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State of the Cetacean Environment Report (SOCER)

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STATE OF THE CETACEAN ENVIRONMENT REPORT (SOCER) 2016

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INTRODUCTION

Several resolutions of the International Whaling Commission, including Resolutions 1997-7 and 1998-5, directed the Scientific Committee to provide regular updates on environmental matters that affect cetaceans. Resolution 2000-7 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 (SC/55/E7) 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 2017 SOCER focuses on the **Indian Ocean,** summarising key papers and articles published from ca. 2015 through 2017 to date.

INDIAN OCEAN

General

First confirmed field observations on newly described Omura's whale and habitat implications

The status of the cetacean environment is particularly important in populations restricted to particular habitats. Omura's whale in northwest Madagascar may be such a small, resident and isolated (sub-) population with low genetic diversity. The range of the species is exclusively restricted to tropical waters, which is rare among baleen whales: it is probably non-migratory, showing no segregation of feeding and breeding habitat. This paper extends its known range into the western Indian Ocean. The authors consider that the ongoing and planned future expansion of hydrocarbon exploration and production within its documented range off Madagascar is a significant conservation concern. Two MPAs (Ankivonjy and Ankarea) that partially overlap this (sub-) population's habitat received permanent status in 2015, offering some protection within relatively small core areas where oil industry activities are restricted. The authors argue for the inclusion of Omura's whales off the northwest coast of Madagascar on the IUCN Red List.

(SOURCE: Cerchio, S., Andrianantenaina, B., Lindsay, A., Rekdahl, M., Andrianarivelo, N., and Rasoloarijao, T. 2015. Omura's whales (*Balaenoptera omurai*) off northwest Madagascar: ecology, behaviour and conservation needs. *R. Soc. open sci.* 2: 150301. http://dx.doi.org/10.1098/rsos.150301)

The State of the Arabian Gulf: Kuwait as a case study

The waters of Kuwait are threatened by local and more distant anthropogenic impacts. The latter include upstream dam construction, which has increased the salinity from 36 ppt in 1981 to 44 ppt in recent years. This decline in the environmental status of the region is reflected in an over 70% loss of historic reefs across the Gulf, with an additional 27% near critical stages. Kuwaiti waters are experiencing significant decreases in major commercial fish and crustacean species due to overfishing and severe deficiencies in sewage treatment. The authors conclude by stating that "the threats to the coastal and marine environments of Kuwait, and the wider Gulf, are both evident and increasing, and the status of many aspects of the region's unique biodiversity are at record low levels".

(SOURCES: Devlin, M.J., Le Quesne, W.L.F., and Lyons, B.P. 2015. Editorial: The marine environment of Kuwait—emerging issues in a rapidly changing environment. *Mar. Pollut. Bull.* 100: 593-596; Sheppard, C. 2015. Coral reefs in the Gulf are mostly dead now, but can we do anything about it? *Mar. Pollut. Bull.* http://dx.doi.org/10.1016/J.marpolbul.2015.09.031)

Pan-Indian Ocean cooperation sought on sustainable whalewatching

The IWC, in cooperation with the Indian Ocean Rim Association (IORA) and supported by Australia, met in February 2016 to discuss a region-wide whalewatching tourism network. Representatives of 15 nations in the Indian Ocean region attended and several recommendations were made. The IWC's 5 Year Whalewatching Strategy, combined with the upcoming online 'Whalewatching Guidelines', will provide the Indian Ocean rim

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(and other regions) with a best-practice framework and tools to develop an industry that promotes economic growth and benefits the marine environment.

(SOURCE: https://iwc.int/sustainable-whalewatching-on-the-agenda-in-the-ind)

First global integrated marine assessment: Indian Ocean

This major overview of the world's oceans by the United Nations found that the Indian Ocean region contains 31 species of marine mammals. The authors point to numerous threats, such as bycatch (in gillnets, seine nets, beach seines and drift nets), habitat degradation and loss, and pollution, including marine debris. The report tends to underline a lack of information. Accordingly, it identifies five research gaps related to marine mammals: a) the need to train and equip local scientists; b) coordinated long-term monitoring; and c) genetic studies. The final two gaps pertain specifically to whales: d) analyses of the biology and ecology of whales and e) impacts of fishing on whales.

(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 36E:* 28pp, www.un.org/Depts/los/woa)

Important ongoing work on threats to cetaceans in the Arabian Sea

The Arabian Sea Whale Network (ASWN) has been working on recommendations made by the IWC's Scientific Committee (Committee). A satellite tracking survey revealed whales ranging along a 1,150 km corridor along the southern coast of Oman and northern Yemen, with a hotspot in the Gulf of Masirah, a habitat that overlaps with emerging industrial activity. Of particular concern are humpback whales; mitigation initiatives are being taken by the port of Duqm (Oman), which "will have strong bearing on other port developments in the Arabian Sea". Container ships (3-fold increase in traffic from 2004-2014) are considered to pose the highest risk to whales, indicating a need for immediate risk assessment work (i.e., addressing humpback whales and ship occurrence in Oman) and a wider assessment to determine priority areas for study. At SC66b, the Committee reiterated its serious concern about the status of this population and noted that progress toward developing a Conservation Management Plan for Endangered Arabian Sea Humpback Whales had stalled, pending endorsement from range states.

(SOURCES: Willson, A., Baldwin, R., Cerchio, S., Collins, T., Findlay, K., Gray, H., Godley, B.J., Al-Harthi, S., Kennedy, A., Minton, G., Sucunza, F., Zerbini, A., and Witt, M.J. 2016. Research update on satellite tagging studies of the Arabian Sea humpback whales in the Sultanate of Oman. Paper presented to the Scientific Committee of the Int Whal Commn, SC/66b/SH28, *J. Cetacean Res. Manage.* 18 (suppl.), p.41; *Arabian Sea Whale Network Newsletter*. 2016. Paper presented to the Scientific Committee of the Int Whal Commn, SC/66b/SH12; Willson, A., Kowalik, J., Godley, B.J., Baldwin, R., Struck, A., Nawaz, R., Witt, M.J. Priorities for addressing whale and ship co-occurrence off the coast of Oman and the wider North Indian Ocean. 2016. Paper presented to the Scientific Committee of the Int Whal Commn, SC/66b/HIM10)

Ocean Health Index rates Indian Ocean

The Ocean Health Index, compiled by the University of California at Santa Barbara, has released its third annual update. It is based on 10 ecological, economic and societal categories or 'goals', each of which is measured and scored based on four dimensions: status, trend, pressures, and resilience. For the high seas (i.e., beyond national jurisdictions), the western Indian Ocean receives a good overall score (79 out of 100), which ranks it first out of 15 FAO major fishing areas. This value is high compared to the overall health of the earth's oceans (69 out of 100). The eastern Indian Ocean, however, receives a score of only 55, which ranks it very low, namely number 13 among these 15 fishing areas. On a country and EEZ basis, the overall Ocean Health Index score ranks India at 130 of 221 EEZs (score 66), Pakistan 208 (score 51), Indonesia 145 (score 65), Madagascar 162 (score 62), Seychelles 7 (score 85), and Maldives 33 (score 77).

(SOURCES: www.oceanhealthindex.org; www.oceanhealthindex.org/region-scores/high-seas:-indian-ocean-western; www.oceanhealthindex.org/region-scores/high-seas:-indian-ocean-eastern)

Habitat degradation

General

Ganges river dolphins potentially threatened by waterway plans in India

South Asian or Ganges river dolphins face an additional, serious threat (beyond bycatch and altered and declining river flows) involving a plan under the National Waterways Act, 2016, to convert 111 river reaches into waterways for inland navigation and goods transport. Moreover, the Indus subspecies in Pakistan is also under potential threat from a recently proposed commercial waterway on the Indus River. The IWC's Scientific

Committee (Committee) expressed serious concern at SC66b for the survival of river dolphins in India given this new information. It agreed that the situation facing South Asian river dolphins is a matter of grave concern and requires immediate attention. Accordingly, the Ganges and other river dolphins will be considered as a potential priority topic at a future meeting.

(SOURCE: IWC/66/17. 2016. Short overview of the work of the Scientific Committee at its 2015 and 2016 Annual Meetings)

Endangered Ganges river dolphin in India: multiple threats

The Ganges River dolphin is one of the most endangered cetaceans in the world and the second rarest freshwater dolphin (< 2000 individuals in Nepal, India and Bangladesh). An assessment was done on the various threats facing these dolphins in the Kulsi River, a tributary of the Brahmaputra in Assam, India. Less than 30 dolphins are estimated to remain in the river system. Numerous potential threats were identified and site visits conducted at various parts of the river system to assess whether and where these threats occurred. Directly observed threats included: river bank erosion, receding water levels, fishery bycatch, sand mining, overfishing and pesticide use in riparian areas and boat traffic. Other potential threats to the dolphins included dams and barrages, invasive species, siltation of habitat and poaching. The researchers concluded that the "need of the hour now is to come up with a conservation plan to stop or at least decrease the magnitude of the effects of these threats".

(SOURCE: Jelil, S.N. 2015. Conservation threats of the Gangetic dolphin *Platanista gangetica gangetica* in River Kulsi, a tributary of Brahmaputra, Assam, India. *NE J. Contemp. Res.* 2: 6-11)

Endangered Ganges river dolphin in Nepal: multiple threats

Only an estimated 37-42 Ganges river dolphins inhabit the rivers of Nepal. Deep pools best predicted dolphin use in three river systems examined (Karnali, Sapta Koshi, Narayani). These pools are river and season specific, so that the authors "strongly recommend site and season-specific conservation actions". In one of these three rivers (Karnali), a major natural flood in 2010 caused the river channel to shift from a protected area (restricted fishing) to an unprotected area. In response to this shift, the dolphins moved to the unprotected area, which the authors refer to as an 'ecological trap'. This is because irrigation demands affect water depth: fishing posed a threat when water levels dropped but not in deeper water. The dolphin distribution here shifted downstream, and the population declined from 11 in 2012 to 6 in 2015. To avoid extinction, the authors call on the Government of Nepal to "prioritize ecologically adequate river flow regimes for implementing efficient irrigation schemes and adaptive fisheries regulations in the Karnali basin". Nepalese fishermen recognised that fisheries posed a risk but believed water pollution and dam/irrigation developments were the greatest threats. This situation underlines that human activities can compound habitat-related problems after unforeseen natural events have already put pressure on a cetacean population.

(SOURCES: Paudel, S., Levesque, J.C., Saavedra, C., Pita, C., Pal, P. 2016. Characterization of the artisanal fishing communities in Nepal and potential implications for the conservation and management of Ganges River Dolphin (*Platanista gangetica gangetica*). *PeerJ 4:e1563;* doi: 10.7717/peerj.1563; Paudel, S., Pal, P., Cove, M.V., Jnawali S.R., Abel, G., Koprowski, J.L., and Ranabhat, R. 2015. The Endangered Ganges River dolphin *Platanista gangetica gangetica* in Nepal: abundance, habitat and conservation threats. *Endang Species Res* 29: 59-68; Khanal, G., Suryawanshi, K.R., Awasthi, K.D., Dhakal, M., Subedi. N., Nath, D., Kandel, R.C., and Kelkar, N. 2016. Irrigation demands aggravate fishing threats to river dolphins in Nepal 2016. *Biol. Conserv.* 204: 386-393)

Fisheries interactions

Cetacean bycatch in tuna fisheries in western and central Indian Ocean

The average annual catch of tuna from the western and central Indian Ocean is 1.1 million tons, mainly involving gillnets (40%), purse seine (26%), longline (12%), handline and troll (11%) and pole-and-line (9%). The major gillnet fishing nations include Iran, India, Sri Lanka, Oman and Yemen, with an estimated 60,000 small cetaceans taken as bycatch each year. Although large-scale gill-netting (> 2.5 km length) is banned by UN convention and IOTC resolution, it continues to be "carried out by Iran, Pakistan and possibly also other countries". Purse seining is dominated by French and Spanish fleets. This has previously involved setting on cetaceans (baleen whales and mostly spotted dolphins and spinner dolphins), which has recently been banned by EU regulation (2007) and IOTC (2013). The author concludes by noting that there has been "a widespread failure to monitor and manage cetacean bycatch in Indian Ocean tuna fisheries, and to develop and implement mitigation measures". The "enormous, and still growing, gillnet capacity in the region should be of particular concern".

(SOURCE: Anderson, R.C. 2014. *Cetaceans and Tuna Fisheries in the Western and Central Indian Ocean*. IPNLF Technical Report 2, International Pole and Line Foundation, London. 133 pages)

Suggestions to reduce dolphin entanglement in shark nets

Gillnets are used on South African beaches to protect human bathers from sharks, but also take a substantive toll on cetaceans through bycatch. Researchers investigated factors that might affect bycatch of Indian Ocean humpback dolphins in Richards Bay, South Africa. Using photo-identification, they found dolphins have a low level of residency but long-term site fidelity, with dolphins paying short, but repeated, visits to the bay, before moving on. The researchers suggested that Richards Bay is important habitat for the dolphins. However, at least 8% of catalogued individuals were found in shark nets, while most bycaught dolphins in Richards Bay were uncatalogued adolescents. There was a notably higher proportion of entangled males than females. Results indicated lower familiarity with nets did not increase bycatch rates. The researchers suggested bycatch might be reduced by removing nets/closing beaches to swimmers in the winter, reducing the number of nets, adding pingers to the nets, or introducing bait and hooks to catch sharks in the bay. Non-lethal suggestions to reduce shark presence included chemical or electrical deterrents and/or observers who can warn bathers about shark presence. The authors concluded that "bycatch of Indian Ocean humpback dolphins in shark nets at Richards Bay may be negatively affecting the wider population, and continued efforts to mitigate the loss are vital".

(SOURCE: Atkins, S., Cantor, M., Pillay, N., Cliff, G., Keith, M., and Parra, G. 2016. Net loss of endangered humpback dolphins: integrating residency, site fidelity, and bycatch in shark nets. *Mar. Ecol. Prog. Ser.* 555: 249–260)

Bycatch in the tuna gillnet fisheries of Pakistan

The ca. 700 gillnet vessels operating off Pakistan incidentally capture a large number of sharks, sea turtles and cetaceans. During the 2013-2015 period, four gillnet vessels reported 208 dolphins and whales as bycatch. A total of 10,150 dolphins were reported killed in tuna gillnet operations in 2014. Along the entire coast of Pakistan in 2015, 17,200 dolphins were killed. The most common bycatch species were Indo-Pacific bottlenose dolphins, common bottlenose dolphins, and spinner dolphins. During a 4-year period since the WWF-Pakistan observer program was initiated, entangled dolphins were successfully released on only three occasions. Whale entanglements were very rare (six species in four years). The authors state that "High catches of protected species, including cetaceans, sharks and marine turtles, poses serious threats to sustainability of the oceans". In 2016, the Governments of Sindh and Balochistan enacted laws for the protection of these species. WWF-Pakistan has initiated a program for safe release of entangled animals that has so far released 32 whale sharks, 14 mobulids, one beaked whale, one guitarfish, two bottlenose dolphins and thousands of sea turtles.

(SOURCES: Sharid, U., Khan, M.M., Nawaz, R., Razzaq, S.A., and Ayub, S. 2016. Bycatch analysis of tuna gillnet fisheries of Pakistan: An analysis of bycatch data from 2013-2016. World Wide Fund for Nature, Karachi, Pakistan, Report for IOTC Meeting; Nawaz, R. and Moazzam, M. 2014. An assessment of cetacean mortality in the tuna fisheries of Pakistan. *IOTC-2014-WPEB 10-INF25*)

Dolphin entanglement risk in Bay of Bengal, Bangladesh, and new MPA

A survey in the Bay of Bengal, Bangladesh, revealed that 28% of photo-identified Indo-Pacific bottlenose and 15% of Indo-Pacific humpback dolphins exhibited injuries related to entanglements with fishing gear. The authors state that this "implies a strong potential for fatal interactions that could jeopardize the conservation status of both dolphin populations which otherwise appear favorable". Ninety gillnetting trips between 2013 and 2015, in the framework of an initiative to protect small coastal cetaceans and to improve safety at sea, documented one fatal entanglement of a humpback dolphin and two fatal entanglements of Indo-Pacific bottlenose dolphins. A new MPA (Swatch of No-Ground: SoNG), covering 1,738 km² and ranging from a submarine canyon to coastal waters offshore of the Sundabarans mangrove forest, was signed into law in 2014. It provides priority habitats for these two species, as well as other cetaceans at conservation risk, and was designed more generally "to safeguard dolphins, whales, sea turtles, sharks, and other oceanic species".

(SOURCE: Smith, B.D., Mansur, R., Strindberg, S., Redfern, J., and Moore, T. 2015. Population demographics, habitat selection, and spatial and photographic analysis of bycatch risk of Indo-Pacific humpback dolphins *Sousa chinensis* and bottlenose dolphins *Tursiops aduncus* in the northern Bay of Bengal, Bangladesh. 2015. Paper presented to the Scientific Committee of the Int Whal Commn, SC/66a/SM19)

Marine Debris

Marine debris on remote Indian Ocean islands

A 1-km stretch of beach on remote Alphonse Island in the western Indian Ocean yielded 4763 items weighing 142 kg. Most of the items had land origins thousands of kilometres away. Surface current models pointed to South East Asia, Somalia, India/Sri Lanka and potentially Madagascar as sources. The authors identified inadequate waste management as the cause. A second study found a daily mean abundance of 35 plastic particles per m² on a small coral island used only for research and environmental education. Although the values were generally lower than on highly contaminated beaches in Mumbai (10-180 particles/m²), the abundance on such a remote island "is a worrying sign for the global distribution of plastic debris". The values would probably have been much higher if particles < 1 mm had been considered. The authors believe the sources could be nearby inhabited islands, tourist islands within the atoll, or debris blown into the sea from 'garbage islands' used for landfilling.

(SOURCE: Duhec, A.V., Jeanne, R.F., Maximenko, N., and Hafner, J. 2015. Composition and potential origin of marine debris stranded in the Western Indian Ocean on remote Alphonse Island, Seychelles. *Mar. Pollut. Bull.* 96: 76-86; Imhof, H.K., Sigl, R., Brauer, E., Feyl, S., Giesemann, P., Klink, S., Leupolz, K. Löder, M.G.J., et al. 2017. Spatial and temporal variation of macro-, meso- and microplastic abundance on a remote coral island of the Maldives, Indian Ocean. *Mar. Pollut. Bull.* 116: 340-347)

Indian Ocean gyre may have greatest marine debris load in the Southern Hemisphere

In a modelling-based effort, the amount of floating plastic in the five subtropical gyres was estimated at 5 trillion pieces, or 264,000 tons. Unexpectedly, the southern hemisphere showed values as high as those in the northern hemisphere, where inputs are considered to be substantially larger. The Indian Ocean contains one of these gyres and, within the Southern Hemisphere, it showed a greater particle count and weight of plastic debris than the South Atlantic and South Pacific Oceans combined. The authors attributed this to a possible between-hemisphere redistribution of wastes, as well as previously unaccounted-for pollution sources such as the Bay of Bengal. The authors underlined that the values they presented were minimum estimates, considering only known inputs into the sea: floating material makes up only a fraction of this material, with the location of the remainder largely unknown, but including "on shorelines, on the seabed, suspended in the water column, and within organisms".

(SOURCE: Eriksen, M., Lebreton, L.C.M., Carson, H.S., Thiel, M., Moore, C.J., Borerro, J.C., Galgani, F., Ryba, P.G., and Reissner, J. 2014. Plastic pollution in the world's oceans: More than 5 trillion plastic pieces weighing over 250,000 tons afloat at sea. *PLoS ONE* 9(12): e111913. doi.org/10.1371/journal.pone.0111913)

Plastic debris in the Persian Gulf

This first assessment of microplastics in the Persian Gulf (Arabian Sea), which is biologically part of the northwest Indian Ocean, found levels in the range of several European sites. The microplastic levels (highest value: 1258 particles/kg) reflected the relative proximity to industrial and urban activities. The likely sources include beach debris, discarded fishing gear, and urban and industrial outflows. Fibres were the most common microplastic type identified, followed by films and fragments. A second study, conducted near the Iranian city of Bandar Abbas, northern Persian Gulf, attributed the larger marine debris items found on beaches primarily to tourism and recreational activities. Both large plastic items and microplastics have been shown to impact ecosystem health, as well as the health of cetaceans, with the problem being clearly as prevalent in the Persian Gulf as in other oceans.

(SOURCES: Naji, A., Esmaili, Z. and Khan, F.R. 2017. Plastic debris and microplastics along beaches of the Strait of Hormuz, Persian Gulf. *Mar. Pollut. Bull.* 114: 1057-1062; Sarafraz, J., Rajabizadeh, M. and Kamrani, E. 2016. The preliminary assessment of abundance and composition of marine beach debris in the northern Persian Gulf, Bandar Abbas City. *J. Mar. Biol. Assoc UK* 96: 131-135)

Ship strikes

Blue whale ship strikes off Sri Lanka: An avertable problem

The southern coast of Sri Lanka hosts high densities of endangered blue whales and is also one of the world's busiest shipping lanes. This overlap means a high risk of ship strikes, and numerous stranded animals with injuries attributable to ship collisions (e.g., blunt force trauma, propeller wounds) have been recorded. The reliable predictability of the distribution of northern Indian Ocean blue whales—even in such a data-poor ecosystem—suggests that shifting the current Traffic Separation Scheme only 15 nm further offshore would reduce the risk by 95%. The Committee agreed that "the combined results of these studies is sufficiently consistent to support a proposal to IMO to move the shipping lanes should Sri Lanka so wish".

(SOURCES: Redfern, J.V., Moore, T.J., Fiedler, P.C., de Vos, A., Brownell Jr., R.L., Forney, K.A., Becker, E.A. and Ballance, L.T. 2017. Predicting cetacean distributions on data-poor marine ecosystems. *Divers. Distrib.* 1-15, doi: 10.1111/ddi.12537; Priyadarshana, T., Randage, S.M., Alling, A., Calderan, S., Gordon, J. Leaper, R. and Porter, L. 2016. Distribution patterns of blue whale (*Balaenoptera musculus*) and shipping off southern Sri Lanka. *Reg. Stud. Mar. Sci.* 3: 181-188; IWC. 2016. *J. Cetacean Res. Manage 18 (Suppl.)* p. 19)

Chemical pollution

Heavy metal contamination in northern part of Persian Gulf

The concentrations of the heavy metals Cu, Zn, Pb and Cd in the coastal sediments of the Hormuz Strait, northern Persian Gulf, were higher than in other coastal sediments. The values in mullet were so high that human consumption "should be of very high concern for public health". Due to bioaccumulation, the high values in the sediment and in fish point to potentially even higher values in species further up the food chain, such as cetaceans.

(SOURCE: Bastami, K.D., Afkhami, M., Mohammadizadeh, M., Ehsanpour, M., Chambari, S., Aghaei, S., Esmaeilzadeh, M., Neyestani, M.R., Lagzaee, F., and Baniaman, M. 2015. Bioaccumulation and ecological risk assessment of heavy metals in the sediments and mullet *Liza klunzingeri* in the northern part of the Persian Gulf. *Mar. Pollut. Bull.* 94: 329-334)

Feeding area in Antarctic waters determines pollutant levels in humpback whales breeding in Indian Ocean

There are four humpback whale stocks breeding in the Indian Ocean and feeding in Antarctic waters. In one of these (Réunion Island; C/C4), HCB and DDTs predominated amongst the seven POPs in the whales, with DDE being the major organohalogenated pollutant. This reflects its long-term accumulation in humpback whales. DDE is the most persistent metabolite of DDT and bioaccumulates in Antarctic krill. The Antarctic environment still receives DDE input. The sources are redistribution of previously deposited DDT in soil and snow/ice and ongoing DDT use in parts of the southern hemisphere. Based on blubber contaminant levels, gender and seasonal differences, the authors concluded that there are significant differences in feeding ground exposure. This is in agreement with data from other Antarctic aquatic species such as krill, fish and penguins. It underlines the importance of individually examining whale stocks and their habitats (in the present case mainly Area III, one of six putative feeding areas around the Antarctic) to determine potential exposure and cetacean health threats.

(SOURCE: Das, K., Malarvannan, G., Dirtu, A., Dulau, V., Dumont, M., Lepoint, G., Mongin, P., and Covaci, A. 2017. Linking pollutant exposure of humpback whales breeding in the Indian Ocean to their feeding habits and feeding areas off Antarctica. *Environ. Poll.* 220: 1090-1099, http://dx.doi.org/10.1016/j.envpol.2016.11.032)

Slight habitat differences determine pollutant levels in sympatric dolphins in the Indian Ocean

At least 10 cetacean species are regularly observed in the waters off La Réunion in the southwest tropical Indian Ocean. Spinner and Indo-Pacific bottlenose dolphins are the most common species, found year-round. Despite their spatial and temporal overlap, the two species are differently exposed to contaminants. For PCBs, HCHs and T-Hg, concentrations were significantly higher in the more coastal bottlenose than in the spinners. MeO-PBDEs (reportedly of natural origin) were the dominant compounds (55% of the total POPs) in spinners, while PCBs dominated (50% contribution) in bottlenose. The authors attributed this to dietary and foraging habitat preferences (more coastal vs more offshore). Other contaminants showed similar profiles for the two species. The levels of each contaminant class were significantly higher in males than females. Interestingly, the higher T-Hg concentrations in the coastal dolphins reflect the volcanic activity of La Réunion, not anthropogenic sources. Again, this underlines the importance of individually examining species regarding feeding area, dietary preferences, gender, potential tissue-related differences, and natural versus anthropogenic contaminant sources to help determine the state of the cetacean environment as it pertains to specific populations.

(SOURCE: Dirtu, A.C., Malarvannan, G., Das, K., Dulau-Drouot, V., Kiszka, J.J., Lepoint, G., Mongin, P., and Covaci, A. 2016. Contrasted accumulation patterns of persistent organic pollutants and mercury in sympatric tropical dolphins from the south-western Indian Ocean. *Environ. Res.* 146: 263-273, http://dx.doi.org/10.1016/j.envres.2016.01.006)

Pesticide release continues to be an issue in the Indian Ocean

In India, an estimated 380,000 tons of pesticides and other halogenated hydrocarbons are used each year (DDT: 107,000 tons). The corresponding values in Pakistan are 11,000 tons, Bangladesh 3000 tons, and Sri Lanka 28,000 tons. A large proportion of pesticides reaches the sea via the atmosphere and rivers in India. This study found that the values detected in an estuarine creek entering the sea in Mumbai exceeded several international guidelines. The authors called for sensitising and educating end users on the appropriate management of pesticides. DDT and other OCPs are persistent in the environment and accumulate along the food chain, affecting long-lived predators such as cetaceans.

(SOURCE: Rekadwad, B.N. and Khobragade, C.N. 2015. A case study on effects of oil spills and tar-ball pollution on beaches of Goa (India). *Mar. Pollut. Bull.* 100: 567-570)

Disease and mortality events

Update on recent whale strandings along the west coast of India

Along the west coast of India from 2015-2016, a total of 11 baleen whales stranded, including two blue whales (one of which was rescued) and two (possibly three) Bryde's whales. The dead blue whale was emaciated and had one large and several smaller wounds. The authors emphasised "the importance of seafaring communities in providing secondary data on whale sightings". In 2016, awareness material, including identification guides for stranded animals, was developed and widely disseminated. An earlier report covering three states of the west coast of India during the period 2000-2015 documented 19 stranded Bryde's and blue whales.

(SOURCES: Sutaria, D., Sule, M., Jog, K., Bopardikar, I., Panicker, D., and Jamalabad, A. 2016. Baleen whale records from the Arabian Sea, India from June 2015 to May 2016. Paper presented to the Scientific Committee of the Int Whal Commn, SC/66b/SH34; Sutaria, D., Sule, M., Bopardikar, I., and Panicker, D. 2015. Recent baleen whale records from the Arabian Sea, India. Paper presented to the Scientific Committee of the Int Whal Commn, SC/66a/SH17)

Harmful Algal Blooms (HABs)

Harmful algal blooms, low oxygen and fish kills an issue in the northwest Indian Ocean

In the last decade, previously unreported phytoplankton (dinoflagellate) species have become the dominant agents causing harmful algal blooms (HABs) in the Sea of Oman. Beyond being directly toxic to marine life, such blooms have an impact on the marine ecosystem through the interplay between bloom degradation, oxygen depletion and fish kills. From 1976 to 2009, 81 HAB events were recorded in the Sea of Oman, of which 10 caused fish kills. There was a significant correlation between oxygen depletion, algal blooms and fish kills from 1988-2011. Warming of surface waters by 1.2°C in the last 50 years has resulted in increased stratification, exacerbating this problem. The authors argued that a better understanding of this phenomenon is important because Oman plans to increase its coastal aquaculture industry, which could both contribute to the problem by releasing nutrients into the sea, while at the same time suffering from the blooms and their effects. Beyond causing general deterioration of the marine environment, HABs have been implicated in mass mortalities of cetacean species.

(SOURCE: Harrison, P.J., Piontkovski, S. and Al-Hashmi, K. 2017. Understanding how physical-biological coupling influences harmful algal blooms, low oxygen and fish kills in the Sea of Oman and the Western Arabian Sea. *Mar. Pollut. Bull.* 114: 25-34)

Rethinking aquaculture in the Indian Ocean

A global alliance has been created to develop novel solutions for environmental problems related to aquaculture in the Indian Ocean. Launched by Australia's Department of Foreign Affairs and Trade, in cooperation with the World Wildlife Fund and others, the global alliance seeks to rethink the future of aquaculture in the region. The focus will be on the feeds being used, aquaculture system redesigns and creating new ocean products to achieve a 'Blue Revolution'. Aquaculture can harm the marine environment by damaging or removing habitats (e.g., mangrove forests), introducing or spreading invasive species and pathogens, and polluting surrounding ecosystems, especially with nutrients (eutrophication). Beyond directly affecting the habitat of coastal cetaceans, the aquaculture industry produces nearly half of all the fish eaten worldwide, thus playing a role in determining the status of food chains in the marine environment in general.

(SOURCE: NEWS. 2016. *Mar. Pollut. Bull.* 106: 5-6)

Oil spills

Oil spills and tar-ball pollution an ongoing problem in the state of Goa (India)

Goa comprises about 105 km of India's total coastline length of 8100 km. The marine ecosystem here is stressed by, *inter alia*, overfishing, destructive fishing practices and contaminants. In addition, large amounts of tar are deposited here every month by high tides and from June to October during monsoon season, posing a problem for the marine environment and for the tourism-based economy. This pollution reflects leakages and oil tanker washes, i.e., normal ship operations, rather than oil tanker accidents. Cetaceans can be affected by continuous contact with floating oil when surfacing to breathe, by the chemical composition of oil components in the water and by consuming contaminated prey.

(SOURCE: Singare, P.U. 2015. Persistent organic pesticide residues in sediments of Vasai Creek near Mumbai: Assessment of sources and potential ecological risk. *Mar. Pollut. Bull.* 100: 464-475)

GLOBAL

Habitat degradation

Fisheries interactions

<u>Ghost gear entanglement of cetaceans worldwide</u>

This review examined 76 publications dating from 1997-2015 and reports on 5400 individuals of 40 different species being recorded as entangled. Marine mammals accounted for 70% of all cases, the most common taxon being cetaceans. Humpback whales were the most recorded species (670 entangled individuals), followed closely by North Atlantic right whales (648). One study reported that half of all humpback whales showed signs of prior entanglement, another that 83% of North Atlantic right whales from the east coast of the USA and Canada showed such evidence. Many observations involved scarred tails. Juvenile cetaceans are apparently most at risk of dying due to entanglement. The review specifically points to a deficit of information from the Indian Ocean (as well as Southern and Arctic Oceans).

(SOURCE: Stelfox, M., Hudgins, J. and Sweet, M. 2016. A review of ghost gear entanglement amongst marine mammals, reptiles and elasmobranchs. *Mar. Pollut. Bull.* 111: 6-17)

<u>The energetic costs of entanglement cause population-level impacts</u>

Entanglement in fishing gear causes significant drag and buoyancy effects on whales. It was estimated that the force on North Atlantic right whales exerted by gear entanglement, for 10 sets of gear investigated or removed from whales in US Atlantic coast waters, ranged from 11-275 Newtons. Entangled whales were tagged during disentanglement efforts to examine the effects of entanglement on swimming. Fluke strokes were significantly shorter and more variable in shape, and 'gliding' behaviour was less frequent. The amount of thrust the whales produced decreased and swimming was generally less efficient. After disentanglement, whales needed 1.2-1.8 times less power to swim. Researchers also compared the blubber thicknesses of entangled and normal North Atlantic right whales and estimated that between entanglement and eventual death the whales will consume $7.4 \times 10_{10}$ J - 1.2×10^{11} J of energy. Whales have to expend 3.95×10^{9} - 4.08×10^{10} J more energy to swim due to the drag from entangling gear. This extra expenditure of energy is roughly equivalent to a reproductive or migration event, in terms of its scale. The greater the drag, the higher the likelihood of mortality. Entanglement therefore inflicts a major energetic cost on right whales; even if the animal is disentangled, the energetic cost could, in females, lead to delay in, or failure of, reproduction. The researchers stated that "[r]ecovery from such physiological stress and disturbance may limit an individual's future reproductive success, making entanglement a potential contributor to fluctuations in population growth" (Van Der Hoop et al., 2017c). They also stated that whale conservation efforts should focus not only on lethal impacts from anthropogenic activities, but also on sub-lethal effects, as energetic costs could lead to a reduction in health and certainly a reduction in, or even cessation of, reproduction, which ultimately could deplete populations.

(SOURCES: Van der Hoop, J., Corkeron, P., Henry, A.G., Knowlton, A.R. and Moore, M.J. 2017a. Predicting lethal entanglements as a consequence of drag from fishing gear. *Mar. Pollut. Bull.* 115: 91-104; Van der Hoop, J., Nowacek, D.P., Moore, M.J. and Triantafyllou, M.S. 2017b. Swimming kinematics and efficiency of entangled North Atlantic right whales. *Endang. Species Res.* 32: 1-17; Van der Hoop, J., Corkeron, P. & Moore, M. 2017c. Entanglement is a costly life-history stage in large whales. *Ecol. Evol.* 7: 92-106)

Marine Debris

<u>Tire abrasion and synthetic clothing identified as major sources of microplastic pollution in the world's oceans</u>

According to an IUCN report, tire particles and the fibres from clothing made of synthetic materials may contribute up to 31% of the 9.5 million tons of plastic that enter the ocean every year. Tire waste generated by abrasion during road use is the main source of primary microplastics in the Americas, Europe and Central Asia, with synthetic textile products as the main offenders in India and Southeast Asia. Microplastics can accumulate in the food web, have been found in most marine animals, including baleen whales, and pose a potential threat to human health.

(SOURCE: NEWS. 2017. *Mar. Pollut. Bull.* 117: 1)

Disease and mortality events

Harmful Algal Blooms (HABs)

<u>Harmful algal blooms and climate change: an emerging issue</u>

Of the 4000 known species of marine phytoplankton, about 300 have properties that make them harmful to humans (e.g., causing neurological disorders) and the marine environment (e.g., causing oxygen crises, fish kills). In a project sponsored by SCOR and IOC of UNESCO, experts are seeking to improve our understanding of, and promote cooperation/partnerships on, the issue of HABs and the role climate change may be playing.

This project (GlobalHAB) will help coordinate research and promote communication between scientists and society. HABs have been identified as a threat to cetaceans by the Committee and are the topic of a pre-meeting at SC67a.

(SOURCE: NEWS, 2016. *Mar. Pollut. Bull.* 106: 7)

Oil spills

Deepwater Horizon (DWH) oil spill: an update

Several studies were published since 2016 on the impacts of the DWH oil spill. Dias et al. (2017) noted 11 cases where dolphins were seen swimming through oil, where oil adhered to their skins, the sheen often persisting for some time afterward. The researchers concluded that "during oil spills in cetacean habitat, direct exposure of whales and dolphins to petroleum products will likely occur" because dolphins cannot detect—and thus cannot avoid—oil spills.

Colegrove et al. (2016) investigated perinatal mortality linked to spill exposure. Common bottlenose dolphins exposed to the spill were found to be significantly more likely to: die in the womb or very soon after birth; show signs of lung collapse; have foetal distress (oxygen deprivation in the womb); and develop pneumonia. Also, there was a higher prevalence of perinates with *Brucella* sp. infections (compared to stranding in Mississippi and Alabama). The researchers concluded that bottlenose dolphins exposed to the DWH oil spill "were particularly susceptible to late-term pregnancy failures and development of *in utero* infections including brucellosis".

Kellar et al. (2017) investigated longer-term reproductive success, using hormone analysis from blubber biopsies, or ultrasound scans taken when animals were collected as part of a capture-release research programme. Animals were followed for a year after the detection of pregnancy; the percentage of successful births in oil-exposed animals was substantially lower (19%) than in other dolphin populations (Sarasota Bay, Florida and South Carolina: 65%). A number of factors were compared (e.g., levels of progesterone, cortisol, thyroid hormone) but only white blood cell counts were correlated with reproductive success. The researchers concluded that the "high reproductive failure rates [in spill-exposed animals] are consistent with mammalian literature that shows a link between petroleum exposure and reproductive abnormalities and failures".

Capture-release animals were also assessed for lung health. Smith et al. (2017) found that four years after the occurrence of the spill, some improvements in lung health had occurred; however, levels of moderate to severe lung disease remained elevated. The researchers "confirmed that dolphins living in areas affected by the [DWH] spill were more likely to be ill; however, some improvement in population health has occurred over time".

These studies show distinct and substantial population-level impacts from the DWH oil spill on common bottlenose dolphins alone. Aerial/vessel surveys and other reports documented over 1100 cetaceans from at least 10 species in thick surface oil or the surface oil sheen from the DWH spill (between April- September 2010), which together with strandings of oiled animals gives a total of 15 species of cetacean recorded as exposed to the oil spill. The impact of the spill on multiple populations of cetacean species, including great whales, in the Gulf of Mexico and adjacent areas, is likely to be substantial.

(SOURCES: Aichinger Dias, L., et al. 2017. Exposure of cetaceans to petroleum products following the *Deepwater Horizon* oil spill in the Gulf of Mexico. *Endang. Species Res.* 33: 119-125; Colegrove, K.M., et al. 2016. Fetal distress and *in utero* pneumonia in perinatal dolphins during the Northern Gulf of Mexico= unusual mortality event. *Dis. Aquatic Org*. 119: 1-16; Kellar, N.M., et al. 2017. Low reproductive success rates of common bottlenose dolphins *Tursiops truncatus* in the northern Gulf of Mexico following the *Deepwater Horizon* disaster (2010−2015). *Endang. Species Res.* 33: 143-158; Smith, C.R., et al. 2017. Slow recovery of Barataria Bay dolphin health following the *Deepwater Horizon* oil spill (2013−2014), with evidence of persistent lung disease and impaired stress response. *Endang. Species Res.* 33: 127-142; Takeshita, R., et al. 2017. The *Deepwater Horizon* oil spill marine mammal injury assessment. *Endang. Species Res.* 33: 95-106; Wilkin, S.M., et al. 2017. Marine mammal response operations during the *Deepwater Horizon* oil spill. *Endang. Species Res.* 33: 107-118)

Climate change

Temperature increases could reach levels not seen for 420 million years

Over the past 420 million years, there has been a slow increase in solar radiance (energy meeting the Earth's surface; a net increase of ~9 Wm^{-2} of radiative forcing), but from a global warming perspective, this has been counteracted and effectively negated by a simultaneous decline in atmospheric CO_2 levels (probably due to an expansion of carbon dioxide-absorbing plants and geological factors). However, today atmospheric CO_2 has reached levels not seen since the early Eocene (50 million years ago). Researchers analysing the interaction of this increase with solar radiance concluded that if "CO_2 continues to rise further into the twenty-third century, then the associated large increase in radiative forcing, and how the Earth system would respond, would likely be without geological precedent in the last half a billion years".

(SOURCE: Foster, G.L., Royer, D.L. and Lunt, D.J. 2017. Future climate forcing potentially without precedent in the last 420 million years. *Nature Comm.* 8: art. 14845. doi:10.1038/nature22049)

Climate change exacerbating harmful algal blooms

Researchers investigated the prevalence of HABs in the North Atlantic and North Pacific Oceans and whether these were linked to climate change-induced warming. They specifically looked at the HAB-producing species *Alexandrium fundyense* and *Dinophysis acuminate* and built predictive models of occurrence. They discovered numerous sites where HABs had not occurred before, but where they could occur as a result of warming. They also discovered higher potential growth rates of such blooms, and longer bloom seasons (particularly on the Atlantic and Alaskan coasts, which is important cetacean habitat).

(SOURCE: Gobler, C.J., Doherty, O.M., Hattenrath-Lehmann, T.K., Griffith, A.W., Kang, Y. and Litaker, R.W. 2017. Ocean warming since 1982 has expanded the niche of toxic algal blooms in the North Atlantic and North Pacific oceans. *Proc. Natl Acad. Sci. USA*, online early. doi: 10.1073/pnas.1619575114)

Record levels of carbon dioxide recorded

In 2017, the Mauna Loa Observatory in Hawaii recorded a carbon dioxide level exceeding 410 ppm for the first time. When the observatory started recording carbon dioxide levels in 1958, they were 280 ppm. In 2013, they passed 400 ppm for the first time. Carbon dioxide levels were last at this level 50 million years ago in the Eocene, a period when the world was 10° C warmer than it is today.

(SOURCE: Khan, B. 2017. We just breached the 410 ppm threshold for CO2**.** *Scient. Amer.* 21 April 2017. https://www.scientificamerican.com/article/we-just-breached-the-410-ppm-threshold-for-co2/)

Discovery of massive meltwater rivers in Antarctica increases concern about ice shelf break up

The current prediction for sea level rise this century, as the result of Antarctic ice sheet meltwater having an impact on the breakup of ice sheets, is one metre. However, researchers analysing satellite images (from 1973 onwards) and aerial photographs (from 1947 onwards) of the surface of Antarctica warn that there is substantial movement of water across the surface of Antarctica, as the result of melting ice, that has not been factored into this prediction. The researchers found rivers of meltwater on the surface of Antarctica as far south as 85° S and as high in elevation as 1,300 m above sea level. These meltwater rivers are up to 120 km long and feed "vast melt ponds up to 80 kilometres long". The researchers raised concerns that this rapidly increasing water flow, whilst being a physical representation of the extent of melting, could exacerbate the breaking up of ice sheets and lead to positive feedback loops that could accelerate the loss of ice around Antarctica.

(SOURCES: Kingslake, J., Ely, J.C., Das, I. and Bell, R.E. 2017. Widespread movement of meltwater onto and across Antarctic ice shelves. *Nature* 544: 349-352; DeConto, R. M. and Pollard, D. 2016. Contribution of Antarctica to past and future sea-level rise. *Nature* 531: 591-597).

Arctic sea ice coverage reaches a record low

The maximum Arctic sea ice coverage in the winter of 2016/2017 was the lowest level ever recorded. The previous record low was in winter 2015/2016. The maximum extent for 2016/2017 was 14.43 million km^2. This was 1.17 million km^2 below the average during 1981-2010. The rate of decline in ice coverage has been 42,700 km^2 per year, or 2.74% per decade. Air temperatures over the Arctic Ocean ranged from 2°C to 6°C above average in nearly every region.

(SOURCE: National Snow and Ice Data Center. http://nsidc.org/arcticseaicenews/)

2016 was the hottest year on record

NASA and NOAA jointly declared that 2016 was the hottest year globally since comprehensive recording was initiated 137 years ago. The hottest year on record previously was 2015, and 2014 before that, marking three years in a row of record-breaking global temperatures. Of the 17 hottest years on record, 16 have occurred in the 21st century (the exception being the strong El Niño year of 1998). To compare how elevated the temperatures were, 2016 was almost 0.9° C warmer than 1998. Temperatures in 2016 were 1.2°C above the average temperatures during the late 19th/early 20th centuries (1881-1910).

(SOURCE: Thompson, A. 2017. 2016 was the hottest year on record. *Scient. Amer.*, 18 January 2017, https://www.scientificamerican.com/article/2016-was-the-hottest-year-on-record/)

Larsen C ice shelf shows signs of imminent collapse

A large (175 km), expanding crack appeared in the Larsen C ice shelf, which suggests that the shelf may be unstable and collapse in the near future. The Larsen C shelf covers 50,000 km^2 and contains ice up to 350 m thick. After the Larsen A and B shelves broke up, it led to an eightfold increase in glacier ice flow into the ocean. Intact ice shelves effectively act as 'fences', preventing ice on land from flowing into the sea via glaciers. If the Larsen C shelf were to break up, the glacier ice that would flow into the ocean would provide enough additional water to raise global sea level by one centimetre. At present, sea level is rising by 3 mm a year, and one-third of this rise is attributable to land-based ice in Greenland and Antarctica flowing into the oceans via glaciers (265 GT/year for Greenland and 95 ± 50 GT/year for Antarctica, which is contributing 0.72 and 0.26 mm/year to global sea level rise, respectively).

(SOURCES: Tollefson, J. 2017. Giant crack in Antarctic ice shelf spotlights advances in glaciology. *Nature* 452: 202.403; Forsberg, R., Sørensen, L.S., and Simonsen, S. B. 2017. Greenland and Antarctica ice sheet mass changes and effects on global sea level. *Surv. Geophys.* 38: 89-104)

Noise impacts

Sperm whales stop resting and feeding when exposed to military sonar

Several studies have investigated the effects of sonar on beaked whales, but there is scant information on other deep-diving species. Two recent studies on sperm whales exposed to sonar reported avoidance behaviour, interruption of foraging and/or resting behaviour, and an increase in social sound production in response to 1-2 kHz (mid-frequency) active sonar. The sperm whales stopped foraging at a cumulative received sound exposure level (SEL) of 135 to 145 dB re 1 μPa. They also displayed avoidance and social call changes in response to 6-7 kHz (high frequency) sonar, although the responses were less pronounced.

(SOURCES: Curé, C., Isojunno, S., Visser, F., Wensveen, P. J., Sivle, L. D., Kvadsheim, P. H., Lam, F. P. A., and Miller, P.J.O. 2016. Biological significance of sperm whale responses to sonar: Comparison with anti-predator responses. *Endang. Spec. Res.* 31: 89-102; Isojunno, S., Curé, C., Kvadsheim, P. K., Lam, F. P. A., Tyack, P. L., Wensveen, P., and Miller, P.J.O. 2016. Sperm whales reduce foraging effort during exposure to 1-2 kHz sonar and killer whale sounds. *Ecol. Applic.* 26: 77-93)

A quieter alternative to seismic survey airguns?

Vibroseis is a method used to conduct seismic surveys where, instead of an explosion, a longer duration vibration is used to gather geological data. This method could be used in the marine environment, potentially as a way to reduce noise-based impacts on cetaceans. Sound levels were modelled from a vibroseis array and an airgun array and compared under different marine scenarios: shallow water, deep water and an underwater slope. At a distance of 100 m, the vibroseis array was 20 dB lower in peak-to-peak SPL vs the airgun array, and 12 dB lower at 5 km. At 100km the SELs were a total of 8 dB lower. In general, the vibroseis array produced lower sound levels than the airgun array, and could be a promising mitigation measure to reduce impacts on cetaceans from seismic surveys.

(SOURCES: Duncan, A.J., Weilgart, L.S., Leaper, R., Jasny, M and Livermore, S. 2017. A modelling comparison between received sound levels produced by a marine Vibroseis array and those from an airgun array for some typical seismic survey scenarios. *Mar. Pollut. Bull.*, in press)

Overlap of blue and fin whales with seismic survey noise in cetacean soundscapes

An analysis was conducted on three soundscapes in the Atlantic Ocean, from the Arctic to the Antarctic, to document sound levels. The highest sound levels were found in the equatorial Atlantic, and this was attributed to high levels of seismic survey noise from oil and gas exploration—at the Ascension Island study site, seismic airgun signals were audible during almost every hour of the study period. Seismic surveys were also occurring in Fram Strait in the Arctic, primarily during the summer, for 10 out of 16 months of recording. During those 10 months, seismic survey noise was detected, on average, 17 hours per day (for a total duration of over 4000 hours during the study period from August 2009 through December 2010). In August and September, the occurrence of blue and fin whales coincided with seismic survey noise in the Arctic site. At the Atlantic site, blue and fin whale calls were heard year round, meaning there was a year-round overlap (and potential masking) with seismic survey noise.

(SOURCE: Haver, S., Klinck, H., Miksis-Olds, J.L., Nieukirk, S.L., Matsumoto, H., and Dziak, R.P. 2017. The not-so-silent world: measuring Arctic, Equatorial, and Antarctic soundscapes in the Atlantic Ocean. *Deep-Sea Res. I* 122: 95-104).

A need to standardise sound measurements for impact policy purposes

Studies that describe the impacts of noise, both in the terrestrial and aquatic environment, often portray sound levels in different ways. For example, sounds might be measured as 1) SPL RMS–the ‘average height’ of the sound wave over a specified time period; and 2) ‘peak-to-peak’ (the difference between the highest and lowest pressure deviations in a given time interval). Depending on how noise is measured, a given sound level may actually vary in practical terms by up to 12 dB. Most managers, environmental advocates and policy-makers are not trained in the physics of underwater sound and fail to realize that the decibel scale is not easily comparable for underwater versus above-water noise. (Editor’s note: For example the ‘loudness’ of sound sources such as seismic survey air guns is often compared to the loudness of a Boeing 747 jet taking off, which is approximately 150 dB (at 25 m) in air. Importantly, however, this would be valued as 215.5 dB (re 1µPa) underwater because of the difference of reference values and the physical nature of water.) A new review on this issue presented marine mammal case studies that highlighted such discrepancies. In one example, two levels were given the same decibel value, although there was actually a 45 dB difference between them. The review called for standardising how sound levels are expressed, especially when dealing with noise impacts. In particular the frequency spectrum should be expressed (e.g., in a format such as ‘40 dB SPL_{max} re 1µPa (10-200 Hz)’). In the case study noted above, for example, the disparity was because measurements were made over different frequency ranges. (Editor’s note: An analogy is trying to count the number of birds in a wood—although the number of birds remains the same, one gets a very different value if counting at midday versus at midnight. The observation ‘window’ needs to be standardised.) Because noise-related damage is often related to the maximum amount of noise in an event, it is important to note the maximum sound level (SPL_{max}), rather than averaging sound levels over a lengthier period. Sound-related damage may also increase as a result of continuous exposure, so that the cumulative sound exposure level (SEL) is also important, with information on the sound duration. The background noise level in an animal’s habitat might also be an important value when measuring impacts. (Editor’s note: For example, a dolphin that inhabits waters near a noisy harbour with a high level of background noise might be affected differently by a passing boat than a dolphin in a quiet bay. This is also an issue when the responses of animals kept in captive settings are used to predict responses of animals in quieter wild settings.) Finally, as noise exposure may cause stress responses, noting the duration of a noise exposure, as well as the duration of subsequent quiet ‘recovery’ periods, is also important. An intense sound that is shortly followed by another intense sound might be more stressful than a sound that is followed by a long quiet period. This calls for standardising how noise levels are expressed in papers and developing improved regulations in order to efficiently manage the impacts of sounds on cetaceans (and other species).

(SOURCE: McKenna, M.F., Shannon, G., and Fristrup, K. 2016. Characterizing anthropogenic noise to improve understanding and management of impacts to wildlife. *Endang. Species Res*. 31: 279-291)

New method to detect noise-related injury in the inner ears of cetaceans

Because of decomposition of acoustic tissues, detecting hearing damage in stranded cetaceans can be difficult. A new method to examine the structure of the inner ear of stranded cetaceans was trialled on two stranded long-finned pilot whales. In one of the animals (a juvenile), many sensory cells in the inner ear were missing, suggesting overexposure to underwater noise, specifically lower frequency noise. The method allowed analysis of ear tissues for damage even 30 hours after death. This approach might be extremely valuable in evaluating the degree of noise-related injury in stranded cetaceans.

(SOURCE: Morell, M., Brownlow, A., McGovern, B., Raverty, S.A., Shadwick, R.E., and André, M. 2017. Implementation of a method to visualize noise-induced hearing loss in mass stranded cetaceans. *Scientific Reports* 7: 41848; doi: 10.1038/srep41848)

Seismic survey sounds dramatically reduce reef fish abundance

The impacts of seismic surveys on cetaceans is an issue that is receiving increasing attention, but few studies have investigated the impacts of these intense sound-producing activities upon the habitats of cetaceans. A new study recorded videos of fish on a reef before and during a seismic survey, to assess the effect on fish abundance. During seismic surveying, reef-fish abundance declined by 78%. This shows that such surveys may not only impact cetaceans, but also their prey species. The researchers stated that “[t]he finding…goes well beyond detection of a startle response from individual fish, instead suggesting a multi-species response to airgun noise” and “these research results augment and confirm issues raised by marine mammal experts and suggest that concerns associated with marine seismic surveys appear to be realistic and well-founded”. Therefore, seismic surveys could have substantial impacts on cetacean prey species, as well as on cetaceans themselves.

(SOURCE: Paxton, A.B., Taylor, J.C., Nowacek, D.P., Dale, J., Cole, E., Voss, C.M., and Peterson, C.H. 2017. Seismic survey noise disrupted fish use of a temperate reef. *Mar. Pol.* 78: 68-73)

Scientific echo-sounder alters pilot whale behaviour

Mid- and low-frequency active military sonar has an impact on several cetacean species, but there is limited information on the impacts of other types of sonars. An experiment was conducted on the impacts of a scientific echo-sounder (EK60) on the behaviour of five short-finned pilot whales. Hidden Markov model analyses found that although foraging behaviour did not change, the animals frequently changed their swimming direction during exposure. This study showed an impact on cetacean behaviour from a sound-producing technology that is often not considered during impact assessments.

(SOURCE; Quick, N., Scott-Hayward, L., Sadykova, D., Nowacek, D., and Read, A. 2016. Effects of a scientific echo sounder on the behavior of short-finned pilot whales (*Globicephala macrorhynchus*). *Can. J. Fish. Aquat. Sci*.: in press)

A new method to analyse behavioural changes in response to disturbance

A new method to measure subtle behavioural impacts from anthropogenic disturbance and noise was developed and trialled with killer whales as the test species. Fractal analysis was used to determine whether animals moved directly (with little deviation), or whether they deviated from their course and changed direction more frequently—a behavioural change that has been reported in response to anthropogenic disturbance. The method was viable for highlighting sometimes subtle and difficult to perceive, but statistically significant, behavioural responses to disturbance.

(SOURCE: Seuront, L. and Cribb, N. 2017. Fractal analysis provides new insights into the complexity of marine mammal behavior: A review, two methods, their application to diving and surfacing patterns, and their relevance to marine mammal welfare assessment. *Mar. Mamm. Sci.*, in press.)

Feeding behaviour of humpback whales significantly reduced during sonar exposure

The (lunge) feeding behaviour of humpback whales was examined during controlled exposure experiments to military low-frequency sonar (1.3−2.0 kHz with SPLs at the source of up to 160-180 dB re 1 μPa). The animals were fitted with acoustic- and motion-sensing devices, which allowed the distinctive actions of lunge feeding to be detected. The first exposure of 12 whales lead to a statistically significant 68% reduction in lunge feeding rates. During a second exposure, the feeding rate was 66% below pre-exposure levels. The researchers stated that "Our results indicate that naval sonars operating near humpback whale feeding grounds may lead to reduced foraging and negative impacts on energy balance".

(SOURCE: Sivle, L.D., Wensveen, P.J., Kvadsheim, P.H., Lam, F.P.A., Visser, F., Curé, C., Harris, C.M., Tyack, P.L., and Miller, P.J.O. 2016. Naval sonar disrupts foraging in humpback whales. *Mar. Ecol. Prog. Ser.* 562: 211-220)

The energetic cost for beaked whales of trying to evade naval sonar

The respiration rate in bottlenose dolphins during swimming was used to calculate the energetic cost of fluke strokes (3.31 ± 0.20 J kg^{-1} $stroke^{-1}$). This was then used to estimate the cost of high speed evasion responses in cetaceans of a variety of sizes. It was found that the larger the cetacean, the greater the relative cost of swimming became. Modelling the energetic cost for the response documented by beaked whales to naval sonar (increased fluking rates and longer bursts of powered swimming) showed a 30.5% increase in metabolic rate, with an elevated rate being maintained for more than 90 min after the exposure to noise. This demonstrates a clear energetic cost associated with the evasion response exhibited by beaked whales to navy sonar.

(SOURCE; Williams, T.E. et al. 2017. Swimming and diving energetics in dolphins: a stroke-by-stroke analysis for predicting the cost of flight responses in wild odontocetes. *J. Exp. Biol.* 220: 1135-1145)

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Appendix 1

GLOSSARY

Species glossary

Blue whale	*Balaenoptera musculus*
Bryde's whale	*Balaenoptera edeni*
Common bottlenose dolphin	*Tursiops truncatus*
Fin whale	*Balaenoptera physalus*
Ganges river dolphin	*Platanista gangetica*
Humpback whale	*Megaptera novaeangliae*
Indian Ocean humpback dolphin	*Sousa plumbea*
Indo-Pacific bottlenose dolphin	*Tursiops aduncus*
Indo-Pacific humpback dolphin	*Sousa chinensis*
Killer whale	*Orcinus orca*
Long-finned pilot whale	*Globicephala melas*
North Atlantic right whale	*Eubalaena glacialis*
Omura's whale	*Balaenoptera omurai*
Short-finned pilot whale	*Globicephala macrorhynchus*
Sperm whale	*Physeter macrocephalus*
Spinner dolphin	*Stenella longirostris*
Antarctic krill	*Euphausia superba*
Mullet	*Liza klunzingeri*

Heavy metals

Cd – Cadmium

Cu – Copper

Hg – Mercury

Pb – Lead

Zn – Zinc

Glossary of terms

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

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

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

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.

Dinoflagellate: A large group of unicellular algae belonging to the phytoplankton.

EEZ: Exclusive Economic Zone.

Estuarine: Related to estuaries or river mouths.

Eutrophication: Input of nutrients into an aquatic system, typically associated with excessive plant growth and oxygen depletion.

FAO: Food and Agriculture Organization, an intergovernmental organization with 194 Member Nations.

Fractal: A rough or fragmented geometric shape that can be split into parts, each of which is (at least approximately) a reduced-size copy of the whole.

Gyre: Large system of rotating ocean currents.

HCB: Hexachlorobenzene, an organochloride compound.

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.

IOC: Intergovernmental Oceanographic Commission of UNESCO.

J: Joule

μPa: Micropascal, a unit of pressure.

MeO-PBDE: Methyloxidated polybrominated diphenyl ether.

Microplastics: Plastic particles 0.3-5 mm in diameter, often the result of larger plastic pieces breaking down over time.

MPA: Marine Protected Area.

NASA: National Aeronautics and Space Agency of the US Government.

Newton: The International System of Units unit of force.

NOAA: National Oceanic and Atmospheric Administration of the US Government.

nm: Nautical mile.

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. See also organohalogen.

Organohalogen: Organic compounds that contain any halogen (i.e., fluorine, chlorine, bromine, or iodine).

PBDE: Polybrominated diphenyl ether.

PCB: Polychlorinated biphenyls.

Perinatal: The period ranging from one month before to one month after birth.

POPs: Persistent organic pollutants, organic compounds that are resistant to degradation and thus persist in the environment.

ppm: Parts per million

ppt: Parts per thousand

rms: Root-mean-square. A measurement of sound pressure.

SCOR: Scientific Committee on Ocean Research of UNESCO.

SEL: Sound exposure level.

Soundscape: The level of natural and anthropogenic sound in the environment.

SPL: Sound pressure level. SPL_{max} refers to maximum SPL.

Stratification: Layering of the water column due to different water densities, as induced for example by temperature or salinity differences.

Sympatric: Occurring in the same geographical area, used with animals and plants.

T-Hg: Total mercury.

UNESCO: United Nations Education, Scientific and Cultural Organization.