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Final State of the Cetacean Environment Report (SOCER) 2021

M. Stachowitsch , N.A. Rose and E.C.M. Parsons (editors)

INTERNATIONAL WHALING COMMISSION
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State of the Cetacean Environment Report (SOCER) 2021

Editors: M. Stachowitsch[1], N.A. Rose[2] and E.C.M. Parsons[3]

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 presented in 2003 and subsequent editions initiated and continued a cycle of focusing on the following regions: Atlantic Ocean, Pacific Ocean, Arctic and Antarctic Oceans, Indian Ocean, and Mediterranean and Black Seas. Each SOCER also includes a Global section addressing the newest information that applies generally to the cetacean environment. The 2021 SOCER features the **Pacific Ocean**, summarising key papers and articles published from ca. 2019 through 2021 to date. This year's regional SOCER represents the second year of the current cycle, which will be combined in a second 5-year compendium (2020: Atlantic Ocean through 2024: Mediterranean and Black Seas; see first 5-year compendium at *https://iwc.int/socer-report*) to present to the Commissioners at IWC/70.

PACIFIC OCEAN

General

DEFINING, MONITORING AND IMPROVING THE HABITAT OF A RESIDENT DOLPHIN POPULATION

A key issue in protecting local cetacean populations is to understand the habitat they occupy and the threats they face there. A small, endangered population of ca. 68 bottlenose dolphins in Doubtful Sound, New Zealand, showed a consistent pattern of habitat use over 13 years, although seasonal variation occurred. The overlap between dolphin protection zones (DPZs) and core areas of habitat was low (< 18%), pointing to the need to expand the DPZs to afford greater protection from main threats (e.g. tourism). Bennington *et al.* (2021) note the importance of identifying what factors determine the habitat use (e.g. food availability) in order to optimise management efforts. Bennington *et al.* (2020) inserted potential prey into a habitat model and determined that such information considerably improved predictions as to which areas the dolphins preferred. This approach helps to improve our understanding of what determines the distribution of these dolphins and of marine predators in general. Brough *et al*. 2019 applied a similar approach to determine the distribution 'hotspots' of Hector's dolphins at Banks Peninsula, New Zealand, and confirmed a consistency based on 9000 sightings over 29 years. This is an important step in suggesting candidate areas for further protection from threats as diverse as tourism activities, vessel strikes, dredging, seismic surveys, aquaculture, and other activities not prohibited in the current Banks Pen insula Marine Mammal Sanctuary.

*(SOURCES: Bennington, S., Rayment, W., Currey, R., Oldridge, L., Henderson, S., Guerra, M., Brough, T., Johnston, D., Corne, C., Johnson, D., Slooten, L. and Dawson, S. 2021. Long-term stability in core habitat of an endangered population of bottlenose dolphins (*Tursiops truncatus*): Implications for spatial management. Aquat. Conserv. 31: 665–676, doi:10.1002/aqc.3460; Bennington, S., Rayment, W. and Dawson, S. 2020. Putting prey into the picture: Improvements to species distribution models for bottlenose dolphins in Doubtful Sound, New Zealand. Mar. Ecol. Prog. Ser. 653: 191–204, https://doi.org/10.3354/meps13492; Brough, T., Rayment, W., Slooten, L. and Dawson, S. 2019. Fine scale distribution for a population of New Zealand's only endemic*

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*dolphin (*Cephalorhynchus hectori*) shows long-term stability of coastal hotspots. Mar. Mamm. Sci. 35: 140–163, doi:10.1111/mms.12528)*

COLLAPSE OF SQUID FISHERY POINTS TO ECOSYSTEM SHIFT IN GULF OF CALIFORNIA AND BEYOND

The fourth largest fishery in all of Mexico, for the jumbo or Humboldt squid in the Gulf of California, has collapsed and shows no signs of recovery. This spells trouble for the Gulf of California's marine ecosystems and fishery-dependent economies. The authors identify shifting weather patterns and ocean conditions as likely causes for the collapse. Specifically, shifting currents and circulation patterns have deprived the squid and their prey of cooler, nutrient-rich waters. The squid respond to the warmer conditions by limiting their growth, shortening their lifespan and reproducing earlier. This situation is emblematic of other factors affecting marine organisms (including cetaceans) and ecosystems across the northeast Pacific, such as marine heatwaves, HABs, mass animal strandings and species range shifts. The authors highlight the need to address potential rapid system changes by introducing adaptive, ecosystem-based management with real-time monitoring.

(SOURCE: Frawley, T., Briscoe, D.K., Daniel, P.C., Britten, G.L., Crowder, L.B., Robinson, C.J. and Gilly, W.F. 2019. Impacts of a shift to a warm-water regime in the Gulf of California on jumbo squid (Dosidicus gigas). ICES J. Mar. Sci. 76(7): 2413–2426, doi:10.1093/icesjms/fsz133)

EARTHQUAKE ALTERS HABITAT OF SPERM WHALES IN NEW ZEALAND

Beyond anthropogenic impacts, natural disturbances have the potential to alter cetacean habitats and habitat use. A magnitude 7.8 earthquake in New Zealand triggered a 'canyon flushing' (underwater slides and turbidity currents) in the submarine canyon of Kaikoura. While the blow rates of sperm whales remained unchanged after this event, the mean surface interval between dives was 25% longer for the following year. Changes in the seafloor and in prey availability possibly changed the diving rates and distribution of core foraging areas. This represents a shift in habitat use for at least one year. The authors call for long-term monitoring, considering the decline in the abundance of this species here and its important economic (and ecosystem) role.

(SOURCE: Guerra, M., Dawson, S., Sabadel, A., Slooten. E., Somerford, T., Williams, R., Wing, L. and Rayment, W. 2020. Changes in habitat use by a deep-diving predator in response to a coastal earthquake. Deep-Sea Res. Pt. I 158: 103226, https://doi.org/10.1016/j.dsr.2020.103226)

EXTINCTION OF SOUTHERN RESIDENT KILLER WHALES PREDICTED AS EARLY AS THE END OF 21ST CENTURY

The northern and southern resident killer whale populations in western Canada are listed as threatened (NRKW) and endangered (SRKW) under the Canadian Species at Risk Act. The recovery plans for these populations developed under the Act prioritise an assessment of the cumulative effects of anthropogenic threats to these populations. A cumulative effects assessment framework consisted of a Pathways of Effects (PoE) conceptual model and a Population Viability Analysis (PVA). The PoE model notes the current understanding of priority threats (prey availability, disturbance and contaminants) and possible threat interactions and potential impacts to population parameters (fecundity and mortality). Its outputs then inform the PVA, together with the latest biological data on the populations. The model results were compared against the whales' observed population trajectories. The models that combined impacts from food (Chinook salmon) abundance, vessel noise/presence, ship strikes, and PCB contamination most closely predicted actual observations. The PVA found that Chinook salmon abundance and its interactions with vessel noise/presence and PCBs strongly influenced modelled killer whale population dynamics. The NRKWs slowly increased until they reached carrying capacity, but the SRKWs declined, with a 26% probability that population extinction would occur in 86 (± 11) years. These results demonstrate the importance of considering cumulative effects of threats when managing populations.

(SOURCE: Murray, C.C., Hannah, L.C., Doniol-Valcroze, T., Wright, B., Stredulinsky, E., Locke, A. and Lacy, R. 2019. Cumulative Effects Assessment for Northern and Southern Resident Killer Whale Populations in the Northeast Pacific. DFO Can. Sci. Advis. Sec. Res. Doc. 2019/056, https://epe.lac-bac.gc.ca/100/201/301/weekly_acquisitions_list-ef/2019/19-41/publications.gc.ca/collections/collection_2019/mpo-dfo/fs70-5/Fs70-5-2019-056-eng.pdf)

Habitat degradation

General

HYPOXIC AREAS IN THE EAST CHINA SEA AMONG THE LARGEST IN THE WORLD

The East China Sea is the largest marginal sea in the western Pacific and one of the most important fishing grounds in China. Hypoxia has been frequently reported here since the 1950s, but the phenomenon has now extended into the autumn months. The area affected (larger than 15,000 km²) makes this one of the three largest hypoxic systems in the world (the others are the Black Sea and Gulf of Mexico). The authors attribute this partly to the "tremendous amount of anthropogenic nutrients discharged from the Chiangjiang River". The authors call for further investigation of the impacts of hypoxia here, given that these events may persist longer than previously thought.

(*SOURCE: Chen, C.-C., Gong, G.-C., Chou, W.-C. and Shiah, F.-K. 2020. Hypoxia in autumn of the East China Sea. Mar. Pollut. Bull. 152: 110875, https://doi.org/10.1016/j.marpolbul.2019.110875)*

LACK OF SALMON PREVENTING COOK INLET BELUGA POPULATION RECOVERY

The Cook Inlet (Alaska) beluga population continues to decline. Models have allowed assessment of Chinook and coho salmon abundance and its effects on beluga reproductive success and calf production. Salmon abundance in the calf year of birth and year prior to birth best fit with the observed calving rates. Simulations predicted that if salmon remained at their current levels, the Cook Inlet beluga whale population would continue with a low birth rate and would probably continue its current slow decline. The birth rate here appears to be related to salmon abundance in the Deshka River, and management plans to bring about the recovery of this threatened population need to include ways to increase salmon levels in this river system.

(*SOURCE: Norman, S.A., Hobbs, R.C., Beckett, L.A., Trumble, S.J. and Smith, W.A. 2020. Relationship between per capita births of Cook Inlet belugas and summer salmon runs: age-structured population modeling. Ecosphere 11(1): e02955: 1–15, https://doi.org/10.1002/ecs2.2955)*

CONSTRUCTION DISTURBANCE OF DOLPHINS IN HONG KONG

A great deal of construction has occurred in the habitat of the Hong Kong population of Indo-Pacific humpback dolphins. In several historically important areas currently affected by chronic construction activity, dolphins now only occur in low numbers. In addition, dolphin swimming speeds were higher in the presence of vessel traffic. Foraging and travelling were the most frequently observed types of behaviour, but resting was only observed in one area where no construction was taking place. The authors recommend that MPAs be established to protect important remaining habitat and to mitigate the effects of disturbance caused by the construction.

(*SOURCE: Piwetz, S., Jefferson, T.A. and Würsig, B. 2021. Effects of coastal construction on Indo-Pacific humpback dolphin (*Sousa chinensis*) behavior and habitat-use off Hong Kong. Front. Mar. Sci. 8: 572535, doi:10.3389/fmars.2021.572535)*

CHANGES IN FIN WHALE BEHAVIOUR DUE TO WHALE WATCHING ACTIVITIES IN CHILE

Chile has a national set of guidelines for the management of whale watching and also an MPA with additional restrictions. Off north-central Chile (Caleta Chañaral de Aceituno), when fin whales were travelling or resting, their movements became more erratic when whale watching vessels arrived. For travelling whales, even after whale watching vessels departed the area, swimming speed significantly increased and movement remained erratic. When resting, whale movement became straighter and more direct as the number of vessels increased, rather than erratic or evasive. Even though the scale of the whale watching industry is still small in this area, behavioural impacts occur; the changes in resting animals is of particular concern. The authors suggest a precautionary approach to managing whale watching here, before the industry expands further.

(*SOURCE: Santos-Carvallo, M., Barilari, F., Pérez-Alvarez, M.J., Gutiérrez, L., Pavez, G., Araya, H., Anguita, C., Cerda, C. and Sepúlveda, M. 2021. Impacts of whale-watching on the short-term behavior of fin whales (Balaenoptera physalus) in a Marine Protected Area in the Southeastern Pacific. Front. Mar. Sci. 8: 623954, doi:10.3389/fmars.2021.623954)*

Fisheries interactions

LIGHT EMITTING DIODES—A PROMISING APPROACH TO REDUCING CETACEAN BYCATCH IN SMALL-SCALE GILLNET FISHERIES

Gillnet fisheries and their bycatch of multiple taxa are a global problem. This has led to the development of bycatch reduction technologies (BRT); for example, acoustic alarms (so-called "pingers"). In Peru, the total length of gillnets set is estimated to exceed 100,000 km per year, and the estimated annual bycatch of small cetaceans is reported to be in the range 10,000–20,000 animals. Deploying light emitting diodes (LEDs) as visual cues on the float lines of paired gillnets on small-scale fishing vessels from three ports reduced the bycatch probability per set for cetaceans by almost 71%, compared to non-illuminated nets. The two most commonly bycaught species were the dusky dolphin and Burmeister's porpoise. Both are considered conservation priorities by the IUCN Cetacean Specialist Group. The relatively low cost of LEDs (compared to pingers) and the current lack of alternate solutions highlight the potential of net illumination as a BRT for cetaceans, but also for sea turtles and seabirds.

(*SOURCE: Bielli, A., Alfaro-Shigueto, J., Doherty, P.D., Godley, B.J., Ortiz, C., Pasara, A., Wang, J.H. and Mangel, J.C. 2020. An illuminating idea to reduce bycatch in the Peruvian small-scale gillnet fishery. Biol. Conserv. 241: 108277, doi.org/10.1016/j.biocon.2019.108277)*

EFFORTS TO BETTER PREDICT THE DISTRIBUTION OF THE CRITICALLY ENDANGERED MAUI DOLPHIN

The current estimated population (63 individuals) of the critically endangered Maui dolphins is now mostly restricted to a short, 140 km-long stretch on the west coast of New Zealand's North Island. De Jager *et al.* (2019) used so-called individual-based modelling to create Maui dolphin probability distribution maps. The resulting distributions fell well outside the current protection zones, exposing them to their key threats, namely gill nets and/or trawling. Overlaying such distribution maps with maps of ongoing fishing activities can help pinpoint the areas where human-dolphin interactions are most likely to cause casualties. The distribution maps could be improved by incorporating information on prey fish, which are typically aggregated rather than evenly distributed. Slooten (2020) notes that the bycatch threats to Maui dolphins have only been partially improved from a previous estimate of five mortalities per year to three, reflecting improvements in gillnet fisheries, but no additional protection from trawling. The author notes that other potential impacts such as pollution, disease and boat strikes are "very difficult to quantify and monitor, let alone reduce or avoid", but that, with an extended protection area, substantial recovery is possible without fisheries mortalities.

(SOURCES: de Jager, M., Hengeveld, G.M., Mooijd, W.M. and Slooten, L. 2019. Modelling the spatial dynamics of Maui dolphins using individual-based models. Ecol. Model. 402: 59–65, https://doi.org/10.1016/j.ecolmodel.2019.04.009; Slooten, E. 2020. Effectiveness of current protection for Maui dolphin. J. Cetacean Res. Manage. 21: 151–155)

THE HABITAT OF THE VAQUITA IS BEING MADE UNINHABITABLE

The vaquita, the world's smallest cetacean and the most endangered marine mammal, is endemic to the upper Gulf of California. Its fate is intimately tied to that of shrimp and the totoaba, itself an endangered fish species. Fishing for shrimp with suboptimal gear and illegal totoaba fishing (hunted for their swim bladders, which are primarily sold on China's black market)—this gear entangles and drowns vaquitas—is driving this species to extinction. The vaquita's fate underlines that even a specially proclaimed refuge and the best efforts of dedicated biologists can be insufficient to prevent a habitat from becoming unlivable for a cetacean species. In an attempt to address one aspect, Dunch (2019) draws a connection between the vaquita's fate and American shrimp consumers (80% of shrimp caught in the Gulf are sold to the Unites States) and argues for closer partnering of scientists with seafood restaurants and chefs.

(SOURCES: Dunch, V. 2019. Saving the vaquita one bite at a time: The missing role of the shrimp consumer in vaquita conservation. Mar. Pollut. Bull. 145: 583–585, https://doi.org/10.1016/marpolbul.2019.06.043; Bessesen, B. 2018. Vaquita: Science, Politics, and Crime in the Sea of Cortez. Island Press, Washington, DC, USA)

RECOVERY OF INDO-PACIFIC FINLESS PORPOISE POPULATIONS MAY BE POSSIBLE WITH SUFFICIENT MANAGEMENT EFFORT

The finless porpoise is susceptible to fishery-caused mortality, and its numbers are thought to be in decline across its entire range. However, population demographics have rarely been quantified for this genus. Data from nearly two decades were collected from stranded carcasses across the Pearl River Delta region in China, and, augmented by previous estimates of life history parameters, a modelled life table was constructed for the Indo-Pacific finless porpoise in the northern reaches of the South China Sea. Results suggested that the species experienced a moderate to high level of decline during 1996–2005, which has subsequently been reversed, leading to a slightly increasing trend in the following decade, although the rate of increase was much lower than the previous decline. This demographic change may be due to changes in fishing effort, which has been declining locally since the late 1990s. The authors note that "[h]aving the population status improve even in the absence of any specific conservation action plan indicates a considerable potential of the species for population recovery". While more study is needed, this situation suggests that regulated management of coastal fisheries can serve as an effective tool in securing the long-term persistence of Indo-Pacific finless porpoise populations. As long as the primary sources of negative pressure are sufficiently lessened, "porpoise populations may be able to bounce back".

(SOURCE: Lin, W., Karczmarski, L., Li, J., Chan, S.C.Y., Guo, L. and Wu, Y. 2019. Differential population dynamics of a coastal porpoise correspond to the fishing effort in a large estuarine system. Aquatic Conserv. 29: 223–234, https://doi.org/10.1002/aqc.2998)

MARINE MAMMAL BYCATCH SURVEY REVEALS CONSUMPTION AND TRADE OF CETACEAN MEAT IN CHINA

Fishers were interviewed to investigate levels of bycatch of marine mammals (cetaceans and dugongs) in Hainan Island, China. Gillnets were the primary fishing gear used in the area, and also the main gear involved in bycatch. Bycatch was most frequent in the spring, possibly because of higher fishing effort, but cases occurred year round. Of fishers who had entangled a cetacean (n = 510; no dugongs were reported as bycatch), approximately half claimed to have released the animal alive. However, 36% admitted that they had eaten—and 9% said they had sold—cetacean meat. Approximately half the fishers surveyed agreed that marine mammal populations in the South China Sea had declined, which they attributed to overfishing, pollution and ship strikes, in addition to bycatch. The authors suggest that an MPA might protect marine mammals around Hainan, but laws prohibiting hunting, killing and trade also need to be enforced. They also recommended a public education programme to increase awareness about marine mammal conservation.

(SOURCE: Liu, M., Lin, M., Turvey, S.T. and Li, S. 2017. Fishers' knowledge as an information source to investigate bycatch of marine mammals in the South China Sea. Anim. Conserv. 20: 182–192, https://doi.org/10.1111/acv.12304)

BYCATCH RATES INCREASING IN AUSTRALIA

Bycatch and entanglement records from Australia dating from 1887 to 2016 (n = 1987) showed that, since 2000, reported bycatch had substantially increased, probably due to improved monitoring, changing levels of fishing effort and the recovery of some species since the cessation of whaling. At least 27 cetacean species were recorded; humpback whales, common bottlenose dolphins and short-beaked common dolphins were entangled most frequently, with three times as many odontocetes entangled as mysticetes. Only a quarter of animals were released alive. Over 30% of records were of threatened, vulnerable or endangered species. Bycatch and entanglement rates were higher on the east and west coast adjacent to areas of high human populations, due to higher fishing effort and also the presence of anti-shark nets, but possibly also reflecting reporting effort. The authors recommend increased monitoring effort and a standardisation of reporting. They express concern that bycatch and entanglement rates may place inshore dolphin populations at risk of depletion, in particular Australian humpback, Indo-Pacific bottlenose, short-beaked common and snubfin dolphins.

(SOURCE: Tulloch, V., Pirotta, V., Grech, A., et al. 2020. Long-term trends and a risk analysis of cetacean entanglements and bycatch in fisheries gear in Australian waters. Biodiv. Conserv. 29: 251–282, https://doi.org/10.1007/s10531-019-01881-x)

Marine Debris

MARINE DEBRIS AND RISK OF CETACEAN EXPOSURE OFF THE COAST OF MAUI, HAWAI'I

Marine debris was found in all areas off the coast of the island of Maui in Hawai'i, USA, with higher concentrations where water channels converged. Of the 1027 debris items collected, most could not be assigned as originating specifically from land or ocean sources. Nearly 90% of items were considered to pose an ingestion risk and 12% an entanglement risk. Plastics accounted for 86% of the debris. The most frequent types of fishing-related debris were buoys with rope and fishing line, with netting representing a much smaller proportion. Plastic containers and foamed polystyrene (e.g. disposable plates, cups) comprised the majority of other types of debris. The overlap between debris distribution and cetaceans was greatest for humpback whales, which also have the greatest number of debris entanglement reports. The authors conclude that "identifying areas of high debris-cetacean density overlap can facilitate species management and debris removal efforts".

(SOURCE: Currie, J.J., Stack, S.H., McCordic, J.A. and Kaufman, G.D. 2017. Quantifying the risk that marine debris poses to cetaceans in coastal waters of the 4-island region of Maui. Mar. Pollut. Bull. 121: 69–77, https://doi.org/10.1016/j.marpolbul.2017.05.031)

CETACEANS OBSERVED IN THE GREAT PACIFIC GARBAGE PATCH

Cetacean sightings were made in 2016 by observers surveying the 'Great Pacific Garbage Patch', a major oceanic accumulation zone for plastics. Four sperm whales (including a mother and calf pair), three beaked whales, two unidentified baleen whales, and at least five other cetaceans were observed. Many surface drifting plastics were also detected, including fishing nets, ropes, floats and fragmented debris. Some of these items were close to the cetaceans, certainly posing entanglement and ingestion risks. Clearly cetaceans do not or cannot avoid this extensive region, although the actual impacts of this exposure on these populations are currently unknown.

(SOURCE: Gibbs, S.E., Salgado Kent, C.P., Slat, B., Morales, D., Fouda, L. and Reisser, J. 2019. Cetacean sightings within the Great Pacific Garbage Patch. Mar. Biodivers. 49: 2021–2027, https://doi.org/10.1007/s12526-019-00952-0)

PLASTIC DEBRIS INGESTION A POTENTIAL ISSUE IN NORTH PACIFIC BALEEN WHALES

The examination of a dead, floating juvenile fin whale off Jeju Island, South Korea, revealed 45 plastic items in its stomach, including fishing lines, plastic filaments, pieces of fishing nets and Styrofoam particles. Some filaments were also found entangled in the baleen plate bristles. The authors note that plastic pollution in the North Pacific Gyre, the habitat of several baleen whale species, including fin whales, is increasing rapidly. They conclude that this poses a potential risk to these whales and call for further research on stranded and incidentally caught carcasses.

*(SOURCE: Im, J., Joo, S., Lee, Y., Kim, B.-Y. and Kim, T. 2020. First record of plastic debris ingestions by a fin whale (*Balaenoptera physalus*) in the sea off East Asia. Mar. Pollut. Bull. 159: 111514, https://doi.org/10.1016/marpolbul.2020.111514)*

MICROPLASTIC POLLUTION IN THE NORTHWEST PACIFIC OCEAN

Microplastic pollution is a recognised threat in marine ecosystems and is ubiquitous on a global scale. In this study, microplastics were detected at all sampling sites, and the average abundance in surface waters of the northwest Pacific was 6.2×10^4 items per km^2, with some stations showing comparatively high abundances exceeding 1.0×10^5 items per km^2. The average value is lower than in the northwest Mediterranean Sea (1.1×10^5 items per km^2) and the average values in the Atlantic and Pacific (1.3 and 1.2×10^5 items per km^2, respectively) and much lower than the peak values in the so-called Great Pacific Garbage Patch (6.8×10^5 items per km^2) or the East Asian Sea (1.7×10^6 items per km^2). The authors note that this highlights the highly heterogeneous distribution of microplastics in the Pacific (and Atlantic) Ocean and underlines the general correlation between microplastic pollution and human population densities, which are the highest in the world along the eastern coast of the Asian continent.

(SOURCE: Pan, Z., Liu, G., Sun, Y., Sun, X. and Lin, H. 2019. Environmental implications of microplastic pollution in the Northwestern Pacific Ocean. Mar. Pollut. Bull. 146: 215-224, https://doi.org/10.1016/j.marpolbul.2019.06.031)

World's Most Plastic-Contaminated Deep-Sea Zone Identified In South China Sea

The Xisha Trough area (1700–1800 m depth) in the northern South China Sea was found to have peak marine debris densities of nearly 52,000 items/km², making it the worst plastic-contaminated deep-sea zone ever recorded. Plastic items (e.g. bags, bottles) dominated, followed by derelict fishing gear. The authors consider that most of the items stem from fishery and navigation activities. As all such items spend considerable time at the surface and/or in the water column before sinking to the seafloor, they highlight the well-known threats to all marine life, including cetaceans. This new information is also useful in helping to answer the much-posed question of where most of the estimated 8 million tons of debris that enter the world's oceans every year ultimately end up.

(SOURCE: Peng, X., Dasgupta, S., Zhong, G., Du, M., Xu, H., Chen, M., Chen, S., Ta, K. and Li, J. 2019. Large debris dumps in the northern South China Sea. Mar. Pollut. Bull. 142: 164–168, https://doi.org/10.1016/marpolbul.2019.03.041)

Action Plan Initiated to Reduce Inputs by World's Largest Plastic Marine Debris Contributor

The accumulation of marine debris on shorelines and in the ocean has been identified as a serious environmental problem in Indonesia. Indonesia, as the world's largest producer of plastic marine debris, has committed to reducing plastic debris by up to 70% in 2025 by establishing a National Plan of Action on Marine Plastic Debris. The plan outlines five strategies: Public education, reducing terrestrial and maritime leakages, creating incentives and disincentives, and strengthening research and development. This will involve improving policy frameworks and investigating emerging technologies. The authors highlight that most research has focused on western Indonesia, with little or no information available on the middle and eastern parts of the country. Moreover, no research on the economic valuation of marine debris in Indonesia has been published. The authors express the hope that the "integrated policy approach with land sources and the use of additional policy instruments will help reduce the economic impacts of marine debris".

(SOURCE: Purba, N.P., Handyman, D.I.W., Pribaldi, T.D., Syakti, A.D., Pranowo, W.S., Harvey, A. and Ihsan, Y.N. 2019. Marine debris in Indonesia: A review of research and status. Mar. Pollut. Bull. 146: 134–144, https://doi.org/10.1016/marpolbul.2019.05.057)

Microplastics In Chinese Indo-Pacific Humpback Dolphins

Microplastics were detected in the intestines of two adult Indo-Pacific humpback dolphins and one stranded calf from Guangxi Beibu Gulf, China. The average amount of microplastics in these individuals ranged from 0.2 to 0.6 items per gram of gut contents. Microplastics were found as fibres, fragments of flakes in different colours (blue, white, pink, black and green, with white and blue being most common) and had an average size of 2.2mm ± 0.4 (SE), ranging from 0.1mm to 4.8mm. This is the first report of microplastics from the gut of a humpback dolphin in China.

(SOURCE: Zhu, J., Yu, X., Zhang, Q., Li, Y., Tana, S., Li, D., Yang, Z. and Wang, J. 2019. Cetaceans and microplastics: First report of microplastic ingestion by a coastal delphinid, Sousa chinensis. Sci. Total Environ. 659: 649–654, https://doi.org/10.1016/j.scitotenv.2018.12.389)

Ship Strikes

Satellite Tagging and Environmental Modelling May Help Avoid Ship Strikes of Pacific Blue Whales

Based on a model that combines oceanographic data (sea surface temperature, ocean productivity, seafloor topography) with the movements of more than 100 tagged blue whales off California, the authors hope to contribute to avoiding collisions between these whales and ships. The whales clearly responded to specific oceanographic conditions that provided good habitat for themselves and their prey. A new app was developed to allow managers and ship crews to predict the location of blue whales when transiting the west coast of North America. This would enable various avoidance strategies such as vessel slow-down or the use of alternate shipping lanes. This approach might also help fisheries avoid entanglement of whales and, ultimately, help reduce the incidental bycatch of other protected species.

(SOURCE: Abrahms, B., Welch, H., Brodie, S., Jacox, M.G., Becker, E.A., Bograd, S.J., Irvine, L.M., Palacios, D.M., Mate, B.R. and Hazen, E.L. 2019. Dynamic ensemble models to predict distributions and anthropogenic risk exposure for highly mobile species. Divers. Distrib. 25:1182–1193, doi:10.1111/ddi.12940)

Ship Strike Risk and Mortality of Large Whales Off the Western Coast of North America

Collision with ships is considered the most pressing conservation issue for many large whale species. Keen *et al.* (2019) modelled diel patterns of surface use, habitat suitability predictions, and ship traffic data to evaluate spatial and temporal trends in fin whale ship-strike risk off the west coast of the United States. Fin whales exhibit strong diel patterns in dive behaviour, remaining near the surface for most of the night. The authors showed that both this increased use of the upper water column and increased ship traffic contribute to elevated ship strike risk to fin whales at night. Speed reductions within shipping lanes would be insufficient mitigation here because only 13% of the risk occurs within those lanes. Therefore, additional speed restrictions in the approaches to lanes would more effectively reduce overall risk. Rockwood *et al.* (2017) estimated that, even without accounting for increased surface time at night, fin whale ship strike mortality rates are 2.7 times the Potential Biological Removal level (PBR, the sustainable limit for human-caused mortality under US law) for this species in these waters. Blue and humpback whales have ship strike mortality estimates 7.8 times and 2 times higher than their PBRs, respectively; for all three species, mortalities along the west coast of the United States are highest off California. Cope *et al.* (2020) reported on a more sophisticated approach for monitoring vessel traffic in San Francisco Bay, using data from multiple sources, which could be applied more widely to improve ship strike management for large whales in this region. Coupled with improved satellite-based AIS (Greig *et al.* 2020), it should be possible to better manage threats to large whales from ship strike along the Pacific coast of North America in the future.

(SOURCES: Keen, E.M., Scales, K.L., Rone, B.K., Hazen, E.L., Falcone, E.A. and Schorr, G.S. 2019. Night and day: Diel differences in ship strike risk for fin whales (Balaenoptera physalus) in the California Current System. Front. Mar. Sci. 6: 730, doi:10.3389/fmars.2019.00730; Rockwood, R.C., Calambokidis, J. and Jahncke, J. 2017. High mortality of blue, humpback and fin whales from modeling of vessel collisions on the U.S. West Coast suggests population impacts and insufficient protection. PLoS ONE 12(8): e0183052, https://doi.org/10.1371/journal.pone.0183052; Cope, S., Hines, E., Bland, R., Davis, J.D., Tougher, B. and Zetterlind, V. 2020. Application of a new shore-based vessel traffic monitoring system within San Francisco Bay. Front. Mar. Sci. 7: 86, doi:10.3389/fmars.2020.00086; Greig, N.C., Hines, E.M., Cope, S. and Liu, X. 2020. Using satellite AIS to analyze vessel speeds off the Coast of Washington State, U.S., as a risk analysis for cetacean-vessel collisions. Front. Mar. Sci. 7: 109, doi:10.3389/fmars.2020.00109)

DRONES A USEFUL TECHNOLOGY FOR OBSERVING GROUP BEHAVIOUR IN A SMALL CETACEAN

Vessel traffic poses a risk to small cetaceans in busy harbour areas. A drone was used to observe the responses of narrow-ridged finless porpoises to vessels in Ariake Sound, Japan. The drone enabled unprecedented resolution of behaviours. The primary response to passing vessels was vertical avoidance (diving). The diving duration decreased significantly when group size was bigger. The results suggested that individuals were motivated to maintain group cohesion even after the risk passed. This study showed the potential of using drones to observe cetacean behaviour when observations from boats might bias results.

(SOURCE: Morimura, N. and Mori, Y. 2019. Social responses of travelling finless porpoises to boat traffic risk in Misumi West Port, Ariake Sound, Japan. PLoS ONE 14(1): e0208754, https://doi.org/10.1371/journal.pone.0208754)

HUMPBACK WHALES AT RISK OF SHIP STRIKE IN AUSTRALIAN MARINE PARK

The multiple-use Great Barrier Reef Marine Park has recently experienced substantial increases in current and proposed port expansions and subsequent shipping. Globally, ship strike is a significant threat to some large whale populations. Within the park, there is spatial conflict between the main breeding ground of the east Australian humpback whale population and the main inner shipping route that services several large natural resource export ports. The formalisation of a two-way shipping route has provided little change to risk, and projected risk estimates indicate a three- to five-fold increase in risk to humpback whales from ship strike over the next 10 years. Currently, the protection area within the park does not cover the main mating and calving areas, but current law could allow such expansion during the peak reproductive season. A common mitigation strategy of re-routing shipping lanes is not a viable option for the park, because of the configuration of the reef. Therefore, speed restrictions are the most feasible mitigation.

(SOURCE: Smith, J.N., Kelly, N., Childerhouse, S., Redfern, J.V., Moore, T.J. and Peel, D. 2020. Quantifying ship strike risk to breeding whales in a multiple-use marine park: The Great Barrier Reef. Front. Mar. Sci. 7: 67, doi:10.3389/fmars.2020.00067)

Chemical Pollution

POLLUTANT CONCENTRATIONS IN NORTHWEST PACIFIC KILLER WHALES EXCEED THRESHOLDS

A comparison of 25 blubber samples between fish-eating and mammal-eating killer whales around Kamchatka Peninsula in the Russian Far East revealed that the latter contained higher concentrations of POPs. This confirmed previous studies elsewhere; the latter ecotype is at a higher trophic level and the phenomenon of bioaccumulation is therefore more strongly expressed. The lowest values in female fish-eating whales is attributed to the transfer of these toxic substances to offspring during lactation. Overall, the concentrations "surpass published thresholds for POPs concentrations which indicate high risk for negative biological effects". The results support the notion that exposure to POPs is a key factor in predicting the collapse of global orca populations due to reproductive and immune system impacts.
(Mean concentrations, ng g^{-1} wet weight: ΣPCB fish-eating males 18,000, fish-eating females 1200, mammal-eating males 420,000; HCB fish-eating males 750, fish-eating females 81, mammal-eating males 6200)

*(SOURCE: Atkinson, S., Branson, M., Burdin, A., Boyd, D. and Ylitalo, G.M. 2019. Persistent organic pollutants in killer whales (*Orcinus orca*) of the Russian Far East. Mar. Pollut. Bull. 149: 110593, https://doi.org/10.1016/j.marpolbul.2019.110593)*

HIGH CONCENTRATIONS OF A HEAVY METAL IN A REMOTE FALSE KILLER WHALE POPULATION

The concentrations of Ag, a heavy metal, were measured in eight tissues from five false killer whales from a mass stranding in the Magellan Strait (Chile) in 2013. The values were highest in the liver. In general, the values were higher than those reported in toothed whales from other marine areas in South America. Overall, the Ag values "exceeded the new proposed toxicological levels in toothed whales" for liver, kidney, muscle and lung tissues. Although the sources of

this contamination are unknown, prey ingestion is assumed to be involved. The authors view this contamination with particular concern considering that this species faces numerous other stressors.
(Concentration min–max, µg g^{-1} dry weight: liver 6.62–10.78; spleen 0.008–7.41; testis 0.004–5.71; kidney 0.757–1.69; lung 0.011–0.078; muscle 0.01–0.038; uterus 0.051; ovary 0.023)

(SOURCE: Cáceres-Saez, I., Haro, D., Blank, O., Aguayo-Lobo, A., Dougnac, C., Arredondo, C., Cappozzo, H.L. and Guevara, S.R. 2019. Stranded false killer whales, Pseudorca crassidens*, in southern South America reveal potentially dangerous silver concentrations. Mar. Pollut. Bull. 145: 325-333, https://doi.org/10.1016/marpolbul.2019.05.047)*

Existence and Persistence of Trace Metals in a Remote Pilot Whale Population

Long-finned pilot whales appear to be particularly susceptible to stranding. A series of trace elements were examined in a group of 127 individuals stranded in 2016 on Clemente Island in northern Patagonia, Chile. These elements are released in the mining, metallurgic, electronic and automobile industries, but their toxic effects on marine organisms are poorly understood. Values of Al and Zn were higher in juveniles, while Ce, Cu, Cr and Tl were higher in adults. The detection of Ce and Tl were the first for this species anywhere; there have been no reports on Tl levels for any marine mammal. Tl was banned by the WHO because it is more toxic for mammals than Cu, Ni or Zn. The authors point to the existence and persistence of such trace elements in a marine top predator from a remote ecosystem and note that negative effects could leave long-finned pilot whales "more vulnerable to suffer massive mortalities".
(Mean concentrations ± SD, in blubber, µg g^{-1} dry weight: Al 138.19 ± 133.22, Zn 58.28 ± 61.32, Ce 5.51 ± 1.92, Cu 1.72 ± 1.26, Tl 1.21 ± 0. 43, Cr 1.09 ± 0.33)

(SOURCE: Garcia-Cegarra, A.M., de A. Padilha, J., Braz, B.F., Ricciardi, R., Espejo, W., Chiang, G. and Bahamonde, P. 2020. Concentration of trace elements in long-finned pilot whales stranded in northern Patagonia, Chile. Mar. Pollut. Bull. 151: 110822, https://doi.org/10.1016/j.marpolbul.2019.110822)

DDT Levels Linked to Parasite Burdens in Pearl River Finless Porpoises

Finless porpoises from the Pearl River Estuary were examined both for parasite burdens and for pollutant levels. Lungworms were a common parasite, but nematode worms were also found in the uterus, intestine and muscle of animals. Levels of p,p′-DDT, p,p′-DDD and o,p′-DDD were significantly higher in porpoises that died of infectious diseases than in 'healthy' animals (animals that died from physical trauma). Moreover, the level of p,p′-DDT was higher than that of DDE in diseased animals. These results are consistent with the previously suggested link between parasite burdens and DDT levels in finless porpoises (see Table 1 for levels of ΣDDTs). Most of the DDT that has entered the oceans is currently found as degradation products (e.g. DDD, DDE) due to widespread bans, and the presence of DDT here underlines that such bans are not in effect worldwide.

(SOURCE: Gui, D., He, J., Zhanga, X.,Tua, Q., Chen, L., Feng, K., Liu, W., Mai, B. and Wua, Y. 2018. Potential association between exposure to legacy persistent organic pollutants and parasitic body burdens in Indo-Pacific finless porpoises from the Pearl River Estuary, China. Sci. Total Environ. 643: 785–792, https://doi.org/10.1016/j.scitotenv.2018.06.249)

High Levels of Per- and Polyfluorinated Alkyl Substances in Pearl River Humpback Dolphins

Sixteen PFASs were measured in liver and kidney tissues of Indo-Pacific humpback dolphins stranded in the Pearl River Estuary, China, for the period 2004–2016. The average concentrations of PFOS, PFOA and many of the other PFASs in the liver samples were the highest reported for cetaceans around the world (see Table 2). Levels of PFOS in 46% of the dolphin liver samples exceeded the hepatic toxicity threshold for cetaceans.

(SOURCE: Gui, D., Zhang, M., Zhang, T., Zhang, B, Lin, W., Sun, X., Yu, X., Liu, W. and Wu, Y. 2019. Bioaccumulation behavior and spatiotemporal trends of per- and polyfluoroalkyl substances in Indo-Pacific humpback dolphins from the Pearl River Estuary, China. Sci. Total Environ. 658: 1029–1038, https://doi.org/10.1016/j.scitotenv.2018.12.278)

Heavy Metals in Stranded New Zealand Long-Finned Pilot Whales

Trace element concentrations were measured in four tissues (blubber, kidney, liver, muscle) of 21 mass-stranded long-finned pilot whales in New Zealand. Maximum Cd concentrations were measured in kidneys and Hg in liver. The Hg values were higher in older and larger individuals. The Hg values of the arrow squid prey in the whales' stomachs correlated with the whale tissue values, suggesting that squids play a key role in the uptake of trace elements by this top predator. The authors note that the estimated methyl-Hg concentrations are potentially genotoxic and that the concentrations in the liver could be hazardous for human consumption.
(Mean concentrations ± SD (min–max), µg g^{-1} dry weight: Hg liver 198.91 ± 191.94 (11.24–704.88); Cd kidney 280.45 ± 137.55 (96.79–614.25))

*(SOURCE: Lischka, A., Betty, E.L.,. Braid, H.E., Pook, C.J., Gaw, S. and Bolstad, K.S.R. 2021. Trace element concentrations, including Cd and Hg, in long-finned pilot whales (*Globicephala melas edwardii*) mass stranded on the New Zealand coast. Mar. Pollut. Bull. 165: 112084, https://doi.org/10.1016/j.marpolbul.2021.112084)*

VERY HIGH CONCENTRATIONS OF TRIPHENYLTIN COMPOUNDS IN DOLPHINS DESPITE LONG-TERM BAN

Very high concentrations of TPTs were found in Indo-Pacific humpback dolphins and finless porpoises in Hong Kong waters. These organotin compounds were widely used in antifouling paints for ship hulls, but were banned globally by the IMO in 2008. Even very low concentrations can cause endocrine disruption or death in marine organisms. The very high concentration in a juvenile finless porpoise was ten times the value reported in that species in 2003. This is the first report on the biomagnification of TPTs in the food webs of cetacean species and highlights the persistence of such compounds in the environment. The authors argue that such high values at the top of the food chain point to potential problems for long-lived apex predators such as cetaceans and also for human health. They call for considering this biomagnification potential in assessing the ecological risks of such compounds.

(Average concentration, ng g^{-1} wet weight, muscle tissue: 1893.8 [Indo-Pacific humpback dolphin], 1477.6 [finless porpoise])

(SOURCE: Sham, R.C., Tao, L.S.R., Mak, Y.K.Y., Yau, J.K.C., Wai, T.C., Ho, K.K.Y., Zhou, G.-J., Li, Y., Wang, X. and Leung, K.M.L. 2020. Occurrence and trophic magnification profile of triphenyltin compounds in marine mammals and their corresponding food webs. Environ. Int. 137: 105567, https://doi.org/10.1016/j.envint.2020.105567)

HEAVY METAL LEVELS IN CETACEANS OF THE SEA OF CORTEZ

The levels of 23 heavy metals and Se in skin samples of seven cetacean species in the Sea of Cortez were evaluated and compared between the years 1999 and 2016/17. Mg, Fe, Al and Zn were found in the highest levels across all species and all years. For small odontocetes, metal levels decreased from 1999 to 2016/2017, except for Fe (2.3 times increase), Ni (3.2 times increase) and Al (1.4 times increase). For sperm whales, more notable changes were recorded—there were significant decreases between 1999 and 2016 of Mg, Zn and Se levels, but a significant doubling of Fe levels (Cr also increased). Overall, heavy metal levels decreased over time, except for Fe, Al, Ni and Cr, with the latter two elements being of concern because of their toxic nature. These increases suggest more heavy metal input from anthropogenic sources into the Sea of Cortez.

(SOURCE: Wise, J.P. Jr., Croom-Perez, T.J., Meaza, I. et al. 2019. A whale of a tale: A One Environmental Health approach to study metal pollution in the Sea of Cortez. Toxicol. Appl. Pharmacol. 376: 58–69, https://doi.org/10.1016/j.taap.2019.05.005)

Disease and mortality events

Direct Takes

MARINE MAMMALS USED AS BAIT IN TUNA FISHERIES USING AGGREGATOR DEVICES

Tuna fisheries often use fish aggregating devices to attract and capture tuna. Off the coast of Ecuador, 31 species of marine mammal were used as bait for improvised fish aggregation devices by artisanal fishers. Pantropical spotted dolphins, short-finned pilot whales and pygmy killer whales were deliberately killed to supply bait. A sperm whale and a humpback whale were also used as bait, but presumably these were carcasses found floating at sea. The South American sea lion was the main species used for bait (80%), with cetaceans representing 19.4% of the bait. The authors warn that “this illegal fishing practice could rapidly expand and lead to further direct kills and conservation problems for targeted marine mammal populations in the eastern tropical Pacific” unless regulated and controlled.

(SOURCE: Castro, C., Van Waerebeek, K., Cárdenas, D. and Alava, J.J. 2020. Marine mammals used as bait for improvised fish aggregating devices in marine waters of Ecuador, eastern tropical Pacific. Endang. Spec. Res. 41: 289–302, http://www.int-res.com/articles/esr2020/41/n041p289.pdf)

LOW MARINE MAMMAL ABUNDANCE IN THE WATERS OF OKINAWA LIKELY DUE TO UNCONTROLLED HUNTING

The first marine mammal surveys of Okinawan waters, using line-transect vessel surveys and passive acoustic monitoring, were conducted in 2011–2012. Despite over 900 km of transect survey effort and over 1000 hours of acoustic monitoring, only a single visual sighting of two common bottlenose dolphins was made ‘on effort’, although several humpback whales, a group of dwarf sperm whales and a large group (120 animals) of common bottlenose dolphins were observed ‘off effort’. Breeding humpback whales were also acoustically detected. The marine mammal populations in the waters of Okinawa were historically diverse and abundant and, as such, “[t]he apparent low density of cetaceans in the Okinawa survey area may seem surprising at first. However, when one considers the extensive hunting that has occurred in Okinawan waters over the past 50+ years, it becomes somewhat easier to understand”. There have been direct takes of at least 6210 small cetaceans from a minimum of 10 species in the waters of Okinawa since 1960. These takes occurred with no assessments of the stocks targeted. The apparent low density of marine mammals in Okinawan waters thus may be due to the depletion of coastal populations from decades of heavy and largely-uncontrolled hunting.

(SOURCE: Jefferson, T.A. and Richlen, M.F. 2019. Apparent low densities of small cetaceans in Okinawa may be due to uncontrolled local hunting. Pac. Sci. 73(2): 275–284, doi:10.2984/73.2.8)

Disease

POOR SKIN CONDITION OF VULNERABLE DOLPHINS

An assessment of skin lesions and injuries on Indo-Pacific humpback dolphins was conducted to evaluate the health and level of anthropogenic risk the populations face. Over half (50.6%) of the dolphins evaluated displayed some sort of negative condition, including pox-like lesions (34.7%), an orange 'film' (25.3%), skin nodules (30.8%), infected rake marks (2.1%) and ulcers (1.8%). One in ten (10.3%) displayed some sort of injury from a vessel collision, propeller or fishing-gear entanglement. Of these, 7.1% were minor injuries, 3% were major and 0.2% were potentially fatal. The high level of lesions may be linked to the high pollutant burdens the dolphins bear; the authors state that "their compromised health conditions are symptomatic of increasingly degraded ecological conditions".

(SOURCE: Chan, S.Y. and Karczmarski, K. 2019. Epidermal lesions and injuries of coastal dolphins as indicators of ecological health. EcoHealth 16: 576–582, https://doi.org/10.1007/s10393-019-01428-0)

THE ROLE OF SOCIAL BEHAVIOUR IN SPREADING LOBOMYCOSIS

Lobomycosis is a chronic skin disease that affects many dolphin populations. It has been observed in common bottlenose dolphins in the Gulf of Guayaquil, Ecuador, since 1990. Although salinity and pollution may play a role in the spread of this disease, cluster and spatial distribution analyses have shown that dolphin social behaviour may also play a role. Individuals with lobomycosis-like lesions were observed in five of the seven dolphin communities in the region, with 8% of adults showing signs. Males may play a role in transferring the disease—a population with an afflicted high-status male had an infection rate of 44%, but rates were lower when infected males were low status (5–13%). However, low-status males often have large ranges and may be responsible for the geographic spread of the disease throughout the Ecuador population. The population has been in decline and has low genetic diversity, which may also increase susceptibility to infection. As stress might exacerbate infection, the authors suggest "Human activities targeting these communities (e.g. dolphin watching, maritime traffic, invasive research) should be strictly regulated to avoid any unnecessary harassment and stress that could increase disease severity".

(SOURCE: Félix, F., Van Bressem, M.-F. and Van Waerebeek, K. 2019. Role of social behaviour in the epidemiology of lobomycosis-like disease (LLD) in estuarine common bottlenose dolphins from Ecuador. Dis. Aquatic. Org. 134: 75–87, https://doi.org/10.3354/dao03356)

***AEROMONAS VERONII*—A NOVEL PATHOGEN IN THE YANGTZE RIVER FINLESS PORPOISE**

A male Yangtze River finless porpoise was found alive and clearly ailing in the Yangtze River, but unfortunately died. Upon necropsy, a number of lesions were found, including pulmonary haemorrhage and necrosis, myocardial haemorrhage, liver swelling and haemorrhage and necrosis of the gastric mucosa, in an otherwise empty stomach. The bacterium *Aeromonas veronii* was identified from the animal's tissues and tests on mice demonstrated the pathogen's virulence. This bacterium is known to cause diseases in freshwater fish, but this is the first report of its pathogenicity in cetaceans.

(SOURCE: Liu, Z.G., Zheng, A.F., Chen, M.M., Lian, Y.X., Zhang, X.K., Zhang, S.Z., Yu, D. and Li. J.K. 2018. Isolation and identification of pathogenic Aeromonas veronii from a dead Yangtze finless porpoise. Dis. Aquat. Org. 132: 13–22, https://doi.org/10.3354/dao03288)

FIRST RECORD OF *BRUCELLA* IN THE SOUTHERN HEMISPHERE

A captive female hybrid of common and Indo-Pacific bottlenose dolphins suffered a stillbirth. Although there were no visible lesions, histologically there were signs of infection of the placenta, and the foetus displayed signs of encephalitis. *Brucella* sp. was isolated from liver, lung, kidney and spleen tissue. The mother was born in 1988 and no new animals have been brought into the population. The strain of *Brucella* most closely resembled *B. ceti* and thus was likely to have a marine source. The authors believe it is possible that the pathogen was transferred via humans that had worked on stranded cetaceans and note that this may be a risk to captive populations in facilities that do rescue, rehabilitation or stranding-related work. Albeit in a captive situation, this is the first report of *Brucella* from a marine mammal in Australia, or indeed the Southern Hemisphere.

(SOURCE: Mackie, J.T., Blyde, D., Harris, L., Roec, W.D. and Keyburnd, A.L. 2020. Brucellosis associated with stillbirth in a bottlenose dolphin in Australia. Australian Vet. J. 98(3): 92–95, https://doi.org/10.1111/avj.12903)

ANALYSING THE BREATH OF WILD DOLPHINS FOR MICROBES

The exhaled breath of Indo-Pacific bottlenose dolphins in Shark Bay, Australia, held a variety of microbial species, including those known to be infectious in marine mammals, such as *Pseudomonas*, *Mycoplasma* and *Streptococcus*. Collecting and analysing exhaled breath is therefore a useful tool for monitoring the health and microbial flora of wild dolphins. The dolphins in Shark Bay host some species that may be cause for concern.

(SOURCE: Nelson, T.M., Wallen, M.M., Bunce, M., Oskam, C.L., Lima, N., Clayton, L. and Mann, J. 2019. Detecting respiratory bacterial communities of wild dolphins: implications for animal health. Mar. Ecol. Prog. Ser. 622: 203–217, https://doi.org/10.3354/meps13055)

Harmful Algal Blooms (HABs)

MASS DUMPING OF DEAD SALMON IMPLICATED IN MASSIVE HARMFUL ALGAL BLOOM IN CHILE

In 2016, two HABs caused "one of the major social and environmental crises in Chilean history". The first event killed 40,000 tons of salmon from farms around Chiloé Island, while the second—an extremely toxic HAB (also known as 'red tides' in some regions, including here, due to the colour of the organisms causing them)—hit a previously unaffected area. Analysing oceanic conditions demonstrated that, beyond strong climate anomalies, the dumping of 4700 tons of rotting salmon could have fuelled or possible even triggered the second bloom. The authors attribute this crisis to highly deficient regulation and risk mismanagement of the Chilean Patagonian Sea. This dumping "violated the London Protocol" and no monitoring was conducted during and after the dumping. This reflects a not uncommon mindset that, based on their diluting volume, the oceans can serve as a dumpsite when other options are inconvenient or more expensive.

(SOURCE: Armijo, J., Oerder, V., Auger, P.-A., Bravo, A. and Molina, E. 2020. The 2016 red tide crises in southern Chile: Possible influence of the mass oceanic dumping of dead salmons. Mar. Pollut. Bull. 150: 110603, https://doi.org/10.1016/j.marpolbul.2019.110603)

HARMFUL ALGAL BLOOMS CAUSED BY DINOFLAGELLATE ON THE INCREASE IN CHINA

Akashiwo sanguinea is a dinoflagellate phytoplankton species that causes harmful—but not toxic—algal blooms. In China, the first *A. sanguinea* HAB was recorded in 1998. Occurrences increased from six in the 2000s to 24 in the 2010s (31 in total up to the year 2017). Thus, the 1990s represented the initial stage, the 2000s a spreading stage and the 2010s the 'burst' stage. The duration of individual blooms ranged from one to 68 days. The HABs of this species form surface layers and lead to mortalities of fishes, scallops and birds, which are disruptive to fisheries and tourism. The authors attribute this development to nutrient enrichment of China's coastal waters and inland seas, specifically to a high ratio of nitrogen to phosphorus. This species apparently has a competitive advantage over other phytoplankton species (e.g. diatoms) based on its tolerance to a wide range of salinities and temperatures (and an ability to benefit from climate change), its ability to use various types of nitrogen compounds, its production of mucus and an ability to form resting cysts.

(SOURCE: Chen, B., Kang, W. and Hui, L. 2019. Akashiwo sanguinea *blooms in Chinese waters in 1998-2017. Mar. Pollut. Bull. 149: 110652, https://doi.org/10.1016/j.marpolbul.2019.110652)*

INCREASING TRENDS IN TOXIC ALGAL BLOOMS IN THE NORTH ATLANTIC AND NORTH PACIFIC OCEANS

A key factor governing HABs is temperature. This study used sea surface temperatures and the growth rates of two of the most toxic and widespread algal bloom species to model recent HAB trends. In both species, the growth rates and duration of bloom seasons significantly increased, especially in the North Atlantic but also in the Salish Sea and along the coast of Alaska in the North Pacific. The authors conclude that continued ocean warming will promote the intensification and redistribution of these and other HABs around the world. HABs pose a threat to fisheries, tourism and human health, and have also been implicated in cetacean mortalities.

(SOURCE: Gobler, C.J., Doherty, O.M., Hattenrath-Lehmann, T.K., Griffith, A.W. and Litaker, R.W. 2020. Ocean warming since 1982 has expanded the niche of toxic algal blooms in the North Atlantic and North Pacific oceans. PNAS 114: 4975–4980, www.pnas.org/cgi/doi/10.1073/pnas.1619575114)

HARMFUL ALGAL BLOOMS GENERALLY DECREASING IN CHINESE SEAS

Between the years 2000 and 2017, a total of 1392 HABs occurred in Chinese seas: 826 in the East China Sea, 201 in the Bohai Sea, 115 in the Yellow Sea, and 250 in the South China Sea. The total area affected was 2.52×10^5 km². However, after a peak of 168 events in 2003, "the frequency and coverage extent of the annual HAB events show significantly decreasing trends". The authors attribute this to improved water quality in the marginal seas off China and changes in sea surface temperature.

(SOURCE: Zeng, J., Yin, B, Wang, Y. and Huai, B. 2019. Significantly decreasing harmful algal blooms in China seas in the early 21st century. Mar. Pollut. Bull. 139: 270–274, doi.org/10.1016/marpolbul.2019.01.002)

Strandings

NEW APPROACH REVEALS INCREASING STRANDINGS AND HOTSPOTS IN CHILE

Cetacean strandings have been increasing consistently between 1968 and 2020 in Chile. A total of 436 cetacean stranding events were documented during this period. Eight cetacean families, 21 genera, and 35 species were recorded. Most events (94%) involved fewer than two individuals, 18 (4%) were mass strandings of 3–24 individuals, and nine (2%)

were unusually large mass stranding events (>25 individuals). A new approach (local tests for spatiotemporal clusters) revealed a number of stranding hotspots in the southern-most part of the country (Chilean Patagonia). The authors cite climate change, changes in the human population, and general awareness as potential explanations for the increase in strandings, but also an increase in monitoring activities. The authors call for strengthening the marine mammal network of sightings, establishing a national strandings network, and research to help better explain the documented patterns.

(SOURCE: Alvarado-Rybak, M., Toro, F., Escobar-Dodero, J., Kinsley, A.C., Sepúlveda, M.A., Capella, J., Azat, C., Cortés-Hinojosa, G., Zimin-Veselkoff, N. and Mardones, F.O. 2020. 50 Years of Cetacean Strandings Reveal a Concerning Rise in Chilean Patagonia. Sci. Rep.-UK 10: 9511, doi.org/10.1038/s41598-020-66484-x)

Climate change

Climate Change May Lead to Loss of Breeding Habitat for Humpback Whales in Oceania

Survey data from countries and territories of Oceania (19 years over 1376 survey days) were used to investigate humpback whale resilience to the impacts of climate change on their breeding habitat. The whales preferred the shallowest waters close to shore or in lagoons; shallow offshore features such as seamounts were also used. Habitat temperatures ranged from 22.3 to 27.8°C in August (varying 2.0°C interannually). There was a negative relationship between sea surface temperature and whale presence. The authors predict that many humpback whale breeding sites will become too warm for this species (> 28°C) by the end of the 21st century. However, alternative breeding habitats may be available, in particular sea mounts and archipelagos, depending on how able humpbacks are to adapt to new breeding locations.

(SOURCE: Derville, S., Torres, L.G., Albertson, R., Andrews, O., Baker, C.S., Carzon, P., Constantine, R., Donoghue, M., Dutheil, C., Gannier, A., Oremus, M., Poole, M.M., Robbins, J. and Garrigue, C. 2019. Whales in warming water: Assessing breeding habitat diversity and adaptability in Oceania's changing climate. Glob. Change Biol. 25: 1466–1481, https://doi.org/10.1111/gcb.14563)

Northward Shifts of Marine Organisms Off California Include Three Dolphin Species

In addition to triggering mass mortalities, harmful algal blooms, and declines in subtidal kelp beds, severe marine heatwaves in the northeast Pacific from 2014 through 2016 caused substantial changes in the geographic distributions and/or abundances of 67 species, including 37 poleward range extensions. Three of these involved cetacean species. The common bottlenose dolphin experienced a 130 km range extension along the California coast, and rare occurrences of southern-ranging species not typically found in northern California included long-beaked and short-beaked common dolphins. Prolonged marine heatwaves and poleward movement may play a role in longer-term shifts in the composition of coastal communities. This information is useful in predicting such shifts in an era of accelerating climate change. These conclusions are supported by Jacox *et al*., who introduce the term 'thermal displacement' to measure the temporary dislocation of ocean surface temperatures and the resulting ecological changes. If marine heatwaves warm an area of ocean, then taxa such as fish, turtles and whales may have to travel great distances if the temperature gradient is weak, and lesser distances if the gradient is strong. The authors note that while the average long-term temperature shift associated with ocean warming is about 20 km per decade, marine heatwaves have displaced temperatures by about 200 km within only months.

(SOURCES: Sanford, E., Sones, J.L., García-Reyes, M., Goddard, J.H.R. and Largier, J.L. 2019. Widespread shifts in the coastal biota of northern California during the 2014–2016 marine heatwaves. Sci. Rep.-UK 9: 4216, https://doi.org/10.1038/s41598-019-40784-3; Jacox, M.G., Alexander, M.A., Bogard, S.J. and Scott, J.D. 2020. Thermal displacement by marine heatwaves. Nature 584: 82–86, https://doi.org/10.1038/s41586-020-2534-z)

Noise impacts

Moving Shipping Routes Could Considerably Decrease Noise Exposure for Endangered Killer Whales

Noise exposure for the SRKW population in the northeast Pacific was estimated with geospatial mapping, in order to identify shipping routes that would minimise noise exposure for the whales. Even small changes in current shipping lanes, increasing travel distance for ships by only 3.4%, could lead to a 56% reduction in the overlap between shipping traffic and sensitive areas for the killer whales.

(SOURCE: Cominelli, S., Leahy, M., Devillers, R. and Hall, G.B. 2019. Geovisualization tools to inform the management of vessel noise in support of species' conservation. Ocean Coastal Manage. 169: 113–128, https://doi.org/10.1016/j.ocecoaman.2018.11.009)

Noise from Pile Driving Displaced Endangered Hector's Dolphins in New Zealand

Pile-driving in the framework of construction in Port Lyttelton, New Zealand, temporarily displaced the local Hector's dolphin population. The higher the sound exposure level, the fewer dolphin echolocations were detected, and the longer the piling events, the longer this reduction lasted. The detection rates took up to 83 hours to return to pre-piling levels. This species has one of the smallest home ranges of any dolphin. This work identifies pile-driving as very probably having a significant impact beyond the main threats posed by incidental catch in gillnets and trawls. The authors argue for alternative piling technologies and seasonal restrictions.

(SOURCE: Leunissen, E.M., Rayment, W.J. and Dawson, S.M. 2019. Impact of pile-driving on Hector's dolphin in Lyttelton Harbour, New Zealand. Mar. Pollut. Bull. 142: 31–42, https://doi.org/10.1016/marpolbul.2019.03.017)

BEAKED WHALES KEEP RETURNING TO A PREY-RICH HABITAT DESPITE MILITARY SONAR USE

In a study using underwater robots, beaked whales were found to prefer feeding within a Navy sonar test range in the San Nicholas Basin off Southern California. Their preferred prey, deep-sea squids, are 10 times more abundant here than in nearby 'sonar-free' areas. Although these cetaceans are highly sensitive to sonar and sonar-related strandings have been reported, they appear to need these prey hotspots to survive; they can acquire the same amount of food with one daily dive here than with a nearly impossible 22–100 dives elsewhere. These results demonstrate the need to include predator-prey dynamics in the management of marine ecosystems.

(SOURCE: Southall, B.L., Benoit-Bird, K.J. and Moline, M.A. 2019. Quantifying deep-sea predator-prey dynamics: Implications of biological heterogeneity for beaked whale conservation. J. Appl. Ecol. 56: 1040–1049, https://doi.org/10.1111/1365-2664.13334)

MAJOR REDUCTIONS IN SHIPPING NOISE POSSIBLE WITH MODEST MANAGEMENT INTERVENTIONS

Shipping is a dominant source of anthropogenic noise in the oceans and can affect the acoustic quality of important whale habitats. The summertime core feeding habitat of SRKWs off Washington State, USA, is among the loudest habitats measured along the Pacific Coast. The authors consider a range of measures that could achieve a 3–10 dB reduction in broadband source levels (i.e. produced by the vessels). This would be equivalent to more than halving the total power radiated by the ships. These measures include reducing speed, removing the noisiest ships, retrofitting vessels with noise reduction technologies, changing ship design, relocating shipping traffic lanes, initiating a convoy approach, and changing the timing of traffic.

(SOURCE: Williams, R., Veirs, S., Veirs, V., Ashe, E., and Mastick, N. 2019. Approaches to reduce noise from ships operating in important killer whale habitats. Mar. Pollut. Bull. 139: 459–469, https://doi.org/10.1016/marpolbul.2018.05.015)

GLOBAL

General

THE ENERGETIC IMPACTS OF DISTURBANCES

Managers of marine ecosystems have a growing interest in synergistic impacts of various anthropogenic and natural pressures on marine mammal populations. The interplay between resource availability and disturbance was assessed via a modelling approach. The energy allocation of female pilot whales was assessed, taking into account metabolism and the energetic costs of growth, foetal development and lactation. Their survival probabilities and those of their calves were then calculated when faced with environmental disturbances. Disturbances that exceeded 20 days in winter resulted in no calves being successfully weaned. Resource availability prior to a disturbance significantly affected the degree of impact—if resources were abundant, whales could compensate for the disturbance, and if resources were low, the negative impact of a disturbance was stronger. Whilst this model was created for long-finned pilot whales, it could be utilised for investigating the effects of disturbance on other cetacean species.

(SOURCE: Hin, V., Harwood, J. and de Roos, A. M. 2019. Bio-energetic modelling of medium-sized cetaceans shows high sensitivity to disturbance in seasons of low resource supply. Ecologic. Applic. 29(5): e01903, https://doi.org/10.1002/eap.1903)

HUMAN PRESSURE ON THE OCEANS INTENSIFIES

Human pressure on the world's oceans has accelerated sharply and shows no signs of slowing. This dramatic rise, coined 'Blue Acceleration' (Jouffray *et al.* 2019), involves an unprecedented extent, intensity and diversity of claims for ocean resources and space. Synthesising 50 years of data from, *inter alia*, shipping, drilling, deep-sea mining, aquaculture and bioprospecting allowed the consideration of risks posed (and opportunities provided). The United Nations embarked on a 'decade of the oceans' in 2021 as "an opportunity to assess the socio-ecological impacts and manage ocean resources for long-term sustainability". In a similar study, Bugnot *et al*. (2021) calculated that the human 'footprint' on the ocean (as modified by human construction) was about 30,000 km² or 1.5% of global EEZs. This includes tunnels, bridges, oil and gas rigs, windfarms, ports, marinas, aquaculture facilities and artificial reefs. This is proportionally comparable to the extent of urbanised land, and is greater than the total area of certain natural marine habitats, such as mangrove forests and seagrass beds. This value increases to 2,000,000 km² when adjoining, affected seascapes are included (0.5% of the ocean). Such infrastructures are projected to increase by 50–70% by 2028, much of it due to expected defences against coastal erosion and inundation due to sea level rise and climate change.

(SOURCES: Jouffray, J.-B., Blasiak, R., Norström, A.V., Österblom, H. and Nyström, M. 2019. The Blue Acceleration: The trajectory of human expansion into the ocean. One Earth 2: 43–54, https://doi.org/10.1016/j.oneear.2019.12.016); Bugnot, A.B., Mayer-Pinto, M., Airoldi, L., Heery, E.C., Johnston, E.L., Critchley, L.P., Strain, E.M.A., Morris, R.L., Loke, L.H.L., Bishop, M.J., Sheehan, E.V,. Coleman, R.A. and Dafforn, K.A. 2021. Current and projected global extent of marine built structures. Nature Sustain. 4: 33–41, https://doi.org/10.1038/s41893-020-00595-1)

Major Report on Ocean Pollution

In the oceans, pollution is widespread, more than 80% of which comes from land-based sources: toxic metals, pesticides, fertilisers, pharmaceutical chemicals, plastics, petroleum products, agricultural runoff, urban and industrial wastes, and sewage. A new report, funded by the US National Science Foundation and National Institute for Environmental Health Sciences, reviewed nearly 600 ocean pollution reports and peer-reviewed studies to assess the impacts of ocean pollution. Drivers of this pollution are: rapid industrialisation; an increase in the manufacturing and release of chemicals and plastics into the environment; the expansion of chemically intensive industrial agriculture; and the uncontrolled development and rapid increase of human populations on coasts. The latter has resulted in massive releases of liquid and solid waste from agriculture, industry and sewage into rivers, estuaries and directly into the ocean. In particular, the report notes Hg is a marine pollutant of major concern. This toxic metal largely travels into the ocean via the atmosphere; a major source is coal-burning power plants and industry. Also, the increasing levels of nutrient pollution, sewage and runoff entering the oceans are causing HABs and more areas of low oxygen and 'dead zones', as well as an increasing abundance of pathogenic bacteria, viruses and parasites. The report makes a number of recommendations, including: banning all uses of mercury; banning single-use plastics; phasing out the burning of coal; reducing chemical fertilisers and pesticides, and reducing and controlling coastal discharges of these; and reducing and controlling discharges of animal waste, industrial discharges and human sewage into coastal waters. Monitoring and mapping all types of pollution, potentially involving technology such as drones, satellites and ocean sensor systems, are essential. Synergistic effects of multiple pollutants and stressors should also be investigated. The report also recommends pollution control programs in all countries and for the international community to support widespread programs for capacity building, training and outreach and communication, as well as pollution reduction. As a means of protecting marine ecosystems and buffering and protecting them from pollution, the report also called for the creation of MPAs**.** The authors note that "ultimately, prevention and control of ocean pollution can be achieved by transition to a circular, more efficient, less wasteful economy and embracing the precepts of green chemistry".

(SOURCE: Landrigan, P.J., Stegeman, J.J., Fleming, L.E. et al. 2020. Human health and ocean pollution. Ann. Glob. Health 86(1): 151, 1–64, https://doi.org/10.5334/aogh.2831)

Habitat degradation

General

The Presence of Vessels Affects Humpback Social Interactions

Dunlop (2020) found that the noise of small fishing boats was sufficient to reduce the communication range of humpback whales off Queensland by a factor of 4. However, the whales also socialised less frequently. While previous studies have examined how vessels affected large whale movements (e.g. avoidance), this was the first study to examine changes in social behaviour. The author concludes that the reduced frequency of group social interactions went beyond any impacts of vessel noise (which can mask the whales' signals): the mere presence of the vessels had a negative effect. While the whale population here has been increasing, these new insights could be important if additional stressors come into play, or for less robust populations elsewhere that have not recovered from whaling to the extent this population has. Dunlop *et al.* (2020) found that ships towing seismic air gun arrays significantly reduced the likelihood that migrating humpback whales participated in social interactions. This effect was recorded regardless of whether the air guns were active, i.e. as with Dunlop (2020), the presence of the vessel alone was sufficient to elicit this behavioural change. Accordingly, whale behaviour is disrupted at lower RLs and at much greater distances than currently accepted thresholds indicate; these thresholds are largely designed to prevent damage to whales' hearing. Moreover, certain mitigation measures such as 'ramp up' are unlikely to reduce the likelihood of an avoidance response or change in social behaviour. The authors argue that current mitigation recommendations are insufficient to prevent impacts.

(SOURCES: Dunlop, R.A. 2020. The effects of vessel noise on the communication network of humpback whales. Roy. Soc. Open Sci. 6: 190967, https://dx.doi.org/10.1098/rsos.190967; Dunlop, R.A., McCauley, R.D. and Noad, M.J. 2020. Ships and air guns reduce social interactions in humpback whales at greater ranges than other behavioral impacts. Mar. Pollut. Bull. 154: 111072, https://doi.org/10.1016/j.marpolbul.2020.111072)

Seeking Global Solutions to Ghost Fishing Gear

Abandoned, lost, or discarded fishing gear (ALDFG) makes up a considerable part of marine debris and poses a major entanglement and ingestion threat to marine organisms, including cetaceans. Richardson *et al.* (2019) presented case studies on ALDFG retrieval, data collection and awareness raising. They underlined the Global Ghost Gear Initiative's role in developing a publicly accessible global ALDFG database as a vehicle to help achieve these goals and fill in data gaps. The emphasis is on communication and collaboration with the various stakeholders and on standardising reporting mechanisms and datasets. Brown and Niedzwecki (2020) developed a model to address the risk of whale entanglement based on multi-year ALDFG accumulation rates and entanglement data. They presented data for the US Atlantic and Pacific coasts as illustrative examples.

(SOURCES: Richardson, K., Asmutis-Silvia, R., Drinkwin, J., Gilardi, K.V.K., Giskes, I., Jones, G., O'Brien, K., Pragnell-Raasch, H., Ludwig, L., Antonelis, K., Barco, S., Henry, A., Knowlton, A., Landry, S., Mattila, D., MacDonald, K., Moore, M., Morgan, J., Robbins,

J., van der Hoop, J. and Hogan, E. 2019. Building evidence around ghost gear: Global trends and analysis for sustainable solutions at scale. Mar. Pollut. Bull. 138: 222–229, https://doi.org/10.1016/j.marpolbul.2018.11.031; Brown, A.H. and Niedzwecki, J.M. 2020. Assessing the risk of whale entanglement with fishing gear debris. Mar. Pollut. Bull. 161: 111720, https://doi.org/10.1016/j.marpolbul.2020.111720)

Marine debris

PLASTICS ENTERING THE OCEANS CONTINUE TO INCREASE

In 2016, an estimated 19 to 23 million metric tons, or 11% of global plastic waste, entered aquatic ecosystems. This figure does not include microplastics or discarded fishing gear, major sources of ocean plastic. If society continues to produce plastic waste at current rates, with no improvements to waste management, this figure could be as much as 90 million metric tons per year by 2030. Even if governments enact the ambitious waste reduction measures they have set (including G7, EU and UN commitments and plans), annual emissions will be from 20 to 53 million metric tons by 2030. The authors warn that, without major technological innovation, not even 10% of annual plastic emissions can be recovered from the environment.

(SOURCE: Borrelle, S., Ringma, J., Law, K.L. et al. 2020. Predicted growth in plastic waste exceeds efforts to mitigate plastic pollution. Science 369 (6510): 1515–1518, doi:10.1126/science.aba3656)

ESTIMATING MICROPLASTIC CONSUMPTION BY BALEEN WHALES BASED ON THEIR PREY SPECIES

Beyond the much-studied issue of large plastic marine debris, the focus of research is shifting to microplastics. One approach to estimating the potential impact on cetaceans is to examine the microplastic content in their prey. In examining the key prey of minke whales (krill and five fish families) and sei whales (copepods and three fish families), high levels of microplastic contamination were reported in fish from the mackerel family in the Atlantic and in anchovy from the northwest Pacific. Specific prey preferences and feeding strategies highlight the need to examine microplastic uptake on a species-by-species basis in cetaceans. Future research should concentrate on the potential physical and toxicological effects of microplastics and their additives when consumed by cetaceans.

(SOURCE: Burkhardt-Holm, P. and N'Guyen, A. 2019. Ingestion of microplastics by fish and other prey organisms of cetaceans, exemplified for two large baleen whale species. Mar. Pollut. Bull. 144: 224–234, https://doi.org/10.1016/marpolbul.2019.04.068)

OCEAN CLEAN-UP DEVICES CANNOT SOLVE THE MARINE DEBRIS PROBLEM

Based on current and future estimates of plastic waste inputs into the world's oceans, clean-up technologies designed to collect such litter from the ocean surface would have a negligible effect. For example, 200 large floating clean-up devices (such as currently being tested in the 'Pacific Garbage Patch') operating for more than a century would eliminate a mere 5% of the estimated total surface plastic (860,000 tons) that is expected in the year 2052. Installing barriers to collect plastic in key polluting rivers is a much more promising solution, but is unlikely to be implemented on a large scale because such rivers are key routes for global shipping. Hohn *et al.* (2020) conclude that reducing plastic production and use, along with reinforced collection and recycling, is the only way to rid the ocean of plastic waste. Borelle *et al*. (2020) concur; in a first global analysis of the magnitude of plastic pollution, their mathematical model showed that despite global commitments to address plastic pollution, growth of plastic waste will continue to outpace reduction. Annual plastic emissions may increase more than 6-fold even if governments adhere to their ambitious plans. A fundamental transformation of the plastics economy is necessary. Helinski *et al*. (2021) address the river-based solution noted above by providing a framework to help water and waste managers select the appropriate devices to capture plastic in rivers before it enters the oceans.

(SOURCES: Hohn, S., Acevedo-Trejos, E., Abrams, J. F., de Moura, J. F., Spranz, R. and Merico, A. 2020. The long-term legacy of plastic mass production. Sci. Total Environ. 746: 141115, https://doi.org/10.1016/j.scitotenv.2020.141115; Borrelle, S.B., Ringma, J., Law, K.L., Monnahan, C.C., Lebreton, L., McGivern, A., Murphy, E., Jambeck, J., Leonard, G.H., Hilleary, M.A., Eriksen, M., Possingham, H.P., De Frond, H., Gerber, L.R., Polidoro, B., Tahir, A., Bernard, M., Mallos, N., Barnes, M. and Rochman, C.M. 2020. Predicted growth in plastic waste exceeds efforts to mitigate plastic pollution. Science 369: 1515–1518, doi:10.1126/science.aba3656; Helinski, O.K., Poor, C.J. and Wolfand, J.M. 2021. Ridding our rivers of plastic: A framework for plastic pollution capture device selection. Mar. Pollut. Bull. 165: 112095, https://doi.org/10.1016/j.marpolbul.2021.112095)

THE UNITED STATES, A TOP OCEAN PLASTICS PRODUCER, NEEDS A BETTER PLASTICS POLICY

The amount of plastic entering the ocean is expected to increase by an order of magnitude by 2025. The United States is in the top 20 of 192 coastal countries with regard to plastic debris entering the ocean. Currently, the United States does not have a federal ban on most single-use plastics or on synthetic gillnets. A federal ban on single-use plastics is recommended, as are alternative materials for fishing nets and increased regulation. Moreover, more research and plastic removal effort is required. Finally, the United States could look to the recent European Plastics Strategy as a showcase policy initiative to reduce marine plastic pollution.

(SOURCE: Iverson, A.R. 2019. The United States requires effective federal policy to reduce marine plastic pollution. Conserv. Sci. Pract. 1: e45, https://conbio.onlinelibrary.wiley.com/doi/epdf/10.1111/csp2.45)

Interactions Between Marine Debris and Large Marine Organisms

Two reviews assessed the interactions between marine animals and plastic debris. Kühn and van Franeker (2020) analysed 747 studies reporting interactions between plastic marine debris and marine megafauna worldwide. They found that 914 species were affected by entanglement and/or ingestion (ingestion: 701 species, entanglement: 354 species). These species included fin whales (five studies), sperm whales (13), Cuvier's beaked whales (six), franciscana (two), narwhals (one), common bottlenose dolphins (nine), and harbour porpoises (nine). The authors call for more specific, standardised methodologies to detect ingested material. For example, traditional methods detected plastics in 6% of porpoises; however, a plastic-dedicated protocol increased that value to 15%. As such, the current reports of ingestion should be seen as minimum estimates, and the authors believe that, with increased studies, all marine species are likely to show examples of direct or indirect ingestion of plastic. Zantis *et al*. (2021) focused more specifically on marine mammal interactions with microplastics. They also called for standardisation, of sample collection, preparation and analysis, as well as reporting. In addition, better global representation is needed in marine debris studies, with the Southern Hemisphere particularly underrepresented.

(SOURCES: Kühn, S. and van Franeker, J.A. 2020. Quantitative overview of marine debris ingested by marine megafauna. Mar. Pollut. Bull. 151: 110858, https://doi.org/10.1016/j.marpolbul.2019.110858; Zantis, L.J., Carroll, E.L., Nelms, S.E. and Bosker, T. 2021. Marine mammals and microplastics: A systematic review and call for standardisation. Environ. Pollut. 269: 116142, https://doi.org/10.1016/j.envpol.2020.116142)

Microplastics in Higher Trophic Level Animals such as Beluga Whales

The gastrointestinal tracts of seven beluga whales sampled in Canada's Eastern Beaufort Sea contained microplastics. The average was 97 items per whale, with eight polymer types detected. Fibres made up 49% of this material. These microplastics may have been ingested with prey rather than directly or deliberately. Whether such particles can become embedded or otherwise cause localised harm in the digestive tracts cannot be excluded, and the potential toxicological effects (leaching of plastic additives or as vectors for heavy metals and POPs) remain unclear. Microplastics are ubiquitous in organisms at lower trophic levels (e.g. filter-feeding invertebrates), but less is known about their presence at higher trophic levels (e.g. carnivores). The finding of microplastics in all examined beluga whales "underscores the global nature of this emerging pollutant, and the vulnerability of remote regions to contamination".

*(SOURCE: Moore, R.C., Loseto, L., Noel, M., Etemadifar, A., Brewster, J.D., MacPhee, S., Bendell, L. and Poss, P.S. 2020. Microplastics in beluga whales (*Delphinapterus leucas*) from the Eastern Beaufort Sea. Mar. Pollut. Bull. 150: 110723, doi.org/10.1016/marpolbul.2019.110723)*

European Workshop on Marine Mammals and Marine Debris

Ingestion of, and entanglement in, marine debris has a serious impact upon cetaceans. As a result, the European Cetacean Society Conference held a workshop in 2017 to bring together the experts from research institutions, NGOs, foundations and international agreements to discuss the issue. The workshop made the following recommendations:
(1) To standardise protocols for the analysis of marine litter in stranded organisms and share knowledge, facilities and samples (especially microplastics analysis);
(2) For national stranding networks to collect/share samples for different marine litter analysis and to establish an international network/community consisting of specialists on marine debris and marine mammals;
(3) To share information, scientific results and images in a database (to be hosted by a web platform);
(4) To define the actual threat to organisms and to identify the most threatened species and hotspot areas according to season and species habitat use in EU waters;
(5) To define new methods to evaluate the exposure to plastics and plastic additives in free-ranging organisms;
(6) To evaluate the presence and effects of micro- and nanoscale plastics, including sub-lethal effects; and
(7) To enhance awareness raising/communication to other scientists and youth.

(SOURCE: Panti, C., Baini, M., Lusher, A. et al. 2019. Marine litter: One of the major threats for marine mammals. Outcomes from the European Cetacean Society workshop. Environ. Pollut. 247: 72–79, https://doi.org/10.1016/j.envpol.2019.01.029)

Microplastics Have Become a Leading Topic in the Marine Pollution Literature

An analysis of the global scientific literature revealed that microplastics are a relatively new field of research, with 17 articles published in 2012, followed by an exponential growth. Thus, a total of 1518 articles on this topic were published by mid-2019. Pauna *et al.* (2019) predict a further increasing trend in the future. Most of the research focused on toxicology and environmental chemistry, but studies examining the impacts of microplastics at the ecosystem level are still limited. The authors therefore call for a more interdisciplinary, holistic approach to analyse the complex relationships between microplastics and marine trophic chains. A second bibliometric analysis on microplastics and nanoplastics in global food chains confirmed the above trend in publications and revealed a shift from investigations of plastic absorption by various organisms to studies on the trophic transfer of such plastics and their contaminants in food webs and their associated negative impacts. Wong *et al.* (2020) emphasise the importance of interdisciplinary approaches and the role of funding agencies in advancing this work. Riechers *et al*. (2021) highlight the transdisciplinary challenge microplastics represent and propose three actions: (a) filtering microplastics from waste waters; (b) mandatory eco-labelling on plastic products packages; and (c) utilising a circular economy for plastic packaging.

(SOURCES: Pauna, V.H., Buoncore, E., Renzi, M., Russo, G.F. and Franzese, P.P. 2019. The issue of microplastics in marine ecosystems: A bibliometric network analysis. Mar. Pollut. Bull. 149: 110612, https://doi.org/10.1016/j.marpolbul.2019.110612; Wong, S.L., Nyakuma, B.B., Wong, K.Y., Lee, C.T., Lee, T.H. and Lee, C.H. 2020. Microplastics and nanoplastics in global food webs: A bibliometric analysis (2009–2019). Mar. Pollut. Bull. 158: 110612, https://doi.org/10.1016/j.marpolbul.2020.111432; Riechers, M., Fanini, L., Apicella, A., Galván, C.B., Blondel, E., Espina, B., E., Kefer, S., Keroullé, T., Klun, K., Pereira, T.R., Ronchi, F., Rodríguez, P.R., Sardon, H., Silva, A.V., Stulgis, M. and Ibarra-González, N. 2021. Plastics in our ocean as transdisciplinary challenge. Mar. Pollut. Bull. 164: 112051, https://doi.org/10.1016/j.marpolbul.2021.112051)

Nanoplastics: A New Field of Research in Marine Pollution Science

Nanoplastics are defined as plastic particles smaller than 100 nm or 1 µm, i.e. several orders of magnitude smaller than microplastics (under 5 mm). The definition includes both primary (manufactured) and secondary (degradation products) nanoplastics, whereby the former includes, e.g. personal care products and industrial abrasives paints. A review of ca. 200 scientific research papers on nanoplastics between 2012 and 2020 revealed that the number of contributions has been basically doubling from year to year. Most studies are still limited to laboratory experiments, but in fish these already reveal a range of potential impacts ranging from weight loss, behavioural disorders, histopathological abnormalities and compromised immune systems. The authors underline the need for new approaches to gauge the impact of nanoplastics on the marine environment and note that, at this stage, the precautionary principle is appropriate.

(SOURCE: Piccardo, M., Renzi, M., and Terlizzi, A. 2020. Nanoplastics in the oceans: Theory, experimental evidence and real world. Mar. Pollut. Bull. 157: 111317, https://doi.org/10.1016/j.marpolbul.2020.111317)

Chemical pollution

Chlorinated Paraffins Found in Antarctic Feeding Humpback Whales

Short-chain chlorinated paraffins (SCCPs) have for the first time been detected in southern hemisphere humpback whales feeding in Antarctic waters. The blubber from whales stranded along the Australian coastline was analysed and SCCPs were detected in 7 out of 9 individuals. Levels of SCCPs were generally low, however, with concentrations up to only 46 ng g^{-1} lipid weight. The presence of these pollutants in the Antarctic ecosystem is nevertheless of concern.

*(SOURCE: Casà, M.V., van Mourik, L.M., Weijs, L., Mueller, J. and Bengtson Nash, S. 2019. First detection of short-chain chlorinated paraffins (SCCPs) in humpback whales (*Megaptera novaeangliae*) foraging in Antarctic waters. Environ. Pollut. 250: 953–959, https://doi.org/10.1016/j.envpol.2019.04.103)*

Effect of DDT on Dolphin Hormone Levels

Relatively few studies have examined hormone disruption in dolphins as a result of DDT exposure. Blubber biopsies of common bottlenose dolphins in an area with high DDT levels showed testosterone and cortisol levels were related to DDT. This suggests higher DDT levels affect androgen and corticosteroid hormone levels, which could affect dolphin health, reproduction and fitness.

(SOURCE: Galligan, T.M., Brian C. Balmer, B.C., Schwacke, L.H., Bolton, J.L., Quigley, B.M., Rosel, P.E., Ylitalo, G.M. and Boggs, A.S.P. 2019. Examining the relationships between blubber steroid hormones and persistent organic pollutants in common bottlenose dolphins. Environ. Pollut. 249: 982–991, https://doi.org/10.1016/j.envpol.2019.03.083)

Cadmium and Mercury Accumulate with Age in Common Dolphins in Argentina

The kidneys and livers of 17 common dolphins bycaught by commercial mid-water trawlers off Patagonia contained the highest values of Hg and Cd of all tissues tested, and the oldest individual (18 years) showed the maximum concentrations. The values were considerably lower than, or within, the limits of tolerance for mammals and therefore are unlikely to represent a severe health concern. Prey is the main source of these heavy metals, including Argentine anchovy and South American long-finned squid. Nonetheless, the authors note that environmental stressors, including climate change, can negatively affect the nutritional composition of fish and squid, as well as increase prey contaminant levels. For top predators such as dolphins, this can be associated with increased daily intake of prey and rising levels of contaminants in their bodies.

(Maximum concentrations, mg g^{-1} wet weight: Hg liver 48.48, kidney 3.69; Cd liver 21.00, kidney 68.75)

(SOURCE: Machovsky-Capuska, G.E., von Haeften, G., Romero, M.A., Rodríguez, D.H. and Gerpe, M.S. 2020. Linking cadmium and mercury accumulation to nutritional intake in common dolphins (Delphinus delphis) from Patagonia, Argentina. Environ. Pollut. 263: 114480, https://doi.org/10.1016/j.denvpol.2020.114480)

Disease and mortality events

Harmful Algal Blooms (HABs)

Explosive Exhalations Observed in Dolphins in Red Tide Events

Common bottlenose dolphin behaviour was observed in Sarasota Bay, Florida, during severe HABs (known there as red tides). The rate of 'chuffing', an explosive type of exhalation, was significantly greater in dolphins observed during the HAB, although no change in respiration rate or activity budget was observed. The researchers suggested this explosive exhalation may be equivalent to the symptoms of respiratory irritation observed in humans exposed to red tides. As the frequency and severity of HABs are increasing in this area, this could pose large-scale chronic impacts to the health and fitness of bottlenose dolphins in the region, as well as to dolphins in other areas where HABs are common.

(SOURCE: Fire, S.E., Miller, G.A. and Wells, R.S. 2020. Explosive exhalations by common bottlenose dolphins during Karenia brevis *red tides. Heliyon 6: e03525, https://doi.org/10.1016/j.heliyon.2020.e03525)*

Climate change

Greenland Ice Loss Could Reach Unprecedented Rates in the Next Century

Greenland is likely to lose ice faster this coming century than at any time in the past 12,000 years. Modelling the historical losses of Greenland ice found the largest pre-industrial rates of mass loss (up to 6000 billion tonnes per century) were near the beginning of the Holocene (10,000–7000 years ago), i.e. at the end of the last ice age. This loss was similar to ice loss rates in the past two decades (6100 billion tonnes per century). The modelled ice losses in the future, under high and low greenhouse gas emission scenarios, range from 8800–10,600 billion tonnes per century for the low greenhouse gas emissions scenario, to 14,000–35,900 billion tonnes per century for the high emissions scenario. Unless major efforts are made to slow down the rate of climate change, the rate of ice loss over the next century could be four times greater than the highest rate seen in the previous 12,000 years. Moreover, the authors predict that Greenland could be completely ice free within the next 1000 years. The effect of this loss on the global cetacean environment is likely to be extreme.

(SOURCE: Briner, J.P., Cuzzone, J.K., Badgeley, J.A. et al. 2020. Rate of mass loss from the Greenland Ice Sheet will exceed Holocene values this century. Nature 586: 70–74, https://www.nature.com/articles/s41586-020-2742-6)

North Atlantic Waters Are the Warmest They Have Been for Three Millennia

An analysis of sediments from a lake on Ellesmere Island in the Arctic circle, to investigate historic sea surface temperatures in the region, found that sediment samples in the past 150 years correlated with sea surface temperatures in that region of the North Atlantic. This correlation allowed the sediments to be used to investigate sea surface temperatures over a 3000-year period. Sea surface temperatures in the North Atlantic were coldest from the late Middle Ages to just before the Industrial Revolution (i.e. from the 1400s to the 1800s), whilst current sea surface temperatures are the warmest they have been for approximately 2900 years.

(SOURCE: Lapointe, F., Bradley, R.S., Francus, P. et al. 2020. Annually resolved Atlantic sea surface temperature variability over the past 2,900 y. PNAS 117(44): 27171–27178, https://www.pnas.org/content/117/44/27171)

Climate Change Effects on Fisheries Have Implications for Cetaceans

Climate change is projected to have several impacts on fisheries, including changes in fish productivity and distributions. These changes are predicted to increase fisheries-related conflicts; for example, when fish populations shift from the fishing boundaries of one nation to another, or if an island nation becomes submerged and its exclusive economic zone becomes a matter of dispute. Current assumptions about the type, abundance, intensity and location of artisanal and commercial fisheries may be undermined. The authors call for strengthening global fisheries management regimes by taking into account climate change and such potential new conflicts. This may require "adopting new management approaches, new technologies, new cooperative mechanisms, and even new customary and formal international law". This can be relevant for cetaceans because cetaceans may follow shifts in their prey (altered cetacean distributions) and may be exposed to new entanglement and bycatch pressures in waters that were previously unfished or for which no fisheries-related management regimes are in place.

(SOURCE: Mendenhall, E., Hendrix, C., Nyman, E., Roberts, P.M., Hoopes, J.R., Watson, J.R., Lam, V.W.Y. and Sumaila, U.R. 2020. Climate change increases the risk of fisheries conflict. Mar. Pol. 117: 103954, https://doi.org/10.1016/j.marpol.2020.103954)

Climate Change Behind Record Sea Temperature Levels

The last two issues of the *Copernicus Marine Service Ocean State Report* underline that global warming is driving an unprecedented rise in sea temperature based on data from 1993–2018, with the largest rise in the Arctic Ocean. They highlight marine heat waves in Europe in 2018 and in the northeast Pacific Ocean (dubbed 'the Blob', 2013, 2018) (see also Sanford *et al*. 2019 and Jacox *et al*. 2020 in the Pacific section). These reports identify other major stressors arising from climate change, including acidification, sea level rise, loss of oxygen and sea ice retreat. The editors conclude that "Changes to the ocean have impacted on these (ocean) ecosystem services and stretched them to unsustainable limits". They call for long-term, comprehensive and systematic monitoring to ensure science-based management of the ocean.

(SOURCE: NEWS. Mar. Pollut. Bull. 161: 111317, https://doi.org/10.1016/j.marpolbul.2020.111772; von Schuckmann, K. and Le Traon, P.-Y. (editors). 2019. Copernicus Marine Service Ocean State Report, Issue 3. J. Oper. Oceanogr. 12 (sup1): S1–S123, https://doi.org/10.1080/1755876X.2019.1633075; von Schuckmann, K. and Le Traon, P.-Y. (editors). 2020. Copernicus Marine Service Ocean State Report, Issue 4. J. Oper. Oceanogr. 13 (sup1), doi:10.1080/1755876X.2020.1785097)

CLIMATE CHANGE PREDICTED TO CAUSE A DECLINE OF MULTIPLE SOUTHERN OCEAN WHALE STOCKS

Modelling efforts linked prey abundance (krill and copepods) and the population dynamics of whale species affected by historical commercial whaling (blue, fin, humpback, Antarctic minke and southern right) in the Southern Ocean with ocean temperature, primary productivity and sea ice. These models predicted that, although whale populations would initially increase because of the cessation of whaling, there would be a decline in krill and copepod prey as ocean temperatures increase. This would increase competition between whale species for resources, with an associated decrease in Pacific blue, fin and southern right whale populations and Atlantic and Indian Ocean fin and humpback whales by 2100. However, ice-associated blue and Antarctic minke whales could improve in status because they might be adaptable to changing habitats and could adjust their migrations and behaviour. The authors note that real-world outcomes may depend on the response of the international krill fishing industry to climate change and declining krill stocks. Moreover, removing other threats, such as ship strikes, underwater noise and bycatch, might partially mitigate the impacts of climate change. The authors state that studies on the recovery of whale stocks from whaling, and management recommendations based on these studies, “did not consider the impact of anthropogenic climate change on food availability in the Southern Ocean”. They go on to say that they found “long-term and potentially irreversible changes to physical processes and the marine environment that are expected with future climate change [to] threaten the recovery of these whale species”.

(SOURCE: Tulloch, V.T.D., Plagányi, É.E., Brown, C., Richardson, A.J. and Matear, R. 2019. Future recovery of baleen whales is imperiled by climate change. Glob. Change Biol. 25: 1263–1281, doi:10.1111/gcb.14573)

Noise impacts

REVIEW ON UNDERWATER SOUND

Marine ‘biophony’ (sounds produced by marine life) has decreased due to factors such as the removal of whales through industrial whaling. Simultaneously, ‘anthrophony’ (sounds produced by humans) has increased, with a high level of sound introduced into the ocean by, *inter alia*, oil and gas exploration, shipping and energy production. Climate change is also changing the distribution of sound in the ocean, affecting biophony in degraded reefs and changing the distribution of whales. At the same time, shipping and energy production activities are increasing in remote habitats such as the Arctic, in addition to ocean acidification changing sound propagation for the worse. However, unlike many other anthropogenic stressors, the authors argue that underwater noise is generally produced by a point source (e.g. a ship) and the impacts quickly decline once this source is removed or restricted. They call for national and international policies to be more ambitious in regulating noise. They note that many international treaties do not even mention noise. Currently existing technology could reduce the incidental noise produced by human activities, such as shipping. In 2014, the IMO approved voluntary guidelines for reducing underwater noise from commercial ships, and companies using these technologies have found vessel efficiency has improved. Many of the suggested mitigation measures have been used successfully in some locations and could be expanded more widely. For example, shipping routes could be re-routed to avoid biologically sensitive areas and speed restrictions introduced to lower noise outputs. “Changing ocean soundscapes have become the neglected ‘elephant in the room’ of global ocean change”, the authors state. “In an era when societies increasingly look to the ‘blue economy’ as a source of resources and wealth, it is essential that ocean soundscapes be responsibly managed to ensure the sustainable use of the ocean”.

(SOURCE: Duarte, C., Chapuis, L., Collin, S.P. et al. 2021. The soundscape of the Anthropocene ocean. Science 371(6529): 583–585)

DOLPHINS REACT TO DIFFERENT SOUND PRESSURE LEVELS AT DIFFERENT FREQUENCIES

Cetaceans are likely to react to sounds based on their hearing sensitivities to the sound’s frequency. Previous studies, however, have used a one-size-fits-all methodology when assessing impact thresholds. With hearing sensitivities taken into account, captive common bottlenose dolphins exhibited avoidance behaviour at different SPLs depending on the frequency: for a 15 kHz sound, they reacted at approximately 65 dB SPL, for 20 kHz at 70 dB SPL and for 50 kHz at 83 dB SPL. In addition, when exposed to these sounds, the dolphins surfaced more frequently and reduced their echolocation click rate. The latter reaction is an important consideration, as passive acoustic monitoring is often used during sound exposure monitoring and a reduction in click rate would make animals harder to detect. The authors describe the dolphins lifting their heads out of the water in addition to surfacing more frequently, which indicates attempts to avoid the sound vertically as well as horizontally (an effort the authors note was limited by the captive environment). Future noise impact studies should incorporate these frequency-related reaction differences into their design.

*(SOURCE: Niu, F., Yang, Y., Xue, R., Zhou, Z. and Chen, S. 2020. Behavioral responses by captive bottlenose dolphins (*Tursiops truncatus*) to 15- to 50-kHz tonal signals. Aquat. Mamm. 46: 1–10, doi:10.1578/AM.46.1.2020.1)*

Noise Regulations May Be Underestimating the Number of Animals Affected

Managers often want a single value for marine life impact thresholds when it comes to managing noise in the marine environment. In addition, regulators want to know what proportion of a population would likely be affected by a sound, and conversely what proportion would be protected if a sound threshold restriction is instituted. The regulatory process estimates the number of animals affected by a sound source using dose-response functions, data on animal distribution and models that predict a decrease in the impacts of sound as distance increases. If any of these factors are not included, and variation and uncertainty are not incorporated, then it could lead to a significant error in the proportion of a population affected by a sound source. As an example, behavioural changes in beaked whales have been reported 100 km from a sonar source, but current regulations assume there will be no impact beyond 50 km. Although the probability of a sound affecting an animal may be low at a greater distance, the absolute number of animals affected may be quite high because of the much larger area ensonified and the higher number of animals occupying this larger area, even at a low probability of impact. A methodology commonly used by regulators to estimate the impacts of a sound source was compared with a more sophisticated model; the traditional model underestimated the number of whales exposed to the sound source at levels that could potentially cause an impact by a factor of nearly 300. The authors emphasise that this result "highlights the importance for conservation of not just accounting for high probabilities of impact on a few animals very near a sound source".

(SOURCE: Tyack, P.L. and Thomas, L. 2019. Using dose-response functions to improve calculations of the impact of anthropogenic noise. *Aquatic Conserv.* 29(S1): 242–253, *https://doi.org/10.1002/aqc.3149*)

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Stachowitsch, M., Rose, N.A. and Parsons, E.C.M. 2003. State of the cetacean environment report (SOCER) 2003: Second draft. Paper SC/55/E7 presented to the IWC Scientific Committee, May 2003, Berlin (unpublished). 13pp. [Paper available from the Office of this Journal].

Appendix 1

GLOSSARY

Glossary of terms

AIS: Automatic identification system, for logging the location of ships.

ALDFG: Abandoned, lost or discarded fishing gear.

Bioaccumulation: Increase in concentration of a pollutant within an organism compared to background levels in its diet. Pollutant levels are highest in older individuals.

Biomagnification: Increase in concentration of a contaminant from one link in a food chain to another. Pollutant levels are highest in top predators.

CHL: Chlordane, an organochlorine pesticide.

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

DDE: Dichlorodiphenyldichloroethylene, a breakdown product of DDT.

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

Diel: Denoting a period of 24 hours.

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

EEZ: Exclusive Economic Zone.

Endocrine disruption: When an outside substance (chemical) interferes with an organism's endocrine system, a system of ductless glands producing hormones that control and moderate metabolic processes in the body.

EU: European Union.

FOSA: Perfluorooctanesulfonamide.
G7: Group of Seven, an intergovernmental organisation that meets periodically to address international economic and monetary issues.
Genotoxic: Causing damage to genetic information in cells.
HAB: Harmful algal bloom.
HCB: Hexachlorobenzene, a chlorinated pesticide.
HCH: Hexachlorocyclohexane, a chlorinated pesticide.
Hypoxia (hypoxic): Absence of adequate oxygen (without adequate oxygen).
Hz: Hertz, a measure of sound frequency (pitch), in wave cycles per second (kHz = 1000 Hz).
IMO: International Maritime Organisation.
IUCN: International Union for Conservation of Nature.
London Protocol: London Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter (1972), an international agreement limiting dumping of hazardous waste at sea.
µg: Microgram, one thousandths of a gram.
MeO-PBDE: Methoxylated polybrominated diphenyl ethers, naturally occurring.
Microplastics: Plastic particles 0.3-5 mm in diameter, often the result of larger plastic pieces breaking down over time.
MPA: Marine protected area.
Mysticete: The taxonomic suborder Mysticeti, denoting whales with baleen plates in the mouth in place of teeth.
Necrosis: The death of most of the cells in an organ or tissue.
ng: Nanogram, one billionth of a gram.
nm: Nanometre, one billionth of a metre.
NRKW: Northern resident killer whale.
Odontocete: The taxonomic suborder Odontoceti, denoting whales with teeth.
p,p′-DDT, p,p′-DDD and o,p′-DDD: Chemical products derived from DDT; o,p′-DDD is mitotane, a chemotherapy treatment.
PAH: Polycyclic aromatic hydrocarbon.
PBB: Polybrominated biphenyl.
PBDE: Polybrominated diphenyl ether.
PCB: Polychlorinated biphenyl.
PFAS: Per- or polyfluoroalkyl substance. These manufactured substances are used in numerous industrial products and materials, including fire-fighting foam, cleaning products, Teflon, paints and stains.
PFBS: Perfluorobutane sulfonic acid, a PFAS.
PFCA: Perfluorinated carboxylic acid, a PFAS.
PFDA: Perfluorodecanoic acid, a PFAS.
PFDoA: Perfluorododecanoic acid, a PFAS.
PFDS: Perfluorodecanesulfonic acid, a PFAS.
PFHpA: Perfluoroheptanoic acid, a PFAS.
PFHxA: Perfluorohexanoic acid, a PFAS.
PFHxDA: Perfluorohexadecanoic acid, a PFAS.
PFHxS: Perfluorohexane sulfonate, a PFAS.
PFPeA: Perfluoropentanoic acid, a PFAS.
PFNA: Perfluorononanoic acid, a PFAS.
PFOA: Perfluorooctanoic acid, a PFAS.
PFODA: Perfluorooctadecanoic acid, a PFAS.
PFOS: Perfluorooctane sulfonate, a PFAS.
PFTeDA: Perfluorotetradecanoic acid, a PFAS.
PFTrDA: Perfluorotridecanoic acid, a PFAS.
PFUdA: Perfluoroundecanoic acid, a PFAS.
POPs: Persistent organic pollutants, organic compounds that are resistant to degradation and thus persist in the environment.
Ramp up: A noise impact mitigation measure, which consists of slowly increasing the sound level of a source (e.g. sonar), intended to give animals in the vicinity an opportunity to vacate the area.
RL: Received level of a sound.
SCCP: Short-chain chlorinated paraffins. Highly complex mixtures containing a large number of similar compounds with carbon chains, used as cutting fluids, flame retardants, plasticisers and additives.
SD: Standard deviation.
SE: Standard error.
SL: Source level of a sound.

SPL: Sound pressure level.
SRKW: Southern resident killer whale.
TPT: Triphenyltins, organotin products used extensively as algicides and molluscicides in antifouling products
UN: United Nations.
Virulence: The severity or harmfulness of a disease or pathogen.
Water column: A conceptual column of water extending from the sea surface down to the seafloor.
WHO: World Health Organisation.

Species glossary

Antarctic minke whale	*Balaenoptera bonaerensis*
Atlantic humpback dolphin	*Souza teuszii*
Australian humpback dolphin	*Sousa sahulensis*
Beluga whale	*Delphinapterus leucas*
Blainville's beaked whale	*Mesoplodon densirostris*
Blue whale	*Balaenoptera musculus*
Bowhead whale	*Balaena mysticetus*
Burmeister's porpoise	*Phocoena spinipinnis*
Common bottlenose dolphin	*Tursiops truncatus*
Common minke whale	*Balaenoptera acutorostrata*
Cuvier's beaked whale	*Ziphius cavirostris*
Dall's porpoise	*Phocoenoides dalli*
Dusky dolphin	*Lagenorhynchus obscurus*
Dwarf sperm whale	*Kogia sima*
False killer whale	*Pseudorca crassidens*
Fin whale	*Balaenoptera physalus*
Franciscana	*Pontoporia blainvillei*
Harbour porpoise	*Phocoena phocoena*
Hector's dolphin	*Cephalorhynchus hectori*
Humpback whale	*Megaptera novaeangliae*
Indo-Pacific bottlenose dolphin	*Tursiops aduncus*
Indo-Pacific finless porpoise	*Neophocaena phocaenoides*
Indo-Pacific humpback dolphin	*Sousa chinensis*
Killer whale	*Orcinus orca*
Long-beaked common dolphin	*Delphinus capensis*
Long-finned pilot whale	*Globicephala melas*
Maui dolphin	*Cephalorhynchus hectori maui*
Narrow-ridged finless porpoise	*Neophocaena asiaeorientalis*
Pantropical spotted dolphin	*Stenella attenuata*
Pygmy killer whale	*Feresa attenuata*
Sei whale	*Balaenoptera borealis*
Short-beaked common dolphin	*Delphinus delphis*
Short-finned pilot whale	*Globicephala macrorhynchus*
Snubfin dolphin	*Orcaella heinsohni*
Southern right whale	*Eubalaena australis*
Sperm whale	*Physeter macrocephalus*
Vaquita	*Phocoena sinus*
Yangtze finless porpoise	*Neophocaena asiaeorientalis asiaeorientalis*
Dugong	*Dugong dugon*
Anchovy	Family Engraulidae
Argentine anchovy	*Engraulis anchoita*
Chinook salmon	*Oncorhynchus tshawytscha*
Coho salmon	*Oncorhynchus kisutch*
Mackerels, tunas	Family Scombridae
Totoaba	*Totoaba macdonaldi*
Arrow squid	*Nototodarus sloanii*
Humboldt (jumbo) squid	*Dosidicus gigas*
Krill	Family Euphausiidae (euphausiids)
South American long-finned squid	*Loligo sanpaulensis*
Lungworms	*Halocercus* sp.
Nematode worms	*Anisakis typica*, *Cystidicola* sp.
Heavy metals	
Ag	Silver
Al	Aluminium

As	Arsenic
Cd	Cadmium
Ce	Caesium
Cr	Chromium
Cu	Copper
Fe	Iron
Hg	Mercury
Mg	Magnesium
Mn	Manganese
Ni	Nickel
Pb	Lead
Se	Selenium
Tl	Thallium
V	Vanadium
Zn	Zinc

Table 1. Maximum contaminant levels from four studies in the Pacific

		MAXIMUM CONTAMINANT LEVEL NG G^{-1} LIPID WEIGHT							
Location	**Species**	ΣPAH	ΣPCB	HCB	ΣHCH	ΣCHLs	ΣPBDEs	ΣDDTs	Σ MeO-PBDEs
Chile	Blue whale	-	975	77.5	-	-	33.4	537	-
Ecuador	Humpback whale	-	7.4	77.3	4.9	10.8	0.9	153.9	2.0
Japan	Finless porpoise	-	-	-	-	-	7.2	-	8.6
Japan	Harbour porpoise	-	-	-	-	-	0.99	-	1.4
Japan	Dall's porpoise	-	-	-	-	-	5.4	-	2.7
Pearl River, China	Finless porpoise	1.35	1.12	219	-	-		746	-

*(SOURCES: Gui, D., He. J., Zhanga, X.,Tua, Q., Chen, L., Feng, K., Liu, W., Mai, B. and Wua, Y. 2018. Potential association between exposure to legacy persistent organic pollutants and parasitic body burdens in Indo-Pacific finless porpoises from the Pearl River Estuary, China. Sci. Total Environ. 643: 785–792; Muñoz-Arnanz, J., Chirife, A.D., Galletti Vernazzani, B., Cabrera, E., Sironi M., Millán, J., Attard, C.R.M. and Jiménez, B. 2019. First assessment of persistent organic pollutant contamination in blubber of Chilean blue whales from Isla de Chiloé, southern Chile. Sci. Total Environ. 650: 1521–1528; Ochiai , M., Nomiyama, K., Isobe, T., Yamada, T.Y., Tajima, Y., Matsuda, A., Shiozaki, A., Matsuishi, T., Amano, M., Iwata, H. and Tanabe, S. 2017. Polybrominated diphenyl ethers (PBDEs) and their hydroxylated and methoxylated analogues in the blood of harbor, Dall's and finless porpoises from the Japanese coastal waters. Mar. Environ. Res. 128: 124–132; Remili, A., Gallego, P., Pinzone, M., Castro, C., Jauniaux, T., Garigliany, M.-M., Malarvannan, G., Covaci, A. and Das, K. 2020. Humpback whales (*Megaptera novaeangliae*) breeding off Mozambique and Ecuador show geographic variation of persistent organic pollutants and isotopic niches. Environ. Pollut. 267: 115575, http://doi.org/10.1016/j.envpol.2020.115575)*

Table 2. Maximum PFAS concentrations (ng g^{-1} wet weight) in livers of Indo-Pacific humpback dolphins from the coastal waters of the Pearl River Delta in China

PFPeA	PFHxA	PFHpA	PFOA	PFNA	PFDA	PFDoA	PFUdA	PFTrDA	PFTeDA	PFHxDA	PFODA	PFBS	PFHxS	PFOS	PFDS
3.74	5.88	33.4	102	242	324	99.1	519	146	30.7	0.62	0.59	1.83	12.3	6690	35.8

(SOURCE: Gui, D., Zhang, M., Zhang, T., Zhang, B, Lin, W., Sun, X., Yu, X., Liu, W. and Wu, Y. 2019. Bioaccumulation behavior and spatiotemporal trends of per- and polyfluoroalkyl substances in Indo-Pacific humpback dolphins from the Pearl River Estuary, China. Sci. Total Environ. 658: 1029–1038, https://doi.org/10.1016/j.scitotenv.2018.12.278)

Table 3. Maximum trace element levels in the tissues of Yangtze River finless porpoises (n = 38)

	Cr	Mn	Cu	Se	Hg*	As	Cd*	Pb	V	Ni	Zn
Concentration µg g^{-1} wet weight	0.521	6.61	24.7	116	250	0.41	7.91	0.25	0.11	0.15	429
Tissue	Liver	Liver	Liver	Liver	Liver	Blubber	Kidney	Skin	Skin	Skin	Skin

* Levels of Hg and Cd are a cause for concern, due to their toxic nature.

*(SOURCE: Xiong, X., Qian, Z., Mei, Z., Wu, J., Hao, Y., Wang, K., Wu, C. and Wang, D. 2019. Trace elements accumulation in the Yangtze finless porpoise (*Neophocaena asiaeorientalis asiaeorientalis*)—A threat to the endangered freshwater cetacean. Sci. Total Environ. 686: 797–804, https://doi.org/10.1016/j.scitotenv.2019.06.031)*

Table 4. Maximum levels of selected trace elements and per- and polyfluoroalkyl substances in mass stranded common dolphins from New Zealand (n = 12)

TRACE ELEMENTS				**PER- AND POLYFLUOROALKYL SUBSTANCES**			
µg g^{-1} wet weight				ng g^{-1} wet weight			
Cu	Zn	Hg	Cd	ΣPFAS	PFOS	FOSA	PFCA
12	148	89	6.2	110.4	42	58	4.6

*(SOURCE: Stockin, K.A., Yi, S., Northcott, G.L., Betty, E.L., Machovsky-Capuska, G.E., Jones, B., Perrott, M.R., Law, R.J., Rumsby, A., Thelen, M.A., Graham, L., Palmer, E.I. and Tremblay, L.A. (in review). Per- and polyfluoroalkyl substances (PFAS), trace elements and life history parameters of mass-stranded common dolphins (*Delphinus delphis*) in New Zealand. Mar Pollut. Bull.)*