitter tags were observed. In one animal, the transmitter fixed at the base of the dorsal fin caused serious ulceration and necrosis. Parasites, as recorded in 97 animals, are suitable indicators of health in cetacean populations. Abnormal growth of tissue (neoplasia) was observed in five bottlenose dolphins and two killer whales, mostly on the jaw, and occasionally affecting the surrounding epidermis. Viruses and chemicals have been shown to cause carcinogenesis in other mammals. In 98 cetaceans, cutaneous anomalies were observed. Among them were skin diseases caused by viral, bacterial or fungal pathogens, which may reflect immunosuppression due to altered environmental conditions.

Interactions between PCB contaminants and disease have been identified in the Strait of Gibraltar, as was discussed at SC/66a (IWC, 2016). It was noted that the issue of unregulated whalewatching operations is being addressed by ACCOBAMS, which is aware of the need for a code of conduct in this region. There was discussion about whether some cases identified as possible fishing gear interactions might be ship strike. The SWG suggested that the photographs might be presented to experts for assistance in determining the potential source of the injuries and scars and that a collaborative process for sharing and evaluating such cases would be valuable to the evaluation of cetaceans in this area.

It was further noted that skin disease in free-swimming cetaceans is difficult to diagnose. These difficulties were identified at workshops in 2007 (IWC, 2008b) and 2008 (IWC, 2009). Even when biopsies are obtained, they are rarely on the leading edge of the lesion, which is necessary for full evaluation of pathology and potential active pathogen if it is infectious. The SWG **agreed** that future studies on cetaceans in the area should include monitoring (following) animals for health impacts or survivorship and examining skin lesion progression over time.

The author was unsure if there were ongoing biopsy collection efforts and associated contaminant or biomarker analyses for cetaceans in this region. The presentation of these data was made possible by the active work of Committee members. The author indicated that the photo-

[2] *http://www.nmfs.noaa.gov/pr/publications/techmemo/opr52.pdf.*

identification work will continue and that the whalewatching group described in SC/66b/E13 continues to be active, but the company has only one biologist and very little funding. The SWG **agreed** that it is important to continue long-term monitoring of these cases in the Strait of Gibraltar and encouraged research groups in the area that are doing similar research on the whales to collaborate on the studies to gain more information on these populations of whales. The SWG thanked the author for presenting these findings on cetaceans from the Strait of Gibraltar.

Four papers describing health monitoring efforts in bowhead whales and other cetaceans from the US Arctic were presented.

SC/66b/E06 presented information on the prevalence of an anisakid parasite in bowhead whales from the Alaskan Arctic. As part of the North Slope Borough Department of Wildlife Management's ongoing retrospective and prospective health assessment work of bowhead whales, the prevalence of 'whale worms' in a large baleen whale was evaluated. Stomach content samples collected from 228 legally harvested bowhead whales over a 32-year time period (1980-2012) have been evaluated for the presence/absence of anisakids, as stomach content analysis is a sensitive detection tool especially for small/midsized worms. The prevalence of *Anisakis spp*. infection was reported to be 17% (38/228) in Bering-Chukchi-Beaufort Seas (B-C-B) bowhead whales; however, there are no post-mortem pathological data to evaluate if there is a worm-associated health impact in bowhead whales (i.e. gastric ulcers, erosions). Limited interannual variation was noted in the whales, but 2001 and 2010 were years with increased detections of the worms in the stomach samples. A single-intermediate host life cycle for anisakid worms in baleen whales is supported by the findings reported in SC/66b/E06. Low abundance of large mature worms suggests bowheads eliminate immature worms (e.g. possibly through a 'novel' baleen hair worm trap) and that larval growth is limited. Monitoring *Anisakis* burden with concurrent molecular species identification may become a useful proxy to monitor northern range expansion of 'new' fish vectors/intermediate hosts and/or definitive hosts. Anisakiasis in the Arctic may become an emerging zoonotic issue.

SC/66b/BRG03 reported on various pathological findings in tissues of Alaskan bowhead whales collected in 2015. As part of the North Slope Borough Department of Wildlife Management's ongoing retrospective and prospective health assessment work of bowhead whales, post-mortem examinations of legally hunted bowhead whales were conducted. Five individual cases with pathological findings, specifically benign hepatic fatty tumours (n=2), a benign uterine tumour, an encapsulated fatty mass, and a chronic thoracitis, were reported. These incidental pathological findings contribute to the body of knowledge of morbidity and mortality in large baleen whales. In discussion, the author noted that when the single whale with thoracitis (>100 abscesses in the thoracic cavity) was butchered, it was deemed unfit for consumption.

SC/66b/BRG14 presented a possible outline for a bowhead health report. Data sources include the North Slope Borough health assessment programme, federally funded ship and aerial surveys, industry monitoring programmes and other sources. The envisioned report is a succinct, possibly annual, bowhead whale health report summarising basic health and life-history information. An update of the proposed bowhead whale health report was presented to the BRG sub-committee (see Annex F, item 2.1.1).

The SWG thanked the authors for the information provided on bowhead whale health issues and for all the work collecting biological and health information on harvested and stranded cetaceans in the US Arctic.

The SWG noted that body mass index or body condition is important to monitor over time. Although body mass index or body condition may fluctuate seasonally, with migration or interannually, they are crucial components of health assessment metrics for many species. For example, body mass index was a component of the health assessments for dolphins from the Gulf of Mexico after the *Deepwater Horizon* oil spill.

Regarding the bowhead whale monitoring program (SC/66b/BRG14), it was noted that compiling annual information on health threats (e.g. proportion of whales with line entanglements, a summary of gross findings, biotoxin prevalence, radionuclide concentrations) in addition to the usual life history data, may also be useful. In addition, it was noted that whale lice infection might be an important tool for documenting ecosystem changes. These types of biological measurement would be included as intrinsic measures when viewing cetaceans as ecosystem monitors or sentinels as well as monitoring indices for population impacts or status (see Fig. 3 in Item 13.2). The SWG **recommended** further work on compiling and refining this framework for monitoring a sentinel or indicator Arctic cetacean species. Such work would be useful to the Circumpolar Biodiversity Monitoring Plan (CBMP) marine expert network[3].

The SWG **agreed** with the recommendation to receive the bowhead health report every two years (see Annex F, item 2.1.1).

Lefebvre *et al.* (2016) reported on the prevalence of two harmful algal toxins in marine mammals, including cetaceans, from Alaska. Under the 'new Arctic normal' with rapid declines in sea ice and increasing water temperatures, harmful algal blooms are likely to expand to the northern geographic range. Toxins associated with harmful algal blooms have caused significant illness and mortality in marine mammals along the west and Gulf coast of the USA, but have not been reported to impact marine mammals foraging in Alaskan waters. To better understand the importance of harmful algal toxins from an Alaskan marine mammal health perspective, a total of 905 faecal, stomach and/or urine samples from 13 marine mammal species (2004-13) were sampled and analysed for domoic acid (causes amnesic shellfish poisoning) and saxitoxin (causes paralytic shellfish poisoning). Marine mammal species in the harmful algal toxins screening included: large baleen whales (humpback whales, *Megaptera novaeangliae*) (n=8), bowhead whales (n=25)), odontocetes (beluga whales, *Delphinapterus leucas*, harbour porpoises, *Phocoena phocoena*), various pinnipeds (northern fur seals, *Callorhinus ursinus*, Steller sea lions, *Eumetopias jubatus*, harbour seals, *Phoca vitulina*, ringed seals, *Phoca hispida*, bearded seals, *Erignathus barbatus*, spotted seals, *Phoca largha*, ribbon seals, *Histriophoca fasciata*, Pacific walruses) and northern sea otters (*Enhydra lutris kenyoni*). The authors reported that domoic acid was detected across trophic levels in all 13 species examined. Domoic acid prevalence in bowhead whales was 68% (17/25) and 38% (3/8) in humpback whales. Saxitoxin prevalence in bowhead and humpback whales was 32% (8/25) and 50% (4/8), respectively. Maternal biotoxin transfer was documented in two foetuses (a beluga whale and a harbour porpoise). Currently, there is no evidence that marine algae

[3] *http://www.caff.is/monitoring.*

toxin exposure levels have negative health consequences for any marine mammals examined in the study. Harmful algal toxin information obtained from this study provides useful baseline data for monitoring bowhead and other baleen whale (e.g. right whales) exposures.

The SWG noted that harmful algal blooms are an emerging issue for cetaceans in many parts of the world, including the Arctic, the west coast of North America, Europe and South America. The authors added that there were plans to measure algal biotoxins in bowhead whale samples collected from 2000 to the present; however, it is not possible to go further back in time because faeces and urine were not routinely collected prior to 2000. Serum might be a possibility in the future if a validated test is available to measure antibody responses to domoic acid. This work is continuing with the Alaska marine mammal community and the plan is to continue sampling the bowhead whale as part of an active biomonitoring program. There are no plans as of yet to include samples from animals at other trophic levels (e.g. krill). The SWG noted that there has not been a focus session on harmful algal blooms in several years (IWC, 2008a), but they have been discussed at this meeting as potentially playing a role or being present in two whale mortality events (in Chile and Argentina; see Item 10.3). The SWG noted that harmful algal blooms are environmentally driven and may be changing with associated changes in climate and temperature. The SWG **agreed** that a harmful algal bloom focused session be planned for SC/67a and established an intersessional steering group to convene the session.

10. STRANDINGS AND MORTALITY EVENTS

10.1 Report of the Workshop on Investigations of Large Mortality Events, Mass Strandings and International Stranding Response

Rowles provided a summary of the report of the Workshop on Investigations of Large Mortality Events, Mass Strandings and International Stranding Response (SC/66b/Rep09) that was held in the Greater Farallones National Marine Sanctuary Office, San Francisco, California, USA, 11-12 December 2015. There were 27 participants from 11 different nations, including veterinarians, veterinary pathologists, biologists and stranding coordinators who are actively involved in responding to large mortality events and mass strandings. The primary objectives of the Workshop were to: (1) facilitate international collaboration and coordination amongst national and regional programs on responses to and investigations of cetacean strandings, with a focus on unusual or large scale mortality events, mass strandings, and disease outbreaks; (2) identify common issues and share information on potential solutions relative to causes, responses, and mitigation of cetacean strandings; (3) promote international data sharing and mutual aid particularly for mass strandings and large mortality events; and (4) discuss current terminology in use with regard to mass strandings, and unusual mortality events, to better characterise and facilitate work amongst countries. There is increasing interest in stranding information to understand anthropogenic and natural stressors that may be impacting cetacean morbidity, mortality, and population health. Of particular focus for the Workshop was to define potential roles that the Commission and the Committee might play in assisting countries with stranding response and investigation, e.g. through expert input, coordination and oversight of events, or through physical or monetary support for emergencies.

The Workshop reviewed case studies on developing baselines, pathologic investigations and recurring events, including information from various countries in North America, South America (i.e. mortality events in southern right whales in Argentina and sei whales in Chile), Europe and Japan. Each presenter shared the successes and challenges associated with their studies. Long-term supported studies and datasets, development of new techniques, collaborations fostered through long-term investigations, well-funded, long-term stranding networks with well-trained personnel, and the creation of stranding databases that provide easily accessible information were identified as activities contributing to successful responses and investigations. Common challenges included logistical limitations of performing an investigation with decomposed carcasses, difficulties in coordinating programs and collaborating with multiple entities, difficulties in sustaining multi-year investigations and in maintaining capacity (funding, logistics, training), loss of key/trained personnel, and maintaining and updating stranding databases. The Workshop developed preliminary lists of key characteristics and anthropogenic factors to consider during unusual cetacean stranding investigations.

The Workshop recommended the following: the development of an Expert Panel such as the Intersessional Working Group on Strandings that would assist in coordination of emergency response when requested at national or regional levels; provide expertise on operating procedures, diagnostics, and response; support capacity building for regional and national networks; support for a centralised data repository; and the reporting of unusual cetaceans events and responses at annual Committee meetings, and/or a summary of unusual cetacean events reported via the website.

10.2 Chair's Summary on Workshop to Develop Practical Guidance for Handling Cetacean Stranding Events

Simmonds presented a summary report of the Workshop to 'Develop Practical Guidance for the Handling of Cetacean Stranding Events', held in Kruger National Park, South Africa, 5-6 May 2016. There were 34 participants from 13 different countries. Participants included individuals from a wide range of stakeholders, including national authorities from Commission Member States; veterinarians and veterinary pathologists; animal welfare specialists; biologists and academics working on aspects of cetacean welfare; and experts from animal welfare organisations. Some participants were actively involved in stranding response and animal rescue efforts. (This Workshop was held back-to-back with the 'Workshop to Support the Consideration of Non-hunting Threats to Cetacean Welfare', which took place 3-4 May 2016). The primary objectives of the Workshop were to assist the Commission in its efforts to build global capacity for effective cetacean stranding response and to promote the Commission as a leading body for the provision of advice through the development of practical guidance for responders. It aimed to assist the Commission in taking forward relevant actions in the Commission's Welfare Action Plan, particularly Objective 2.4 (i.e. to work through existing strandings networks to produce specific recommendations to the Commission in relation to the welfare implications of responding to cetacean stranding events) and Action 2.4.1 (to organise a mass strandings workshop to progress the development of shared best practice and guidance in responding to such events).

The Workshop considered a series of case studies illustrating examples of the challenges faced by countries in developing an effective strandings response. These included submissions relating to Argentina, Spain, the Republic of Ireland, Netherlands, New Zealand, South Africa, UK and USA. Challenges can include lack of necessary resources (e.g. in terms of human capacity, suitable equipment and financial support), lack of clear national protocols, guidelines and responsibilities and the significant health and safety issues that can be associated with strandings response.

Finally, the Workshop discussed the potential role of the Scientific Committee in further developing guidelines and protocols for strandings and in acting as a repository for the identification and dissemination of best practise. It recommended, *inter alia*, that the Commission establish a framework to provide advice to Contracting Governments on critical elements to include in the establishment of a national strandings response network.

The SWG considered the recommendations from both Workshops. In order for this work area to be effectively progressed and to assume the role envisaged by the Workshops to provide guidance for response, investigations, and support the science needs of the Scientific Committee, the SWG **recommended** the establishment of both an Expert Panel (to guide and inform activities) and a Coordinator (to oversee the implementation of activities).

The SWG **agreed** that initial funding would be required for the Expert Panel's first meeting and for support of the Coordinator and requests the Commission and member nations to consider options.

The SWG **recommended** the establishment of the Expert Panel and agreed to facilitate its first meeting according to the Terms of Reference below (noting that the Expert Panel, working with the SWG, may further refine its Terms of Reference to support this work area, whilst taking into account the full recommendations of the two Workshops). The SWG **agreed** to establish an intersessional working group to select the panel, oversee its first meeting (including the development of the budget), and to work with the Secretariat as appropriate.

Expert Panel Terms of Reference

The Expert Panel should include the following representation and areas of expertise.

(1) Regional experts in stranding response, including those leading the work on the Global Marine Animal Stranding Toolkit (GMAST).
(2) Diverse agencies and organisations (e.g. governmental, NGO, academia).
(3) Multi-disciplinary expertise (e.g. logistics, biology, medicine, pathology, epidemiology, toxicology, data-base management, stranding management).
(4) International Stranding Response Coordinator.

The Expert Panel will aim to:

(1) Identify and, as appropriate, develop 'best practise' for stranding response, including protocols for how to respond effectively, sampling protocols, how to conduct scientific investigations to meet the needs of the Committee, and how to communicate stranding science and management decisions.
(2) Assist member states to build strandings response capacity, in general and specifically, through:
    (a) the development of curricula for training (live strandings response and scientific investigation) and a plan for the delivery of training events;
    (b) a strategy for handling requests received by the Secretariat;
    (c) a strategy for the development of information through a variety of avenues; and
    (d) opportunities for communication and collaboration.

The SWG thanked Simmonds and Rowles for presenting these workshop reports and encouraged continued work in further developing the international stranding response and investigations, developing guidelines for stranding response and mortality events, updating the stranding response organisation list, and international communication and collaboration.

10.3 Review new information on mass stranding and mass mortality events

In the last 25 years, dolphin morbillivirus (DMV) was deemed to be the cause of two major epidemic outbreaks in the Mediterranean Sea (1990s and 2006-08). Two additional minor mortality events due to this virus were reported in 2011 and 2013 that included bottlenose and striped dolphins, as well as fin whales, with evidence of DMV infection found in more than half of the animals examined (Mazzariol *et al.*, 2016). The sequencing of the main structural proteins of the virus showed a 99% homology with the viral strain responsible for the previous epidemic outbreaks, but punctiform nucleotidic substitutions observed were similar to those occurring in canine distemper virus adaptation to new hosts (i.e. from wild canids to lions and mustelids) due to increased infectious pressure. A new, sensitive two-step nested PCR technique targeting 200 base pairs of the H gene was developed for cases of stranded large whales or poor preservation status of tissues of a carcass (Centelleghe *et al.*, 2016). The host range expansion was also observed in the following year with a sperm whale (*Physeter macrocephalus*) mass stranding event that occurred in the Southern Adriatic Sea, in which DMV was detected by molecular and immunohistochemistry analyses in all the dead whales, and in a single report of a stranded beaked whale. The above findings, coupled with the progressive expansion of the range of DMV-susceptible species that has occurred over the past five years in the Mediterranean, argue in favour of an endemic circulation of DMV among Mediterranean cetaceans. In a similar context, periodic and self-limiting disease outbreaks may occur, due to a decreased level of the population's antiviral immunity, as occurred in 2011 and 2013 (Mazzariol *et al.*, 2016). Furthermore, while the viral 'infectious pressure' may be reasonably expected to increase under similar conditions, a simultaneous impairment of host immune response, whether it be age or pregnancy (many of the recent cases of DMV infection have been diagnosed in newborns, calves or pregnant females) or pollutant-related, may facilitate cross-species infection, thereby also underscoring how vertical transmission is one of the preferred infection routes for such species (Di Guardo and Mazzariol, 2016).

In discussion, it was noted that vertical transmission of the dolphin morbillivirus has been documented previously, but not in the fin whale. The phylogenetic trees for this virus are currently under construction. Differences in pathology between host cetacean species have been found, but this finding may be related to the timing of infection or examination. Some cases appear to have classical morbillivirus lesions, but others do not. In the USA, the full genome sequence is being analysed as part of the unusual mortality (from 2013 to 2015) investigation in the Atlantic, and differences have been observed in the Gulf of Mexico and in the Atlantic. Phylogenetic trees are also being constructed for North American viruses.

The SWG **welcomed** these updates on the dolphin morbillivirus and **encouraged** continued studies on the virus in the Mediterranean Sea, North America, and other regions of the world, as well as modelling of the effects of the virus in populations.

Gulland provided information on a letter from the Wildlife Health Specialist Group of the International Union for Conservation of Nature (IUCN) to the CITES Secretariat requesting development of a procedure for transboundary transport of diagnostic specimens for disease investigations in emergency situations. When animal die-offs occur remotely, away from diagnostic facilities, samples need to get to reference labs that are often located across international boundaries. Currently permits are required for each specimen, which often delays transport and analysis. The IUCN is seeking support of other intergovernmental organisations to aid and support the development of this procedure.

The SWG **welcomed** this information and **recommended** that Commission Member Governments evaluate this request and enter into discussions regarding effective ways to assist transboundary sample transport in the face of emergencies (die-off or disease outbreaks). Although it may be too late to table a resolution at the upcoming CITES Conference of the Parties, the SWG noted that discussions on the issue may occur during the meeting. The SWG noted that this has been an issue in some investigations relating to marine mammals, including transboundary transport of cetacean samples for diagnostic analyses.

In SC/66b/E01, information on mass strandings of sei whales in southern Chile was presented. In 2015, more than 360 dead sei whales washed ashore in the Gulf of Penas in southern Chile. Efforts to determine cause of death were hampered by the extreme remoteness of the location and the state of decomposition of the carcasses. Carcasses were first reported in April 2015 and a subset of the carcasses was examined by an official expedition in May 2015. Additional information on the extent of mortality was gathered by two overflights of the area (one by the Huinay Scientific Field Station in June 2015 and an official overflight in February 2016). There was no evidence observed to suggest human-caused mortality (e.g. noise impact, collision with vessels) as there was an absence of marks or cuts and acoustic impacts analysis by computed tomography of ear bones was negative. The positioning of the carcasses (ventral side up) strongly suggests that death occurred outside of the channel where they were found. The combination of death likely occurring outside the channel, the number of individuals involved and the results of the biotoxin analyses, plus the high presence of *Alexandrium* spp. in mussels during the time of the mortality event, point to exposure and subsequent poisoning due to toxins produced by harmful algal blooms as the leading hypothesis for these whale deaths. The most likely vectors for the toxins include sardines and krill. Both vectors are key parts of the food chain of these fjords and thus a potentially important link for whales in this region.

This cetacean mass mortality event demonstrates an unprecedented event, both in Chile and globally, in terms of number of affected individual baleen whales. A total of 23 individuals genetically analysed from both expeditions corresponded to the sei whale species. Poisoning caused by harmful phytoplankton blooms has been described for other species of cetaceans around the world, mainly in the Northeast Pacific. Harmful algal bloom toxin exposure might have an effect over time at the population level, particularly for those species listed in some threatened category (vulnerable or endangered, as is the case of many species of whales).

The author noted in discussion that, due to the advanced state of decomposition of the sei whale carcasses, only a limited number of partial necropsies were conducted. Harmful algal biotoxins were detected in stomachs of a small number of the whales, and mussel samples collected in the region; however, water samples collected months after the bloom did not contain detectable levels of the harmful algae. If the mortalities were caused solely by biotoxins, it is not clear why sei whales were the only taxa apparently affected, but it might be related to their prey preference. The author also noted that harmful algal blooms have been implicated in stranding and large mortality events in other parts of the world and some blooms have been associated, in part, with eutrophication. The SWG noted that, although biotoxins were detected in some of the sei whales, there may be multifactorial processes implicated in these mortalities. For example, topography of the coastline also may act as a trap for whales (similar to Cape Cod in the USA or the North Sea) and there may be interactions between killer whales and sei whales. The SWG **recommended** that live animal monitoring as well as annual surveys and examination of stranded animals in the area should be included in follow-up efforts.

In further discussion, the author noted that there are no dedicated expeditions to investigate the ongoing whale mortalities in this remote region of Chile. Although research efforts unrelated to cetaceans are being conducted in this area, there are no targeted plans to respond to the whale mortalities during these operations. The SWG emphasised the importance of monitoring the whales and their habitat in this remote region of Chile after such an unprecedented event and **recommended** funds be dedicated to investigate the sei whale mortalities. Furthermore, the SWG **recommended** that, if the mortalities continue, plans to increase aerial surveys and carcass marking of whales in this region should be continued. The SWG asked that these recommendations be brought to the attention of the Government of Chile.

It was noted that, in addition to being endangered, the sei whales are ecosystem indicators for factors that are important to humans. For example, harmful algal blooms recently caused losses of salmon at a salmon farm in the Gulf of Penas and there has been much interest in understanding these blooms and their overall impacts to marine life and marine ecosystems. Phytoplankton monitoring for human health purposes are currently being conducted[4].

SC/66b/BRG02 presented an update on the southern right whale (*Eubalaena australis*) calf mortality. A total of 737 dead whales have been recorded on the Península Valdés calving ground and surrounding areas along the Argentine coast since 2003. These deaths included high annual losses between 2007 and 2012, and a peak number of deaths (n=116) in 2012. The number of dead whales was 23 in 2014 and 42 in 2015. As in previous years, most of the dead whales were newborn calves (89%). Most whales died in August-September (65%) in 2014, and in July-August (60%) in 2015. Five leading hypotheses to explain the high mortalities have been proposed: decreased availability of food, exposure to biotoxins, infectious disease, the role of kelp gull (*Larus dominicanus*) attacks on whale health and density-dependent processes (IWC, 2011; 2015b; Thomas *et al.*, 2013). Efforts have focused on collecting samples and information that would help to further investigate these hypotheses (SC/66b/BRG02). Evidence of the whale

[4]see *http://sig-acuicultura.ifop.cl/medioambientEReportes2015_mroja/?mroja2015=Ir+al+S.I.G.*

exposure to biotoxins included trace levels of paralytic shellfish toxins (PSTs) and domoic acid (DA) in tissues of some dead whales, and fragments of *Pseudo-nitzschia* spp. frustules in whale faeces (Wilson *et al.*, 2016). Post mortem examination and pathogen testing was performed on 212 whales. A known or probable cause of death was established in 14 whales (6.6%) of cases) and included ship strike in one juvenile, blunt trauma or lacerations (*n*=5), pneumonia (*n*=4), myocarditis (*n*=2), meningitis (*n*=1), or myocarditis and meningitis (*n*=1) in calves. Ante-mortem gull parasitism was the most common gross finding: it was associated with systemic disease in a single 1-2 month old calf (McAloose *et al.*, 2016). Intensified kelp gull harassment at Península Valdés may be compromising calf health and thereby contributing to the high average rate of calf mortality observed in recent years, but it cannot explain the large year-to-year variance in calf deaths since 2000 (Maron *et al.*, 2015; Annex F, item 4.1).

In discussion, it was noted that, in the event that there is an unknown pathogen that has not been discovered through these investigations, it is likely that effects of an unknown pathogen would be exacerbated by the gulls that prevent the calves from nursing and resting. Possible impacts of the biotoxin exposure were discussed. Dose-dependent biotoxin effects on baleen whales are not known, although there is a wealth of data on pinnipeds, including clinical, neurological, as well as changes in behaviour and olfaction. Clinical signs have not been observed in small cetaceans; however, mortality has occurred concurrently with behaviourally-altered sea lions. In experimental models, rodents and primates are affected similarly so it is hypothesised that other mammals with glutamate receptors would be as well, but there are no data to confirm this.

The SWG applauded these consistent, long-term, and thorough investigations in the face of difficult logistics and limited funding. In addition, the SWG **agreed** with the recommendations made by the BRG sub-committee related to this issue (Annex F, item 4.1).

The SWG recognised that investigations of large whale die-offs are extremely challenging. For example, during the gray whale unusual mortality event that occurred in 1999-2000 along the west coast of North America only a few whales received full necropsies. As noted in the recent large whale unusual mortality events in Alaska, it is extremely difficult to bring floating whales ashore for examination or conduct necropsies on private beaches. The SWG **strongly encouraged** that large whale stranding or mortality events should be investigated and appropriate efforts and funding be made to conduct necropsies and determine cause of death. In addition, the SWG **recommended** that the Expert Panel (see Item 10.2) provide guidance for abbreviated necropsies for large whales that may be in remote locations or hard to access for full necropsy.

11. EFFECTS OF ANTHROPOGENIC SOUND

This agenda item was considered in a joint session with the Whalewatching sub-committee (see Annex N, item 11).

11.1 Review the report from the Workshop on Acoustic Masking and Whale Population Dynamics

SC/66b/Rep10 provided information on a pre-meeting Workshop on Acoustic Masking and Whale Population Dynamics that took place just prior to SC/66b. The Workshop was held on 4-5 June 2016, in Bled, Slovenia and was attended by 24 participants. The Terms of Reference for the Workshop were threefold, namely to:

(1) provide an update on progress made on 'masking sound', with emphasis on noise from shipping;
(2) provide overview of Population Consequences of Disturbance (PCoD) framework; and
(3) explore ways that the PCoD and similar frameworks could be modified to predict population consequences of acoustic masking to cetaceans.

The Workshop reviewed international efforts to monitor ocean noise levels to characterise the acoustic environment, including the USA's development of a NOAA Ocean Noise Strategy and EU efforts to include underwater noise as an indicator of Good Environmental Status under the Marine Strategy Framework Directive. The Workshop considered the 17 Sustainable Development Goals agreed in August 2015 by the 193 member nations of the United Nations, and agreed that addressing ocean noise was essential to meet stated targets with respect to reducing pollution and fully protecting 10% of coastal and marine areas. Recognising the efforts of the IUCN Joint Species Survival Commission/World Commission on Protected Areas Task Force on Marine Mammal Protected Areas, the Workshop recommended that efforts to identify and protect Important Marine Mammal Areas should integrate information on anthropogenic noise into site selection and management, and where possible, reduce ocean noise levels in the Important Marine Mammal Areas.

The Workshop reviewed the scientific work needed to progress the goal endorsed by the Committee in 2010 (IWC, 2010a) of reducing noise from shipping (i.e. 3dB in 10 years; 10dB in 30 years in the 10-300Hz band). The Workshop recommended that ship source characteristic data be evaluated to identify the noisiest ships and quantify their relative contribution to overall ocean noise. The Workshop further recommended that those ships that contribute disproportionately to ocean noise be considered a priority for replacement or application of ship-quieting technologies. To accomplish this goal, the Workshop encouraged further studies to generate a better understanding of the source-level speed relationship for a range of vessel types. The Workshop also recommended the use of Automatic Identification System (AIS) and source characteristic data to relate shipping density data to estimated loss of acoustic habitat from shipping noise.

In discussions regarding the Commission's collaboration with the International Maritime Organization (IMO), the Workshop recommended that the Commission develop a paper for submission to the IMO Marine Environment Protection Committee, providing an update of recent information, available since the IMO guidelines were adopted in 2014, related to the extent and impacts of underwater noise from shipping.

The Workshop reviewed the report from a two-day Workshop held in April 2014 in Leiden, Netherlands, entitled 'Predicting Soundfields: Global Soundscape Modelling to inform Management of Cetaceans and Anthropogenic Noise'. The 2014 Workshop was hosted by the Commission, International Quiet Ocean Experiment (IQOE), NOAA, Office of Naval Research Global, the Netherlands Organization for Applied Scientific Research and Nether-lands Ministry of Infrastructure and the Environment. The Workshop endorsed the recommendations of the 2014 meeting, and offered specific technical recommendations about how best to accomplish shared goals with respect to generating reliable soundfield maps (SC/66b/Rep10, table 1).

The Workshop covered three presentations on acoustic masking, which was defined as the interference of noise with hearing; or, more specifically, both the process and the amount by which the threshold of hearing of one sound is raised by the presence of another.

Reyes Reyes *et al.* (2016) discussed the potential acoustic masking of clicks and whistles of Commerson's dolphins (*Cephalorhynchus commersonii)* from high and mid-frequency ship noise in shallow waters off the Argentine Patagonian coast. The Workshop encouraged further work on acoustic masking in small cetacean species.

The Workshop considered a recent, exhaustive review of masking in cetaceans (Erbe *et al.*, 2016). This review was taken as a guiding document regarding available evidence and data gaps on the subject. The Workshop recommended a set of research efforts (SC/66b/Rep10, table 2) be undertaken to better quantify the factors underlying masking.

Clark presented a review of communication space in cetaceans, whereby each species occupies different acoustic spaces depending on the characteristics and functions of their sounds, and showed how various anthropogenic sounds overlap with those spaces. This way of addressing ocean noise from the perspective of a particular listener creates a paradigm shift from viewing chronic ocean noise as a factor that influences the acoustic environment (i.e. ocean noise levels, independent of any listener's perspective) to viewing ocean noise as something that addresses the quality of acoustic habitat (i.e. from a listener's perspective). The Workshop reviewed several studies in which chronic ocean noise was shown to cause substantial loss of communication space in many cetacean species. The Workshop recommended the continued development of clear and concise statements and compelling audio-visual tools to convey the importance and impact of ocean noise. The Workshop recognised that noise is one of many stressors whale populations face, and recommended mitigating the most tractable stressors, such as noise, as a way to increase populations' resilience and improve their future prospects in the face of less tractable stressors, such as climate change.

The Workshop covered two complementary ways to incorporate masking into statistical models to predict population consequences of chronic ocean noise to cetacean populations. One approach represents a family of statistical models, including the Population Consequences of Disturbance (PCoD) model and its derivatives for cases where key data are lacking. Another approach includes population viability analyses, which allow for empirical prey-demography relationships to be modified by noise levels that are hypothesised to reduce cetacean foraging efficiency. The Workshop further recommended focused research to quantify the relationship between reduction in acoustic space and reduction in prey intake. The Workshop recommended further efforts to expand both statistical frameworks to predict population consequences of masking.

In summary, the Workshop agreed that there is now compelling evidence that chronic anthropogenic noise is having an effect on the marine acoustic environment in many regions and recognised emerging evidence that compromised acoustic habitat can affect some cetacean populations adversely. Given cetacean dependence on listening to and producing sounds for their survival, the Workshop recommended increased research and management consideration of the importance of acoustic habitat in cetacean conservation efforts. The Workshop recommended research that explores linkages between masking of sounds and the effect on other life functions than foraging. The Workshop recommended that absence of scientific certainty should not prevent member nations from undertaking management efforts now to keep quiet areas quiet and make noisy areas quieter.

The SWG and the Whalewatching sub-committee both **endorsed the recommendations** of the Workshop and highlighted, in particular, the inherent difficulty of drawing causal linkages between loss of acoustic habitat and adverse effects on cetacean populations, and **agreed** with the Workshop recommendations that the lack of scientific certainty should not hinder management actions to reduce ocean noise. The SWG **agreed** it is acceptable to endorse management action in the face of uncertainty and that this philosophy extends beyond this topic to the entire Committee.

In addition, it was noted that many quiet areas are likely to be found in the less industrialised waters of the southern hemisphere. It was **agreed** that efforts are needed to involve more scientists from the Southern Hemisphere, working in these quiet areas, to participate in the Committee's ongoing work on ocean noise.

11.2 Progress on plans on workshop on stress

The SWG decided to highlight stress (i.e. including responses to noise, but also nutritional stress and other endocrine responses to a changing environment) as a potential special focus session in the future when more scientific data are available. If there was a session that related stress to anthropogenic noise, it is expected that this session would be held jointly with the Whalewatching sub-committee.

11.3 Review ACCOBAMS and other regional, national or international work on ocean noise

The SWG received an update on activities by US NOAA to develop an Ocean Noise Strategy (ONS), which adopts an acoustic habitat approach to the management of underwater noise. The ONS Roadmap contains six elements, which will guide the development of NOAA-wide Implementation Plans (*http://cetsound.noaa.gov*). Several recommendations of the ONS Roadmap would benefit by collaboration with international partners, including the IMO, JIP, IQOE, EU-MSFD, ICMMPA-IUCN and others.

The SWG welcomed the update on NOAA's ONS program and endorsed the acoustic habitat approach to ocean noise management.

Panigada presented information on the efforts currently underway by the Joint CMS, ASCOBANS and ACCOBAMS Noise Working Group on sensitive areas for offshore exploration activities in the Mediterranean Sea. This stems from ACCOBAMS Resolution 4.17: 'Guidelines to Address the Impact of Anthropogenic Noise on Cetaceans in the ACCOBAMS Area' (ACCOBAMS Noise Guidelines). Specifically, Resolution 4.17 recognises that anthropogenic ocean noise as a form of pollution, caused by the introduction of energy into the marine environment, which can have adverse effects on marine life, ranging from disturbance to injury and death. In April 2014 the ACCOBAMS's scientific committee recommended that all seismic explorations in the ACCOBAMS area should comply with Resolution 4.17 and Resolution 5.15. The Joint Noise Working Group (JNWG) has produced a statement to help facilitate Resolution 4.17 and to emphasise the importance of a pan-Mediterranean common approach to regulating the impact of noise on cetaceans.

Maglio *et al.* (2016) identified areas of high anthropogenic pressure on the marine environment. As underwater noise is considered a major threat for cetaceans, the ACCOBAMS Agreement has undertaken work aimed at identifying noise hotspots and areas of potential conflicts with cetacean conservation. The main aim is to gather baseline knowledge on noise-producing human activities in the Mediterranean Sea. Specific tasks include: making an inventory of noise-producing human activities; mapping areas where such

activities are carried out; and recommending, on the basis of the findings, a methodology to monitor noise from human pressures and noise sources over time.

A proposal has been presented for the establishment of a web-based common database at the international level to centralise structured data on human activities producing impulsive noise in the Agreement area.

The results of Maglio *et al.* (2016) provide key information on the spatial extent of different noise-generating activities in the Mediterranean Sea and yield the first basin-wide overview on areas where potential conflicts between noise-producing activities and cetacean conservation may occur. The authors reported that these results provided strong evidence of multiple stressors acting on the marine environment and of the need for urgent management and conservation actions. The authors noted inadequacy of information concerning time frames in which human activities are carried out in the region.

The SWG **expressed concern** about the number of problematic areas (with respect to noise) in the Mediterranean and welcomed this important work by ACCOBAMS (Maglio *et al.*, 2016). It was noted that the proposed tasks identified by ACCOBAMS are in line with the EU Marine Strategy Framework Directive on noise, and efforts are ongoing to coordinate efforts on this topic between ACCOBAMS and the European Commission.

ASCOBANS has developed Guidelines on underwater noise with respect to best practises currently applied in Europe, including effective mitigation guidance for intense noise generating activities. It was suggested that the Scientific Committee could refer to these guidelines as a general resource[5].

11.4 Effectiveness of marine mammal observers as a mitigation measure

The use of Marine Mammal Observers (MMOs) is regarded frequently as an effective mitigation measure for reducing the risk of injury to marine mammals from seismic surveys. This generally involves shutting down the sound source if whales are detected visually within a certain safety zone. Leaper *et al.* (2015) note that the effectiveness of such practices has rarely been quantified. The paper describes a simulation framework based on using data from visual sightings surveys to evaluate the effective risk reduction that might be achieved based on simple assumptions about sound propagation. Results indicate that there will be many cases where using MMOs results in minimal risk reduction, but these situations may not always be immediately apparent. Without an adequate quantified assessment of the risk reduction, mitigation measures may often be applied inappropriately or result in regulators granting approval for activities on the basis of measures that do little to reduce risk. The simple simulation model is easy to apply but does need to be performed on a case-by-case basis using input data that correspond as closely as possible to the scenario being investigated. However, in general, the study concluded that there will be very few instances where mitigation using visual observers can achieve a greater risk reduction than would be achieved by a 3dB reduction in source level throughout the survey.

In discussing this approach, the SWG **recommended** that, wherever MMOs are used as a measure for trying to mitigate risk of injury from noise sources, the expected risk reduction should be quantified. Noting that the results also indicate that small reductions in source level will generally be a more effective way of reducing injury risk than shut-downs in response to sightings by MMOs, the SWG **recommended** increased attention from the seismic industry towards developing new technologies and operating practices that reduce the source levels required during seismic surveys.

11.5 New sources of sound of concern for cetaceans

Smith *et al.* (2016) presented a review of small unmanned aerial systems (UAS, also referred to as drones or unmanned aerial vehicles) that have become more accessible to civilian operators and are quickly being integrated into existing research and business paradigms. As a result, there is a growing body of anecdotal evidence that UAS have the potential to disturb marine mammals and other wildlife species if not used responsibly. This is particularly relevant as recreational UAS operators are not required to have pilot certifications, have vague guidelines in place for responsible use, and are increasingly targeting marine mammals. Smith *et al.* (2016) synthesised the current state of scientific understanding of the impacts of UAS on marine mammals. The authors found that relatively few studies have systematically documented effects on various species of marine mammals (Smith *et al.*, 2016, table 1). Disturbance by UAS manifests from both acoustic and visual cues. With respect to cetaceans, there appeared to be no behavioural disturbance reported within the literature (used within an altitude range of 9-200m, from both fixed wing and rotary systems). However, there is anecdotal evidence of brief behavioural change: the authors reported one instance in which bottlenose dolphins chased shadows that were cast from an overhead rotary system. The review of published literature generally reflects disturbance within the context of non-invasive research (i.e. UAS were operated by trained pilots with the intent to avoid disturbance). Also omitted from the literature is the consideration of multiple stressors and related impacts from multiple UAS devices targeting animals, or UAS being used concurrently with other activities that may impact wildlife. Likewise, the lack of an observed behavioural response does not indicate a lack of impact. For example, American black bears (*Ursus americanus*) are known to increase their heart rates when small UAS were hovering above (Ditmer *et al.*, 2015). It is possible that other species, including marine mammals, exhibit a similar physiological response. The authors suggested that most evidence of behavioural responses to UAS is inconclusive, and more research is needed to understand the full effects of UAS on cetaceans. The authors recommend that better data reporting and evaluation of behavioural responses across various taxa are warranted. Information regarding distance thresholds at which visual or acoustic cues elicit behavioural responses, as well as general context of use, is especially needed. Such data can inform conservation and user groups about potential effects, as well as aid in the development of appropriate guidance and mitigation measures.

In discussion, three primary users of UAS were identified: research, commercial and recreational. These users are regulated, or not, to varying degrees across jurisdictions, and examples found on social media display a lack of awareness about the impacts of UAS on cetaceans. In general, it was noted that the less expensive the UAS, the more prone it seems to failure. It was noted that Canada and the USA are developing specific reporting requirements with respect to documenting behavioural responses of cetaceans to UAS as a condition of permitting UAS use. The

[5]The guidelines can be found at: *http://www.ascobans.org/en/species/threats/underwater-noise*.

SWG **recommended** that, in light of the large data gaps on cetacean responses to UAS, researchers should incorporate an impact aspect, such as behavioural reactions, into any proposed UAS study involving cetaceans. In the context of whalewatching, the sub-committee on whalewatching has considered impacts from recreational as well as commercial whalewatching vessels. With UAS, there is a similar division; the SWG **recommended** that managers consider recreational use of UAS, as well as commercial or research use, when developing regulations or guidelines for their use around cetaceans. Finally, noting that many countries do not have a research or commercial permitting system for UAS, and given their potential to disturb or even harm marine mammals (e.g. by strike/collision), the SWG **recommended** that such countries should develop a precautionary permitting system that considers the cumulative effects of UAS operations (including multiple UAS targeting cetacean groups or individuals) and other means of approach (e.g. by vessel).

11.6 Other noise concerns

The SWG noted that underwater noise from activities related to oil and gas development continues to be an issue of concern for the western gray whales that summer offshore of Sakhalin Island in the Sea of Okhotsk. It was noted that an update on activities of the Western Gray Whale Advisory Panel (WGWAP) was presented to the BRG sub-committee (Annex F, item 3.2.3), including recent meetings of their Noise Task Force. The SWG **strongly recommended** that the Acoustic Masking Workshop recommendations (SC/66b/Rep10) be conveyed to the WGWAP Noise Task Force (chaired by Donovan) to support a collaborative approach to noise management.

12. EFFECTS OF CLIMATE CHANGE ON CETACEANS

SC/66b/E05 reported on a just-concluded survey of the published scientific literature concerning climate change and marine mammals, conducted through literature searches using four databases: CAB abstracts, Web of Science, Science Direct, and Google Scholar. Overall, the literature has expanded greatly in recent years with a particular emphasis on the Arctic region, and there are a growing number of papers that directly link observed changes in the field to climatic factors. Relatively little has been published to date about tropical species in general and far less about river dolphins and beaked whales than about other cetacean taxa.

In discussion, it was noted that the rapid development of scientific endeavour as evidenced by the scientific literature for the Arctic is understandable and commendable given the rapid rate of change and the growing conservation concerns there, but that it may be appropriate to try to stimulate further research for those species and regions where research seems to be limited. It was noted that a recent, increasing freshwater influx to the Gulf of Mexico has been associated with skin lesions and illnesses in dolphins and is, thus, an example of an environmental effect outside of the Arctic that is under investigation. The potential vulnerability of species with restricted habitats has been highlighted previously (IWC, 2010b; 2012) and this would probably include many populations of river dolphins and beaked whales.

The SWG thanked Simmonds for the update on climate change and marine mammals. The SWG noted that there are some taxa and regions that have no data and encouraged work to be conducted in these areas. The SWG **agreed** to continue the intersessional working group to further develop a strategy to address potential vulnerability of such species.

13. ARCTIC ISSUES

13.1 Progress from intersessional group

In March 2014, the IWC held a workshop on the 'Impacts of Increased Marine Activities on Cetaceans in the Arctic' (Reeves *et al.*, 2016). Four priority recommendations from the workshop provided a framework for provisional discussions at SC/65b (IWC, 2015a, pp.39-44), which fostered the formation of an intersessional Steering Group (Arctic SG) to review and prioritise responsive actions (IWC, 2016a, pp.322-323).

The intersessional Steering Group discussed responsive actions, primarily through email exchange, and presented a number of possible actions for each of the four recommendations from the 2014 Workshop. The SWG discussed responsive actions to each recommendation, with a brief summary provided here:

Recommendation 1. Progress towards a summary of present knowledge is being made via peer-reviewed publications, reports to the Committee (e.g. via the BRG sub-committee and HIM working group), and reports from various workshops and working groups, especially the Arctic Council Conservation of Arctic Flora and Fauna (CAFF) and Protection of the Arctic Marine Environment (PAME) Working Groups. However, a fully comprehensive list of current literature on Arctic cetaceans is not available, and would take considerable effort to compile.

Recommendation 2. Plans for co-hosted workshops should be undertaken with other Scientific Committee sub-committees and working groups and, where possible, with Arctic Council Working Groups, relevant NGOs and other stakeholders. See the examples listed below.

(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: this should be coordinated with the HIM working group, the Arctic Council's PAME working group, NGOs and other stakeholders.

(b) Evaluation of non-direct threats to cetaceans at the population level including chemical pollution, noise, climate change, HABs, etc. (for noise, see SC/66b/Rep10 and relevant background documents). Workshops could be coordinated with the Arctic Council CAFF, PAME and Arctic Monitoring and Assessment Program (AMAP), and also the Western Gray Whale Advisory Panel (WGWAP) Noise Task Force.

(c) Methods to examine synergistic and cumulative effects of a range of actual and potential threats at the population level. For this issue, see SC/66b/Rep10 and relevant background documents; build on work on health and condition of marine mammals since the 2007 Marine Mammal Commission's Valencia Workshop (Simpkins *et al.*, 2009); review progress of the US National Academy of Sciences (NAS) panel on developing/improving methods for evaluating cumulative effects[6]; seek ways for the Commission to collaborate with NAS to undertake development of methods to evaluate cumulative effects; see the recent publication

[6]*http://www8.nationalacademies.org/cp/projectview.aspx?key=49715.*

which models the aggregate effects of several noise sources on B-C-B bowheads (Ellison *et al.*, 2016). Moreover, a workshop could be held to further this effort specifically for bowheads, which might be applicable for other stocks and species.

(d) Specific recommendations with respect to data requirements and monitoring for the Arctic region in the light of projected human activities within the region. For this item, see recommendations in Laidre *et al.* (2015) and Arctic Council CAFF State of Arctic Marine Biodiversity Report (SAMBR) project.

Recommendation 3. The vast array of Committee recommendations ('advice') would be very labour-intensive to summarise. One activity that might be instructive is to review the IUCN's WGWAP's recommendations catalogue[7]. Nevertheless, the collation of the Committee's recommendation list for Arctic issues would be quite challenging and possibly not worth the time, effort and expense.

Recommendation 4. In 2015, the Secretariat sent a letter to the International Maritime Organisation (IMO). This letter and the IMO's response with respect to placing the Marine Mammal Observers on NSR voyages are on file at the Secretariat. In addition, the Secretariat's Head of Science joined the Arctic Council's PAME working group meeting. These are just two recent examples of actions to increase the prominence of Committee activities. In regard to developing 'common standards' for measures and monitoring - one example is Arctic Council's CAFF/Circumpolar Biodiversity Monitoring Plan (CBMP) Marine Mammal plan, now being revised in the State of the Arctic Marine Biodiversity Report (SAMBR). The Committee could also consider providing input to the Arctic Council's 'Framework for a Pan-Arctic network of marine protected areas'[8] and the IMO's work on its Polar Code for shipping.

In addition, the Arctic SG proposed four priority topics to guide future work of the SWG, which include the following.

(1) Updates on cetacean species that routinely occur in the Arctic, including 'seasonal' species (e.g. humpback, fin, minke and killer whales), but with a priority on endemic species (i.e. bowhead, beluga, narwhal). Such updates, compiled from recent peer-reviewed publications and reports, should include: estimates of population size (for endemics, updated from Laidre *et al.* (2015); description of seasonal movements and habitat selection; and evaluation of body condition and diet. A comparison of cetacean updates, between Pacific and Atlantic sectors, could be particularly informative.

(2) To minimise risks to cetaceans related to anthropogenic commercial activities in the Arctic, integrate the work of the SWG with that of other Scientific Committee sub-committees (e.g. BRG and HIM), as well as Arctic Council Working Groups (e.g. CAFF, PAME, MPA Network Expert Group (MPA-EG), Working Group on an Arctic Biodiversity Assessment and a Circumpolar Protected Area Network (CPAN)), and AMAP, the IMO, NGOs and other stakeholders.

(3) Work with the Secretariat and Scientific Committee members to identify colleagues active in Arctic Council Working Groups (e.g. CAFF/CBMP-Marine) and (potentially) the IUCN Cetacean Specialist Group, to increase awareness of Arctic issues and to develop common standards for pan-Arctic monitoring of Arctic-endemic cetacean populations.

(4) Contribute to the development of Arctic disaster response plans to include cetaceans, building on the oil spill response plan, and mutual assistance, for e.g. die-offs, disease outbreaks, spills, assessment of health, working with Arctic Council Working Groups (e.g. CAFF/CBMP-Marine, EPPR) (see Item 8.3).

The SWG discussed seasonal versus endemic Arctic species for Arctic priority topic 1 and Moore clarified that updates on seasonal species would focus on their impacts on endemic species. For Arctic priority topic 4, the Arctic intersessional steering group will work to ensure that cetaceans are considered and included as appropriate in Arctic response plans.

The SWG **endorsed** the four priority topics and the SWG **encouraged** ongoing engagement of its members with the Arctic Council on marine mammal and marine biodiversity issues as well as Arctic disaster response plans. The SWG **reiterated** that prevention of disasters, such as oil spills, is the most important action. However, in the event of disaster, preparedness and appropriate response are essential.

13.2 Review regional, national or international work on Arctic issues

A short report on national and international activities focused on the Pacific Arctic region was given and this included a description of the Distributed Biological Observatory (DBO) and the Synthesis of Arctic Research (SOAR) programs. The DBO is envisioned as a long-term ocean observatory, providing repeated sampling in biodiversity hotspots across a latitudinal gradient ranging from the northern Bering to the Beaufort Sea[9]. The DBO is international in scope and, since 2010, has achieved annual coordinated multidisciplinary sampling, including a visual watch for cetaceans and all other marine mammals. The SOAR program has provided the means for researchers to form cross-disciplinary teams to synthesise analyses and produce peer-reviewed papers; outcomes have included a special issue of *Progress in Oceanography*, with a second special volume of *Deep-Sea Research II* anticipated in 2017[10]. These activities, combined with the anticipated development of an Arctic-focused Marine Mammal Health Map[11], provide the means to track the role of cetaceans in the Pacific Arctic ecosystem, via integrated ecological and physiological investigations. Cetaceans are upper trophic level (UTL) species that can act as sentinels of ecosystem variability associated with climate change, because they respond to environmental alteration by shifts in range, phenology and habitat selection (extrinsic responses), which lead to changes in body condition and/or other intrinsic responses - see Fig 3 and (Moore *et al.*, 2014). Integration of data from oceanographic sampling with that from ecological and physiological investigation of cetaceans provide a strong foundation for understanding how cetaceans are responding to the rapid climate change ongoing in the Arctic (Moore and Stabeno, 2015).

The SWG thanked Moore for these updates on Arctic issues and **recommended** the continuation of these integrated studies including evaluation of intrinsic and extrinsic responses.

[7] *http://www.iucn.org/wgwap/wgwap/recommendations/.*
[8] *https://oaarchive.arctic-council.org/bitstream/handl E11374/417/MPA_final_web.pdf?sequence=1&isAllowed=y*
[9] *http://www.arctic.noaa.gov/dbo.*
[10] *http://www.arctic.noaa.gov/soar.*
[11] *http://www.nmfs.noaa.gov/pre/health.*

14. MARINE DEBRIS[12]

14.1 Progress of the intersessional group

SC/66b/E12 provided an update on engagement with other intergovernmental organisations on marine debris. Commission discussions on marine debris have highlighted the desirability of working in collaboration with other intergovernmental bodies. Subsequently, at SC/66a, the Committee recommended that the Secretariat liaise with members of the intersessional working group on marine debris to identify appropriate opportunities for engaging with other IGOs. In response, the Secretariat has collaborated with the intersessional working group to identify and take forward a number of opportunities for engaging with other IGOs, based on existing Commission recommendations, as well as new and emerging opportunities.

SC/66b/E10 provided an update on progress and next steps. Much of the work discussed in the paper related to ongoing, and wider efforts by the Secretariat and others to strengthen relationships with other IGOs on a range of issues. S. Smith highlighted some specific marine debris initiatives with respect to efforts to strengthen relationships with: (i) the United Nations Environment Programme (UNEP); (ii) the Food and Agriculture Organisation of the United Nations (FAO) and its Committee on Fisheries (COFI); and (iii) the Global Ghost Gear Initiative (GGGI).

At the invitation of UNEP, the Secretariat provided some input into a report of the UNEP Executive Director on marine plastic debris and microplastics (UNEP/EA.2/5) presented to the second meeting of the United Nations Environment Assembly (UNEA), held 23-27 May 2016. At this meeting, UNEA adopted a resolution on marine debris that welcomed the work of the Committee on the impacts of marine debris on marine biological diversity and invited the coordination of this with other relevant work under the Global Partnership for Marine Litter (GPML). As such, the Secretariat proposed that the Committee should consider joining the GPML as a means of networking, information exchange and progress monitoring on marine debris.

SC/66b/E12 also made recommendations on strengthening relationships with the FAO and COFI, including input to the forthcoming COFI meeting (11-16 July 2016) with respect to the Draft Guidelines for the Implementation of a System for the Marking of Fishing Gear, which will be presented at this meeting. The Secretariat proposed to make a supportive statement on gear marking at this meeting and to highlight the potential value of gear marking for the mitigation of entanglement in active fishing gear and Abandoned, Lost or otherwise Discarded Fishing Gear (ALDFG).

The Secretariat received an invitation to join the Global Ghost Gear Initiative (GGGI)[13], a cross-sectoral alliance committed to driving solutions to the problem of ALDFG worldwide. It was suggested that the Secretariat liaise with members of the intersessional working group on marine debris to determine the best way to engage with this initiative.

Simmonds noted that the group had continued to monitor the relevant scientific literature but that its main activity had been to provide advice to the submission made by the Commission to the UN[14]. This is the first substantive contribution made by the Commission to a United Nations process.

[12]Marine debris may also be referred to as marine litter; for consistency with SWG work over time the topic will continue to be referred to as marine debris.
[13]*http://www.ghostgear.org/.*
[14]see *http://www.un.org/Depts/los/general_assembly/contributions71.htm.*

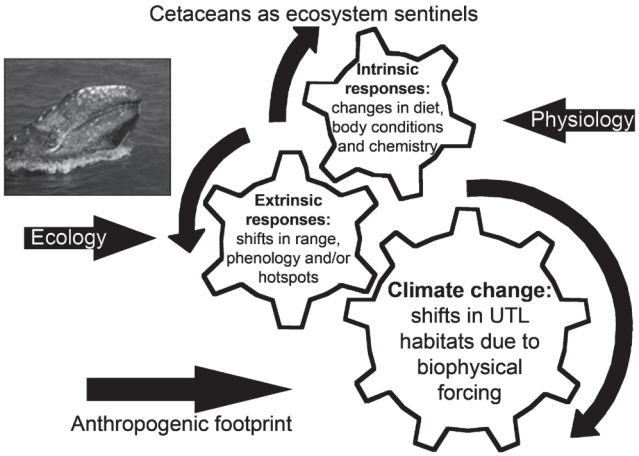

Fig. 3. Cetaceans can act as sentinels of ecosystem variability, as they exhibit extrinsic and intrinsic responses to environmental variability associated with climate change (Moore *et al.*, 2014). The impacts of anthropogenic activities will combine with shifts in cetacean habitats due to biophysical forcing. Figure revised from Moore and Stabeno (2015).

The SWG welcomed the progress that had been made on engaging other bodies on marine debris and **endorsed** the suggestions in the document, including further international outreach and collaboration including with the Global Partnership for Marine Litter and the Global Ghost Gear Initiative. It **recommended** that the Secretariat continue to work with the intersessional working group on marine debris and the Committee with respect to strengthening relationships with other IGOs working on this issue. The SWG also **recommended** that the intersessional Working Group on Marine Debris coordinate Scientific Committee input for a statement on gear marking, which is to be delivered by the Secretariat at the forthcoming UN Food and Agriculture Organisation Committee on Fisheries meeting (in July 2016).

14.2 New information on marine debris impact on cetaceans

SC/66b/E09 reported information on sperm whales that stranded along the coasts of the North Sea in 2016. In January and February 2016, 30 whales stranded outside of their natural habitat along the North Sea coastline. The gastrointestinal tracts of 22 whales were examined, with marine debris detected in nine whales. A total of 322 debris items were collected from the whales, including many small pieces of monofilament and plastic foils, as well as large fishing nets of more than 13m length, a plastic bucket and a part of a car. The largest amount of debris (based on mass) in one whale totalled more than 24kg, with fishing related-debris comprising 78% of all items found. None of the whales died as a result of this ingested debris. In this study, it could not be determined where, and when, the sperm whales ingested the debris. However, detection of nets from the local shrimp fishery suggests ingestion of these in the North Sea. Furthermore, some animals would likely not have survived very long with the large amount of debris in their stomachs, also suggesting recent uptake. It is also unclear why the animals ingested the debris; perhaps ending up in a foreign habitat without their usual prey led them to increase uptake of debris, or increased exposure to debris items contributed, or perhaps sperm whales are generally more susceptible to ingestion of debris. Altogether, the findings demonstrate the high level of exposure to marine debris and associated risks for large predators, such as the sperm whale.

In discussion, it was noted that the stranded sperm whales were healthy young males. It is unknown where the debris was acquired (e.g. North Sea) or how long the debris was in the ocean environment prior to ingestion. It was also noted that, in sperm whales that stranded off the coast of California, netting found in whale stomachs (determined to be the cause of death) consisted of gear types that had not been produced in a long time; thus, it was concluded that the debris was likely ghost netting. Although information on the breakdown of plastic-related chemicals in the stomach of the whales would be useful, it is unknown if there are methods available to do these types of analyses.

In further discussion, it was noted that sperm whales do not usually inhabit waters of the North Sea but that they may have entered this area following prey migrating from the Norwegian shelf region. The physical characteristics (e.g. shallow, mud flats) of this portion of the North Sea coastline may have prevented the whales from being able to leave the area. Age and inexperience may also have contributed to this out-of-habitat situation and thus affected their ability to escape the North Sea, leading to their subsequent deaths. In addition, other unusual sightings of killer whales and dolphins were reported in the North Sea in 2016.

It was also noted that recent reviews on the effects of debris on cetacean stranding events suggest that deep-diving species (e.g. beaked whales) are particularly sensitive due to the high concentration of marine debris in their foraging habitats and their method of foraging (suction-feeding). While the stranding process may also result in peri-mortem ingestion of plastics on the beach, this seems less applicable for sperm whales and other deep-divers than for small cetaceans.

The SWG welcomed the information provided on the sperm whale stranding event. It was also noted that more information on this unusual North Sea mass mortality event will be soon forthcoming and the SWG encouraged the presentation of this material to the SWG in due course. The SWG encouraged the evaluation for and reporting of debris in stomachs of all stranded cetaceans so as to assess the species affected, the impacts of, and types of debris, including information on debris ingestion by deep-diving species. The SWG **recommended** studies on tools and techniques to determine the timing of debris ingestion; however, it recognised the inherent difficulties in aging floating gear, determining at what stage it might have been ingested, and determining the impacts and time sequence for decomposition of synthetic fibres by stomach acids. The SWG noted that the HIM working group discussed degradation forensics with floating gear (see Annex J). The SWG also **recommended** gear marking at short intervals (e.g. every 3m) to aid in identifying gear removed from entangled whales or from the gastrointestinal tract of stranded whales. Based on the interest in gear marking and method development to identify the origin of gear and time in water expressed across the Committee, work on this issue will need to be coordinated (Annex J, item 6).

Based on the information presented in Item 7.3, the SWG **agreed** that further evaluation of scale, types and impacts of plastics (ingested as macro and microplastics) is warranted and should be a topic for a focused workshop in the future.

15. OTHER HABITAT-RELATED ISSUES

SC/66b/SM04 provided information on the collapse of a mine tailing dam that occurred in 2015 in an ecologically important region of southeastern Brazil that supports a number of species, including the endangered Guiana dolphin (*Sotalia guianensis*) and franciscana dolphin (*Pontoporia blainvillei*) (Annex L, item 8.6). A torrent of mud was released into the Doce River, Brazil, when one tailing dam holding at least 34 million cubic meters of iron-mining waste, construction material and water, collapsed on 5 November 2015. The contaminated river waters went downstream 650km and reached the Atlantic Ocean at Regência, on 21 November 2015, killing aquatic life in this river basin *en route*. This river mouth is known for its extreme ecological significance, which includes the two most endangered cetaceans of the southwestern Atlantic Ocean: Guiana dolphin and franciscana dolphin. This report is to briefly introduce the potential short and long-terms impacts of this dam disaster on these two endangered species. Examining Landsat 8-derived images, it was demonstrated that the plume spread over 2,580 km^2 of surface waters, i.e. two times the extent of the natural plume observed two months before the incident. The high concentrations of dissolved metals, including toxic heavy metals in the habitat, may distort or/and require adaptations of the dolphins' echolocation under such conditions. Therefore, this catastrophic incident may significantly increase the threat level of the northern franciscana population. SC/66b/SM04 contains a list of recommendations of actions to be implemented for an in-depth evaluation of the impacts of the mud on these dolphin populations. They include:

(a) implement passive acoustic monitoring in the mouth of the Doce River to ascertain the presence of cetaceans in the impacted area;
(b) implement short, medium and long-term monitoring of heavy metal concentrations in key components of the aquatic biota, including invertebrates, fish, turtles, seabirds and cetaceans. In the case of franciscana and Guiana dolphins, background information on the burden of heavy metals and the use of biomarkers in tissues should be addressed as reference data; and
(c) launch an outreach campaign with fishermen and local communities to increase awareness of the potential impacts of the mud on these dolphins.

The SWG **endorsed** the three recommendations above.

In discussion, the author noted that although mining operations have ceased, there is some continued leakage from the dam for which the responsible party is tasked with repairing. In addition, the responsible party is required to monitor environmental impacts in the region for five years and is just starting to organise this task. The SWG **expressed deep concern** about the amount of contaminated water discharged, the fact that the dam is still leaking contaminated water into the ecosystem and, moreover, that the dam is still vulnerable to additional losses. The SWG **recommended** that stabilisation of the dam and work to decontaminate and restore this ecosystem should proceed as soon as possible.

The SWG **agreed** that there is a critical need to learn from disaster situations such as this, to determine how long impacts last, what can be done to prevent such disasters in the future, and how to improve cleanup efforts and promote recovery after disasters. Injury assessment recommendations proposed here, and lessons learned from the *Deepwater Horizon* oil spill, should be incorporated into current franciscana work and, if possible, to identify other regions at risk from similar accidents ahead of the next disaster.

16. WORK PLAN

See Table 17 in the main Scientific Committee Report for the work plan for the SWG on Environmental Concerns. See Annex V for a summary of intersessional groups.

17. ADOPTION OF REPORT

The report was adopted at 21:09 on 15 June 2016. The SWG thanked Rowles and Parsons for their guidance during discussions and Greig and Ylitalo for their efficient rapporteuring.

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Appendix 1

AGENDA

1. Convenor's opening remark
2. Election of Chairs
3. Appointment of rapporteurs
4. Adoption of agenda
5. Review of available documents
6. State of the Cetacean Environment Report - SOCER
7. Chemical pollution
   - 7.1 Pollution 2020
   - 7.2 Data integration and mapping of POPs and trends
   - 7.3 Other chemical pollution
8. Oil spill impacts
   - 8.1 Review progress of the intersessional group
   - 8.2 Oil spill impact updates
   - 8.3 Review national, international or regional work on oil spill impacts on cetaceans
9. Cetacean diseases of concern
   - 9.1 Progress on website and intersession working group
   - 9.2 Other health issues in cetaceans
10. Strandings and mortality events
    - 10.1 Report of the intersessional Workshop on the Investigations of Large Mortality Events, Mass Strandings and International Stranding Response
    - 10.2 Chair's Summary of the IWC Workshop to Develop Practical Guidance for Handling Cetacean Stranding Events
    - 10.3 Review new information on mass stranding and mass mortality events
11. Effects of anthropogenic sound
    - 11.1 Review the report from the Workshop on Acoustic Masking and Whale Population Dynamics
    - 11.2 Progress on plans on workshop on stress
    - 11.3 Review ACCOBAMS and other regional, national or international work on ocean noise
    - 11.4 Effectiveness of marine mammal observers as a mitigation measure
    - 11.5 New sources of sound of concern for cetaceans
    - 11.6 Other noise concerns
12. Effects of climate change on cetaceans
13. Arctic issues
    - 13.1 Progress from intersessional group
    - 13.2 Review regional, national or international work on Arctic issues
14. Marine debris
    - 14.1 Progress of the intersessional group
    - 14.2 New information on marine debris impact on cetaceans
15. Other habitat-related issues

Appendix 2

LIST OF ACRONYMS

ACCOBAMS: Agreement on the Conservation of Cetaceans in the Black Sea Mediterranean Sea and Contiguous Atlantic Area
ALDFG: Abandoned, Lost or otherwise Discarded Fishing Gear
ASCOBANS: Agreement on the Conservation of Small Cetaceans of the Baltic and North Seas
AIS: Automatic Identification System
AMAP: Arctic Monitoring and Assessment Programme
CAFF: Conservation of Arctic Flora and Fauna (biodiversity working group of the Arctic Council)
CBMP: Circumpolar Biodiversity Monitoring Programme
CITES: The Convention on International Trade in Endangered Species of Wild Fauna and Flora
COFI: Committee on Fisheries (subsidiary body of the FAO Council)
CPAN: Circumpolar Protected Areas Network
DBO: Distributed Biological Observatory
EPPR: Emergency Prevention, Preparedness and Response (A Working Group of the Arctic Council)
FAO: Food and Agriculture Organization of the United Nations
GGGI: Global Ghost Gear Initiative
GMAST: Global Marine Animal Stranding Toolkit
ICMMPA: International Conference on Marine Mammal Protected Areas (IUCN)
IMO: International Maritime Organization
IQOE: International Quiet Ocean Experiment
IUCN: International Union for Conservation of Nature
JARPN and JARPNII: Japanese Whale Research Program under Special Permit in the North Pacific
JIP: Joint Institute of Petroleum
MPA-EG: Marine Protected Area Network Expert Group (reports to PAME)
MSFD: Marine Strategy Framework Directive (European Union)
NOAA: National Oceanic and Atmospheric Administration
ONS: Ocean Noise Strategy
PAME: Protection of the Arctic Marine Environment (A Working Group of the Arctic Council)
SAMBR: State of Arctic Marine Biodiversity Report
SOAR: Synthesis of Arctic Research
SOCER: State of the Cetacean Environment Report
SPAMI: Specially Protected Area of Mediterranean Importance
TINRO and ChukotTINRO: Pacific Research Fisheries Center, Russia
UNEP: United Nations Environment Programme
WGWAP: Western Gray Whale Advisory Panel

Appendix 3

STATE OF THE CETACEAN ENVIRONMENT REPORT (SOCER) 2016

Editors: M. Stachowitsch*, E.C.M. Parsons+ and N.A. Rose@

INTRODUCTION

Several resolutions of the International Whaling Commission, including Resolutions 1997-7 (IWC, 1998) and 1998-5 (IWC, 1999), directed the Scientific Committee to provide regular updates on environmental matters that affect cetaceans. Resolution 2000-7 (IWC, 2001) welcomed the concept of the State of the Cetacean Environment Report (SOCER) and requested the annual submission of this report to the Commission. The first full SOCER (Stachowitsch *et al.*, 2003) was submitted in 2003 and subsequent editions initiated and continued a cycle of focusing on the following regions: Mediterranean and Black Seas, Atlantic Ocean, Pacific Ocean, Arctic and Antarctic Oceans, Indian Ocean. Each SOCER also includes a Global section addressing the newest information that applies generally to the cetacean environment. The 2016 SOCER focuses on the polar oceans (Arctic and Antarctic), summarising key papers and articles published from *ca* 2014 through 2016 to date.

POLAR OCEANS

General

RAPID RETREAT OF EAST ANTARCTIC GLACIER A CAUSE FOR CONCERN

A study of the history of the advances and retreats of Totten Glacier in East Antarctica, coupled with an analysis of its underlying geology, predicted that if climate change continues at the current rate, within the next century the glacier may retreat to a threshold (100-150km from the coast) where the underlying geology is unstable. Further loss of the glacier would be exceedingly rapid and effectively unstoppable (causing it to withdraw 300+ km from the coast). The contribution to sea level rise from the retreat of this glacier alone would be 0.9-2.0m.

(SOURCE: Aitken, A.R.A., Roberts, J.L., van Ommen, T.D., Young, D.A., Golledge, N.R., Greenbaum, J.S., Blankenship, D.D. and Siegert, M.J. 2016. Repeated large-scale retreat and advance of Totten Glacier indicated by inland bed erosion. *Nature* 533: 385-389).

MARINE MAMMALS AND COD AS COMPETITORS IN THE BARENTS SEA

Cod, harp seals and minke whales are the top three main predators in the Barents Sea and compete for resources. During the last decade, cod abundance increased considerably, seal abundance declined, and the whale population remained stable. The success of cod was attributed to a greater availability of prey (mostly capelin) and a wider range of prey species than for the two mammals. A closer examination of body condition, however, revealed important details. Smaller cod fared better than larger cod, and the body condition (blubber thickness) declined in minke whales and even more so in seals, the latter species being more dependent on the ice edge. The authors underlined the importance of more routinely collecting condition data from mammals. They also called for improving multispecies models, which currently deliver contradictory results, to better include bottom-up versus top-down effects.

(SOURCE: Bogstad, B., Gjosaeter, H., Haug, T., and Lindstrom, U. 2015. A review of the battle for food in the Barents Sea: Cod *vs* marine mammals. *Front. Ecol. Evol.* 3: 1-17. doi:10.3389/fevo.2015.00029).

BOWHEAD WHALE BODY CONDITION IMPROVES IN THE PACIFIC ARCTIC

Over the past 2.5 decades, bowhead whale body condition, as measured by an index based on girth, has improved in the Beaufort Sea. This development is attributed to a series of physical changes in the Arctic. These include an overall reduction of sea ice, increased duration of open water, and favourable upwelling conditions. The duration of the melt season and the later date of freeze-up have also played a role. Together, these factors may have increased the productivity of the Pacific Arctic marine ecosystem, providing more food for whales. The authors provided a conceptual model of how changes in Arctic sea ice can affect bowhead whale body condition. This study underlines the importance of holistic approaches for better understanding and predicting changes in Arctic cetacean habitats.

(SOURCE: George, J.C., Druckenmiller, M.L., Laidre, K.L., Suydam, R., and Person, B. 2015. Bowhead whale body conditions and links to summer sea ice and upwelling in the Beaufort Sea. *Prog. Oceanog.* 136: 250-262, *http://dx.doi.org/10.1016/j.pocean.2015.05.001*).

CETACEAN BODY CONDITION IN THE BEAUFORT SEA IS CHANGING

Studies on the body condition of five marine predators in the Beaufort Sea over the past 20-40 years show changes that reflect changes in the marine ecosystem. The body condition of sub-adult bowhead whales (filter feeders) has apparently been improving, whereas condition has declined in beluga whales (predators). The direct causes of these opposing tends are unknown, but the former might be attributed to increased productivity (larger plankton populations) of this water body as sea ice cover declines, and the latter to a decline in the availability of preferred prey species (cod). The authors therefore called for studies that include multiple marine vertebrate species in order to establish baselines and to identify critical habitats of the respective species. These studies should be coordinated with oceanographic sampling at appropriate spatial and temporal scales to better explain the trends.

(SOURCE: Harwood, L.A., Smith, T.G., George, J.C., Sandstrom, S.J., Walkusz, W., and Divoky, G.J. 2015. Change in the Beaufort Sea ecosystem: Diverging trends in body condition and/or production in five marine vertebrate species. *Prog. Oceanog.* 136: 263-273, *http://dx.doi.org/10.1016/j.pocean.2015.05.003*).

FIRST GLOBAL INTEGRATED MARINE ASSESSMENT: ARCTIC OCEAN

This major overview of the world's oceans states that 'changes in ice cover, ocean warming, altered salt stratification, alterations in water circulation and fronts, and shifts in advection patterns show that oceans within the Arctic are subjected to significant change, and may face even more change in future'. The Arctic, for example, has warmed at more than twice the global rate, and sea-ice loss is accelerating. This negatively affects the location and timing of the algal blooms that form the base of the food chain. Arctic warming and sea-ice loss will facilitate the invasion of new species, hosts, harmful microorganisms and diseases. The retreating ice will also promote the introduction of shipping, fishing, petroleum activities and tourism, with their related

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threats. Arctic marine ecosystems are also 'highly likely to undergo significant changes' due to ocean acidification. For marine mammals, these combined developments increase the risks of direct mortality, displacement from critical habitats, noise disturbance, and increased exposure to hunting. The authors pointed to the need for 'adaptive and ecosystem-based management efforts to limit negative effects of existing and potential human use'.

(SOURCE: Inniss, L. and Simcock, A. (joint coordinators); Rice, J. (lead member of 12 contributors). 2016. The first global integrated marine assessment: World ocean assessment I. *United Nations, Chapter 36G:* 47pp, *http:/www.un.org/Depts/los/woa*).

FIRST GLOBAL INTEGRATED MARINE ASSESSMENT: SOUTHERN OCEAN

The Southern Ocean accounts for about 10% of the world's oceans. Fifty percent is covered by ice in winter, decreasing to 10% in summer. Overall, the Antarctic ice cover has been increasing, but modelling predicts a reduction of 33% by the end of the century. This general trend masks dramatic regional trends, e.g. declines in the Bellingshausen Sea and increases in the Ross Sea. The Southern Ocean is critical habitat for several baleen whale species that depend on a direct plankton food chain (diatoms-krill-vertebrates). Whaling and fisheries have altered the structure and functioning of the ecosystem. For whales, populations of their main prey, krill, appear to have declined considerably and partially been replaced by salps. Moreover, the Southern Ocean is at higher risk from ocean acidification than other oceans, and the hatching rates of krill eggs are known to be negatively affected by the level of acidification predicted for the end of the century. Overall, the expected changes from a unique ice-shelf covered ecosystem are 'likely to be among the largest ecosystem changes on the planet'.

(SOURCE: Inniss, L. and Simcock, A. (joint coordinators); Marschoff, E.R. (lead member of 10 contributors). 2016. The first global integrated marine assessment: World ocean assessment I. *United Nations, Chapter 36H:* 41pp, *http://www.un.org/Depts/los/woa*).

ANTARCTIC WATERS UNDER THREAT OF INCREASED USE AND LESS PROTECTION

CCAMLR is the legal doctrine presiding over the exploitation of marine life in the waters around Antarctica. It prioritises conservation. Recently, the concept of 'rational use', which is included in the Convention, has been interpreted by some of the 24 member states to imply an unconditional right to fish and to stall progress on establishing marine protected areas (MPAs) in the Southern Ocean. The latter also pertains to the Ross Sea, perhaps the healthiest large intact marine ecosystem left on the planet. The CCAMLR negotiation process even failed in its attempt to use the 'rational use' concept to ban shark finning. Considering the importance of the Southern Ocean for many of the world's cetacean populations, such interpretations of international environmental law should be viewed with concern and may help explain the efforts to introduce and maintain multiple, parallel levels of protection for cetaceans here and elsewhere.

(SOURCES: Jacquet, J., Blood-Patterson, E., Brooks, C., and Ainley, D. 2016. 'Rational use' in Antarctic waters. *Mar. Pol.* 63: 28-34; News. 2015. *Mar. Pollut. Bull.* 101: 3).

STATUS OF ARCTIC MARINE MAMMAL POPULATIONS AND CONSERVATION RECOMMENDATIONS

This paper summarised the available information on the abundance and trends for 78 Arctic marine mammal subpopulations (11 species). Importantly, because many of these species are closely associated with sea ice, the authors related this information to trends in sea ice habitat and differentiated 12 different Arctic regions. In all regions except the Bering Sea, the duration of the summer period (the period with less ice) has increased by 5-10 weeks (>20 weeks in the Barents Sea). Arctic marine mammals serve as biological indicators and are important for ecosystem health and traditional subsistence. The authors called for the following conservation measures: Improve co-management by local, federal and international partners; recognise spatial and temporal variability in subpopulation responses to climate change; implement monitoring programs with clear goals; mitigate cumulative impacts of human activity; and recognise limits of current protected species legislation.

(SOURCE: Laidre, K.L., Stern, H., Kovacs, K.M., Lowry, L., Moore, S.E., Regehr, E.V., Ferguson, S.H., Wiig, Ø., Boveng, P., Angliss, R.P., Born, E.W., Litovka, D., Quakenbush, L., Lydersen, C. Vongraven, D., and Ugarte, F. 2015. Arctic marine mammal population status, sea ice habitat loss, and conservation recommendations for the 21st century. *Conserv. Biol.* 29: 724-737. doi: 10.1111/cobi12474).

SYNTHESIS OF RESEARCH IN THE PACIFIC ARCTIC

The Synthesis of Arctic Research (SOAR) project was initiated to describe the biophysical changes in the Pacific Arctic region. These changes are recognised as extreme, leading to a 'new normal' Pacific Arctic marine ecosystem. SOAR conceptually outlines the past benthic-dominated, as opposed to future pelagic-dominated, system associated with the loss of sea ice. In cetaceans, such an ecosystem shift will be reflected in extrinsic (e.g. altered ranges, migration timing or abundance hotspots) and intrinsic (e.g. altered diet, body condition) responses. In bowhead whales, this may actually lead to improved body condition (increased girth) due to improved feeding opportunities. The authors introduced a new conceptual model (Arctic marine pulses model or AMP) that would help integrate the available knowledge and focus synthesis efforts on defined key areas and key processes. Cetaceans play an important role in these efforts, as sentinel species for ecosystem variability, food and cultural keystones for Arctic residents, and icons of the Arctic region for non-residents.

(SOURCE: Moore, S.E. and Stabeno, P.J. 2015. Synthesis of Arctic Research (SOAR) in marine ecosystems of the Pacific Arctic. *Prog. Oceanog.* 136: 1-11, *http://dx.doi.org/10.1016/j.pocean.2015.05.017*).

Habitat degradation

General

ARCTIC SHIPPING IN A CHANGING ENVIRONMENT

The retreat of Arctic sea ice due to climate change will make greater parts of the Arctic Ocean available to shipping and also significantly increase maritime activity there. This raises concerns over potential environmental impacts. This paper presents a framework for a quick and accurate environmental accounting for Arctic shipping. It is based on the use of the Automatic Identification System (AIS), which transmits a ship's identity code, position, heading and speed. Specifically, AIS information, coupled with information from ship registers, can provide crucial information on two key impacts - black carbon emissions (operational pollution) and carried fuel oil amounts (oil spill potential). This can be further expanded to include other ship-related pollution sources and combined with risk assessments, providing decision-makers with the best possible basis for better managing the impacts of Arctic shipping.

(SOURCE: Mjelde, A., Martinsen, K., Eide, M., and Endresen, Ø. 2014. Environmental accounting for Arctic shipping - A framework building on ship tracking data from satellites. *Mar. Pollut. Bull.* 87: 22-28).

Chemical pollution

SKIN OF SUBANTARCTIC DOLPHINS USEFUL IN BIOMONITORING MERCURY

The skin of nine by-caught Commerson's dolphins recovered from the shores of Tierra del Fuego showed that the mercury content in skin biopsies serve as good indicators of levels in internal organs (e.g. liver). Mercury is of particular

concern because it is harmful to wildlife and humans at very low concentrations and bioaccumulates, with highest values in top predators (such as dolphins). Mercury values ranged from 1.3-45μg g^{-1}, which is considerably lower than the 10-5,000μg g^{-1} in Mediterranean odontocetes and is among the lowest values for other dolphins from the South Atlantic Ocean. This type of mercury bioindication 'is a non-lethal approach that allows screening of a large number of specimens'. The authors considered this to be valuable in subantarctic waters, which are poorly studied regarding mercury levels, sources and processes.

(SOURCE: Cáceres-Saez, I., Goodall, R.N.P., Dellabianca, N.A., Cappozzo, H.L., and Guevara, S.R. 2015. The skin of Commerson's dolphins (*Cephalorhynchus commersonii*) as a biomonitor of mercury and selenium in subantarctic waters. *Chemosphere* 138: 535-743, *http://dx.doi.org/10.1016/j.chemosphere.2015.07.026*).

PFASS FOUND IN GREENLAND KILLER WHALES

PFASs were measured in killer whales from East Greenland (2012-13). A total of 17 PFASs were detected, including in a mother and calf, which suggests that PFASs can cross the placenta into a foetus. The mean level of total PFASs was 269ng.g^{-1} (±90SE). The ratio of contaminants suggested that killer whales lack the metabolic ability to degrade some of these toxic compounds, compared to other marine mammal species. The effects of these levels of contaminants on cetacean health are unknown, but this study documents a broad suite of this type of contaminant in Arctic cetaceans.

(SOURCE: Gebbink, W.A., Bossi, R., Rigét, F.F., Rosing-Asvid, A., Sonne, C. and Dietz, R. 2016. Observation of emerging per- and polyfluoroalkylsubstances (PFASs) in Greenland marine mammals. *Chemosphere* 144: 2,384-2,391).

(RELATIVELY LOW) CONCENTRATIONS OF PESTICIDES IN ARCTIC GRAY WHALES REFLECT GLOBAL PESTICIDE BACKGROUND

HCH and DDT are not present naturally in any ecosystem - any amount detected has anthropogenic origins. Compared to other regions, western Bering Sea gray whales had higher HCH values than DDT. This is probably due to a more active use of lindane and technical HCH in agriculture in the Russian Far East. Overall, concentrations of organochlorine pesticides in the tissues of western Bering Sea gray whales are relatively low compared to cetaceans from other regions, consistent with the area having little industry. Toxic substances found in the Arctic mostly originate further south. The authors concluded that detection of organochlorine contaminants in the Arctic reflects their widespread and global footprint. (Maximum contaminant levels (µg.g-1 lipid weight in liver tissue): α -HCH 6.16; β-HCH 2.75; γ-HCH 2.16; DDT 1.55; DDD 0.24; DDE 3.13)

(SOURCE: Tsygankov, V.Yu., Boyarova, M.D., and Lukyanova, O.N. 2015. Bioaccumulation of persistent organochlorine pesticides (OCPs) by gray whale and Pacific walrus from the western part of the Bering Sea. *Mar. Pollut. Bull.* 99: 235-239).

WASTEWATER PRODUCED BY OFFSHORE OIL AND GAS PRODUCTION IDENTIFIED AS A PROBLEM IN THE ARCTIC

The wastewater ('produced water') originating from offshore oil and gas production is composed of formation water, re-injected water and treatment chemicals, and contains petroleum hydrocarbons, heavy metals and toxic treatment chemicals. Tens of millions of barrels of such wastewater are produced worldwide every day and the volumes are steadily increasing. However, the number of available and emerging management technologies to address produced water is significantly limited in harsh environments. Beyond these technical difficulties, the Arctic ecosystem is considered to be more vulnerable to this type of pollution. The fact that offshore oil and gas production is moving into the harsher Arctic, and that this region is critical habitat for numerous cetacean species, is therefore a cause for concern.

(SOURCE: Zheng, J., Chen, B., Thanyamanta, W., Hawboldt, K., Zhamg, B., and Liu, B. 2016. Offshore produced water management: A review of current practice and challenges in harsh/Arctic environments. *Mar. Pollut. Bull.* 104: 7-19).

Disease and mortality events

Harmful Algal Blooms (HABs)

TOXIC ALGAE IN ARCTIC MARINE MAMMALS

HABs are predicted to increase in the Arctic as temperatures increase and sea ice declines due to climate change. Two of the most common neurotoxins produced in the region by toxic algae are domoic acid (DA) and saxitoxin (STX). These compounds are responsible for fish kills and can cause severe illness and death in humans, including amnesic shellfish poisoning and paralytic shellfish poisoning. They have also been shown to impair memory and cause developmental and behavioural abnormalities in marine mammals, and are linked to baleen whale mortalities. The authors examined data from 905 Alaskan marine mammals from 13 species. DA was detected in all species and had the highest prevalence in humpback whales (68%). STX was detected in 10 species, with the highest prevalence in humpback and bowhead whales. Moreover, foetuses from a beluga whale and a harbour porpoise contained detectable levels of DA; this means DA can be transferred from mothers to calves. The authors concluded that HAB toxins have the potential to negatively affect marine mammal health in the Arctic marine environment, both directly and indirectly (e.g. through potential increases in ship strikes on large cetaceans), as well as the health of humans that consume cetaceans in aboriginal hunts.

(SOURCE: Lefebvre, K.A., Quakenbush, L., Frame, E., Burek Huntington, K., Sheffield, G., Stimmelmayr, R., Bryan, A., Kendrick, P., Ziel, H., Goldstein, T., Snyder, J.A., Gelatt, T., Gulland, F., Dickerson, B., and Gill, V. 2016. Prevalence of algal toxins in Alaskan marine mammals foraging in a changing arctic and subarctic environment. *Harmful Algae* 55: 13-24, *http://dx.doi.org/10.1016/j.hal.2016.01.007*).

Climate change

INVADING PREDATORS PREDICTED TO RADICALLY RESTRUCTURE ANTARCTIC PENINSULA ECOSYSTEM

The Antarctic Peninsula is one of the most rapidly warming places on Earth. This warming is predicted to allow large predatory king crabs, now restricted to depths below 800m, to move from their deep-sea habitat upward into shallow shelf waters. This would have catastrophic consequences for the unique seafloor communities here, which have not evolved to withstand such predators. In shallower waters, the exchange processes between the seafloor communities and the overlying water ('benthic-pelagic coupling') are strong, so changes to these communities can affect processes in open Antarctic waters, the habitat for many cetacean species.

(SOURCES: Aronson, R.B., Smith, K.E., Vos, S.C., McClintock, J.B., Amsler, M.O., Moksnes, P.-O., Ellis, D.S., Kaeili, J. *et al.* 2016. 'Rational use' in Antarctic waters. *PNAS* 112: 12997-13002; News. 2015. *Mar. Pollut. Bull.* 100: 2).

HISTORICAL RECORDS SHOW THAT HUMPBACK WHALE CONDITION WAS LINKED TO SEA ICE EXTENT

The effect of krill abundance and whale body condition was assessed by examining historical records of humpback whale oil yields (1947-63) and annual estimates of sea ice extent, which was used to estimate krill abundance in humpback whale foraging grounds. Whale oil yield, and hence body condition, was significantly correlated with winter sea ice extent, i.e. levels of krill. The authors concluded that if sea 'ice extent declines in the future, as predicted under some climate change scenarios, whale food will decline and, in turn, energy acquisition will be hindered' and that 'changes in sea

ice and concomitant changes in krill abundance have long-term implications for [whale] condition and reproductive success'. Moreover, they suggested that malnourished whales encountered recently off the Australian coast might be the result of recent low Antarctic sea ice coverage.

(SOURCE: Braithwaite, J., Meeuwig, J.J., Letessier, T.B., Jenner, K.C.S., and Brierley, A.S. 2015. From sea ice to blubber: Linking whale condition to krill abundance using historical whaling records. *Polar Biol.* 38: 1,195-1,202).

SEA LEVEL RISE COULD BE TWICE THAT PREVIOUSLY ESTIMATED DUE TO INCREASED ANTARCTIC ICE MELTING

New models that account for how glaciers melt have predicted that sea level rise could be twice what was previously estimated, if current greenhouse gas emission rates continue. Large and irreversible sea level rise could occur by 2100, leading to major impacts for coastal environments. The models predict 1 m of sea level rise from Antarctica alone by the end of the century, for a total of nearly 2m, instead of the previously estimated ~1m rise. By 2500, Antarctic ice melt could contribute to 15m of sea level rise. The new models forecast a much higher rate of ice melting in Greenland and Antarctica than earlier models. One of the worst case emission scenarios saw the entire Larsen C ice shelf collapse by 2055, and the collapse of the entire West Antarctic ice sheet within 250 years. Such changes would have massive significance for all marine mammals and their habitats.

(SOURCE: DeConto, R.M. and Pollard, D. 2016. Contribution of Antarctica to past and future sea level rise. *Nature* 531: 591-597).

CHEMICAL ANALYSIS OF BALEEN PROVIDES INSIGHTS INTO WHALE MIGRATIONS, SEA ICE AND ARCTIC CLIMATE

A comparison of the stable isotopes of oxygen and hydrogen in the baleen of western Arctic bowhead whales and their zooplankton prey showed that the whales' migrations varied with sea ice concentration. The isotope values varied along the length of the baleen, reflecting the change in diet between the whales' seasonal habitats. The authors concluded that sea ice determines habitat accessibility for these whales and that baleen may also record historical sea ice concentrations and the Arctic climate, which would be especially valuable for periods earlier than the available sea ice records.

(SOURCE: deHart, P.A.P. and Picco, C.M. 2015. Stable oxygen and hydrogen isotope analysis of bowhead whale baleen as biochemical recorders of migration and arctic environmental change. *Polar Science* 9: 235-248, *http://dx.doi.org/10.1016j.polar.2015.03.002*).

SEA LEVEL RISE OF 3M FROM THE MELTING OF THE WEST ANTARCTIC ICE SHEET MAY BE INEVITABLE

Accelerating ice melt in Antarctica, coupled with measured instability of the west Antarctic ice sheet, have led to predictions of a major loss of Antarctic shelf ice. An analysis of glacier melting coupled with Antarctic topography suggested that 'a local destabilization causes a complete disintegration of the marine ice in West Antarctica'. The authors predicted that after 60 years of ice melting at the current rate, West Antarctica will become so unstable that it will effectively slide into the Southern Ocean, and topographic features will not be able to halt or hinder this process. As a result, 'Antarctica will irrevocably contribute at least 3m to global sea-level rise'. Some models suggest that increases in sea level rise resulting from Antarctic glacier melting might be counteracted by heavier snowfall over Antarctica, but an analysis of over 30,000 years' worth of snow and ice deposition suggested that increased snowfall will not offset the sea level rise caused by Antarctic ice loss. This significant sea level rise will, of course, have major impacts on global coastal and Antarctic ecosystems.

(SOURCES: Feldmann, J. and Levermann, A. 2015. Collapse of the West Antarctic Ice Sheet after local destabilization of the Amundsen Basin. *Proc. Nat. Acad. Sci.* 112: 14,191-14,196; Fudge, T.J., Markle, B.R., Cuffey, K., Buizert, C., Taylor, K., Steig, E.J., Waddington, E., Conway, H. and Koutnik, M. 2016. Variable relationship between accumulation and temperature in West Antarctica for the past 31,000 years. *Geophys. Res. Ltrs.* 43: 3,795-3,803).

ANOMALOUS AREAS OF HIGH PRODUCTIVITY IN THE ARCTIC

Anomalously high productivity (measured via chlorophyll-*a* levels) was found in multiple areas in the Arctic during the summer of 2015, including the Bering Sea shelf edge, off the southwest of Greenland, the Laptev Sea, the Sea of Okhotsk, the Labrador Sea and Fram Strait. The trend of productivity measured since 2003 has been increasing, especially in the Barents, Greenland and Laptev Seas and the eastern Arctic. The changing patterns of productivity in the Arctic include some areas of important cetacean habitat, and the shift in ecosystem productivity could have important ecological effects.

(SOURCE: Frey, K.E., Comiso, J.C., Cooper, L.W., Gradinger, R.R., Grebmeier, J.M. and Tremblay, J.É. 2015. Arctic Ocean primary productivity, *http://www.arctic.noaa.gov/reportcard/ocean_primary_productivity.html*).

MELTING ICE AND STRATIFICATION OF THE OCEANS COULD LEAD TO GREATER CLIMATE CHANGE IMPACTS THAN PREVIOUSLY PREDICTED

Researchers used numerical climate simulations, paleoclimate data, and modern observations to study the effect of increasing ice melt from Antarctica and Greenland. Melting will cause a stratification of polar oceans, with a pool of cold freshwater on the ocean surface, over a warmer ocean layer below. This stratification could reach the base of ice sheets that sit below sea level, causing the sheets to melt from below, exacerbating ice sheet melting. This stratification could lead to the shutdown of overturning circulation in the north Atlantic off the coast of Greenland, as well as to a weakening circulation and upwelling in the Southern Ocean. These changes could have catastrophic impacts on marine ecosystems. Changes in circulation would lead to a cooling of the North Atlantic, while temperature would increase in the equatorial region. The temperature differential between the two regions would drive more intense mid-latitude storms and hurricanes/cyclones. There may also be a greater sea level rise than predicted by the International Panel on Climate Change (IPCC), as previous models did not account for the exacerbating effect of ice melting. Sea level rise could reach 'several meters over a timescale of 50-150 years'. The authors noted that their modelling predicts outcomes differing substantively from IPCC assessment predictions and they concluded that 2°C of warming above preindustrial levels could be dangerous.

(SOURCE: Hansen, J., Sato, M., Hearty, P., Ruedy, R., Kelley, M., Masson-Delmotte, V., Russell, G., Tselioudis, G., Cao, J., Rignot, E., Velicogna, I., Tormey, B., Donovan, B., Kandiano, E., von Schuckmann, K., Kharecha, P., Legrande, A. N., Bauer, M., and Lo, K.-W. 2006. Ice melt, sea level rise and superstorms: Evidence from paleoclimate data, climate modeling, and modern observations that 2°C global warming could be dangerous. *Atmos. Chem. Phys*. 16: 3,761-3,812).

LOW ARCTIC ICE COVERAGE AND RECORD AIR TEMPERATURES IN 2015

The average annual sea ice extent in the Arctic during 2015 was 4.25 million square miles, the sixth smallest annual value since 1979. December sea ice coverage was the fourth lowest since 1979, at 300,000 square miles. This is 6% below the 1981-2010 Arctic sea ice average. Maximum Arctic sea ice extent (on 25 February 2015) occurred 15 days earlier than average and it was the lowest maximum value since 1979. In Alaska, 2015 tied with 2002 as the warmest years since record-

keeping began in 1929. The average air temperature over Arctic land areas (October 2014-September 2015) was 1.3°C above average - the highest since records began in 1900. More broadly, air temperatures over the Arctic were 3°C higher than at the beginning of the 20th century. Finally, there was melting on more than 50% of the surface of the Greenland ice sheet, with an observed increase in ice velocity and decrease in total mass of Greenland glaciers emptying into the sea.

(SOURCES: NOAA. 2016. Global Summary Information - December 2015, *https://www.ncdc.noaa.gov/sotc/summary-info/global/201512*; NOAA. 2016. Warmer air and sea, declining ice continue to trigger Arctic change, *http://www.noaanews.noaa.gov/stories2015/121515-arctic-report-card-warmer-air-and-sea-declining-ice-continue-to-trigger-arctic-change.html*; NOAA. 2016. Arctic Report Card: Update for 2015, *http://www.arctic.noaa.gov/reportcard/*).

SHIFTS IN WHALE POPULATIONS IN THE NORWEGIAN SEA POINT TO HIGH ECOLOGICAL PLASTICITY

The Norwegian Sea has been characterised by elevated average sea surface temperatures and reduced zooplankton biomass over the past two decades. This is reflected in altered cetacean abundances and distributions. For example, toothed whales show higher densities, which is interpreted as their ability to herd scattered fish schools into denser groups to improve predation success. Baleen whales, in turn, are less adapted to utilising low-biomass zooplankton densities and have apparently shifted their diet and/or their distribution; minke whales have shifted to herring and to more northern latitudes to follow krill, whereas fin whales have shifted to a capelin diet further north. Humpback whales are less frequently observed than previously, indicating a shift in habitat preference. Combined, these results point to high ecological plasticity, i.e. relatively rapid responses of cetaceans to changing prey densities and distributions and to elevated sea-surface temperatures.

(SOURCE: Nottestad, L., Kraft, B.A., Anthonypillai, V., Bernasconi, M., Langard, L., Mork, H.L., and Fernö, A. 2015. Recent changes in distribution and relative abundance of cetaceans in the Norwegian Sea and their relationship with potential prey. *Front. Ecol. Evol*. 2: 1-11. doi:10.3389/fevo.2015.00083).

ICELANDIC WATERS: CHANGES IN ENVIRONMENTAL CONDITIONS, CHANGES IN BALEEN WHALES

Pronounced oceanographic changes, including a rise in sea water temperature and increased flow of warm Atlantic water, have occurred in Icelandic waters since the mid-1990s. This has apparently caused a northward shift in the distribution of several fish species, a decrease in krill abundance and a collapse of the sandeel population off southern and western Iceland. These developments, in turn, have been associated with an increase in fin and humpback whale abundance, a decrease in minke whales, and a northward shift of blue whales. For example, the blue whale shift may reflect the decreased krill abundance south of Iceland, whereas the decrease in minke whales may reflect the decreased abundance of sandeel and capelin in two shelf areas. The developments relating to fin and humpback whales, however, are apparently more complex and difficult to explain or data are lacking, prompting the authors to call for continued monitoring of cetacean distribution and abundance and for studies on their feeding ecology.

(SOURCE: Víkingsson, G.A., Pike, D.G., Valdimarsson, H., Schleimer, A., Gunnlaugsson, T., Silva, T., Elvarsson, B.Þ, Mikkelsen, B. Øien, N., Desportes, G., Bogason, V., and Hammond, P.S. 2015. Distribution, abundance, and feeding ecology of baleen whales in Icelandic waters: Have recent environmental changes had an effect? *Front. Ecol. Evol*. 3: 1-18. doi:10.3389/fevo.2015.00006).

Noise impacts

SPECIFIC LEVELS OF SEISMIC SURVEY NOISE CAUSE BOWHEAD WHALES TO STOP CALLING

Bowhead whales decrease their calling rates when exposed to seismic survey sounds, but there has been little information on the exact level needed to cause this reaction. A study in the Alaskan Beaufort Sea found that initially, when seismic sounds were detected, bowhead calling rates increased, but the rate levelled off at a cumulative (over 10 minutes) received sound exposure level of approximately 94 dB re 1 μPa2/s. Bowhead calls started to decrease when the cumulative sound exposure level exceeded 127 dB re 1 μPa2/s and calls ceased entirely above 160 dB re 1 μPa2/s. These results give clear guidance on the level of seismic survey sound that can cause impacts on biologically important behaviours for these Arctic whales.

(SOURCE: Blackwell, S.B., Nations, C.S., McDonald, T.L., Thode, A.M., Mathias, D., Kim, K.H., Greene, C.R., and Macrander, A.M. 2015. Effects of airgun sounds on bowhead whale calling rates: Evidence for two behavioral thresholds. *PLoS ONE* 10(6): e0125720).

LARGE ICE ENTRAPMENTS OF NARWHALS COINCIDE WITH SEISMIC SURVEYS IN THE ARCTIC

There is increasing interest in exploring Arctic waters for oil and gas deposits, which require seismic surveys. An iconic Arctic species, the narwhal, has not been studied vis-à-vis seismic survey impacts. Three recent, large (1000, 30-100 and 50-100 narwhals, in 2008, 2009 and 2010, respectively) ice entrapments were coincident with seismic survey activities. The narwhals did not migrate offshore and became trapped in ice, which led to their deaths. While it is not clear if the seismic surveys prevented these narwhals from migrating offshore, the authors concluded 'that extreme caution should be taken by companies and agencies involved in planning and conducting marine seismic surveys in or in close proximity to narwhal summering grounds and migratory routes'.

(SOURCE: Heide-Jørgensen, M.P., Hansen, R.G., Westdal, K., Reeves, R.R. and Mosbech, A. 2015. Narwhals and seismic exploration: Is seismic noise increasing the risk of ice entrapments? *Biolog. Conserv.* 158: 50-54).

NOISE FROM A DRILLSHIP SHEDS LIGHT ON A NEW THREAT TO ARCTIC MARINE MAMMALS

Underwater noise in polar regions is of particular concern because the hydrographic conditions promote long-distance transmission of sound and the relatively pristine environment has little anthropogenic noise. Importantly, marine mammal densities are also high here. Marine mammals critically depend on sound for communication, orientation and feeding. The noise emitted by a drillship working in 484 m water depth in Baffin Bay off Greenland (maintenance work - 190 dB re 1 Pμa; drilling - 184 dB re 1 μPa) corresponded to the highest values for vessels such as icebreakers and tankers. Received levels were above background 16-38 miles away. Drillships are presumed to be the noisiest method of ocean drilling. The authors called for better describing other relevant noise sources and for examining overlapping exposures and cumulative impacts when evaluating potential new projects involving drillships in the Arctic.

(SOURCE: Kyhn, L.A., Sveegaard, S., and Tougaard, J. 2014. Underwater noise emissions from a drillship in the Arctic. *Mar. Pollut. Bull.* 86: 424-433, *http://dx.doi.org/10.1016/j.marpolbul.2014.06.037*).

PROLONGED EXPOSURE TO SOUND REDUCES BELUGA WHALE AUDITORY RESPONSES

An experimental study on a beluga whale found that prolonged exposure to a series of short and longer (1500 seconds) sounds led to a reduced auditory response in animals over time, although a response never entirely disappeared. The authors postulated that 'If prolonged sounds (in particular, man-made noises) produce adaptation to higher sound levels, the perception of 'target' sounds of lower levels may be negatively affected'. In other words, exposure to louder continuous sounds may result in cetaceans not responding

to quieter sources of biologically important sounds. The authors also suggested that prolonged sound exposure may cause 'a reduction or extinction of defensive and aversive behavioral reactions due to habituation', which could be dangerous for animals in cases where aversive behaviour might prevent, for example, a collision with a boat.

(SOURCE: Popov, V.V., Sysueva, E.V., Nechaev, D.I., Rozhnov,V.V. and Supin, A.Y. 2016. Auditory evoked potentials in the auditory system of a beluga whale *Delphinapterus leucas* to prolonged sound stimuli. *J. Acoust. Soc. Am.* 139(3): 1,101-1,109).

GLOBAL

General

ONLY A THIRD OF GLOBAL FISHERIES ARE BIOLOGICALLY HEALTHY

A review of 4,713 fisheries worldwide (representing 78% of global reported fish catch) found that only one third of these fisheries were in good biological (albeit not necessarily economic) condition. The authors noted that the average fishery is in poor health (overfished, with further overfishing occurring). The current poor status of fisheries is a concern for any species, including cetaceans, dependent on fish for survival. However, the authors also reported that if modern fishery management plans (such as 'catch shares') were implemented internationally, then by 2050 every fishery could be healthy and, moreover, there would be a 64% increase in fishery profits (US$53 billion a year).

(SOURCE: Costelloa, C., Ovandoa, D., Clavellea, T., Strauss, C.K., Hilborn, R., Melnychuk, M.C., Branch, T.A., Gainesa, S.D., Szuwalskia, C.S., Cabrala , R.B., Rader, D.N., and Leland, A. 2016. Global fishery prospects under contrasting management regimes. *PNAS*: in press doi:10.1073/pnas.1520420113).

WHALE DIET RESPONDS TO, AND WHALE SKIN REFLECTS, VARIABLE OCEAN CONDITIONS

Whales can serve as sentinel species for ecosystem processes and climate-related changes. Some cetaceans in some regions, such as humpback whales, exhibit plasticity in their diet and can adapt their foraging behaviour to the available prey. The diet of humpback whales in the California Current System, for example, switched from a krill-dominated diet to schooling fish with changes in the Pacific Gyre, sea surface temperatures and upwelling conditions, i.e. overall ecosystem dynamics. Importantly, this diet-related response to ecosystem shifts was detected non-lethally by analysing the isotopic signatures in the tissues of the predator, which reflect the signatures in the prey. The results lend further support to the notion that changes in environmental conditions and at lower trophic levels can be amplified at higher trophic levels based on non-linear responses.

(SOURCE: Fleming, A.H., Clark, C.T., Calambokidis, J., and Barlow, J. 2016. Humpback whale diets respond to variance in ocean climate and ecosystem conditions in the California Current. *Global Change Biol.* 22: 1214-1224, doi:10.1111/gcb.13171).

SPERM WHALES REDUCE FORAGING AND TIME AT SURFACE IN RESPONSE TO RESEARCH 'TAGGING' VESSEL

A study on tagged sperm whales in Norway analysing tag-recorded data found that sperm whales spent 34% less time at the sea surface and 60% more time in a non-foraging state in the presence of the research boat from which the tagging was being conducted. This study not only shows a reduction in biologically important foraging activity in the presence of a single vessel, but also shows that research vessels could have an impact on cetaceans by disturbing biologically important behaviours. The reduction in surface time has implications for sighting surveys and also visual mitigation surveys.

(SOURCE: Isojunno, S. and Miller, P.J.O. 2015. Sperm whale response to tag boat presence: Biologically informed hidden state models quantify lost feeding opportunities. *Ecosphere* 6: 1-46).

CURRENT MARINE PROTECTED AREAS POORLY REPRESENT BIODIVERSITY

This study assessed the overlap between the ranges of more than 17,000 marine species and MPAs. The results show that more than 97% of the species have less than 10% of their ranges represented in stricter MPA conservation classes. Marine mammals, for example, are by far the most poorly represented - more than 80% of the species have an overlap of less than 2% with MPAs. This stands in strong contrast to the minimum of 10% to which marine conservation plans aspire. The authors underlined the importance of EEZs and the role that individual countries could play in improving this situation - almost all of the very poorly represented species are found in EEZs. MPAs are an accepted, fundamental strategy for protecting marine biodiversity. The shortfalls presented in this paper are an additional incentive to pursue the agreed goal (within the Convention on Biological Diversity) of protecting more than 10% of the marine environment by 2020.

(SOURCES: Klein, C.J., Brown, C.J., Halpern, B.S., Segan, D.B., McGowan, J., Beger, M., and Watson, J.E.M. 2015. Shortfalls in the global protected area network at representing marine biodiversity. *Scient. Rep.* 5: 1-7. doi:10.1038/srep17539; News, *Mar. Pollut. Bull.* 102: 6).

CETACEANS HELP DETERMINE THE 'STATE OF THE CETACEAN ENVIRONMENT'

In examining the state of the cetacean environment, the degree to which cetaceans themselves shape and influence the marine environment is sometimes overlooked. This paper refers to whales as ecosystem engineers because they exert a more powerful and positive influence on the function of the oceans, global carbon storage and the health of commercial fisheries than previously thought. The 'great whales' (baleen and sperm whales) play an important role as predators and as prey. Whales also transfer nutrients (as faecal material) from the depths to the surface, where they promote plankton growth, and long-distance from feeding to calving areas. Finally, whale carcasses on the seafloor ('whale falls') provide a habitat for many endemic species. The authors went beyond outlining these roles in ecosystem function and listed a series of ecosystem services provided by whales. They concluded that the recovery of whales from commercial exploitation 'may help to buffer marine ecosystems from destabilising stresses and could lead to higher rates of productivity in locations where whales aggregate to feed and give birth.'

(SOURCES: Roman, J., Estes, J.A., Morisette, L., Smith, C., Costa, D., McCarthy, J., Nation, J.B., Nicol, S., Pershing, A., and Smetacek, V. 2014. Whales as marine ecosystem engineers. *Front. Ecol. Environ.* 12: 377-385, doi:10.1890/130220; News, *Mar. Pollut. Bull.* 85:4).

DISTURBANCE DURING PREGNANCY COULD LEAD TO LOSS OF GRAY WHALE CALVES

The actual effects of anthropogenic disturbance are often hard to quantify, but there has been some progress with estimating the bioenergetic impacts of such disturbances. A model was created for a female gray whale over a two-year reproductive cycle with three disturbance scenarios. The authors reported that a 4% energetic loss during the year of pregnancy would result in the female not producing a calf. During lactation if the female experienced a 37% energetic loss, the female would wean the calf early, with the calf having a lower-than-average body mass. If the female experienced a 30-35% energy loss pre-pregnancy, she would be unable to become pregnant, and a 40-42% energy loss could lead to female mortality. The study found that energy loss due to disturbance could lower reproductive success and even cause mortality, with reduced reproductive rates after just a small energy loss (4%) during the year of

pregnancy. In short, 10 days of lost foraging opportunities, due to disturbance, from e.g. noise or climate-related effects, could result in an unsuccessful pregnancy/loss of a calf.

(SOURCE; Villegas-Amtmann, S., Schwartz, L.K., Sumich, J.L. and Costa, D.P. 2015. A bioenergetics model to evaluate demographic consequences of disturbance in marine mammals applied to gray whales. *Ecosphere* 6: 1-19).

Habitat degradation

Fisheries interactions

ENTANGLEMENT IN FISHING GEAR IS A CAUSE OF MORTALITY AND SEVERE INJURY FOR SEVERAL WHALE SPECIES

A review of cases of whales entangled in fishing gear along the east coast of the USA and Canada (from 1994 to 2010) found that the gear's breaking strength ranged from 0.80 to 39.63kN, with a mean of 11.64kN. The average rope diameter was 9.5mm. The breaking strength of ropes entangling right and humpback whales was significantly higher than those entangling minke whales. In addition, ropes entangling adults were stronger than ropes entangling juveniles. The authors suggested that an increase in injuries in right whales was due to increasing breaking strength of gear (an increase that occurred during the mid-1990s). The authors concluded that 'broad adoption of ropes with breaking strengths of ≤7.56kN…could reduce the number of life-threatening entanglements for large whales by at least 72%, and yet could provide sufficient strength to withstand the routine forces involved in many fishing operations'.

(SOURCE; Knowlton, A.R., Robbins, J., Landry, S., McKenna, H.A., Kraus, S.D., and Werner, T.B. 2015. Effects of fishing rope strength on the severity of large whale entanglements. *Conserv. Biol.* 30: 318-328).

NEW INSIGHTS INTO FISHING GEAR ENTANGLEMENT OF CETACEANS

Beyond immediate drowning and severe injury, a key concern in whale entanglements worldwide is the longer-term damage and stress caused to cetaceans that tow fishing gear behind them, often across great distances. This study, for the first time, quantifies the amount of drag created by various types of fishing gear (rope, buoys, lobster and crab traps) collected from past right whale entanglements. The experimental results show that entanglement increases drag by an average of 1.5 times compared with a non-entangled whale, with buoys and floats having a significant effect. This causes entangled animals to spend twice as much energy to swim. Importantly, reducing the length of the trailing line by 75% decreases the drag by 85%, supporting the intuitive past efforts of disentanglement response teams. These new results are important in gauging the seriousness of injury and in supporting the decision-making process of disentanglement teams.

(SOURCES: van der Hoop, J.M., Corkeron, P., Kenney, J., Landry, S., Morin, D., Smith, J., and Moore, M.J. 2016. Drag from fishing gear entangling North Atlantic right whales. *Mar. Mamm. Sci.* 32: 619-642. doi:10.1111/mms.12292; News, *Mar. Pollut. Bull*. 102: 4).

Marine debris

MICROPLASTICS: A NEW HOT TOPIC IN MARINE RESEARCH

Plastics in the ocean have long been recognised as a severe threat to marine organisms, but the amount of, and hazards posed by, microplastics has only been recognised relatively recently. Microplastics are generally defined as measuring less than 5mm in diameter and include two categories: original plastic items (e.g. the plastic pellets used in the plastics industry) and fragments of larger items. Whereas larger plastic items pose an ingestion and entanglement threat to marine life, including cetaceans, microplastics pose a threat due to the effects of marine pollutants they can absorb onto their surfaces and the fact that the smallest fragments can be incorporated in the cells of marine organisms. Moreover, the term 'Plastisphere' has been coined to describe the microscopic life thriving on such tiny debris. DNA sequencing shows that Plastisphere bacteria differ between ocean basins and between plastic types. The number of papers written on microplastics is increasing rapidly; such papers have been published in 30 different scientific journals. Microplastics have been recorded directly or indirectly in almost all marine organisms, including cetaceans.

(SOURCES: Barboza, L.G.A and Giminez, B.C.G. 2016. Microplastics in the marine environment: Current trends and future perspectives. *Mar. Pollut. Bull.* 97: 5-12; Amaral-Zettler, L.A., Zettler, E.R., Slikas, B., Boyd, G.D., Melvin, D.W., Morrall, C.E., Proskurowski, G., and Mincer, T.J. 2015. The biogeography of the Plastisphere: Implications for policy. *Front. Ecol. Environ.* 13: 541-546. doi:10.1890/150017).

MICROPLASTICS FOUND IN THE INTESTINES OF A HUMPBACK WHALE

Large pieces of plastic (macroplastic) are known to be ingested by baleen whales; however, a new study reported substantive amounts of microplastic in the intestines of a humpback whale. Several varieties of plastic polymer (polyethylene, polypropylene, PVC, PET and nylon) were found, ranging in size from 1mm to 17cm. Despite these levels of microplastic in the whale's intestine, they may be lower than in other baleen whales, as humpbacks are lunge feeders rather than skimmers.

(SOURCE: Besseling, E., Foekema, E.M., Van Franeker, J.A., Leopold, M.F., Kühn, S. Rebolledo, E.L.B., Heße, E., Mielke, L., IJzer, J., Kamminga, P., Koelmans, A.A. 2015. Microplastic in a macro filter feeder: Humpback whale *Megaptera novaeangliae. Mar. Pollut. Bull.* 95: 248-252).

MORE PLASTIC THAN FISH IN THE WORLD'S OCEANS IN THE NEAR FUTURE

The use of plastic has increased 20-fold in the last half-century and is predicted to double again in the next 20 years. Ninety-five percent is not recycled into the economy (after a relatively short first use), while 32% escapes collection systems. Millions of tons enter the sea every year. A report (The New Plastics Economy) states that 'In a business as usual scenario, the ocean is expected to contain one tonne of plastic for every three tonnes of fish by 2025, and by 2050, more plastics than fish (by weight).' Beyond being an ecological issue, marine litter has become a socio-economic problem, prompting a detailed report commissioned by the United Nations Environment Programme (UNEP) and conducted by the Institute for European Environmental Policy. Finally, more than 150 countries in the United Nations Environment Assembly (UNEA) have adopted a resolution on marine plastic debris and microplastics, and called for joining the Global Partnership on Marine Litter (*http://www.unep.org/gpa/gpml*) and the online marine litter network (*http://www.marinelitternetwork.org*).

(SOURCES: *The New Plastics Economy: Rethinking the Future of Plastics*. 2016. World Economic Forum and the Ellen MacArthur Foundation, 36 pp.; Watkins, E., Brink, P., Withana, S., Mutafoglu, K. Schweitzer, J-P., Russi, D., and Kettunen, M. 2015. *Marine litter: Socio-economic study*. Scoping Report. London, Brussels. May 2015; UNEP, Resolution UN/EA-1/6).

Ship strikes

WATER LAYERING IN THE SUMMER INCREASES COLLISION RISK FROM SHIPPING IN SPERM WHALES

Stratification of water layers (especially in warm waters) can dramatically affect underwater sound transmission. A modelling exercise examined noise level exposure of sperm whales to an approaching merchant vessel (15 knots) and a fast ferry (37 knots) in Mediterranean waters. The model found that received levels of noise generally were low, but

increased dramatically when vessels were in close proximity, and this was exacerbated in summer months when waters were stratified. Sperm whales were estimated to have just 28 seconds' warning of the approach of a fast ferry in summer (due to the sudden increase in sound level), making the ability to conduct an avoidance manoeuvre unlikely (70 seconds in winter). For a merchant vessel, the possible response time was 175 seconds in winter and 70 seconds in summer. To decrease collision likelihood, the authors recommended that shipping lanes avoid high densities of cetaceans, but 'speed limitation in whale high density areas remains an obvious way to augment the vessel's ability to avoid a collision and is also efficient at providing the whale with enough time to escape an imminent collision'.

(SOURCE: Gannier, A. and Marty, G. 2015. Whales' ability to avoid approaching vessels is affected by sound reception in stratified waters. *Mar. Pollut. Bull.* 95: 283-288).

THE DIVING BEHAVIOUR OF BLUE WHALES IN RESPONSE TO SHIPPING INCREASES THE RISK OF SHIP STRIKES

Tagged blue whale behaviour and ship movements were recorded off the coast of California. Fifty-five percent of blue whales engaged in shallow dives when in the path of on-coming ships, but they did not try to avoid ships horizontally. They also did not appear to avoid areas of dense shipping traffic. The authors concluded that the responses of blue whales 'limit their ability to adjust their response behaviour to different ship speeds' and that this 'is likely a factor in making blue whales, and perhaps other large whales, more vulnerable to ship strikes'. If the whales are in a busy shipping lane they may be particularly vulnerable because, after responding to one ship, they spend an extended period near the surface, and may be more likely to be hit by a following vessel. Their lack of horizontal avoidance also keeps the whales within the busy shipping lanes, again increasing collision risk.

(SOURCE: McKenna, M.F., Calambokidis, J., Oleson, E.M., Laist, D.W. and Goldbogen, J.A. 2015. Simultaneous tracking of blue whales and large ships demonstrates limited behavioral responses for avoiding collision. *Endang. Species Res*. 27: 219-232).

REAL TIME ALERTS FOR MARINERS MIGHT BE A FEASIBLE WAY TO AVOID WHALE COLLISIONS

A survey was administered to mariners to determine their attitudes to endangered whales and determined that approximately three-quarters were interested in receiving information on whales and conservation measures. The preferred method (84%) for receiving information was via their navigational telex (NAVTEX), as this was generally considered not to be disruptive to their activities (72%). A possible secondary method was via Automatic Identification Systems (AIS), which was suggested by 72%, although this would be slightly more disruptive to routine operations. In summary, the authors considered that mariners were 'moderately receptive' to receiving alerts about whales while underway. Real time alerts for whales and mitigation actions might be the 'solution to reducing the risk of vessel strikes to whales by bringing current and updated information on whale locations to mariners'.

(SOURCE: Reimer, J., Gravel, C., Brown, M.W. and Taggart, C.T. 2016. Mitigating vessel strikes: The problem of the peripatetic whales and the peripatetic fleet. *Mar. Pol.* 68: 91-99).

MANDATORY SHIP REPORTING SYSTEM FOR ATLANTIC RIGHT WHALES DEEMED SUCCESSFUL

North Atlantic right whales are among the world's most endangered cetacean species, with ship strikes posing their most serious threat. In 1998, the USA, in cooperation with the IMO, created two Mandatory Ship Reporting (MSR) systems in two key right whale habitats (New England and Georgia/Florida), designed to improve mariner awareness of ship strikes. In their analysis, the authors evaluated more than 26,000 messages over the 15-year history of these MSRs. Compliance - based solely on 'good faith' - is apparently good and vessel speeds have decreased (a requirement as of 2008). The authors concluded that MSRs have 'probably provided an important function in notifying a broad international community about vessel/whale collisions', although better information about reporting requirements is one of the recommended improvements. Finally, the threat of collisions may have also been reduced by the global economic situation (reduced ship traffic and a shift to the use of fewer but larger ships).

(SOURCE: Silber, G.K., Adams, J.D., Asaro, M.J., Cole, T.V.N., Moore, K.S., Ward-Geiger, L.I., and Zoodsma, B.J. 2015. The right whale mandatory ship reporting system: A retrospective. *PeerJ* 3:e866; DOI 10.7717/peerj.886).

Chemical pollution

FLAME RETARDANTS FOUND IN DOLPHIN BRAIN TISSUE AT HIGHER LEVELS THAN EXPECTED

Twenty-six dolphins of five species were examined for halogenated flame retardants (such as PBDE and HBB) in both the brain and blubber. Flame retardants were found in the brain, showing that they can cross the blood-brain barrier. Moreover, some compounds, such as HBB, were found in higher concentrations in brain than in blubber. This has major toxicological implications, as these halogenated hydrocarbons could be potentially more neurotoxic than previously assumed.

(SOURCE: Barón, E., Hauler, C., Gallistl, C., Giménez, J., Gauffier, P., Castillo, J.J., Fernández-Maldonado, C., de Stephanis, R., Vetter, W., Eljarrat, E., and Barcelo, D. 2015. Halogenated natural products in dolphins: Brain-blubber distribution and comparison with halogenated flame retardants. *Environ. Sci. Technol.* 49: 9,073-9,083).

DETERMINING CONTAMINANT LEVELS THAT IMPAIR MARINE MAMMAL IMMUNE SYSTEMS

This study assessed field and laboratory data thresholds for immune system responses of marine mammals to a variety of contaminants. Across all the marine mammals investigated, levels of contaminants that inhibit lymphocyte (white blood cell) proliferation were between 0.001-10 ppm for PCBs, 0.002-1.3ppm for mercury, 0.009-0.06ppm for methyl mercury and 0.1-2.4ppm for cadmium. Similarly, thresholds for suppression of phagocytosis (engulfing of pathogens by white blood cells) were 0.6-1.4ppm and 0.08-1.9ppm for PCBs and mercury, respectively. Specifically for cetaceans, the threshold level at which lymphocyte proliferation impairment began was 5.42ppm±2.15 for PCBs (with 50% affected at 48.4ppm±9.26), 0.047ppm±0.059 (50% at 0.36ppm±0.2) for mercury, 0.016ppm±0.0049 (50% at 0.039ppm±0.0059) for methyl mercury and 0.21ppm±0.45 (50% at 5.64ppm±5.05) for cadmium. The phagocytosis threshold for cetaceans was 1.1ppm±0.7 (50% affected: 8.2ppm±1.1) for PCBs and 1.88ppm±36.16 (50% at 10.42ppm±10.00) for mercury. This provides important information on the levels of contaminants that can affect cetacean immune systems and therefore increase their vulnerability to, and mortality risk from, disease.

(SOURCE: Desforges, J.P.W., Sonne, C., Levin, M., Siebert, U., De Guise, S., and Dietz, R. 2016. Immunotoxic effects of environmental pollutants in marine mammals. *Environ. Inter.* 86: 126-139).

HEAVY METAL POLLUTION MAY PROMOTE SKIN FUNGUS IN CETACEANS

Cetaceans, positioned at the top of the food chain, typically accumulate the highest level of toxic pollutants such as heavy metals. The most widely used non-invasive method to test cetaceans is to analyse skin samples. The authors used skin biopsies from 40 false killer whales mass-stranded on

South Africa's Cape Peninsula. They report a link between the occurrence of fungus (128 species in 22 skin samples) and higher aluminium:selenium and aluminium:zinc ratios. The conclusion is that elevated levels of some toxic metals such as aluminium can compromise the immune response of cetaceans, rendering them susceptible to fungal invaders. This supports the approach of using cetacean skin to monitor the bioaccumulation of trace elements and provide an indication of animal and ecosystem health.

(SOURCE: Mouton, M., Przybylowicz, W., Postma, F., Thornton, M., Archer, E., and Botha, A. 2015. Linking the occurrence of cutaneous opportunistic fungal invaders with elemental concentrations in false killer whale (*Pseudorca crassidens*) skin. *Environ. Microbiol. Rep.* 7: 728-737, doi:10.1111/1758-2229.12302).

RADIOACTIVE CONTAMINATION FROM FUKUSHIMA DISASTER DETECTED IN JAPANESE CETACEANS

Radiocaesium levels (^{134}Cs and ^{137}Cs) were analysed in the muscle of stranded cetaceans on the coast of Hokkaido, Japan, after the Fukushima nuclear power plant accident (in March 2011). Radiocaesium was mainly detected in cetaceans stranded along the North Pacific coast of Hokkaido between June and October 2011. Contaminated cetacean species included Pacific white-sided dolphin, harbour porpoise, Dall's porpoise, humpback whale and common minke whale, including a by-caught Pacific white-sided dolphin and Dall's porpoise. ^{137}C was also found in pygmy sperm whales. The highest level of radioactive contamination was found in a common minke whale (^{134}Cs: 14.39 Bq kg^{-1}; ^{137}Cs: 19.88 Bq kg^{-1}). The authors suggested that contamination was from exposure to contaminated sea water rather than ingesting contaminated prey. In addition, two red meat samples from common minke whales caught off Kushiro during the JARPN program were obtained from retail stores in June and October 2011, and were analysed. The samples were contaminated with ^{137}Cs (1.05 and 2.87 Bq kg^{-1} respectively).

(SOURCE: Nakamura, T., Kimura, O., Matsuda, A., Matsuishi, T., Kobayashi, M. and Endo, T. 2015. Radiocesium contamination of cetaceans stranded along the coast of Hokkaido, Japan, and an estimation of their travel routes. *Mar. Ecol. Prog. Ser.* 535: 1-9).

MARINE MAMMAL TOXICOLOGY ENTERING A NEW ERA

A special journal issue has been devoted to marine mammal toxicology. Marine mammals are exposed to a wide variety of pollutants and, due to bioaccumulation and biomagnification, often exhibit the highest concentrations of toxic substances. The practical, legal and ethical constraints on toxicological research call for new and innovative approaches to gauging the risks to the health of these organisms and, indirectly, to their habitats. The authors - guest editors for the special issue - argued for a more efficient interplay between in vivo, in vitro and in silico research. This is a major challenge considering the ever-changing environment, changing exposures, the role of 'old' pollutants, and the rapid introduction of novel and emerging compounds. Streamlined conservation and management programmes will increasingly require a combination of site-specific knowledge and a more holistic approach, in order to apply the findings to population-, species-, or habitat-related risk assessments and to identify causal relationships.

(SOURCE: Weijs, L. and Zaccaroni, A. 2016. Toxicology of marine mammals: New developments and opportunities. *Arch. Environ. Contam. Toxicol.* 70: 1-8, doi:10.1007/s00244-015-1233-9).

Disease and mortality events

Harmful Algal Blooms (HABs)

DO SOME BOTTLENOSE DOLPHINS HAVE A GENETIC RESISTANCE TO HARMFUL ALGAL BLOOM TOXINS?

A comparison was made among genetic profiles of common bottlenose dolphins along the eastern US Atlantic that experienced HAB events, and a genetic difference was found between live and dead dolphins. This suggests that some dolphin populations might have a genetic resistance to HABs, with 'patterns suggesting a common genetic-based mechanism of resistance to brevetoxins in bottlenose dolphins'. It is possible that other cetacean species might also show genetic resistance or susceptibility.

(SOURCE: Cammen, K.M., Schultz, T.F., Rosel, P.E. and Wells, R.S. 2015. Genomewide investigation of adaptation to harmful algal blooms in common bottlenose dolphins (*Tursiops truncatus*). *Molec. Ecol.* 24: 4,697-4,710).

ELEVATED SOUTHERN RIGHT WHALE CALF MORTALITY OVER LAST DECADE PROBABLY DUE TO HARMFUL ALGAL BLOOMS

Beginning in the year 2005, the number of southern right whale deaths at Península Valdés, Argentina, jumped more than 10-fold, i.e. from less than 10 to 65 per year. This situation has been classified as an 'unusual mortality event'. Ninety percent of these deaths in this important nursery ground were very young calves. New research results point to a correlation between these mortalities and concentrations of toxic dinoflagellate algae. These planktonic algae produce a potent neurotoxin; blooms were associated with higher mortalities, whereas lower algal densities were associated with lower mortalities. Such HABs force the closure of shellfish harvesting, but these new results show that even the largest creatures in the ocean are vulnerable. Moreover, the frequency of HABs has been linked to eutrophication, and HABs are also expected to increase with climate change.

(SOURCES: Wilson, C., Sastre, A.V., Hoffmeyer, M., Rowntree, V.J., Fire, S.E., Santenelli, N.H., Ovejero, D., and 10 others. 2016. Southern right whale (*Eubalaena australis*) calf mortality at Península Valdés, Argentina: Are harmful algal blooms to blame? *Mar. Mamm. Sci.* 32: 423-451; News. 2015, *Mar. Pollut. Bull.* 101: 1).

Oil spills

HIGH CALF MORTALITY ASSOCIATED WITH DEEPWATER HORIZON OIL SPILL

The high level of dolphin mortality associated with the *Deepwater Horizon* oil spill was notable for the large proportion of perinatal (just before or after birth) mortalities. A comparison of stranding data with adjacent areas and an analysis of histological samples determined that dolphin calves exposed to the *Deepwater Horizon* spill were more likely to have died *in utero* or very soon after birth and to have pneumonia (not associated with lungworm infection). There was also a high proportion of calves with *Brucella* spp. infections. The authors also noted that '[e]xposure to oil spill-associated contaminants and immune system perturbations could have potentially led to an increase in non-*Brucella* infections affecting the placenta or to moderate to severe lung disease and bacterial pneumonias identified in live and dead, non-perinatal dolphins during the [mass mortality event]'. Moreover these infections and 'late-term pregnancy losses or poor post-partum survival of [these calves] may be directly related to the poor health of dolphin dams following the [*Deepwater Horizon*] oil spill'.

(SOURCE: Colegrove, K.M., Venn-Watson, S., Litz, J., Kinsel, M.J.,Terio, K.A., Fougeres, E., Ewing, R., Pabst, D.A., McLellan, W.A., Raverty, S., Saliki, J., Fire, S., Rappucci, G., Bowen-Stevens, S., Noble, L., Costidis, A., Barbieri, M., Field, C., Smith, S., Carmichael, R.H., Chevis, C., Hatchett, W., Shannon, D., Tumlin, M., Lovewell, G., McFee, W. and Rowles, T.K. 2016. Fetal distress and *in utero* pneumonia in perinatal dolphins during the Northern Gulf of Mexico unusual mortality event. *Dis. Aquat. Org.* 119: 1-16).

INCREASED MORTALITY AND REDUCED CALVING RATES IN DOLPHINS AFTER DEEPWATER HORIZON OIL SPILL

After 47 months of monitoring 10 pregnant bottlenose dolphins exposed to the *Deepwater Horizon* oil spill, only 20% had produced calves (as compared to 83% in a comparison population). This lower calving rate was

statistically significant. It was noted that 57% of the pregnant females that did not produce a calf showed signs of moderate to severe lung disease. In addition, the animals' survival rate was lower (86.8%) than the survival rates in comparable populations (e.g. 95.1% and 96.2%). The authors concluded that 'evidence suggests that dolphin reproduction and survival is being impacted by chronic disease, indicating that the effects of the [*Deepwater Horizon*] oil spill have been long-lasting'.

(SOURCE: Lane, S.M., Smith, C.R., Mitchell, J., Balmer, B.C., Barry, K.P., McDonald, T., Mori, C.S., Rosel, P.E., Rowles, T.K., Speakman, T.R., Townsend, F.I., Tumlin, M.C., Wells, R.S., Zolman, E.S. and Schwacke, L.H. 2015. Reproductive outcome and survival of common bottlenose dolphins sampled in Barataria Bay, Louisiana, USA, following the *Deepwater Horizon* oil spill. *Proc. R. Soc. B* 282: 20151944, 1-9).

BOTTLENOSE DOLPHIN MORTALITIES AS A RESULT OF THE DEEPWATER HORIZON OIL SPILL

The US Government declared a UME due to an unusually high number of cetacean mortalities after the *Deepwater Horizon* oil spill. Histological samples from common bottlenose dolphins stranding before and after the oil spill were compared and the results show that animals after the spill event were significantly more likely to have bacterial pneumonia (22% *vs* 2%) and a thin adrenal cortex (33% *vs* 7%) than animals before the UME. For 70% of the dolphins that had bacterial pneumonia, it was a major factor in their death. The lesions found were similar to those described from other petroleum-related exposures. The causes of death were likely due to increased susceptibility to pneumonia due to impaired immune systems, or to some effect of inhaling oil, and/or to life-threatening adrenal problems due to oil-related adrenal damage during stressful events such as pregnancy, disease or cold temperature. The authors concluded that 'Exposure of dolphins to elevated petroleum compounds present in coastal [Gulf of Mexico] waters during and after the [*Deepwater Horizon*] oil spill is proposed as a cause of adrenal and lung disease and as a contributor to increased dolphin deaths'. This clearly shows that oil spills are a threat to cetaceans.

(SOURCE: Venn-Watson, S., Colegrove, K.M., Litz, J., Kinsel, M., Terio, K., Saliki, J., Fire, S., Carmichael, R., Chevis, C., Hatchett, W., Pitchford, J., Tumlin, M., Field, C., Smith, S., Ewing, R., Fauquier, D., Lovewell, G., Whitehead, H., Rotstein, D., McFee, W., Fougeres, E. and Rowles, T. 2015. Adrenal gland and lung lesions in Gulf of Mexico common bottlenose dolphins (*Tursiops truncatus*) found dead following the *Deepwater Horizon* oil spill. *PLoS ONE* 10(5): e0126538. doi:10.1371/journal.pone.0126538).

Climate change

FAILURE TO ADAPT FISHERIES MANAGEMENT TO CLIMATE CHANGE EFFECTS LED TO FISH STOCK COLLAPSE

For the past decade, Gulf of Maine water temperatures have increased more rapidly than 99% of other areas. This led to increased mortality, and reduced recruitment, of cod in this region. As fishery management regimes were not monitoring or considering the effects of climate change, this ultimately led to greater extraction of fish than was sustainable, and cod became overfished. The authors concluded that 'The experience in the Gulf of Maine highlights the need to incorporate environmental factors into resource management'. Although the study is in a limited area, the findings are applicable to other regions and the implications are important for the management of all marine living resources - rapid management responses to climate change effects are essential.

(SOURCE: Pershing, A.J., Alexander, M.A., Hernandez, C.M., Kerr, L.A., Le Bris, A., Mills, K.E., Nye, J.A., Record, N.R., Scannell, H.A., Scott, J.D., Sherwood, G.D., and Thomas, A.C. 2015. Slow adaptation in the face of rapid warming leads to collapse of the Gulf of Maine cod fishery. *Science* 305: 809-812).

LONGER ICE-FREE SEASONS INCREASE NUMBER OF GRAY WHALE CALVES AND EL NIÑO INFLUENCES BREEDING LOCATION

Concern has been expressed about the effects of climate change on the distribution and migration of gray whales. A recent study investigated the effect of summer sea ice coverage on gray whale feeding grounds and on numbers of mother-calf pairs in breeding lagoons in Mexico, and whether the El Niño/Southern Oscillation (ENSO) influenced the distribution of mother-calf pairs in breeding lagoons. The results indicate that the number of calves increased after an extended ice-free summer, with fewer calves during a shorter ice-free season. The ENSO also affected the winter distribution of mother-calf pairs, with whales preferring southern breeding areas during years with colder sea temperatures (La Niña) and more northern breeding areas during warmer periods (El Niño), perhaps to reduce thermal-stress for new-born calves and their mothers. The southern-most breeding area experiences a high level of whale-watching vessel traffic, and it is possible that this ENSO-related shift could be used to predict periods of high anthropogenic impact. Accordingly, during La Niña years, animals may be exposed to more whale-watching vessels. This study is particularly important because it illustrates the ability for climate change to directly influence reproductive rates in large whales.

(SOURCE: Salvadeo, C.J., Gómez-Gallardo, A., Nájera-Caballero, M., Urbán-Ramirez, J. and Lluch-Belda, D. 2015. The effect of climate variability on gray whales (*Eschrichtius robustus*) within their wintering areas. *PLoS ONE* 10(8): e0134655).

PREDICTED IMPACTS OF CLIMATE CHANGE ON MARINE VERTEBRATES

Various shifts in marine food webs are predicted as the result of climate change. For example, a decline in copepods in the North Sea would affect not only right whales (copepods are their primary prey species), but also Atlantic herring and sandeel (which prey upon copepods). These latter two are important prey species for species such as common minke whales. In the California Current system, Humboldt squid are predicted to increase, which will lead to a decrease in mesopelagic fish, but could lead to an increase in krill. Changes in timing of life events (e.g. breeding) will change for a variety of species. 'Changing climate creates systemic effects that will ripple through marine food webs, affecting all trophic levels. Most climatic effects on seabird and mammalian consumers…will be indirect, operating via changes in ocean productivity and food webs' (p.776).

(SOURCE: Sydeman, W.J., Poloczanska, E., Reed, T.E. and Thompson, S.A. 2015. Climate change and marine vertebrates. *Science* 350: 772-777).

Noise impacts

THE STRATEGIES OF WHALES FOR COPING WITH NOISIER HABITAT MAY NOT WORK WITH ANTHROPOGENIC SOUND SOURCES

In this study, the response of humpback whales to increasing noise varied according to whether the noise source was natural (wind) or anthropogenic (vessels). None of the examined strategies for coping with an increasingly noisy environment (e.g. changing the volume of vocalisations or the type of communication signals) were observed when the whales were exposed to vessel noise, but some were observed in response to wind noise. This suggests that humpbacks may not be able to cope with louder anthropogenic sound sources in the same way they cope with louder natural sources. While humpbacks may have multiple strategies to cope with increases in natural noise, these strategies may be ineffective in the face of increasing anthropogenic noise.

(SOURCE: Dunlop, R.A. 2016. The effect of vessel noise on humpback whale, *Megaptera novaeangliae*, communication behaviour. *Anim. Behav.* 111: 13-21).

HARBOUR PORPOISES ARE AFFECTED BY SHIPPING MORE THAN PREVIOUSLY PREDICTED

It is often assumed that harbour porpoises, given that they have poor low frequency hearing, will have minimal reactions to shipping noise. However, a study examining porpoises in a sea pen determined that low levels of mid- to high frequency noise (0.25-63kHz) produced by passing ships were enough to elicit a response. Received sound levels eliciting a response were 113-133 dB re 1 μPa (rms). Levels that caused reactions would be expected at distances of 1 km or more from the source. The authors noted that reactions occurred 50% of the time at 123 dB re 1 μPa (rms) averaged over 30s, and this would be a better level for mitigating harbour porpoise impact then the levels currently used. The authors concluded that 'vessel noise is a, so far, largely overlooked, but substantial source of disturbance in shallow water areas with high densities of both porpoises and vessels'.

(SOURCE: Dyndo, M., Wiśniewska, D.M., Rojano-Doñate, L. and Madsen, P.T. 2015. Harbour porpoises react to low levels of high frequency vessel noise. *Scien. Repts.* 5: 11083, 1-9).

A 'RAMP-UP' OR 'SOFT START' OF SEISMIC SURVEY ARRAYS MAY BE AN EFFECTIVE MITIGATION METHOD

A slow increase in source level of seismic survey air guns, also known as a 'ramp-up' or 'soft start', is a mitigation measure that is frequently used to reduce impacts on cetaceans, but there has been little research into its efficacy. Observations of humpback whale responses to a seismic source using 'ramp-up', a seismic source that did not 'ramp up' and a control vessel simply dragging a seismic survey array, were compared. Whales moved away from the seismic survey vessel regardless of whether the air guns were in use or not, but avoidance was more substantive when air guns were active. The authors stated that 'there was no evidence that either 'ramp-up' or the constant source at a higher level was superior for triggering whales to move away from the source vessel'. However, ramping up the source level does mean that the sounds start at lower levels, reducing the intensity of sound exposure the whales experience, especially when an animal is near to an array when operations begin. The authors concluded that humpback whales 'are likely to move away from a source during a ramp-up sequence, and by doing so would be exposed to lower received levels while close to the source'.

(SOURCE: Dunlop, R.A., Noad, M.J., McCauley, R.D., Kniest, E., Slade, R., Paton, D., and Cato, D.H. 2016. Response of humpback whales (*Megaptera novaeangliae*) to ramp-up of a small experimental air gun array. *Mar. Pollut. Bull.* 103: 72-83).

REVIEWS ON UNDERWATER NOISE IMPACTS

Several reviews on underwater noise impacts have been produced in the past year. One addresses masking, i.e. underwater noise that can interfere with or 'smother' important acoustic behaviour and calls. A second addresses the evolution of underwater noise management in the USA and Europe. It also summarises data needs for conservation, such as data on impacts of offshore windfarm construction and operation on baleen whales, effective mitigation methods and technology, and the cumulative effects of underwater noise, including the effects of chronic stress on cetacean reproduction, health and survival. The third review conducted a bibliometric analysis on underwater noise publications. There has been an increase in publications on underwater noise in an increasing range of journals on an increasing range of species. There has also been an evolution in research on impacts of underwater noise, beyond injury (such as temporary and permanent threshold shifts) toward population level effects of underwater noise, and also an evolution of ocean management with respect to noise. The reviewers concluded that whilst the field of, and knowledge about, underwater noise are rapidly increasing, so too is degradation of ocean habitats because of underwater noise. Moreover, managers need to anticipate impacts better before they occur (e.g. noise due to oil and gas exploration in the Arctic) and 'choose precautionary measures for the quietest sites, such that they become, at best, acoustic refuges'.

(SOURCES: Erbe, C., Reichmuth, C., Cunningham, K., Lucke, K. and Dooling, R. 2016. Communication masking in marine mammals: A review and research strategy. *Mar. Pollut. Bull.* 103: 15-38; Dolman, S.J. and Jasny, M. 2015. Evolution of marine noise pollution management. *Aquat. Mamm.* 41: 357-374; Williams, R., Wright, A.J., Ashe, E., Blight, K.L. *et al*. 2015. Impacts of anthropogenic noise on marine life: Publication patterns, new discoveries, and future directions in research and management. *Ocean Coast. Manag.* 115: 17-24).

THE FULL IMPACT OF SEISMIC SURVEY SOUNDS IN SHALLOW WATERS MAY NOT BE ADDRESSED BY PRESENT MITIGATION MEASURES

Seismic surveys produce high-intensity sounds that affect cetaceans. Few studies, however, have investigated seismic surveys in shallow waters, where complex submarine topography and layering of the water column may lead patterns of sound propagation that differ from those in deeper waters. Three types of seismic airgun were assessed; the received sound levels of all three had a significant component within the hearing range of cetaceans, even harbour porpoises, which are high frequency specialists. The authors concluded that there was 'substantial potential for significant behavioural responses [of cetaceans] out to several km from the airgun'. Current industry practises have a 'safe' zone of 0.5km around seismic survey sources, beyond which received sound levels are assumed to have no impact. This study shows that, in shallow waters, sound levels could cause behavioural impacts that potentially extend a kilometre or more beyond this zone.

(SOURCE: Hermannsen, L., Tougaard, J., Beedholm, K., Nabe-Nielsen, J. and Madsen, P.T. 2015. Characteristics and propagation of airgun pulses in shallow water with implications for effects on small marine mammals. *PLoS ONE* 10(7): e0133436. doi:10.1371/journal.pone.0133436).

VOCALISING LOUDER IN NOISIER ENVIRONMENTS MAY RESULT IN HIGHER ENERGETIC COSTS

Several studies have found that cetaceans in areas with high levels of anthropogenic noise increase the amplitude of their vocalisations. It has been hypothesised that this reaction significantly increases metabolic rate and oxygen consumption when vocalising. Albeit with a small sample size, this study suggests this hypothesis is correct; there is an energetic cost for cetaceans that vocalise louder in noisier habitat.

(SOURCE: Holt, M.M., Noren, D.P., Dunkin, R.C. and Williams, T.M. 2015.Vocal performance affects metabolic rate in dolphins: Implications for animals communicating in noisy environments. *J. Exper. Biol.* 218: 1,647-1,654).

VESSEL THREATS TO CETACEANS: SPEED = NOISE

Noise is one of several major threats identified by the IWC's Standing Working Group on Environmental Concerns. This is the first study to examine the relationship between the characteristics of small vessels and noise levels received by an endangered whale species or population. The authors measured the noise levels received by acoustically tagged southern resident killer whales (population estimated at *ca* 80 individuals) in Washington State and British Columbia waters. Results showed that vessel speed was the only significant predictor of noise levels. Accordingly, reducing vessel speed in the vicinity of killer whales would reduce their noise exposure. Moreover, reducing speed is known to be the most effective way of reducing ship strikes, so this approach would have multiple advantages.

(SOURCES: Houghton, J., Holt, M.M., Giles, D.A., Hanson, M.B., Emmons, C.K., Hogan, J.T., Branch, T.A., and VanBlaricom, G.R. 2015. The relationship between vessel traffic and noise levels received by killer whales (*Orcinus orca*). *PLOS One* 10: e0140119. doi:10.1371/journal.pone.0140119; News, *Mar. Pollut. Bull.* 102: 4).

SPERM WHALES STOP FEEDING WHEN EXPOSED TO LOW FREQUENCY ACTIVE SONAR

Acoustic tags were attached to sperm whales and the behaviour of the animals was monitored in response to exposure to low frequency (1-2 kHz, 214 dB re 1 μPa m^{-1} source level) and mid-frequency (6-7 kHz; 199 re 1 μPa m^{-1}) active sonar, as well as playbacks of killer whale calls. The whales' behaviour did not change in response to the mid-frequency sonar, but the whales did stop foraging when exposed to low frequency sonar, as well as when exposed to killer whale calls. The authors concluded that cessation of foraging as the result of low frequency sonar exposure 'could lead to a significant reduction in prey intake if the behavioral changes persisted over longer or repeated exposures to either [low frequency sonar] or predator sounds'. This is one of the first studies to show an impact of low frequency active sonar on sperm whales. Moreover, the loss of energy from reduced feeding could have an impact on sperm whale health, and potentially reproduction, if exposure is sustained.

(SOURCE: Isojunno, S., Curé, C., Helgevold, P., Lam, F.P.A., Tyack, P.L., Wensveen, P.J. and Miller, P.J.O. 2016. Sperm whales reduce foraging effort during exposure to 1-2 kHz sonar and killer whale sounds. *Ecol. Appl.* 26: 77-93).

IMPACT OF SEAL SCARERS ON PORPOISES

Seal scarers are often used to deter pinnipeds from fish farm sites and concerns have been raised about their impact on acoustically sensitive species such as porpoises. Two brands of seal scarers (with source SPLs of 189 and 193 dB re 1 μPa at 1 m (rms)) were tested on harbour porpoises; there was no behavioural response at a received SP level of 77-91 dB re 1 μPa (depending on brand). However, at 117-121 dB re 1 μPa, porpoises altered their behaviour slightly, whereas, at 139 and 151 dB re 1 μPa, porpoises actively swam away from the source. This confirms that seal scarers can cause displacement of porpoises and indicates the levels at which this can occur.

(SOURCE: Kastelein, R.A., Hoek, L., Gransier, R., de Jong, C.A.F., Terhune, J.M. and Jennings, N. 2015. Hearing thresholds of a harbor porpoise (*Phocoena phocoena*) for playbacks of seal scarer signals, and effects of the signals on behavior. *Hydrobiologia* 756: 89-103).

PINGERS COULD DISPLACE HARBOUR PORPOISES FROM THEIR HABITAT

Acoustic deterrent devices, or 'pingers', are now frequently used on fishing gear as a mitigation measure to reduce harbour porpoise by-catch. Nonetheless, few studies are available on the effects of pingers on habitat usage. Two types of pinger decreased porpoise detection rates (measured acoustically) by 56% when pingers were active. If there was periodic exposure to pingers, detection rates increased slightly with time, suggesting there might be some habituation. However, if pingers operated continuously, there was no increase in detection rate. Even two months after the cessation of pinger activity, porpoise detection rates were 30% below pre-exposure levels. Three control areas (2.5, 3 and 5km away from pingers) showed no change in detection rates, 'suggesting that porpoises were displaced either <2.5km or >5km away'. Therefore, the use of current types of pingers (especially if producing sound continuously) has the potential to displace porpoises from their habitat.

(SOURCE: Kyhn, L.A., Jørgensen, P.B., Carstensen1, J., Bech, N.I., Tougaard, J., Dabelsteen, T. and Teilmann, J. 2015. Pingers cause temporary habitat displacement in the harbour porpoise, *Phocoena phocoena*. *Mar. Ecol. Prog. Ser.* 526: 253-265).

SUBSTANTIAL BEHAVIOURAL RESPONSES OF NORTHERN BOTTLENOSE WHALES TO MID-FREQUENCY NAVAL SONAR EVEN AT LOW LEVELS

Northern bottlenose whales were one of the most heavily hunted beaked whales, yet relatively little is known about the species. This study found that mid-frequency active sonar, at received levels of 107 dB re 1 μPa (1-2kHz), caused a northern bottlenose whale to move 'in an unusually straight course and then [to make] a near 180° turn away from the source, and [perform] the longest and deepest dive (94min, 2,339m) recorded for this species'. The behaviour of the whale was significantly different from normal for at least 7 hours after exposure and at a distance of 33-36km from the sound source, when the tag monitoring the animal fell off. The bottlenose whale also did not produce echolocating clicks for this period, indicating that it had ceased foraging for a substantial period of time. Moreover, 'a sharp decline in both acoustic and visual detections of conspecifics after exposure suggests other whales in the area responded similarly'. This indicates that northern bottlenose whales have 'high sensitivity' to military sonar and their behaviour is heavily impacted, ceasing biologically important behaviours for long periods of time, after receiving only relatively low levels of mid-frequency active sonar.

(SOURCE: Miller, P.J.O., Kvadsheim, P.H., Lam, F.P.A., Tyack, P.L., Curé, C., DeRuiter, S.L., Kleivane, L., Sivle, L.D., van IJsselmuide, S.P., Visser, F.,Wensveen, P.J., von Benda-Beckmann, A.M., Martín López, L.M.,Narazaki, T. and Hooker, S.K..2015. First indications that northern bottlenose whales are sensitive to behavioural disturbance from anthropogenic noise. *R. Soc. Open Sci.* 2: 140484, 1-11).

PROPOSAL FOR ANTHROPOGENIC NOISE TO BE ADDRESSED THROUGH MARPOL OR A NEW CONVENTION

Marine seismic surveys use powerful sound blasts (≥ 230 dB re 1 μPa (rms)) to investigate submarine geological features for oil and gas deposits, and there is concern about the impacts of this noise source on cetaceans. A recent review of seismic survey management determined that environmental impact assessments are rarely done in a way that can accurately assess, monitor or effectively mitigate the impacts of these surveys in appropriate spatial or temporal scales. Exposure levels that are deemed safe for marine mammals do not account for the latest science on sound impacts or cumulative exposures and effects. The review proposed 'that anthropogenic ocean noise be addressed through the revision of the existing MARPOL Convention or negotiation of a new convention that more comprehensively evaluates the associated risks, benefits, and procedures [of seismic surveys]'.

(SOURCE: Nowacek, D.P., Clark, C.W., Mann, D., Miller, P.J.O., Rosenbaum, H.C., Golden, J.S., Jasny, M., Kraska, J. and Southall, B.L. 2015. Marine seismic surveys and ocean noise: Time for coordinated and prudent planning. *Front. Ecol. Environ.* 13: 378-386).

PROTOTYPE ALARMS TO PREVENT WHALE ENTANGLEMENT PROVE INEFFECTIVE

Acoustic alarms have been suggested as mitigation to warn baleen whales of fishing gear presence and thus avoid entanglement. However, behavioural observations of Australian humpback whales after exposure to two test alarms (a 2 kHz swept tone, and a 5 kHz tone with a duration and inter-tone interval of 1.5 and 8 seconds and 0.4 and 5 seconds, respectively) found no behavioural response from the whales for either alarm. The authors concluded that 'the lack of measurable response suggests that the types of tones used are not likely to be effective in alarms intended to reduce entanglement of northward migrating Australian humpback whales'.

(SOURCE: Pirotta, V., Slip, D., Jonsen, I.D., Peddemors, V.M., Cato, D.H., Ross, G. and Harcourt, R. 2016. Migrating humpback whales show no detectable response to whale alarms off Sydney, Australia. *Endang. Spec. Res.* 29: 201-209).

JET-PROPELLED CRAFT ARE QUIETER THAN PROPELLER CRAFT - IMPLICATIONS FOR WHALES

An experimental study investigated the acoustic footprint of a large (117m) high-speed (>37 knots) jet-propelled ship. The sound source level was 10-20dB lower than an equivalent propeller-driven vessel (with peak frequencies below 100Hz). Although quieter propulsion would decrease the overall amount of noise energy entering the ocean, there was concern that a quieter vessel might be more difficult for a whale to detect, especially a vessel travelling at high speed. This would reduce the response time for the whale and increase the likelihood of a fatal collision if the whale could not avoid the vessel in time.

(SOURCE: Rudd, A.B., Richlen, M.F., Stimpert, A.K. and Au, W.W.L. 2015. Underwater sound measurements of a high-speed jet-propelled marine craft: Implications for large whales. *Pac. Sci.* 69: 155-164).

PORPOISES AFFECTED BY NOISE AT LOWER LEVELS THAN PREDICTED

A review of noise exposure experiments determined that harbour and finless porpoises are more sensitive to sound than previously predicted (largely based on extrapolations from bottlenose dolphin studies). The behavioural reaction and likelihood of temporary threshold shifts (TTS) varies with the frequency of the sound; behavioural reactions occur 40-50dB above the porpoise's hearing threshold, and TTS occurs at 100dB above. Predicting the impact of a sound therefore relies on knowing the received sound's frequency and the hearing capability of a porpoise at that frequency. The review found that porpoises tend to show avoidance behaviour towards low frequency pile driving noise 20km away, at 1-7.5km away for 'mid-frequency' seal scarers, and 200m away for 'high-frequency' pingers. The authors noted that it 'remains important, however, to note that behavioural responses will occur below the levels of exposure required to [cause avoidance,] as could other potential fitness-related impacts (such as masking of predator signals)'.

(SOURCE: Tougaard,J., Wright, A.J., and Madsen, P.T. 2015. Cetacean noise criteria revisited in the light of proposed exposure limits for harbour porpoises. *Mar. Pollut. Bull.* 90: 196-208).

SEISMIC SURVEY MITIGATION GUIDELINES ARE STILL INSUFFICIENT

In 1998, the UK's Joint Nature Conservation Committee (JNCC) developed guidelines to mitigate the impacts of seismic surveys. These mitigation measures have largely become the industry standard, but have been heavily criticised as being insufficient to protect marine mammals from the impacts of airgun blasts. The JNCC guidelines were modified in 2010; however, a review of these updated guidelines found that changes were minor and have not kept pace with recent science. The authors reiterated many recommendations made in previous critiques that have still not been incorporated. These include establishing safety zones that are biologically relevant, accounting for the sound level of the seismic source and the sound propagation characteristics of the area.

(SOURCE: Wright, A.J. and Cosentino, A.M. 2015. JNCC guidelines for minimising the risk of injury and disturbance to marine mammals from seismic surveys: We can do better. *Mar. Pollut. Bull.* 100: 231-239).

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Appendix 1

GLOSSARY

Species glossary

Beluga whale	*Delphinapterus leucas*
Blue whale	*Balaenoptera musculus*
Bowhead whale	*Balaena mysticetus*
Commerson's dolphins	*Cephalorhynchus commersonii*
Common bottlenose dolphin	*Tursiops truncatus*
Common minke whale	*Balaenoptera acutorostrata*
Dall's porpoise	*Phocoenoides dalli*
Fin whale	*Balaenoptera physalus*
Gray whale	*Eschrichtius robustus*
Harbour porpoise	*Phocoena phocoena*
Humpback whale	*Megaptera novaeangliae*
Killer whale	*Orcinus orca*
Narwhal	*Monodon monoceros*
North Atlantic right whale	*Eubalaena glacialis*
Northern bottlenose whale	*Hyperoodon ampullatus*
Pacific white-sided dolphin	*Lagenorhynchus obliquidens*
Pygmy sperm whale	*Kogia breviceps*
Southern right whale	*Eubalaena australis*
Sperm whale	*Physeter macrocephalus*
Atlantic herring	*Clupeus harengus*
Capelin	*Mallotus villosus*
Cod	*Gadus morhua*
Harp seal	*Pagophilus groenlandicus*
Humboldt squid	*Dosidicus gigas*
King crab	*Paralomis birsteini*
Krill	*Euphausia spp.*
Sandeels	*Family Ammodytidae*

Glossary of terms

Benthic: Of or related to the bottom level of the ocean, including the sediment or ocean floor.

Benthic-pelagic coupling: The cycling of nutrients between bottom sediments and the overlying water column.

Bioaccumulation: Increase in concentration of a pollutant within an organism compared to background levels in its diet.

Biomagnification: When a pollutant increases in concentration from the environment to the first and subsequent organisms in a food chain. Pollutant levels in top predators are highest.

Bottom-up effects: Effects of varying prey abundance on predator populations (see also top-down effects).

Brevetoxin: A class of dangerous neurotoxins produced during blooms (red tides) of certain algae.

Brucella: Various species of bacteria that cause the disease brucellosis.

Bq: Becquerel, the International System of Units unit of radioactivity, equal to one nuclear decay or other nuclear transformation per second.

CCAMLR: Convention for the Conservation of Antarctic Marine Living Resources

dB: Decibel - a logarithmic measure of sound pressure level.

DDD: The organochlorine dichlorodiphenyldichloroethane, a breakdown product of the pesticide DDT.

DDE: The organochlorine dichlorodiphenyldichloroethylene, a breakdown product of the pesticide DDT.

DDT: The organochlorine pesticide dichlorodiphenyltrichloroethane, which tends to accumulate in the ecosystem and in the blubber and certain internal organs of cetaceans.

Diatom: Common type of phytoplankton, a one-celled alga encased in a silica cell wall. The species *Pseudo-nitzschia australis* produces domoic acid, which poisons mammals, causing paralysis and reproductive failure.
Dinoflagellate: A large group of unicellular algae belonging to the phytoplankton.
Domoic acid: See diatom - also responsible for amnesic shellfish poisoning.
EEZ: Exclusive Economic Zone.
ENSO: El Niño/Southern Oscillation.
Euphausiid: Of the family Euphausiidae, to which krill belong (may also include the single species found in the family Bentheuphausiidae).
Eutrophication: Input of nutrients into an aquatic system, typically associated with excessive plant growth and oxygen depletion.
Gyre: Large system of rotating ocean currents.
HBB: Hexabromobenzene, a halogenated flame retardant.
HCH: Hexachlorocyclohexane, a polyhalogenated compound.
Hz: Hertz, a measure of sound frequency (pitch), in wave cycles per second (kHz = 1000 Hertz).
IMO: International Maritime Organisation.
In utero: In the womb; before birth.
kN: A kilonewton. The newton is the International System of Units unit of force. One thousand newtons is a kilonewton.
Lindane: Also known as *gamma*-hexachlorocyclohexane, (γ-HCH), gammaxene, and Gammallin, lindane is an organochlorine chemical variant of HCH, which has been used both as an agricultural insecticide and as a pharmaceutical treatment for lice and scabies.
Lipid weight: A basis of measurement whereby concentrations of a substance are compared to the lipid (fat) content of a material.
μPa: Micropascal, a unit of pressure.
Microplastics: Plastic particles 0.3-5 mm in diameter, often the result of larger plastic pieces breaking down over time.
MPA: Marine Protected Area.
OCP: Organochlorine pesticide.
Organochlorine: Organic compounds that contain chlorine. Many are toxic and used as pesticides. Most of these compounds persist in the environment (are not biodegradable) and also tend to accumulate in fatty tissue (e.g. blubber) of cetaceans and other marine organisms.
PBDE: Polybrominated diphenyl ether.
PCB: Polychlorinated biphenyls.
PFASs: Per- and polyfluoroalkyl substances, which have many manufacturing and industrial applications because they are fire resistant and repel oil, stains, grease and water.
Pelagic: Of or related to the open ocean.
PET: Polyethylene terephthalate, a plastic.
Phytoplankton: Free-floating marine plants (versus zooplankton - free-floating marine animals).
Polyethylene, polypropylene: Plastics.
POPs: Persistent organic pollutants, organic compounds that are resistant to degradation and thus persist in the environment.
ppm: Parts per million.
PVC: Polyvinyl chloride, a plastic.
rms: Root-mean-square. A measurement of sound pressure.
Salp: A free-swimming tunicate (marine filter feeders with a water-filled, sac-like body structure and tubular openings, known as siphons, through which they draw in and expel water) with a transparent, barrel-shaped body.
Saxitoxin: Neurotoxin found in marine dinoflagellates - the cause of paralytic shellfish poisoning.
SOAR: Synthesis of Arctic Research project.
SPL: Sound pressure level.
Stratification: Layering that occurs in most sedimentary rocks and in those igneous rocks formed at the earth's surface.
Top-down effects: Mortalities of prey induced by predators (see also bottom-up effects).
UME: Unusual mortality event, any set of related strandings that involves a greater number of animals than is typical for a certain time period.
Wet weight: A basis of measurement whereby concentrations of a substance are calculated without the water being removed from the respective organism or sediment.
Zooplankton: Free-floating marine animals.

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