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State of the Cetacean Environment Report (SOCER) Global Compendium 2014 - 2018

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The cover image merges two photographs: Antarctica and Morocco.

State of the Cetacean Environment Report (SOCER) Global Compendium 2014 - 2018

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Introduction

The conservation status of cetaceans and the roles they play in their ecosystems can be understood only in the framework of the environments they inhabit. Those environments range from the open ocean to shallow coastal areas to freshwater rivers and lakes: all are undergoing rapid, primarily anthropogenically driven change. The multitude of threats, their severity and their ubiquity have shifted the topic of environmental concerns from a lower-level ranking in the International Whaling Commission's Scientific Committee deliberations to a central hub interlinking every issue. Whether the topic be quota calculations, survey frequencies, whale watching or small cetaceans, all are influenced by the state of the respective species' environment.

The State of the Cetacean Environment Report (SOCER) is one part of the IWC's effort to reflect this insight. The mission, based on a Commission Resolution in 1997 (IWC, 1998), has been to provide a non-technical summary of the most recently published research, legislation and other relevant developments. The focus is on the marine and certain freshwater environments, not necessarily directly on cetaceans per se. Nearly 1000 entries since 2003 (Stachowitsch et al., 2003) have provided updates on habitat degradation (including issues such as marine debris and ship strikes), chemical pollution, disease, noise impacts and mortality events (such as after oil spills). Welcome developments such as new marine protected areas or marine debris collection schemes have also been highlighted.

Fifteen SOCERs have been produced since the current format was finalised in 2004. That long-term effort has revealed increasing trends for most threats (e.g. noise) and the full recognition of new and emerging threat categories relevant to cetaceans (e.g. marine debris, harmful algal blooms). Some are locally or regionally relevant, others globally (e.g. climate change). All the threat categories have been documented to some extent in every region. Each SOCER has two major components: a specific regional focus and a more general global update (plus a glossary of species names and technical terms). The regional focus rotates on a 5-year cycle and the regions are: North and South Atlantic, North and South Pacific, Arctic and Antarctic (polar), Indian Ocean and Mediterranean and Black Seas. To date, the SOCERs have been available as separate, regional documents (see www.iwc.int/socer). This compendium reflects an effort to put this fragmented presentation into a single, handy, global document covering the most recent 5-year cycle.

Ecosystem shifts, ecosystem function and services, shifting baselines, 'new normal' marine ecosystems: these and many other terms have been coined to get a better grasp on the health of the world's oceans. The editors and the IWC Scientific Committee hope that this compendium proves to be a useful document to help gauge the status of the oceans relevant to cetaceans and to inform decisions and organisations' strategies.

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Atlantic Ocean (2014)

General

World's first large marine ecosystem legal framework

One trend in improving the state of the oceans is attempting to incorporate ever larger regions into conservation and management schemes. Angola, Namibia and South Africa have signed the Benguela Current Convention, which aims to promote the conservation and sustainable use of the Benguela Current Large Marine Ecosystem, one of the richest ecosystems on earth. This Southern Atlantic cold-water current flows northward along the west coast of Africa. This cross-national agreement was supported by the United Nations Development Programme and the Global Environment Facility. Such large-scale approaches have the potential to provide the greatest benefits, including for highly migratory species such as cetaceans.

(SOURCE: News. 2013. *Mar. Pollut. Bull.* 71: 3)

Dredging operations linked for the first time to behavioural changes in a dolphin population

This study is the first to conclusively link dredging operations to a measurable behavioural response in a marine predator. The bottlenose dolphin population along the northeastern coast of Scotland has experienced a range expansion, whereby Aberdeen Harbour has progressively become a foraging area. Nonetheless, higher intensities of dredging have caused the dolphins to spend less time in the harbour, even though there was already a high baseline level of anthropogenic disturbance there. As opposed to the habituation to some other stressors, the lack of any change in tolerance to dredging might be explained by the irregular nature of the disturbance. Currently 1481 dredging vessels are operating worldwide, a capacity increase of 75% since 2000: this reflects the need to accommodate rising levels of shipping and offshore energy exploitation in cetacean management.

(SOURCE: Pirotta, E., *et al*. 2013. Dredging displaces bottlenose dolphins from an urbanised foraging patch. *Mar. Pollut. Bull.* 74: 396-402)

Link between decreasing prey, decreasing body condition and decreasing reproductive rate in baleen whales

An analysis on the effect of linkages between prey availability, body condition and reproductive rates was conducted for North Atlantic fin whales. As prey abundance declined, blubber thickness declined, and pregnancy rates in breeding age females similarly declined, suggesting a link between food availability and reproductive rate. This study has important repercussions for the impacts of a variety of stressors such a prey decline due to overfishing, climate change or pollution, or disruption of feeding behaviour by disturbance from noise-producing activities or boat traffic, which could ultimately lead to a decline in reproductive rates and therefore effect the recovery of baleen whale populations. This study gives important evidence to a link that had been previously been postulated.

(SOURCE: Williams, R., *et al*. 2013. Evidence for density-dependent changes in body condition and pregnancy rate of North Atlantic fin whales over four decades of varying environmental conditions. *ICES J Mar. Sci.* 70: 1273-1280)

Habitat degradation

General

Water quality in European waters assessed by remote sensing

Determining water quality is important for marine ecosystems, their inhabitants, and the human population. In Europe, the Water Framework Directive (WFD) and the Marine Strategy Framework Directive (MSFD) have been approved, the goal being to achieve a 'good' surface water status by 2015. This study used satellite imagery to develop a tool to better estimate the sea surface chlorophyll-*a* within coastal waters of Spain from 2005-2010. This approach helped estimate this parameter with a frequency 40 times higher when compared to field sampling and revealed that the water body showed a high quality status. The authors consider this to be a powerful tool to efficiently evaluate waters within the EEZs of European countries.

(SOURCE: Novoa, S., *et al*. 2012. Water quality assessment using satellite-derived chlorophyll-*a* within the European directives, in the southeastern Bay of Biscay. *Mar. Pollut. Bull.* 64: 739-750)

Decreased harbour porpoise abundance around wind farm shows slight recovery over time

The Nysted Offshore Wind Farm was built in the Danish western Baltic Sea in 2001, and at the time was the largest offshore wind farm in the world, with 72 2.3MW turbines. The impact of the wind farm on harbour porpoises was investigated by examining distribution via acoustic monitoring over a 10-year period. Researchers found that the "results show that [harbour porpoise] echolocation activity declined in Nysted Offshore Wind Farm after the baseline in 2001–2…and has not fully recovered yet", but the impact of the wind farm on porpoises "is gradually diminishing", with an increase in numbers, from 11% of the baseline level immediately after construction to 29% of the baseline 10 years later, which they attribute to habituation, reduced fishing effort in the wind farm area, and possibly an artificial reef effect of the turbine platforms.

(SOURCE: Teilmann, J. and Carstensen, J. 2012. Negative long term effects on harbour porpoises from a large scale offshore wind farm in the Baltic – evidence of slow recovery. *Environ. Res. Ltrs.* 7: doi:10.1088/1748-9326/7/4/045101)

Fisheries interactions

Bottlenose dolphins interact with fishery gear in Florida

Most of the fishery-related bottlenose dolphin strandings in Florida involved hook and line gear (as opposed to trap pot gear and fishing nets). Total fishery gear cases increased over time (1997-2009). Adult male individuals had a greater number of interactions than expected, related to their higher tendency to engage in unnatural foraging behaviours such as depredation and scavenging. These behaviours are probably reinforced due to the overlap between popular recreational fishing spots and prime feeding habitat for dolphins. Such studies are crucial for improving conservation and management efforts.

(SOURCE: Adimey, N.M., *et al*. 2014. Fishery gear interactions from stranded bottlenose dolphins, Florida manatees and sea turtles in Florida, U.S.A. *Mar. Pollut. Bull.* 81: 103-115, *http://dx.doi.org/10.1016/j.marpolbul.2014.02.008)*

Marine debris

Microplastics abundant in the Atlantic

Microplastics represent marine debris at the smallest scale, either the degradation products of large plastic items or the small 'plastic pellets' that provide the raw material for producing plastic items. An examination of 125 beaches on three islands in the North Atlantic Canary current revealed enormous concentrations, reaching 100g of plastic per litre of sediment. These beaches are in highly protected natural areas, demonstrating that this material is brought from distant coasts and the open ocean. All microplastics on shorelines spent time in coastal and open water habitats, and evidence is mounting that these particles and the toxic compounds that adhere to them are taken up by marine organisms, including those at the top of the food chain such as cetaceans.

(SOURCE: Baztan, J., *et al*. 2014. Protected areas in the Atlantic facing the hazards of micro-plastic pollution: First diagnosis of three islands in the Canary Current. *Mar. Pollut. Bull.* 80: 302-311)

Computer-generated mapping tools improve removal of derelict fishing gear

Lost and discarded fishing gear poses a threat to marine habitats and their inhabitants, including cetaceans. Removal of such gear has become a major management issue. In Biscayne National Park, Florida, lobster trap debris 'hot spot' maps were created that combine remotely sensed data on habitat type and depth with previous locations of debris collection. This GIS-

based approach effectively reduced the search area by 95%. An expanded system incorporating water currents, locations of known fishing effort and distance from port could further improve such efforts and would be a promising approach elsewhere where the relationship between fishing effort, debris occurrence and entanglement risk have been established.

(SOURCE: Martens, J. and Huntington, B.E. 2012. Creating a GIS-based model of marine debris "hot spots" to improve efficiency of a lobster trap debris removal program. *Mar. Pollut. Bull.* 64: 949-955)

Riverine input of litter into the North Sea: Case study Thames River

The input of litter into the sea by rivers is considered to be a major source of marine debris. The Port Authority of London, for example removes about 250 tons of debris and rubbish each year from the Thames—a major input route into the North Sea—using purpose-built vessels and special debris collectors. This study deployed various types of bottom nets to collect submerged debris. Most was plastic and amounts were highest near sewage treatment works. Many items were sanitary products not designed to be disposed via lavatories, calling for a change in consumer behaviour and for applying pressure on manufacturers of such products to improve their biodegradability. The results underline that, beyond visible debris floating on the surface, consideration must also be given to submerged items reaching the sea via rivers.

(SOURCE: Morritt, D., Stefanoudis, P.V., Pearce, D., Crimmen, O.A., and Clark, P.F. 2014. Plastic in the Thames: A river runs through it. *Mar. Pollut. Bull.* 78: 196-200)

South Atlantic Ocean 'garbage patch' detected

Plastic and other marine debris have been recognized as a severe marine pollution problem, and the IWC has recently highlighted the ingestion and entanglement threat posed to cetaceans by marine litter. This study demonstrated that floating debris is accumulating along the margins of the South Atlantic Gyre as far south as 34-35°S. Almost all the litter (97%) was composed of plastic, and in most cases litter far outnumbered floating seaweeds. The author speculate there are even higher densities of litter in the core of the gyre.

(SOURCE: Ryan, P.G. 2014. Litter survey detects the South Atlantic 'garbage patch'. *Mar. Pollut. Bull.* 79: 220-224)

Ship strikes

Rules to reduce collisions with right whales along US Atlantic coast made permanent

The US National Oceanic and Atmospheric Administration (NOAA) has taken steps to permanently implement the temporary rules (expiration date December 2013) governing ship traffic in areas containing North Atlantic right whales along the Atlantic coast of the United States. This Ship Strike Rule specifies reduced speeds (10 knots or less) of vessels longer than 65 feet during certain times of the year in 10 so-called Seasonal Management Areas (SMAs) between Maine and Florida. These rules have significantly reduced collisions between ships and whales since 2008. Compliance has been good, although three large commercial vessels were fined for violations in late 2011. One study reported a decrease in large whale vessel-strike mortalities from 2.0 per year from 2000-2006 to 0.33 from 2007-2012, whereby the number decreased within SMAs and increased outside them. The 450 right whales in the Northwest Atlantic are among the most endangered animals in the world. The authors suggest increasing the spatial and temporal extent of SMAs in the mid-Atlantic because the current ones encompass only 36% of historical right whale vessel-strike mortalities.

(SOURCES: News. 2013. *Mar. Pollut. Bull.* 72: 4-5; News. 2012. *Mar. Pollut. Bull.* 64: 460; van der Hoop, J.M., *et al*. 2014. Vessel strikes to large whales before and after the 2008 Ship Strike Rule. *Conserv. Lett.* 8: 24-32. doi: 10.1111/conl.12105)

Chemical pollution

Perfluorinated compounds in bottlenose dolphins

Perfluorinated compounds (PFCs) are used as surface coatings and are a focus of interest in pollution studies due to their persistence, bioaccumulation and global distribution. The blood plasma of bottlenose dolphin populations from two US southeast Atlantic sites was examined. Dolphins from the Charleston, South Carolina, site had some of the highest PFC levels reported in marine mammals (same order of magnitude as occupationally exposed humans). Importantly, the highest values were found in juveniles (significantly higher than in adult males and females). Such high levels during rapid growth and development may involve greater health risks and are probably due to PFC transfer from the mother by milk and by prey consumed during early years. This class of pollutants is known to contain endocrine disruptors, tumour promoters and immunosuppressors.

(SOURCE: Fair, P.A., *et al.* 2012. Assessment of perfluorinated compounds (PFCs) in plasma of bottlenose dolphins from two southeast US estuarine areas: Relationship with age, sex and geographic locations. *Mar. Pollut. Bull.* 64: 66-74)

High persistent organic pollutant levels in east Atlantic common dolphins

Blubber samples were analysed for POPs from 42 female short-beaked common dolphins that were taken as bycatch between 1992 and 2006 by fisheries operating off the southwest coast of the UK At least 1000 common dolphins are taken as bycatch each year here. Seventy-two percent of the examined individuals had PCB concentrations above an established toxicity threshold (17 mg kg^{-1} lipid weight), and the dolphins from UK waters "represented the upper end of the concentrations reported" in the literature. These elevated PCB levels are a cause for concern regarding potential risk of death due to infectious diseases. The levels are expected to be even higher in males, which cannot offload such contaminants to their offspring as breeding females do.

(SOURCE: Law, R.J., *et al.* 2013. Organochlorine pesticides and chlorobiphenyls in the blubber of bycaught female common dolphins from England and Wales from 1992-2006. *Mar. Pollut. Bull.* 69 (1-2): 238-242)

Ban of tributyltin has proven to be effective in UK waters

Tributyltin (TBT) is a toxic compound used as an additive to antifouling paints for boat hulls. After EU and IMO initiatives, it was banned in 2003 (with complete prohibition on ship hulls phased in through 2008 due to painting intervals). This study shows that 1) the TBT concentrations have declined in harbour porpoises and 2) the percentage of porpoises in which TBT was detected has declined (from 100% in the 1990s to 4.3% in 2009). The authors conclude that "the ban has proven to be effective in reducing inputs to the seas from vessels". Similar trends have been documented in other 'legacy' pollutants such as organochlorine pesticides and certain flame retardants, but not for PCBs (due to continuing diffuse inputs and the large reservoir already present in the environment).

(SOURCE: Law, R.J., *et al.* 2012. Butyltin compounds in liver of harbour porpoises (*Phocoena phocoena*) from the UK prior to and following the ban on the use of tributyltin in antifouling paints (1992-2005 and 2009). *Mar. Pollut. Bull.* 64: 2576-2580)

Pollutant levels in humpback whales across the Atlantic indicate sources and timing of inputs

The levels of persistent organic pollutants (POPs) were examined in two eastern North Atlantic humpback whale populations (Cape Verde and Ireland) and compared with a western North Atlantic (Gulf of Maine) population. The PCB concentrations were below the estimated threshold toxicity value. The ratio of DDT to its breakdown product DDE indicates more recent DDT inputs for the eastern North Atlantic sites. The DDT: PCB ratios from the eastern North Atlantic individuals indicate that agricultural sources of these pollutants are more important than industrial sources. The results show the potential for POPs as tracers to help clarify unresolved aspects of population structure in humpback whales in the North Atlantic. The low POP concentrations suggest that they are an unlikely factor in the poor recovery of humpback whales in Cape Verde.

(SOURCE: Ryan, C., *et al.* 2013. Levels of persistent organic pollutants in eastern North Atlantic humpback whales. *Endang. Species Res.* 22: 213-223)

DDT levels declining

The analysis of the pesticide DDT and its breakdown products (DDD and DDE) in thousands of bivalve samples taken from coastal water of the United States revealed that average concentrations were declining along both the West and East Coast. The highest values in Atlantic waters were in Delaware and the Hudson/Raritan Estuary; in the Gulf of Mexico in Alabama and northwestern Florida. Values are declining with an environmental half-life between 10 and 14 years and are expected to drop to below 10% of today's concentrations by 2050. This indicates that this pollutant is slowly disappearing from environments where no new production or inputs occur. Unfortunately, the use of this pesticide is not banned worldwide. This pollutant is subject to bioaccumulation and is therefore found in relatively high amounts in top marine predators such as cetaceans.

(SOURCE: Sericano, J.L., Wade, T.L., Sweet, S.T., Ramirez, J., and Lauenstein, G.G. 2014. Temporal trends and spatial distribution of DDT in bivalves from the coastal marine environments of the continental United States, 1986-2009. *Mar. Pollut. Bull.* 81: 303-316, *http://dx.doi.org/10.1016/j.marpolbul.2013.12.049*)

Disease and mortality events

General

Cause of death in one-third of stranded cetaceans on the Canary Islands is anthropogenic

An examination of 233 stranded cetaceans from 19 species in the Canary Islands, Northeast Atlantic, revealed that the cause of death in one-third of the cases was anthropogenic. The most common causes of death were fishery interactions (bycatch), ship collisions (particularly in sperm whales), atypical mass strandings linked to naval exercises (beaked whales),

and ingestion or entrapment by marine debris. The most important non-anthropogenic causes of death were starvation and a range of infectious and non-infectious diseases. This highlights the many threats facing cetaceans and provides valuable input for cetacean conservation and management efforts here.

(SOURCE: Arbelo, M., *et al.* 2013. Pathology and causes of death of stranded cetaceans in the Canary Islands (1999-2005). *Dis. Aquat. Org.* 103: 87-99. doi: 10.3354/dao02558)

Oil spills

***Deepwater Horizon* spill impacts dolphin health**

Bottlenose dolphins in Barataria Bay, Louisiana, are showing several disease conditions that are uncommon and consistent with petroleum hydrocarbon exposure. This bay in the Gulf of Mexico received heavy and prolonged oiling related to the *Deepwater Horizon* incident. The 29 dolphins examined showed evidence of adrenal toxicity and were five times more likely to have moderate to severe lung disease. Almost half of the animals were given a guarded or worse prognosis, with 17% of these not expected to survive. A comparable but unexposed population in Sarasota Bay, Florida, showed a significantly lower prevalence and severity of symptoms. Mortalities in Barataria Bay are considered to be part of an ongoing Unusual Mortality Event (UME) covering the northern Gulf of Mexico and encompassing 1051 cetacean strandings since early November 2013.

(SOURCE: Schwacke, L.H., *et al.* 2014. Health of common bottlenose dolphins (*Tursiops truncatus*) in Barataria Bay, Louisiana, following the *Deepwater Horizon* oil spill. *Environ. Sci. Tech*. 48: 93-103)

Disease

Novel morbillivirus in South Atlantic dolphin

Although major morbillivirus outbreaks and mortalities have been reported in cetaceans from the Northern Hemisphere, only one fatal case, in a bottlenose dolphin, has been reported in the Southern Hemisphere (southwest Pacific Ocean). This is the first reported case in the South Atlantic, affecting the coastal and estuarine Guiana dolphin. The stranded female calf contained a novel strain of morbillivirus. Accordingly, morbillivirus infection is extant in Guiana dolphins in Brazil and dolphin calves are susceptible.

(SOURCE: Groch, K.R., *et al.* 2014. Novel cetacean morbillivirus in Guiana dolphin, Brazil. *Emerg. Infect. Dis.* 20: 511-513)

***Brucella* infection found in harbour porpoise stranded on Belgian coast**

The bacterium *Brucella ceti* was found in a stranded adult female harbour porpoise on the Belgian coast. The necropsy revealed the bacterium in multiple organs, a recent pregnancy and the possibility of a spontaneous abortion. *Brucella* is known to cause abortions in terrestrial animals and could therefore also affect reproduction in cetaceans. The results also point to potential vertical and horizontal transmission to new-borns. The authors also emphasize the health risk posed to humans of contracting this disease by handling infected cetaceans in the framework of, e.g. strandings, bycatches, rehabilitation centres.

(SOURCE: Jauniaux, T.P., *et al.* 2010. *Brucella ceti* infection in harbor porpoise (*Phocoena phocoena*). *Emerg. Infect. Dis.* 16: 1966-1968)

Morbillivirus in an Atlantic dolphin closely related to virus in Mediterranean dolphins

A morbillivirus detected in a live-stranded juvenile bottlenose dolphin in the Canary Islands, eastern North Atlantic Ocean, is nearly identical to the morbillivirus reported in striped dolphins in the Mediterranean Sea. This supports the hypothesis that transmission occurs between species and shows that the dolphin populations in the Mediterranean and Atlantic are in contact through the Strait of Gibraltar. This information could help clarify the infectious source(s) of the die-off of bottlenose dolphins along the East Coast of the United States in 2013.

(SOURCE: Sierra, E., *et al.* 2014. Fatal systemic morbillivirus infection in bottlenose dolphin, Canary Islands, Spain. *Emerg. Infect. Dis.* 20 (2), *http://dx.doi.org/10.3201/eid2002.131463doi*)

Climate change

Anomalous gray whale sightings in the Atlantic and Mediterranean reflect changes in Arctic

The reduction in seasonal sea ice coverage in the Arctic has resulted in an expansion of the distribution of gray whales. Observations of a gray whale in the Mediterranean Sea in 2010 and one off Namibia in 2013 (the first record of a gray whale

in the Southern Hemisphere) could be harbingers of the future if reductions in sea ice continue and the northwest and northeast passages become ice-free.

(SOURCES: Elwen, S.H. and Gridley, T. 2013. Gray whale (*Eschrichtius robustus*) sighting in Namibia (SE Atlantic) – first record for Southern Hemisphere. Paper SC/65a/BRG30 presented to the Scientific Committee of the International Whaling Commission; Scheinin, A.P., Kerem, D., MacLeod, C.D., Gazo, M., Chicote, C.A., and Castellote, M. 2011. Gray whale (*Eschrichtius robustus*) in the Mediterranean Sea: anomalous event or early sign of climate-driven distribution change? *Mar. Biodiver. Rec.* 4, e28)

Possible impacts of climate change for UK waters

Temperatures in UK waters show an overall upward trend. Changes in primary production are expected throughout UK waters, with southern waters becoming 10% more productive (e.g. the English Channel) and northern regions (e.g. central and northern North Sea) becoming 20% less productive. Shifts of cetacean species have been reported, with various species of dolphins (including white-beaked dolphins, Atlantic white-sided dolphins, short-beaked common dolphins and striped dolphins) moving northwards, and novel stranding of warmer water species being reported for the first time (such as Blainville's beaked whale), suggesting a temperature-change-linked shift for a variety of cetacean species.

(SOURCE: Marine Climate Change Impacts Partnership. 2014. *Report Card 2013*. Marine Climate Change Impacts Partnership. *In*: Evans, P.G.H. and Bjørge, A. 2013. Impacts of climate change on marine mammals. Marine Climate Change Impacts Partnership: Science Review, *http://www.mccip.org.uk/media/13291/2013arc_backingpapers_15_marm.pdf*)

Reduction of ocean circulation in North Atlantic could lead to cooling

Although the Marine Climate Change Impacts Partnership described warming of the waters in the North Atlantic, another study determined that the Atlantic Meridional Overturning Circulation (AMOC) decreased 10-15% since 2004. This study analysed data from floating sensor arrays in the North Atlantic over an eight-year period. If the AMOC is strong, more heat is transferred into the surface waters of the North Atlantic; if weak, less heat is transferred. It was also suggested that the AMOC may have actually declined by 20% or more. Although climate change is likely a factor in weakening ocean circulation, it was suggested that the change is more dramatic than would be expected by climate change alone and that other factors may be involved.

(SOURCE: Robson, J., Hodson, D., Hawkins, E., and Sutton, R. 2014. Atlantic overturning in decline? *Nature Geoscience* 7: 2-3; Smeed, D.A., *et al.* 2013. Observed decline of the Atlantic Meridional Overturning Circulation 2004 to 2012. *Ocean Sci.* 10: 1619-1645)

Noise impacts

Canary Islands: No mass strandings since sonar ban

The Canary Islands has been a hotspot for mass strandings, particularly of beaked whales. These strandings have been attributed to naval exercises, specifically those involving high-intensity sonar. No mass strandings have been reported since the Spanish government imposed a moratorium on naval exercises in these waters in 2004. This demonstrates that prompt political action can result in conservation success for whales and dolphins.

(SOURCE: Fernandez, A., Arbelo, M., and Martin, V. 2013. No mass strandings since sonar ban. *Nature Corres.* 497: 317)

Substantial disturbance of German harbour porpoise stock possible during wind farm construction

Aerial surveys in the German North Sea investigated harbour porpoise abundance and seasonal changes in distribution. Porpoises moved into German waters in the spring, became more abundant in the early part of the summer and then apparently move out of German waters in the autumn. The surveys found that there were specific areas where porpoises aggregated, or 'hotspots', in the spring and summer. This distribution was compared with proposed and existing sites for wind farms. The authors proposed that wind farm licences should not be granted for one of the hotspot areas (Sylt Outer Reef) and construction should not occur during the spring for a second (Borkum Reef Ground). Assuming that porpoises were disturbed within 20km of a construction site, it was estimated that as much as "39% of the harbour porpoise stock in the German EEZ could be affected during construction".

(SOURCE: Gilles, A., Scheidat, M. and Siebert, U. 2009. Seasonal distribution of harbour porpoises and possible interference of offshore wind farms in the German North Sea. *Mar. Ecol. Prog. Ser.* 383: 295–307)

Military exercises responsible for common dolphin mass stranding in southwest England

On 9 June 2008, short-beaked common dolphins mass-stranded in Falmouth Bay, Cornwall; at least 26 died. They were well fed, had no signs of algal toxin exposure and had low pollutant levels in tissues. However, five animals had microscopic

haemorrhages in the ear. Several potential causes of the stranding were excluded, including "infectious disease, gas/fat embolism, boat strike, bycatch, predator attack, foraging unusually close to shore, chemical or algal toxin exposure, abnormal weather/climatic conditions, and high-intensity acoustic inputs from seismic airgun arrays or natural sources (e.g. earthquakes)". There was, however, a naval exercise on the morning of the mass stranding. The authors suggested that the initial naval exercise drove the pelagic dolphins into the enclosed waters of Falmouth Bay, and then subsequent helicopter activity caused them to strand. The authors concluded "naval activity to be the most probable cause of the Falmouth Bay [mass stranding event]".

(SOURCE: Jepson, P.D., *et al.* 2013. What caused the UK's largest common dolphin (*Delphinus delphis*) mass stranding event? *PLoS ONE* 8(4): e60953. doi:10.1371/journal.pone.0060953)

Acoustic behavioural responses of bottlenose dolphins to shipping in the Sado Estuary, Portugal

The Sado Estuary, Portugal, has a particularly high level of boat traffic. The group size and acoustic and visual behaviour of common bottlenose dolphins resident in this area was monitored and correlated with the presence or absence of vessels within a 1km radius of dolphin groups. Overall, mean call rates decreased significantly in the presence of boats. Production of creaks (fast click trains) was significantly lower in the presence of ferry boats. Significant differences in dolphin whistle minimum, maximum, and start frequencies were also observed, suggesting vessel traffic is having an impact on communication within this small dolphin population.

(SOURCE: Luís, A.R., Couchinho, M.N., and Santos, M.E. 2014. Changes in the acoustic behavior of resident bottlenose dolphins near operating vessels. *Mar. Mamm. Sci.* 30: 1417-1426)

New attempt to tackle underwater noise in a coastal North Atlantic case study

Underwater noise levels have been increasing worldwide and are a recognized threat for cetaceans. This study characterized the noise levels at two sites in Moray Firth, Scotland, an important marine mammal habitat (Special Area of Conservation). It established a pre-development baseline and presented ship noise monitoring methods. These relied partially on shore-based time-lapse footage and on the ship-tracking AIS. By tying the results to EU Marine Strategy Framework Directive indicators, this study shows a way forward in how international regulations can best address the anthropogenic noise issue.

(SOURCE: Merchant, N.D., Pirotta, E., Barton, T.R., and Thompson, P.M. 2014. Monitoring ship noise to assess the impact of coastal developments on marine animals. *Mar. Pollut. Bull.* 78: 85-95)

Killer whale response thresholds to sonar lower than predicted by US Navy mitigation measures

Killer whale groups in Norway were exposed to experimentally controlled military sonar at 1-2 kHz and 6-7 kHz, with the source level increasing and the sonar source in increasing proximity, to determine the threshold at which behavioural changes occurred. Responses occurred between 94 and 164 dB re 1 µPa SPL. These response thresholds did not seem to be influenced by sonar frequency or prior exposure to sonar. The mean response threshold was 142 ± 15 dB (SD) re 1 µPa SPL. The researchers concluded that the "dose-response functions indicate that some killer whales started to avoid sonar at received [sound levels] below thresholds assumed by the US Navy". Moreover, the "predicted extent of habitat over which avoidance reactions occur…was large enough to raise concerns about biological consequences to the whales".

(SOURCE: Miller, P.J.O., *et al.* 2014. Dose-response relationships for the onset of avoidance of sonar by free-ranging killer whales. *J. Acoust. Soc. Amer.* 135: 975)

Decrease in killer whale abundance linked to naval sonar when prey abundance is low

Monitoring with visual and passive acoustic surveys was conducted before, during and after a naval exercise in Norway and the effect noted on killer whales. Although the main factor that affected killer whale presence was the availability of herring (the whales' main prey species), when herring presence was low, naval sonar activity had a negative impact on killer whale presence.

(SOURCE: Sanna Kuningas, S., Kvadsheim, P.H., Lam, F.P.A. and Miller, P.J.O. 2013. Killer whale presence in relation to naval sonar activity and prey abundance in northern Norway. *ICES J. Mar. Sci.* 70:1287-1293)

PACIFIC OCEAN (2015)

General

T-PODs help identify improvements to dolphin protection areas

T-PODs were used to document habitat use by bottlenose dolphins in Doubtful Sound, New Zealand, over a 12-month period, collecting data over 76,104 hours. T-POD records show that dolphin distribution varied seasonally, with inner fiord sites being used most often in austral summer and autumn, and outer fiord sites during austral winter and spring. This seasonal pattern was positively correlated with surface water temperature. The data suggest that parts of the 'Dolphin Protection Zone', in which boat traffic and tourism is restricted, are used frequently while other parts are not. This provides a basis for refining the shape and size of the protected areas to make this management tool more effective.

(SOURCE: Elliott, R.G. Dawson, S.M. and Henderson, S.D. 2011. Acoustic monitoring of habitat use by bottlenose dolphins in Doubtful Sound, New Zealand. *NZ J. Mar. Freshwat. Res.* 45: 637-639)

Ocean Health Index rates earth's oceans

The Ocean Health Index, compiled by the University of California at Santa Barbara, has released its third annual update. It rates the overall health of the earth's oceans at 67 out of 100. For the high seas, the Pacific values are:

Pacific Eastern Central: score 67 (global rank 100 of 236)
Pacific Northeast: 68 (global rank 85)
Pacific Northwest: 53 (global rank 208)
Pacific Southeast: 76 (global rank 26)
Pacific Southwest: 65 (global rank 115)
Pacific Western Central: 65 (global rank 113)

Pacific countries whose values (within their EEZs) were rated below 60 (and therefore in the bottom 25%) include (alphabetically) Cambodia, Colombia, Cook Islands, Costa Rica, El Salvador, Nicaragua, North Korea, Papua New Guinea, Panama, Peru, Philippines, Samoa, Taiwan, Tonga, and Vietnam.

(SOURCES: News. 2014. *Mar. Pollut. Bull.* 88: 3; *www.oceanhealthindex.org*)

Continued decline of New Zealand dolphin populations

The New Zealand dolphin, also known as Hector's dolphin, is endemic and endangered, with the North Island subspecies (Maui's dolphin) listed separately as critically endangered. The Threat Management Plan for Hector's dolphins identifies bycatch in gillnet and trawl fisheries as the number one threat. Fisheries mortality has resulted in rapid population declines, with total population size estimated at 27% of 1970 numbers. Reduced use of gillnets and trawling in NZ dolphin habitat has slowed population declines in some areas. A long-term study in the Banks Peninsula Marine Mammal Sanctuary (South Island east coast) shows a significant increase in survival rates (by 5.4%) and indicates that the previously rapid population decline of 6% per year has slowed substantially to 1% per year. Nationwide, NZ dolphin populations

are predicted to continue declining under current management mainly due to continuing bycatch in areas with little or no dolphin protection measures (e.g. South Island north and west coasts). Extending protection to the 100m depth contour throughout NZ dolphin habitat should result in rapid population recovery. This case study shows that area-based management can work, if the protected area is large enough, in the right place, effectively manages key threats, impacts are removed rather than displaced to other areas and no new threats are added (e.g. marine mining, tidal energy generation, pollution).

(SOURCE: Slooten, E. 2013. Effectiveness of area-based management in reducing bycatch of the New Zealand dolphin. *Endang. Spec. Res.* 20: 121-130)

Habitat degradation

General

Ocean acidification is dissolving planktonic snails off US west coast

The acidity of shelf waters off the US west coast has reached a level at which the shells of more than 50% of the tiny free-swimming marine snails known as pteropods are severely corroded. This value is estimated to be twice that of the pre-industrial era and is expected to triple by 2050. Pteropods, as zooplankton, are at the base of the food chain and are consumed by fish and by baleen whales. This provides yet another example of how pollution (especially carbon dioxide emissions) can affect the larger marine environment and cetaceans by affecting their food chain.

(SOURCES: Bednarsek, N., Feely, R.A., Reum, J.C.P., Peterson, B., Menkel, J., Alin, S.R., and Hables, B. 2014. *Proc. Roy. Soc. B 281: 20140123*, *http://dx.doi.org/10.1098/rspb.2014.013*; News. 2014. *Mar. Pollut. Bull.* 83: 7)

Bottlenose dolphins leaving Doubtful Sound

The bottlenose dolphin population in Doubtful Sound, New Zealand, has dramatically increased the amount of time it spends outside the Sound. Capture-recapture modelling, based on photo-identification data, demonstrated a dramatic decline in capture probability within the Sound between 2005-2009 and 2010-2011. Potential reasons for this change in distribution include changes in food availability, tourism pressure and freshwater input from a hydro power scheme.

(SOURCE: Henderson, S.D., Dawson, S.M., Rayment, W.J. and Currey, R.J.C. 2013. Missing in action? Are the resident dolphins of Doubtful Sound becoming less resident? *Endang. Spec. Res.* 20: 99-107)

Radioactive plume from Fukushima crosses the Pacific

The radioactivity discharged into the northwest Pacific from the 2011 nuclear reactor accident at Fukushima in Japan has now crossed the Pacific and reached North American waters. The signal arrived 1500 km west of British Columbia in 2013 and reached the Canadian continental shelf in February 2014. Although the radioactivity levels do not pose an immediate threat to marine life, including cetaceans, or human health, they demonstrate three important points: 1) This single accident doubled the fallout background values from the atmospheric nuclear bomb tests in the 1950s; 2) this single accident is a long-term pollution issue; values are expected to increase until 2016 before they return to earlier background levels by 2021; and 3) pollution events can have ocean-wide implications, calling for international efforts and cooperation to tackle marine pollution issues more globally.

(SOURCE: Smith, J.N., Brown, R.M., Williams, W.J., Robert, M., Nelson, R. and Moran, S.B. 2015. Arrival of the Fukushima radioactivity plume in North American continental waters. *PNAS* 112: 1310-1315)

Increased eutrophication of China's coastal seas

Eutrophication has become one the most devastating forms of marine pollution. Through oxygen depletion it can lead to the collapse of entire ecosystems, and worldwide more than 400 eutrophication-related so-called 'dead zones' have been identified. Between 1970 and 2000, the amounts of the dissolved nutrients nitrogen and phosphorus released into the Bohai Gulf, Yellow Sea and South China Sea have increased 2-5 times. A further increase of 30-200% is expected by 2050. This poses a serious threat of other eutrophication-related symptoms as well; the authors predict an increased risk of harmful algal blooms in all three coastal seas. They call for better sewage treatment and more efficient agricultural practices to counter this trend.

(SOURCE: Strokal, M., Yang, H., Thang, Y., Kroeze, C., Li, L., Luan, S., Wang, H., Yang, S., and Zhang, Y. 2014. Increasing eutrophication in the coastal seas of China from 1970 to 2050. *Mar. Pollut. Bull.* 85: 123-140)

Fisheries interactions

Dolphin bycatch pervasive in an Australian trawl fishery

Data from skippers' logbooks and independent observers were used to assess common bottlenose dolphin bycatch patterns between 2003 and 2009 in the Pilbara trawl fishery, Western Australia. Both datasets indicated that dolphins were caught in all fishery areas, across all depths and throughout the year. Observer reported bycatch rates (12.6 dolphins/1,000 trawls) were about double those reported by skippers (6.5 dolphins/1,000 trawls). One trawl vessel caught significantly more dolphins than three other boats assessed. The lowest bycatch rates were between 00:00hrs and 05:59hrs and bycatch was reduced 45% in nets with bycatch reduction devices (BRDs) after their introduction. These results indicated that differences among vessels (or skippers' trawling techniques) and dolphin behaviour influenced dolphin bycatch rates more than location or time of year; thus, spatial or seasonal adjustments to trawling effort would be unlikely to significantly reduce dolphin bycatch. Modified BRDs, with top-opening escape hatches from which dolphins might escape to the surface, may be a more effective means of further reducing dolphin bycatch.

(SOURCE: Allen, S.J., Tyne, J.A., Kobryn, H.T., Bejder, L., Pollock, K.H., and Loneragan, N.R. 2014. Patterns of dolphin bycatch in a north-western Australian trawl fishery. *PLoS ONE* 9: e93178. doi:10.1371/journal.pone.0093178)

Sperm whale bycatch in US Pacific waters exceeds sustainable levels

Bycatch of sperm whales in the California swordfish drift gillnet fishery has been documented since the observer program started in 1990. The fishery was observed from 1990 through 2012, with a total of 8,365 drift gillnet sets observed. Ten sperm whales were entangled during six different observed sets, yielding a bycatch rate of about 1.1 sperm whales per 1,000 observed sets. All of the entanglements occurred during October through December in waters deeper than 1,500 m, in proximity to steep continental shelf bathymetry. Recent bycatch of sperm whales in this fishery has exceeded allowable potential biological removal levels set under the US Marine Mammal Protection Act.

(SOURCE: Carretta, J.V., Oleson, E., Weller, D.W., Lang, A.R., Forney, K.A., Baker, J., Hanson, B., Martien, K., Muto, M.M., Lowry, M.S., Barlow, J., Lynch, D., Carswell, L., Brownell, R.L., Mattila, D.K., and Hill, M.C. 2013. U.S. Pacific Marine Mammal Stock Assessments: 2012. NOAA Technical Memorandum, NMFS-SWFSC-504)

Fishing interactions continue to threaten Maui's dolphin

Maui's dolphin is a subspecies of Hector's dolphin and current population estimates indicate that only about 55 Maui's dolphins over 1 year of age remain. A risk assessment workshop attributed 95.5% of human-induced mortalities to commercial, recreational, customary or illegal fishing-related activities combined, and the remaining 4.5% to non-fishing-related threats. There is high confidence that total human-induced mortality is higher than the population can sustain. Population projections indicate a 95.7% likelihood that the population will decline if threats remain at current levels (i.e. at the time of the workshop and prior to the introduction of interim measures).

(SOURCE: Currey, R.J.C., Boren, L.J., Sharp, B.R., and Peterson, D. 2012. *A Risk Assessment of Threats to Maui's Dolphins*. Ministry for Primary Industries and Department of Conservation, Wellington. 51 pp., *http://www.doc.govt.nz/Documents/conservation/native-animals/marine-mammals/maui-tmp/mauis-dolphin-risk-assessment.pdf*)

'Recreational' gillnetting still a threat to Hector's dolphins

T-POD acoustic data-loggers were moored in outer, mid and inner Akaroa Harbour to quantify variation in habitat utilisation by Hector's dolphins over the course of a year, to determine if they use the inner harbour where 'recreational' (non-commercial) gillnetting is allowed for eight months of the year (April-September). T-POD data showed a much higher level of use of the inner harbour in austral winter than was expected, indicating that the current compromise allowing gillnetting in this area poses genuine risk of entanglement.

(SOURCE: Dawson, S.M., Fletcher, D. and Slooten E. 2013. Habitat use and conservation of an endangered dolphin. *Endang, Spec. Res.* 21: 45-54)

More than half of New Zealand's fishing effort is not reported

New Zealand's reported marine fisheries data are incomplete due to the lack of reporting significant numbers of landings in commercial fisheries, fish that are discarded and fish that are taken by recreational and traditional fishers. This analysis reconstructed total catches in New Zealand waters from reported catches for the period 1950-2010. A baseline was constructed using publically available official catch data. Added to this baseline were data from stock assessment reports, peer-reviewed literature, grey literature, data obtained under the Official Information Act, and data from a wide range of industry experts and personnel. The reconstructed total catch was about 2.9 times greater than the 14 million tonnes reported to the FAO on behalf of New Zealand for that period. Unreported commercial catch and discards accounted for

the bulk of the difference. While some estimates of unreported catches and discards are included in stock assessment reports, the lack of comprehensive and transparent reporting has implications for the quota management system and for the management of fisheries impacts on cetaceans, including direct impacts (e.g. bycatch) and indirect impacts (e.g. reduction of prey availability for cetaceans).

(SOURCE: Simmons, G., Bremner, G., Stringer, C., Torkington, B., Teh, L., Zylich, K., Zeller, D., Pauly, D. and Whittaker, H. 2015. Preliminary reconstruction of marine fisheries catches for New Zealand, 1950-2010. Working paper #2015-87, University of British Columbia Fisheries Centre)

Indo-Pacific humpback dolphins interact with fisheries in eastern Taiwan Strait

In the eastern Taiwan Strait, there is substantial overlap between Indo-Pacific humpbacked dolphins and several kinds of fishing gear known to cause dolphin mortality. Large numbers of fishing vessels operated from ports within dolphin habitat, with an average of 32 fishing craft per km observed along a 200 km stretch. More than 30% of the fewer than 100 dolphins in this population exhibited injuries caused by fishing gear. Three individuals were photographed with fishing gear attached to their bodies and one dolphin was found dead with fresh injuries caused by fishing gear. In order to ensure population recovery, mortalities due to human causes should be reduced to below one individual every seven years. Trammel nets, other gillnets and trawling pose the greatest threat and occur throughout the dolphins' habitat. Other fishing methods are available; using the most selective, sustainable fishing methods will benefit not only dolphins but also seabirds and fish stocks, meaning the fishing industry that depends on these stocks will also benefit.

(SOURCE: Slooten, E., Wang, J.Y., Dungan, S.Z., Forney, K.A., Hung, S.K., Jefferson, T.A., Riehl, K.N., Rojas-Bracho, L., Ross, P.S., Wee, A., Winkler, R., Yang, S.C., and Chen, C.A. 2013. Impacts of fisheries on the critically endangered humpback dolphin, *Sousa chinensis*, population in the eastern Taiwan Strait. *Endang. Spec. Res.* 22: 99-114)

Marine debris

Microplastics are abundant in northeast Pacific waters

Microplastics have been identified as posing a risk to marine organisms, including cetaceans. This risk involves the particles themselves, the substances they contain, and the toxic chemicals that adhere to their surfaces. This study revealed between 8 and 9200 particles/m^3 in Canadian waters, with values being lower offshore and increasing 6- to 27-fold closer to shore. Some microplastics apparently originated locally from land-based sources, while others appeared to be accumulated by oceanographic conditions. The authors argue for heightened scrutiny given the widespread contamination of the northeast Pacific and the oncoming debris from the 2011 Tohoku tsunami.

(SOURCE: Desforges, J.-P.W., Galbraith, M., Dangerfield, N, and Ross, P.S. 2014. Widespread distribution of microplastics in subsurface seawater in the NE Pacific Ocean. *Mar. Pollut. Bull*. 79: 94-99)

Presence of large 'garbage patch' confirmed in the South Pacific

A 4489 km-long transect through the South Pacific subtropical gyre (SPSG) revealed an average of nearly 27,000 plastic particles per kilometre. The amount of plastics on the surface increased toward the centre of the gyre, verifying the presence of a 'garbage patch' in the southern hemisphere. The highest value near the centre of the predicted accumulation zone was nearly 400,000 particles per kilometre. These values are still below those reported from the North Pacific subtropical gyre (NPSG), but underline the pervasive, large-scale threat that marine debris poses to the marine environment and its inhabitants.

(SOURCE: Eriksen, M., Maximenko, N., Thiel, M., Cummins, A., Lattin, G., Wilson, S., Hafner, J., Zellers, A., and Rifman, S. 2013. Plastic pollution in the South Pacific subtropical gyre. *Mar. Pollut. Bull.* 68: 71-76)

Marine debris a major factor affecting the coastal ecosystem in South Korea

Experts in South Korea, along with local participants working through an open access website, identified 21 marine species affected by marine debris between 2010 and 2012. This included a finless porpoise. Ten types of marine debris were recorded as causing impacts. Recreational fishing gear, especially fish hooks, affected wildlife most frequently. The authors call for South Korea to prioritize recreational fishing activities in the management of marine debris.

(SOURCE: Hong, S., Lee, J., Jang, Y.C., Kim, Y.J., Kim, H.J., Han, D., Hong, S.H., Kang, D., and Shim, W.J. 2013. Impacts of marine debris on wild animals in the coastal area of Korea. *Mar. Pollut. Bull.* 66: 117-124)

Amount of plastic marine debris in East Asian seas predicted to increase dramatically

Anthropogenic litter in the marine environment (marine debris, beach litter) is a worldwide problem that has been especially highlighted by the so-called 'Great Pacific Garbage Patch,' trapped in the central north Pacific Ocean by major oceanic currents (gyres). Over the next 10 years, the amount of plastic litter reaching beaches in East Asian marginal seas (Yellow Sea, East China Sea, Japan Sea) is predicted to increase dramatically, with some beaches potentially experiencing a 250-fold increase in the amount of debris washed ashore. This trend is expected to continue even if inputs are reduced. In South Korea, an attempt was made to determine the economic costs. A marine debris pollution event on Geoje Island in 2011, attributed to heavy rainfall and flooding, washed debris into the sea via the Nakdong River. This event coincided with the summer vacation season and reduced the number of tourists here by 37%, leading to an estimated tourism revenue loss of US$37 million. Overall, the Pacific Ocean has a major marine debris problem, which affects all marine organisms that spend time at the sea surface.

(SOURCES: Kako, S., Isobe, A., Kataoka, T., and Hinata, H. 2014. A decadal prediction of the quantity of plastic marine debris littered on beaches of the East Asian marginal seas. *Mar. Pollut. Bull.* 81: 174-184; Jang, Y.C., Hong, S., Lee, J., Lee, M.J., and Shim, W.J. 2014. Estimation of lost tourism revenue in Geoje Island from the 2011 marine debris pollution event in South Korea. *Mar. Pollut. Bull.* 81: 49-54)

Rivers transport large amounts of litter to the ocean and beaches of the Southeast Pacific

A study of four rivers in Chile showed that the litter composition of each river reflects the human influences along its course. Riverine litter was deposited on both sides of the river mouths but tended to be more abundant on beaches north of the inflows, pointing to the influence of the prevailing water currents. The most abundant items on beaches were plastic, followed by polystyrene and manufactured wood. Such 'persistent buoyant' litter travels the farthest. More abundant litter and more distinct patterns occur during the rainy season, when more litter is washed into the ocean. Marine debris has multiple ecological impacts, including entanglement and ingestion by cetaceans.

(SOURCE: Rech, S., Macaya-Caquilpan, V., Pantoja, J.F., Rivadeneira, M.M., Jofre Madariaga, D., and Thiel, M. 2014. Rivers as a source of marine litter – a study from the SE Pacific. *Mar. Pollut. Bull.* 82: 66-75)

Ship strikes

Ship collisions with Bryde's whales in Hauraki Gulf, New Zealand, must be reduced

Ship strikes are the main cause of mortality for one of the few known resident populations of Bryde's whales in the world. In those whales in which the cause of death could be determined (just under half), 83% were attributed to ship strikes, with an average of two whales per year suffering lethal injuries. This rate of collision-related mortality might not be sustainable for the local population. Tag data showed that the whales spent more than 90% of their time between the surface and a depth of 12 m, within the range of the draught of ships entering Auckland Harbour. Based on the broad distribution of whales in the Gulf and other considerations, rerouting vessel traffic, visual detection and acoustic monitoring were all considered to be ineffective measures to reduce ship strikes. The authors suggested that reducing vessel speed to 10 knots (current speeds often in excess of 20 knots) would reduce the risk of whale death from ship strikes to 25%. This and other recommendations were incorporated into a Large Whale Warning System (LWWS), whose success was critically evaluated: although most ships passed clear of a reported whale location, only few notably changed course, so that more information must be gathered to better understand how and whether the communication between vessels and the LWWS is functioning properly. Year-round mandatory speed restrictions have never been implemented anywhere by the IMO and may take several years to be implemented here.

(SOURCES: Constantine, R., Aguilar Soro, N., and Johnson, M. 2012. Sharing the waters: minimising ship collisions with Bryde's whales in Hauraki Gulf. *Research Progress Report*, 22 pp.; Constantine, R., Johnson, M., Riekkola, L., Jervis, S., Kozmian-Ledward, L., Dennis, T., Torres, L.G., and Aguilar de Soto, N. 2015. Mitigation of vessel-strike mortality of endangered Bryde's whales in the Hauraki Gulf, New Zealand. *Biol. Conserv.* 186: 149-157; Riekkola, L. and Constantine, R. 2014. An assessment of the Large Whale Reporting System December 2012 – November 2013. *LWWS Report.* 32 pp.)

Increasing ship strikes of humpback whales in Hawaiian Islands

Records for the Hawaiian Islands going back 37 years were examined for evidence of vessel collisions with humpback whales. From 1975-2011, 68 whale collisions were reported (59 witnessed collisions and nine whale injuries consistent with collision). None of these collisions appeared to have been lethal. Over 63% involved calves and sub-adults, suggesting younger animals may be more susceptible to ship strikes. Collision rates are increasing, which the authors suggest is due to increasing whale abundance, although moderate-sized (7.9 m to 19.8 m) vessels have also increased – the category most involved in ship strikes, accounting for two-thirds of incidents.

(SOURCE: Lammers, M.O., Pack, A.A., Lyman, E.G., and Espiritu, L. 2013. Trends in collisions between vessels and North Pacific humpback whales (*Megaptera novaeangliae*) in Hawaiian waters (1975-2011). *J. Cet. Res. Manage.* 13: 73-80)

Blue whales interact with shipping and mining operations

Blue whale distribution around New Zealand is poorly understood. Their survival depends on the ability to reliably encounter large aggregations of euphausiid prey. Therefore, documenting and protecting blue whale foraging grounds are fundamental to their recovery. Evidence suggests that the South Taranaki Bight, between the North and South Islands of New Zealand, is used as a foraging ground for a common euphausiid prey that aggregates due to a nearby coastal upwelling system. Blue whale distribution was compared with ship traffic density and the distribution of seabed mining activities, revealing close proximity between whales and these potential threats. The author calls for a greater understanding of blue whale habitat use patterns to manage human activities effectively. While a proposal for sand mining here was declined by the New Zealand Environmental Protection Agency, this area already has several oil and gas platforms and a busy shipping lane.

(SOURCE: Torres, L.G. 2013. Evidence for an unrecognised blue whale foraging ground in New Zealand. *NZ J. Mar. Freshwat. Res.* 47: 235-248)

Chemical pollution

Mercury levels expected to rise in Pacific Ocean fish in coming decades

Methyl mercury is the toxic form of mercury. Inorganic mercury is transformed into methyl mercury by bacteria. This study found that up to 80% of this toxic form found in deep-feeding north Pacific fish is produced in the ocean (at 50-400 m depth) by bacteria clinging to sinking particles. North Pacific fisheries are downwind from rapidly industrializing China and India, which rely on coal-burning power plants, a major source of mercury pollution. Mercury may travel thousands of miles before being 'rained-out' into the ocean. Levels are expected to increase in coming decades and perhaps even to double by mid-century. Mercury also bioaccumulates, with highest values in top predators such as cetaceans. Combined with expanding Oxygen Minimum Zones (OMZs) in the Pacific (and elsewhere), this poses a threat to north Pacific fisheries, the world's most important source of marine protein.

(SOURCES: Blum, J.D., Popp, B.N., Drazen, J.C., Choy, C.A., and Johnson, M.W. 2014. Methylmercury production below the mixed layer in the North Pacific Ocean. *Nat. Geosci.* 6. doi:10.1038/NGEO1918; News: *Mar. Pollut. Bull*. 75: 4)

High levels of persistent organic pollutants in Yellow Sea minke whales

This study examining the PCB, OCP and PBDE concentrations in 32 marine species inhabiting the Yellow Sea revealed that the pelagic food chain is an important biomagnification pathway for many of these compounds. Muscle tissues of bycaught minke whales had higher concentrations of all contaminants than those found in the other species. The Yellow Sea is a major feeding and breeding ground for fish and an important habitat of minke whales in the northwest Pacific. This is one of dozens of recent publications on elevated concentrations of pollutants in Chinese and Korean waters.

(SOURCE: Byun, G.-H., Moon, H.-B., Choi, J.-H., Hwang, J., and Kang, C.-K. 2013. Biomagnification of persistent chlorinated and brominated contaminants in food web components of the Yellow Sea. *Mar. Pollut. Bull.* 73: 210-219)

Mercury levels in Pacific albacore and bigeye tuna indicate increasing inputs into the Pacific

Large predatory fish are often used as indicators of mercury contamination because they bioaccumulate some of the highest (and therefore human-health-relevant) heavy metal concentrations through the food chain. The samples collected in this study from the western and central Pacific showed high enough levels based on FAO/WHO's 'tolerable weekly intake levels' to limit consumption by humans. The values in this and other studies in the 21st century revealed that muscle mercury concentrations for these species are higher than values from 1983. This trend points to an increased input of mercury into the Pacific Ocean. This is also relevant for predatory cetaceans at the top of the food chain.

(SOURCE: Chen, C.-Y., Lai, C.-C., Chen, K.-S., Hsu, C.-C., Hung, C.-C., and Chen, M.-H. 2014. Total and organic mercury concentrations in the muscles of Pacific albacore (*Thunnus alalunga*) and bigeye tuna (*Thunnus obesus*). *Mar. Pollut. Bull.* 85: 606-612)

DDE levels in Gulf of California long-beaked common dolphins

DDT levels were measured in long-beaked common dolphins (n=16) in the Gulf of California. While DDD and DDT levels were generally below detection levels, DDE concentrations averaged 16 $\mu g.g^{-1}$ lipid weight (max.: 87.3 $\mu g.g^{-1}$ lipid weight in a juvenile female). This provides baseline contamination data for a little-studied species and location.

(SOURCE: Gallo-Reynoso. J.P., Malek, T.B., García-Hernández. J., Vázquez-Moreno. L., and Segura-García, I. 2015. Concentrations of DDE in blubber biopsies of free-ranging long-beaked common dolphins (*Delphinus capensis*) in the Gulf of California. *Bull. Environ. Contam. Toxic.* 94: 6-11)

Plastic from the North Pacific identified as a source of persistent organic pollutants in fish and birds

There is a growing concern about food web contamination due to plastic waste. PCBs, OCPs and PBDEs were detected in all samples of juvenile yellowtail fish caught in the North Pacific Subtropical Convergence Zone (NPCG). Synthetic items were found in the stomachs of 10% of the fish. This is the first evidence of the bioaccumulation of PCBs, DDTs and other chlorinated pesticides, PBDEs and NP in fish from the NPCG. NP is produced in large quantities in the US and Japan to manufacture detergents and as an antioxidant and stabilizer in many plastics. The authors attribute the fish contamination with NP, and possibly with other compounds, to plastic debris. In another study, PBDEs were found in short-tailed shearwaters in the north Pacific Ocean. The same compounds were detected in plastic found in the stomachs of the birds. These studies demonstrate that marine debris-derived chemicals are present in marine organisms.

(SOURCES: Gassel, M., Harwani, S., Park, J.-S., and Jahn, A. 2013. Detection of nonylphenyol and persistent organic pollutants in fish from the North Pacific Central Gyre. *Mar. Pollut. Bull.* 73: 231-242; Tanaka, K., Takada, H., Yamashita, R., Mizukawa, K., Fukuwaka, M, and Watanuki, Y. 2013. Accumulation of plastic-derived chemicals in tissues of seabirds ingesting marine plastics. *Mar. Pollut. Bull.* 69: 219-222)

Persistent organic pollutants in Indo-Pacific humpback dolphins

Of 11 persistent organic pollutants (POPs) examined in various tissues of stranded Indo-Pacific humpbacked dolphins in Hong Kong waters, ∑DDTs, ∑HCHs and mirex were generally higher than those found in cetaceans from other geographic regions. Unprecedented amounts of POPs have been released into this estuary over the last three decades. The levels of POPs in the testes of one male suggested an increasing risk of infertility. This species, classified as 'threatened' by the IUCN, consumes many of the same fish species as the local human population, making this investigation important for risk assessments and the protection of human health, as well as dolphin health.

(SOURCE: Gui, D., Yu, R., He, X., Tu, Q., and Wu, Y. 2014. Tissue distribution and fate of persistent organic pollutants in Indo-Pacific humpback dolphins from the Pearl River estuary, China. *Mar. Pollut. Bull.* 86: 266-273)

Toxic petroleum compounds concentrated in zooplankton in East China Sea

The most toxic petroleum hydrocarbon compounds are polycyclic aromatic hydrocarbons (PAHs). They have been classified as primary pollutants by the US EPA due to their carcinogenicity, toxicity and mutagenicity. The Changjiang (Yangtze) River transports thousands of tons of pollutants, including PAHs, into the East China Sea, a marginal sea of the Pacific Ocean. PAHs were highly concentrated in zooplankton along salinity fronts. This sea has high values of primary productivity and therefore supports many key fisheries stocks. The authors suggest that PAH-contaminated zooplankton may pose increased risk due to biomagnification in the marine food web. This underlines how compromising organisms at the base of the food chain can potentially affect top predators, including cetaceans.

(SOURCE: Hung, C.-C., Ko, F.-C., Gong, G.-C., Chen, K.-S., Wu, J.-M., Chiang, H.L., Peng, S.-C., and Santschi, P.H. 2014. Increased zooplankton PAH concentrations across hydrographic fronts in the East China Sea. *Mar. Pollut. Bull.* 83: 248-257)

PBDE levels in Taiwanese spotted dolphins

PBDEs are a type of contaminant found in flame retardants, plastics, circuit boards and other products. Pantropical spotted dolphins (n=8) stranded on the coast of Taiwan were analysed for PBDEs; levels ranged up to 0.443 $\mu g.g^{-1}$ lipid weight. Levels were correlated with body length and thus may bioaccumulate, with highest levels in blubber and males having significantly higher levels than females. The authors conclude that "PBDEs should be considered an increasing pollution problem in the Asia-Pacific region, which may be of great concern in the future".

(SOURCE: Ko, F. C., We, N.Y. and Chou, L.S. 2014. Bioaccumulation of persistent organic pollutants in stranded cetaceans from Taiwan coastal waters. *J. Hazard. Mat.* 277: 127-133)

High heavy metal levels in certain western Pacific Ocean cetaceans

A study on the feeding ecology of seven cetacean species in the western Pacific Ocean (based on stranded or bycaught individuals) revealed extremely high levels of arsenic (AS) and cadmium (CD) in the livers and kidneys two toothed whale species, Fraser's dolphins and Risso's dolphins. This threat is prey-derived, whereby Fraser's dolphins feed on hatchetfishes and Risso's dolphins on squid. The authors assume a health threat and call for investigating AS and CD levels in these prey organisms to better understand the food chain pathways of these heavy metals.

(SOURCE: Liu, J.-Y., Chou, L.-S., and Chen, M.-H. 2015. Investigation of the trophic level and niche partitioning of 7 cetacean species by stable isotopes, and cadmium and arsenic tissue concentrations in the western Pacific Ocean. *Mar. Pollut. Bull.* 93: 270-277)

High levels of contaminants in newly described dolphin species

The Burrunan dolphin is a newly described species from southeastern Australia. Contaminant levels were measured in live animals (collected via biopsies; n=20) and stranded animals (n=10). ΣPCB levels in stranded animals ranged from 258.80–8055 µg.g-1 wet weight. Mean mercury levels in the liver of stranded animals (n=6) were 420 µg.g-1 wet weight. Comparing mercury levels in the blubber of live and stranded animals showed stranded animals had mercury levels three times higher (mean 3.64, up to 7.4 µg.g-1 wet weight in blubber), although levels in live animals were also high (mean 1.32, up to 4.4 µg.g-1 wet weight in blubber). The region of Australia these animals inhabit has considerable industrial activity, including gold mining – a known source of mercury pollution. These high contaminant levels are a cause of concern for this new species.

(SOURCE: Monk, A., Charlton-Robb, K., Buddhadasa, S., and Thompson, R.M. 2014. Comparison of mercury contamination in live and dead dolphins from a newly described species, *Tursiops australis*. *PLoS ONE* 9: e104887)

High DDT content in seafood in East China Sea

The OCP contents were examined in 13 types of seafood in four Chinese counties bordering the East China Sea. This area is influenced by the Yangtze and Qiantang rivers; the Yangtze River estuary is the largest agricultural production base in China. Sixteen OCPs were detected, whereby the combined DDT content was the highest, making up 32-89% of the total OCP content. DDT has been banned in many parts of the world. This analysis showed that some of the DDT stems from historical usage, but that there are possible fresh inputs in two of the four areas investigated. DDT is also still used as an additive in antifouling paints for fishing ships, and three DDT-based antifouling paint manufacturers are located here. High contents in fish point to potentially high contents in other top predators such as cetaceans, of which 16 species have been recorded in the East China Sea.

(SOURCE: Wang, J., Yu, X., and Fang, L. 2014. Organochlorine pesticide content and distribution in coastal seafoods in Zhoushan, Zhejiang Province. *Mar. Pollut. Bull.* 80: 288-292)

Heavy metal pollution in coastal waters of South China

The authors review over 90 publications on heavy metal concentrations in South China. The levels were closely associated with the degree of local industrialization, with some areas being severely contaminated. The seafood safety limits were exceeded in several cases, such as for molluscs in Hong Kong or seafood from Lingdingyang (molluscs: 51-fold higher than the standard), as well as Guangxi and Hainan provinces. Due to bioaccumulation, this poses a risk to marine organisms higher up the food chain, such as cetaceans. Indeed, heavy metals (mercury) consumed in seafood are the only type of marine pollution that has definitively caused human mortalities (i.e. 'Minamata disease'). The authors call for more stringent environmental protection measures and better public awareness.

(SOURCE: Wang, S.-L., Xu, X.-R., Sun, Y.-X., Liu, J.-L., and Li, H.-B. 2014. Heavy metal pollution in coastal areas of South China: A review. *Mar. Pollut. Bull*. 76: 7-15)

Disease and mortality events

Disease

Toxoplasmosis identified as a factor in the decline of endangered Hector's dolphins and critically endangered Maui's dolphins

The death of 7 of 28 examined Hector's dolphins was attributed to an atypical strain of toxoplasmosis. This included 2 of 3 critically endangered Maui's dolphins, a subspecies of Hector's dolphin. This study provides first evidence that infectious disease could be important in the population decline and potential extinction of this endemic New Zealand species (see Currey *et al.* under 'Habitat degradation'). Toxoplasmosis can also impact behaviour and promote dolphin foetus mortality. Although it has typically been considered a secondary disease of immunosuppressed dolphins, the authors pointed to the possibility that this strain could be highly pathogenic and emphasised that this source of mortality is currently not being considered in threat management plans (focusing on fisheries bycatch) for this species. This underlines the difficulty in incorporating the cumulative effects of multiple concurrent threats to cetaceans.

(SOURCE: Roe, W.D., Howe, L., Baker, E.J., Burrows, L. Hunter, S.A. 2013. An atypical genotype of *Toxoplasma gondii* as a cause of mortality in Hector's dolphins (*Cephalorhynchus hectori*). *Veter. Parasit. 192*: 67-74)

Oil spills

Progress in improving information on and response to oil spills in the eastern Pacific

Risk zones for oil spill impacts were determined for the 23 coastal provinces of Thailand. Four zone categories (from low

to very high risk) were determined, in part based on seabird, sea turtle, dugong and cetacean populations. This analysis yielded risk maps that could help improve regulations related to shipping. In another effort, the IMO teamed up with IPIECA to launch a new global initiative program designed to improve oil spill preparedness and response capabilities in southeast Asia. This program was initiated to address "the increased level of oil spill risk due to higher levels of shipping traffic, and increased exploration and production activities across the region". A third study presented an improved prediction system for oil spills in the Yellow Sea, prompted by the *HV Hebei Spirit* accident in 2007, which resulted in the largest oil spill ever recorded in the Yellow Sea.

(SOURCES: Singkran, N. Classifying risk zones by the impacts of oil spills in the coastal waters of Thailand. *Mar. Pollut. Bull.* 70: 24-43; News. *Mar. Pollut. Bull.* 70: 3; Kim, C.-S., Cho, Y.-K., Choi, B.-JH., Jung, K.T., and You, S.H. 2013. Improving a prediction system for oil spills in the Yellow Sea: Effect of tides on subtidal flow. *Mar. Pollut. Bull.* 68:85-92)

Harmful algal blooms (HABs)

High stranding mortalities in Peru attributed largely to toxic algal blooms

In 2014, 1132 small cetaceans and 13 whales stranded in Peru, mostly between Lambayeque and Piura. The peak stranding events occurred in January and February (904 mortalities). The species most affected was the long-beaked common dolphin, but at least seven other species were recorded, including Bryde's whales and humpback whales. This report notes unusual oceanographic conditions and cites toxic algae along these coasts during those two months as the probable cause of these unusually high mortalities. It also mentions repeated closures of a bay due to biotoxins in scallop banks. Additionally, 22 animals showed fishing net marks and mutilated body parts for consumption or bait. Of the 13 baleen whales, four died due to entanglement and one due to ship strike. The report notes the severe deficiency in the control of artisanal and large vessels, as well as marine traffic especially during the migration season of humpback whales.

(SOURCE: IMARPE (Instituto del Mar del Peru). 2014. Cetacean unusual mortality event 2014. 7 pp)

Large increase in anthropogenic nitrogen in the North Pacific

Transport of nitrogen from the atmosphere to the open ocean has more than doubled globally over the past 100 years. The increase in nitrogen deposition has been particularly high in the north Pacific due to increasing human populations and industrial growth in Asia. The authors note that "The possible impacts of this anthropogenic perturbation on the open-ocean nitrogen cycle are numerous", including altering patterns of primary productivity, altering phytoplankton composition in the Pacific and "in the long term, the structure of the ecosystem". The authors warn that this increase in nitrogen levels in the ocean could "constitute another example of a global-scale alteration of the Earth system".

(SOURCE: Kim, I.N., Lee, K., Gruber, N., Karl, D.M., Bullister, J.L., Yang, S., and Kim, T.W. 2014. Increasing anthropogenic nitrogen in the North Pacific Ocean. *Science* 346: 1102-1106)

Toxic red tides on the increase in Chinese waters

Red tides typically involve blooms of specific planktonic organisms that discolour the water and emit toxic substances, often associated with fish kills. This long-term study revealed that 172 red tide events occurred around the Yangtze River Estuary between 1972 and 2009. The frequency of red tide outbreaks increased significantly after the year 2000, with often more than 10 events per year. Importantly, large outbreaks (exceeding 1000 km^2) became much more common after 2000. The authors report that these have caused great harm to offshore and coastal economies and to human health. Red tides are increasingly being associated with coastal pollution and affect the entire food chain, therefore also posing a threat to cetaceans.

(SOURCE: Liu, J.Z., Zheng, B., Cai, W., Kin, K., and Tang, J. 2013. Temporal and spatial distribution of red tide outbreaks in the Yangtze River Estuary and adjacent waters, China. *Mar. Pollut. Bull.* 73: 213-221)

Noise impacts

Dolphin mother-calf pairs are more sensitive to tourism

The effects of tour boats and a research boat on the group structure and vocal behaviour of bottlenose dolphins were quantified in Doubtful Sound, New Zealand. Groups with mother-calf pairs were significantly less cohesive and coordinated when tour boats were audible. They were more vocal when boats were close and while moving away, presumably to re-establish group structure. Furthermore, groups with calves increased their whistle rates when tour boats were travelling faster, while groups without calves became quieter. Dolphins also responded to boat noise with alterations in whistle frequency and duration. These findings indicate that boat noise affects communication, and groups with calves are particularly sensitive to boat presence and noise. Group structure and whistle parameters were also affected by the

research boat, highlighting the importance of accounting for observer effects in studies of tourism impacts. The particular sensitivity of groups with calves to boats has important implications for the management of impacts on this population due to its endangered status and history of low calf survival.

(SOURCE: Guerra, M.G., Dawson, S.M., Brough, T.E. and Rayment, W.J. 2014. Effects of boats on the surface and acoustic behaviour of an endangered population of bottlenose dolphins. *Endang. Spec. Res.* 24: 221-236)

Atypical mass stranding of beaked whales coincident with naval exercise off Guam

On 23 March 2015, three beaked whales stranded simultaneously but in different locations along the southern coast of Guam. It was confirmed that a joint US-Japanese naval exercise incorporating sonar use and anti-submarine activities, involving eight ships, was being conducted in nearby waters during 23-27 March.

(SOURCE: *http://www.kuam.com/story/28628542/2015/03/27/sonar-was-being-tested-when-whales-were-beached*)

Population of bottlenose dolphins in New Zealand is in decline

Concern has been raised about disturbance by boat traffic (tourism-related and otherwise) on the small population of bottlenose dolphins in the Bay of Islands, New Zealand. There was a 7.5% annual decline in the population between 1997 and 2006, probably due to emigration/displacement or mortality. The calving rate increased between 1997–1999 and 2003–2005, from 0.13 to 0.25 (i.e. one calf every four years), but this is still lower than for other studied populations. Calf mortality rates were higher than rates reported elsewhere. A combination of population decline, high calf mortality rates and low recruitment gives a poor prognosis for this population's viability. Chronic disturbance may be having a population-level effect. The authors conclude that "management should focus on minimizing sources of anthropogenic disturbance [i.e. boat traffic] and enforcing compliance with current legislation".

(SOURCE: Tezanos-Pinto, G., Constantine, R., Mourão, F., Berghan, J. and Baker, C.S. 2015. High calf mortality in bottlenose dolphins in the Bay of Islands, New Zealand – a local unit in decline. *Mar. Mamm. Sci.* 31: 540-559)

POLAR OCEANS (2016)

General

Rapid retreat of East Antarctic glacier a cause for concern

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

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

Marine mammals and cod as competitors in the Barents Sea

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

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

Bowhead whale body condition improves in the Pacific Arctic

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

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

Cetacean body condition in the Beaufort Sea is changing

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

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

First global integrated marine assessment: Arctic Ocean

This major overview of the world's oceans states that "changes in ice cover, ocean warming, altered salt stratification, alterations in water circulation and fronts, and shifts in advection patterns show that oceans within the Arctic are subjected to significant change, and may face even more change in future". The Arctic, for example, has warmed at more than twice the global rate, and sea-ice loss is accelerating. This negatively affects the location and timing of the algal blooms that form the base of the food chain. Arctic warming and sea-ice loss will facilitate the invasion of new species, hosts, harmful microorganisms and diseases. The retreating ice will also promote the introduction of shipping, fishing, petroleum activities and tourism, with their related threats. Arctic marine ecosystems are also "highly likely to undergo significant changes" due to ocean acidification. For marine mammals, these combined developments increase the risks of direct mortality, displacement from critical habitats, noise disturbance, and increased exposure to hunting. The authors pointed to the need for "adaptive and ecosystem-based management efforts to limit negative effects of existing and potential human use".

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

First global integrated marine assessment: Southern Ocean

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

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

Antarctic waters under threat of increased use and less protection

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

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

Status of Arctic marine mammal populations and conservation recommendations

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

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

Synthesis of research in the Pacific Arctic

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

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

Habitat degradation

Arctic shipping in a changing environment

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

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

Chemical pollution

Skin of subantarctic dolphins useful in biomonitoring mercury

The skin of nine by-caught Commerson's dolphins recovered from the shores of Tierra del Fuego showed that the mercury content in skin biopsies serve as good indicators of levels in internal organs (e.g. liver). Mercury is of particular concern because it is harmful to wildlife and humans at very low concentrations and bioaccumulates, with highest values in top predators (such as dolphins). Mercury values ranged from 1.3-45 μg g^{-1}, which is considerably lower than the 10-5000 μg g^{-1} in Mediterranean odontocetes and is among the lowest values for other dolphins from the South Atlantic Ocean. This type of mercury bioindication "is a non-lethal approach that allows screening of a large number of specimens". The authors considered this to be valuable in subantarctic waters, which are poorly studied regarding mercury levels, sources and processes.

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

PFASs found in Greenland killer whales

PFASs were measured in killer whales from East Greenland (2012-2013). A total of 17 PFASs were detected, including in a mother and calf, which suggests that PFASs can cross the placenta into a foetus. The mean level of total PFASs was 269 $ng.g^{-1}$ (± 90 SE). The ratio of contaminants suggested that killer whales lack the metabolic ability to degrade some of these toxic compounds, compared to other marine mammal species. The effects of these levels of contaminants on cetacean health are unknown, but this study documents a broad suite of this type of contaminant in Arctic cetaceans.

(SOURCE: Gebbink, W.A., Bossi, R., Rigét, F.F., Rosing-Asvid, A., Sonne, C. and Dietz, R. 2016. Observation of emerging per- and polyfluoroalkylsubstances (PFASs) in Greenland marine mammals. *Chemosphere* 144: 2384-2391)

(Relatively low) concentrations of pesticides in Arctic gray whales reflect global pesticide background

HCH and DDT are not present naturally in any ecosystem – any amount detected has anthropogenic origins. Compared to other regions, western Bering Sea gray whales had higher HCH values than DDT. This is probably due to a more active use of lindane and technical HCH in agriculture in the Russian Far East. Overall, concentrations of organochlorine pesticides in the tissues of western Bering Sea gray whales are relatively low compared to cetaceans from other regions, consistent with the area having little industry. Toxic substances found in the Arctic mostly originate further south. The authors concluded that detection of organochlorine contaminants in the Arctic reflects their widespread and global footprint.

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

Wastewater produced by offshore oil and gas production identified as a problem in the Arctic

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

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

Disease and mortality events

Toxic algae in Arctic marine mammals

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

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

Climate change

Invading predators predicted to radically restructure Antarctic Peninsula ecosystem

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

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

Historical records show that humpback whale condition was linked to sea ice extent

The effect of krill abundance and whale body condition was assessed by examining historical records of humpback whale oil yields (1947-1963) and annual estimates of sea ice extent, which was used to estimate krill abundance in humpback whale foraging grounds. Whale oil yield, and hence body condition, was significantly correlated with winter sea ice extent, i.e. levels of krill. The authors concluded that if sea "ice extent declines in the future, as predicted under some climate change scenarios, whale food will decline and, in turn, energy acquisition will be hindered" and that "changes in sea ice and concomitant changes in krill abundance have long-term implications for [whale] condition and reproductive success". Moreover, they suggested that malnourished whales encountered recently off the Australian coast might be the result of recent low Antarctic sea ice coverage.

(SOURCE: Braithwaite, J., Meeuwig, J.J., Letessier, T.B., Jenner, K.C.S., and Brierley, A.S. 2015. From sea ice to blubber: Linking whale condition to krill abundance using historical whaling records. *Polar Biol.* 38: 1195-1202)

Sea level rise could be twice that previously estimated due to increased Antarctic ice melting

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

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

Chemical analysis of baleen provides insights into whale migrations, sea ice and Arctic climate

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

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

Sea level rise of 3m from the melting of the West Antarctic ice sheet may be inevitable

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

level rise caused by Antarctic ice loss. This significant sea level rise will, of course, have major impacts on global coastal and Antarctic ecosystems.

(SOURCES: Feldmann, J. and Levermann, A. 2015. Collapse of the West Antarctic Ice Sheet after local destabilization of the Amundsen Basin. *Proc. Nat. Acad. Sci.* 112: 14191-14196; Fudge, T.J., Markle, B.R., Cuffey, K., Buizert, C., Taylor, K., Steig, E.J., Waddington, E., Conway, H., and Koutnik, M. 2016. Variable relationship between accumulation and temperature in West Antarctica for the past 31,000 years. *Geophys. Res. Ltrs.* 43: 3795-3803)

Anomalous areas of high productivity in the Arctic

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

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

Melting ice and stratification of the oceans could lead to greater climate change impacts than previously predicted

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

(SOURCE: Hansen, J., Sato, M., Hearty, P., Ruedy, R., Kelley, M., Masson-Delmotte, V., Russell, G., Tselioudis, G., Cao, J., Rignot, E., Velicogna, I., Tormey, B., Donovan, B., Kandiano, E., von Schuckmann, K., Kharecha, P., Legrande, A. N., Bauer, M., and Lo, K.-W. 2006. Ice melt, sea level rise and superstorms: Evidence from paleoclimate data, climate modeling, and modern observations that 2 °C global warming could be dangerous. *Atmos. Chem. Phys*. 16: 3761-3812)

Low Arctic ice coverage and record air temperatures in 2015

The average annual sea ice extent in the Arctic during 2015 was 4.25 million square miles, the sixth smallest annual value since 1979. December sea ice coverage was the fourth lowest since 1979, at 300,000 square miles. This is 6% below the 1981–2010 Arctic sea ice average. Maximum Arctic sea ice extent (on 25 February 2015) occurred 15 days earlier than average and it was the lowest maximum value since 1979. In Alaska, 2015 tied with 2002 as the warmest years since record-keeping began in 1929. The average air temperature over Arctic land areas (October 2014-September 2015) was 1.3°C above average – the highest since records began in 1900. More broadly, air temperatures over the Arctic were 3°C higher than at the beginning of the 20th century. Finally, there was melting on more than 50% of the surface of the Greenland ice sheet, with an observed increase in ice velocity and decrease in total mass of Greenland glaciers emptying into the sea.

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

Shifts in whale populations in the Norwegian Sea point to high ecological plasticity

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

high ecological plasticity, i.e. relatively rapid responses of cetaceans to changing prey densities and distributions and to elevated sea-surface temperatures.

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

Icelandic waters: Changes in environmental conditions, changes in baleen whales

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

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

Noise impacts

Specific levels of seismic survey noise cause bowhead whales to stop calling

Bowhead whales decrease their calling rates when exposed to seismic survey sounds, but there has been little information on the exact level needed to cause this reaction. A study in the Alaskan Beaufort Sea found that initially, when seismic sounds were detected, bowhead calling rates increased, but the rate levelled off at a cumulative (over 10 minutes) received sound exposure level of approximately 94 dB re 1 $\mu Pa^2/s$. Bowhead calls started to decrease when the cumulative sound exposure level exceeded 127 dB re 1 $\mu Pa^2/s$ and calls ceased entirely above 160 dB re 1 $\mu Pa^2/s$. These results give clear guidance on the level of seismic survey sound that can cause impacts on biologically important behaviours for these Arctic whales.

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

Large ice entrapments of narwhals coincide with seismic surveys in the Arctic

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

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

Noise from a drillship sheds light on a new threat to Arctic marine mammals

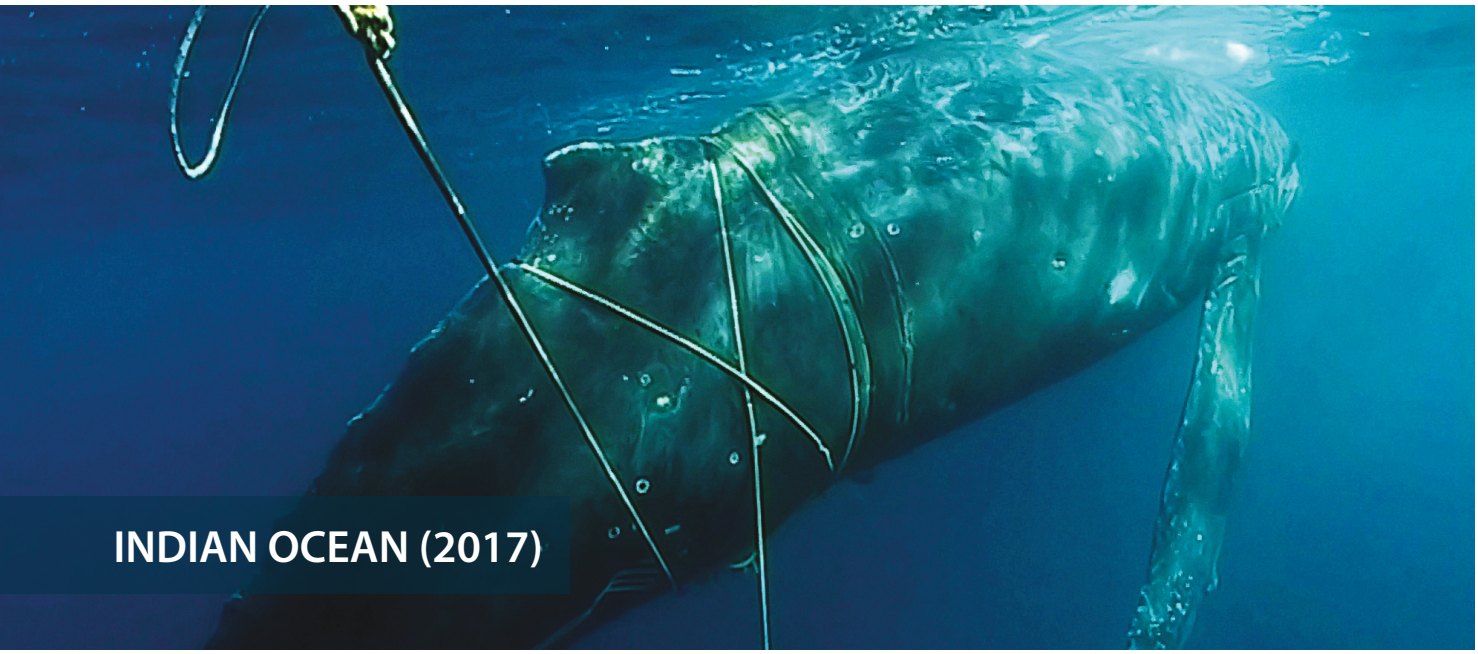
Underwater noise in polar regions is of particular concern because the hydrographic conditions promote long-distance transmission of sound and the relatively pristine environment has little anthropogenic noise. Importantly, marine mammal densities are also high here. Marine mammals critically depend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

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

Prolonged exposure to sound reduces beluga whale auditory responses

An experimental study on a beluga whale found that prolonged exposure to a series of short and longer (1500 seconds) sounds led to a reduced auditory response in animals over time, although a response never entirely disappeared. The authors postulated that "If prolonged sounds (in particular, man-made noises) produce adaptation to higher sound levels, the perception of 'target' sounds of lower levels may be negatively affected". In other words, exposure to louder continuous sounds may result in cetaceans not responding to quieter sources of biologically important sounds. The authors also suggested that prolonged sound exposure may cause "a reduction or extinction of defensive and aversive behavioral reactions due to habituation", which could be dangerous for animals in cases where aversive behaviour might prevent, for example, a collision with a boat.

(SOURCE: Popov, V.V., Sysueva, E.V., Nechaev, D.I., Rozhnov,V.V., and Supin, A.Y. 2016. Auditory evoked potentials in the auditory system of a beluga whale *Delphinapterus leucas* to prolonged sound stimuli. *J. Acoust. Soc. Am.* 139(3): 1101-1109)



INDIAN OCEAN (2017)

General

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

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

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

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

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

(SOURCES: Devlin, M.J., Le Quesne, W.L.F., and Lyons, B.P. 2015. Editorial: The marine environment of Kuwait—emerging issues in a rapidly changing environment. *Mar. Pollut. Bull.* 100: 593-596; Sheppard, C. 2015. Coral reefs in the Gulf are mostly dead now, but can we do anything about it? *Mar. Pollut. Bull.* 105: 593-598, *http://dx.doi.org/10.1016/J.marpolbul.2015.09.031*)

Pan-Indian Ocean cooperation sought on sustainable whale watching

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

tools to develop an industry that promotes economic growth and benefits the marine environment.

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

First global integrated marine assessment: Indian Ocean

This major overview of the world's oceans by the United Nations found that the Indian Ocean region contains 31 species of marine mammals. The authors point to numerous threats, such as bycatch (in gillnets, seine nets, beach seines and drift nets), habitat degradation and loss, and pollution, including marine debris. The report tends to underline a lack of information. Accordingly, it identifies five research gaps related to marine mammals: 1) the need to train and equip local scientists; 2) coordinated long-term monitoring; and 3) genetic studies. The final two gaps pertain specifically to whales: 4) analyses of the biology and ecology of whales and 5) impacts of fishing on whales.

(SOURCE: Inniss, L. and Simcock, A. (Joint coordinators); Rice, J. (Lead member of 12 contributors). 2016. The first global integrated marine assessment: World ocean assessment I. *United Nations, Chapter 36E:* 28 pp, *www.un.org/Depts/los/woa*)

Important ongoing work on threats to cetaceans in the Arabian Sea

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

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

Ocean Health Index rates Indian Ocean

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

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

Habitat degradation

General

Ganges River dolphins potentially threatened by waterway plans in india

South Asian or Ganges River dolphins face an additional, serious threat (beyond bycatch and altered and declining river flows) involving a plan under the National Waterways Act, 2016, to convert 111 river reaches into waterways for inland navigation and goods transport. Moreover, the Indus subspecies in Pakistan is also under potential threat from a recently proposed commercial waterway on the Indus River. The IWC's Scientific Committee expressed serious concern at SC66b for the survival of river dolphins in India given this new information. It agreed that the situation facing South Asian river dolphins is a matter of grave concern and requires immediate attention. Accordingly, the Ganges and other river dolphins will be considered as a potential priority topic at a future meeting.

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

Endangered Ganges River dolphin in India: Multiple threats

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

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

Endangered Ganges River dolphin in Nepal: Multiple threats

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

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

Fisheries interactions

Cetacean bycatch in tuna fisheries in western and central Indian Ocean

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

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

Suggestions to reduce dolphin entanglement in shark nets

Gillnets are used on South African beaches to protect human bathers from sharks, but also take a substantive toll on cetaceans through bycatch. Researchers investigated factors that might affect bycatch of Indian Ocean humpback dolphins in Richards Bay, South Africa. Using photo-identification, they found dolphins have a low level of residency but long-term site fidelity, with dolphins paying short, but repeated, visits to the bay, before moving on. The researchers suggested that Richards Bay is important habitat for the dolphins. However, at least 8% of catalogued individuals were found in shark nets, while most bycaught dolphins in Richards Bay were uncatalogued adolescents. There was a notably higher proportion of entangled males than females. Results indicated lower familiarity with nets did not increase bycatch rates. The researchers

suggested bycatch might be reduced by removing nets/closing beaches to swimmers in the winter, reducing the number of nets, adding pingers to the nets, or introducing bait and hooks to catch sharks in the bay. Non-lethal suggestions to reduce shark presence included chemical or electrical deterrents and/or observers who can warn bathers about shark presence. The authors concluded that "bycatch of Indian Ocean humpback dolphins in shark nets at Richards Bay may be negatively affecting the wider population, and continued efforts to mitigate the loss are vital".

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

Bycatch in the tuna gillnet fisheries of Pakistan

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

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

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

A survey in the Bay of Bengal, Bangladesh, revealed that 28% of photo-identified Indo-Pacific bottlenose and 15% of Indo-Pacific humpback dolphins exhibited injuries related to entanglements with fishing gear. The authors state that this "implies a strong potential for fatal interactions that could jeopardize the conservation status of both dolphin populations which otherwise appear favorable". Ninety gillnetting trips between 2013 and 2015, in the framework of an initiative to protect small coastal cetaceans and to improve safety at sea, documented one fatal entanglement of a humpback dolphin and two fatal entanglements of Indo-Pacific bottlenose dolphins. A new MPA (Swatch of No-Ground: SoNG), covering 1,738 km^2 and ranging from a submarine canyon to coastal waters offshore of the Sundabarans mangrove forest, was signed into law in 2014. It provides priority habitats for these two species, as well as other cetaceans at conservation risk, and was designed more generally "to safeguard dolphins, whales, sea turtles, sharks, and other oceanic species".

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

Marine debris

Marine debris on remote Indian Ocean islands

A 1-km stretch of beach on remote Alphonse Island in the western Indian Ocean yielded 4763 items weighing 142 kg. Most of the items had land origins thousands of kilometres away. Surface current models pointed to South East Asia, Somalia, India/Sri Lanka and potentially Madagascar as sources. The authors identified inadequate waste management as the cause. A second study found a daily mean abundance of 35 plastic particles per m^2 on a small coral island used only for research and environmental education. Although the values were generally lower than on highly contaminated beaches in Mumbai (10-180 particles/m^2), the abundance on such a remote island "is a worrying sign for the global distribution of plastic debris". The values would probably have been much higher if particles < 1 mm had been considered. The authors believe the sources could be nearby inhabited islands, tourist islands within the atoll, or debris blown into the sea from 'garbage islands' used for landfilling.

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

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

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

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

Plastic debris in the Persian Gulf

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

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

Ship strikes

Blue whale ship strikes off Sri Lanka: An avertable problem

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

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

Chemical pollution

Heavy metal contamination in northern part of Persian Gulf

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

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

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

There are four humpback whale stocks breeding in the Indian Ocean and feeding in Antarctic waters. In one of these (Réunion Island; C/C4), HCB and DDTs predominated amongst the seven POPs in the whales, with DDE being the major

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

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

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

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

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

Pesticide release continues to be an issue in the Indian Ocean

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

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

Disease and mortality events

General

Update on recent whale strandings along the west coast of India

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

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

Harmful algal blooms (HABs)

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

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

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

Rethinking aquaculture in the Indian Ocean

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

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

Oil spills

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

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

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

MEDITERRANEAN and BLACK SEAS (2018)

General

The European Marine Strategy Framework Directive and cetacean conservation

The European Marine Strategy Framework Directive seeks to implement a precautionary and holistic ecosystem-based approach for managing European marine waters. A questionnaire survey was distributed to nations bordering the Mediterranean and Black Seas to investigate implementation of the Framework, specifically with respect to cetaceans. Those reporting (50% return rate) noted that their national implementation of the Framework did refer to cetaceans, but the specifics of these various implementations were heterogeneous. This unevenness in implementation may hinder transboundary collaboration and, therefore, cetacean conservation. ACCOBAMS could help stimulate collaboration amongst scientists involved in cetacean monitoring and develop transboundary conservation initiatives. The authors note that "Transboundary conservation is most cost-efficient when there is true coordination between countries", which is currently lacking. The authors also suggest that "Marine mammal experts should promote to their respective governments the monitoring of cetaceans at regional, rather than national scales".

(SOURCE: Authier, M., Descroix Commanducci, M.F., Genov, T., Holcer, D., Ridoux, V., Salivas, M., Santos, M.B., and Spitz, J. 2017. Cetacean conservation in the Mediterranean and Black Seas: Fostering transboundary collaboration through the European Marine Strategy Framework Directive. *Mar. Pol.* 82: 98-103)

New conservation action plan for cetaceans in Israeli waters

Israel has 180 km of coast on the Mediterranean Sea and has legal influence over 26,000 km^2 of ocean surface area, with 12 species of cetaceans recorded from this area. An Action Plan for 2017-2022 seeks to "ensure that marine mammal populations in the waters of Israel enjoy a 'favourable conservation status'… arising from a combination of legislative, management, research, education and awareness initiatives". The plan notes bycatch, underwater noise and prey depletion as the highest priority threats to Israeli cetaceans. Chemical pollution, climate change and habitat degradation are possible major threats, and marine debris, directed takes, ship strikes, oil pollution and disturbance are possible minor threats. The plan outlines numerous legislative, institutional and research initiatives, as well as proposals for local capacity building, cetacean conservation and public outreach.

(SOURCE: Bearzi G. 2017. *Action Plan for Marine Mammals in Israel*, 2017–2022. Israel Marine Mammal Research and Assistance Center (IMMRAC), Michmoret, Israel)

The recent decline of the Black Sea harbour porpoise: A historical context

An analysis of archaeological specimens of cetaceans from the Black Sea (from 800 to 1600 years ago) suggests that cetaceans were subjected to fisheries bycatch, as well as directed hunting, in the past. Therefore, there has been a long history of anthropogenic takes of cetaceans in the Black Sea, from the late Classical through the medieval era. Genetic analyses of harbour porpoise specimens suggest that, despite these removals, there was an expansion of porpoise

numbers in the Black Sea, followed by a dramatic decline over the past century. This decline illustrates that recent anthropogenic removals of porpoises greatly exceed the historical impact of fisheries bycatch and directed takes.

(SOURCE: Biard, V., Gol'din, P., Gladilina, E., Vishnyakova, K., McGrath, K., Vieira, F.G., Wales N., Fontaine, M. C., Speller, C., and Olsen, M.T. 2017. Genomic and proteomic identification of Late Holocene remains: Setting baselines for Black Sea odontocetes. *J. Archaeol. Sci.: Rep.* 15: 262-271)

A distinct harbour porpoise population in the Azov Sea

The Azov Sea is a small enclosed body of water (37,000 km^2) that connects to the Black Sea via the narrow Kerch Strait. The sea is seasonally occupied by harbour porpoises. Analyses of porpoise skulls showed that the Azov and Black Sea porpoises are distinct from North Atlantic skulls, i.e. supporting their status as part of the subspecies *Phocoena phocoena relicta*. However, the skulls of Azov Sea porpoises were distinct from Black Sea porpoises, suggesting that the Azov Sea porpoise is a genetically distinct population, which would warrant special conservation consideration.

(SOURCES: Gol'din, P. and Vishnyakova, K. 2016. Habitat shapes skull profile of small cetaceans: Evidence from geographical variation in Black Sea harbour porpoises (*Phocoena phocoena relicta*). *Zoomorphology* 135(3): 387-393; Gol'din, P.E. and Vishnyakova, K.A. 2015. Differences in skull size of harbour porpoises, *Phocoena phocoena* (Cetacea), in the Sea of Azov and the Black Sea: Evidence for different morphotypes and populations. *Vestn. Zool.* 49(2): 171-180)

First global integrated marine assessment: Mediterranean Sea

A major UN overview of the world's oceans noted that the Mediterranean Sea is a marine biodiversity hotspot (ca. 17,000 species). This includes nine species of marine mammals (five of the family Delphinidae and one each of Ziphiidae, Physeteridae, Balaenopteridae and Phocidae). Its habitats and ecosystem types are also diverse. At present, habitat loss and degradation, followed by fishing, climate change, pollution, eutrophication and the establishment of invasive species are the major threats to most of the taxonomic groups and habitats. These threats are all expected to increase in the future, especially climate change and habitat degradation.

(SOURCE: Inniss, L. and Simcock, A. (Joint coordinators); Rice, J. (Lead member of 14 contributors). 2016. The first global integrated marine assessment: World ocean assessment I. *United Nations, Chapter 36A:* p. 18-20, *http://www.un.org/Depts/los/global_reporting/WOA_RPROC/Chapter_36A.pdf*)

Survey gaps for cetaceans in the eastern and southern Mediterranean

An analysis of cetacean surveys found there were serious gaps in survey coverage in the eastern and southern Mediterranean Sea. This means that there is a gap in our understanding of cetacean distribution, abundance and environmental factors in these regions of the Mediterranean.

(SOURCE: Mannocci, L., Roberts, J.J., Halpin, P.N., Authier, M., Boisseau, O., Bradai, M.N., Cañadas, A., Chicote, C., David, L., Di-Méglio, N., Fortuna, C.M., Frantzis, A., Gazo, M., Genov, T., Hammond, P.S., Holcer, D., Kaschner, K., Kerem, D., Lauriano, G., Lewis, T., Notarbartolo di Sciara, G., Panigada, S., Raga, J.A., Scheinin, A., Ridoux, V., Vella, A., and Vella, J. 2018. Assessing cetacean surveys throughout the Mediterranean Sea: A gap analysis in environmental space. *Sci. Rep.-UK* 8: 3126, 1-14. doi:10.1038/s41598-018-19842-9)

Marine issues in the Mediterranean Sea

This book on Mediterranean marine mammals is a valuable contribution to conservation efforts, presenting the latest information on cetaceans and their habits, as well as attempting to bridge the gap between scientific insights and policy. The Mediterranean Sea is a hotspot of marine and coastal diversity. Although no cetacean species is endemic here, unique populations have formed, requiring special conservation consideration. Of the 12 common marine mammal species, six are considered Mediterranean 'subpopulations' and are listed as Threatened on the IUCN's Red List. Many decision-makers are apparently unaware of "how serious the predicament is for these species and their fragile habitat". The first chapter outlines the Mediterranean regions and the overall status and threats of their marine mammals. The remaining chapters are devoted to key species such as sperm, fin and Cuvier's beaked whale, killer whales, long-finned pilot whales, and Risso's, rough-toothed and bottlenose dolphins, as well as to selected regions. The overall threats are identified as naval sonar, seismic exploration, whale watching disturbance, ship strikes, epizootics, fisheries, pollution, coastal development and climate change. The final chapter discusses international legal conservation frameworks, regional agreements (e.g. ACCOBAMS) and specific treaties (e.g. Pelagos Sanctuary). The authors conclude by underlining that "what is probably lacking are specific provisions having a legally binding nature that directly address a number of threats affecting Mediterranean marine mammals, such as underwater noise, collisions with ships, bycatch in fishing gear and ingestion of plastic litter".

(SOURCE: Notarbartolo di Sciara, G., Podestà, M., and Curry, B.E. (eds). 2016. *Advances in Marine Biology Vol. 75: Mediterranean Marine Mammal Ecology and Conservation.* Elsevier, London. 428 pp.)

Ocean Health Index and the Mediterranean Sea

The Ocean Health Index, compiled by the University of California at Santa Barbara, has released its third annual update. It is based on 10 ecological, economical and societal categories or 'goals', each of which is measured and scored based on four dimensions (status, trend, pressures and resilience). By country, the values diverge considerably around the Mediterranean, from a low ranking for Libya (ranking 220 out of 220, index score 44 out of 100) to a high for Malta (rank 19, score 79). For comparison, the overall health of the oceans globally is 70 out of 100 points. Six of the nine Mediterranean countries evaluated lie below this global average (although some only marginally so).

(SOURCE: *http://www.oceanhealthindex.org*)

Marine protected areas in the Mediterranean Sea

CBD Aichi Target 11 seeks to protect at least 10% of important marine and coastal habitats, with MPAs being the main global strategy for the conservation of marine biodiversity. The Mediterranean Sea contains variously designated protected areas: Natura 2000 sites, national sites, Ramsar sites, Specially Protected Areas of Mediterranean Importance, the Pelagos Sanctuary and Biosphere Reserves. Mediterranean MPAs are very unevenly distributed, with 80% concentrated in just three countries in the northwest part of the basin. This geographic distribution can be improved, although size, spacing and shape of existing MPAs are favourable: one third, for example, are bigger than the average ecological threshold of 20 km^2. However, these reasonably good MPA designs are apparently 'accidental', i.e. the result of largely independent national and regional nature conservation processes. Efforts to consolidate an ecologically coherent network of Mediterranean MPAs are clearly required.

(SOURCE: Rodríguez-Rodríguez, D., Rodríguez, J., Blanco, J.M., and Malak, D.A. 2016. Marine protected area design patterns in the Mediterranean Sea: Implications for conservation. *Mar. Pollut. Bull*. 110:335-342, *https://doi.org/10.1016/j.marpolbul.2016.06.044*)

Habitat degradation

General

Cetacean abundance and ecosystem trends in the northwest Mediterranean

Trends in cetacean abundance were investigated via sighting data from ship-board surveys (1990-2014) covering an area of approximately 29,000 km^2 in the northwest Mediterranean, and via strandings data collected from the Ligurian coast (1986-2014). The analysis revealed a significant annual increasing trend in sightings of striped dolphins and sperm whales but a significant decrease in encounters with fin whales and Risso's dolphins. No trends were found for Cuvier's beaked whales. Striped and Risso's dolphin strandings decreased over time, but fin whale strandings increased. The decrease in striped dolphin strandings was influenced by a spike in mortality from a morbillivirus outbreak early in the period. Examining strandings both spatially and temporally, fin whales and striped dolphins appeared to be shifting northwards into more coastal waters, while Risso's dolphins shifted into more oceanic waters. No trends were found for sperm or Cuvier's beaked whales. Risso's dolphin and sperm whale encounter rates appeared to be associated with sea surface temperature and surface water chlorophyll levels. Striped dolphin and fin whale encounter rates were correlated, respectively, to the number of fishing boats (negatively) and number of ferries (positively), the former suggesting a conflict between cetaceans and fishing vessels. Moreover, sperm whale group size was inversely correlated to the number of boats. The relative abundance of striped and Risso's dolphins and sperm and fin whales might be correlated with the concurrent decreasing productivity in the region (as measured by decreasing chlorophyll and fishery productivity).

(SOURCE: Azzellino, A., Airoldi, S., Lanfredi, C., Podestà, M., and Zanardelli, M. 2017. Cetacean response to environmental and anthropogenic drivers of change: Results of a 25-year distribution study in the northwestern Mediterranean Sea. *Deep Sea Res. Pt. II: Topic. Stud. Oceanogr.* 141: 104-117)

Narrow ecological niche of Mediterranean fin whales makes them vulnerable to anthropogenic change

An isotopic analysis was conducted to investigate the diet and ecological niche of fin whales in the Mediterranean Sea and North Atlantic. The analysis showed that Mediterranean fin whales, which are known to feed mainly on krill, had a much narrower dietary niche than the Atlantic whales, which have a more diverse diet. The authors suggest that a narrow ecological niche makes Mediterranean fin whales "more susceptible to ecosystem fragmentation and other anthropogenic impacts".

(SOURCE: Das, K., Holleville, O., Ryan, C., Berrow, S., Gilles, A., Ody, D., and Michel, L.N. 2017. Isotopic niches of fin whales from the Mediterranean Sea and the Celtic Sea (North Atlantic). *Mar. Environ. Res.* 127: 75-83)

Fisheries interactions

Sicilian fishing capacity decrease is correlated with dolphin strandings decrease

This analysis compared strandings of bottlenose and striped dolphins in Sicily with values of engine power, based on fishing vessels registered in 48 Sicilian ports, from 1995 through 2012. Fishing capacity decreased during this period, as did strandings; this correlation was statistically significant. Strandings tended to be clustered near ports with high fishing capacity. Bottlenose dolphin strandings were more frequent where bottom otter trawls were more frequently used. Therefore, while fishing capacity can be an indicator of the level of threat to cetaceans, it can also predict decreases in dolphin mortality.

(SOURCE: Crosti, R., Arcangeli, A., Romeo, T., and Andaloro, F. 2017. Assessing the relationship between cetacean strandings (*Tursiops truncatus* and *Stenella coeruleoalba*) and fishery pressure indicators in Sicily (Mediterranean Sea) within the framework of the EU Habitats Directive. *Eur. J. Wildlife Res.* 63: 55-68, *https://doi.org/10.1007/s10344-017-1111-8*)

Seasonal closure of gillnet fisheries in the Azov Sea might reduce bycatch levels

Stranding and bycatch data for harbour porpoises from 1999 to 2013 in the Azov Sea showed a peak in strandings in July and August, a period when females are lactating and very young animals are newly foraging independently. The stranding peak did not coincide with the regional peak of the turbot, shad and sturgeon fisheries, which is in the spring. Bycatch reduction could therefore be achieved by closing coastal gillnet fisheries in the peak stranding period. Because this is not peak fishing season, such time-area closures would minimise the economic impact on local fisheries.

(SOURCE: Vishnyakova, K. and Gol'din, P. 2015. Seasonality of strandings and bycatch of harbour porpoises in the Sea of Azov: The effects of fisheries, weather conditions and life history. *ICES J. Mar. Sci.* 72(3): 981-991)

Marine debris

Coastal macro-litter in the Turkish Mediterranean Sea

Thirteen beaches along the northeast Mediterranean shores of Turkey yielded an average density of 0.9 litter items/m^2. Eight of these beaches were classified either as 'dirty' or 'extremely dirty'. Litter from convenience food consumption and smoking made up more than half of the litter collected. Agricultural, industrial and fisheries-related items contributed only 6%. Plastic items made up over 89%. Less than 4% had been transported from neighbouring countries. The researchers identified direct deposition as the main source of this litter and underlined poor local awareness and the need for educational programs to help reduce coastal litter.

(SOURCE: Aydin, C., Güven, O., Salihoglu, B., and Kideys, A.E. 2016. The influence of land use on coastal litter: An approach to identify abundance and sources in the coastal area of Cilician Basin, Turkey. *Turk. J. Fish. Aquat. Sci.* 16: 29-39. doi: 10.4194/1303-2712-v16_1_04)

Microplastics found in prey fish of cetaceans

Three commercially relevant demersal fish species—the lesser spotted dogfish, European hake and red mullet—are currently used as biomonitors for marine pollution in Spain. The stomachs of 212 specimens revealed that about 18% contained microplastics. Red mullet had the highest abundance (33%) in the Mediterranean (Barcelona). Most of the documented material was fibres, with potential sources being hygiene and cosmetic products, textiles and industrial fishing gear (especially neutrally or negatively buoyant nylon). Laboratory studies have shown that microplastics may have the ability to enter and propagate through the marine food web. Hake and mullet are prey of Mediterranean cetaceans, pointing to a potential direct transfer of marine debris to dolphins and porpoises.

(SOURCE: Bellas, J., Martínez-Armental, J., Martínez-Cámara, A., Besada, V., and Martínez-Gomez, C. 2016. Ingestion of microplastics by demersal fish from Spanish Atlantic and Mediterranean coasts. *Mar. Pollut. Bull.* 109: 55-60, *https://doi.org/10.1016/j.marpolbul.2016.06.026*)

Plastic in the Mediterranean Sea

The Mediterranean Sea is heavily affected by marine debris. The average density of plastic (1 item/4 m^2) and its frequency (100% of all sites sampled) are comparable to the accumulation zones described for the five subtropical gyres (e.g. Great Pacific Garbage Patch), and the proportion of large objects is even higher than in those gyres. The authors attribute this to high human pressure and the semi-enclosed geography of the Mediterranean.

(SOURCE: Cózar, A., Sanz-Martin, M., Marti, E., Gonzalez-Gordillo, J.I., Ubeda, B., Galvez, J.A., Irigoien, X., and Duarte, C.M. 2015. Plastic accumulation in the Mediterranean Sea. *PLOS ONE*. doi:10.1371/journalpone.0121762)

Floating macro-litter and cetaceans: They will meet

This is one of the first studies to directly compare the distribution of marine debris with cetacean presence. The researchers

recorded 1993 floating items (overall density: 15 items/km^2) along the coast of France between Marseille and Monaco (281 transects, more than 5000 km travelled). Most items were plastic bags/packaging. Sightings (n=259, of 2194 individuals) of six species of cetaceans corresponded by ca. 50% with plastic distribution. Considering the ingestion, entanglement and strangulation risk of cetaceans in marine litter, this high overlap and thus potential for interaction is cause for concern, particularly for endangered sperm whales. Importantly, this study's transects partially overlapped with the Pelagos Sanctuary, revealing a sensitive situation. The authors note that they monitored only the 'tip of the iceberg' because, in the Mediterranean, litter densities on the seafloor are higher than for floating litter. They call for actions to reduce the presence of macro-litter at sea.

(SOURCE: Di-Méglio, N. and Campana, I. 2017. Floating macro-litter along the Mediterranean French coast: Composition, density, distribution and overlap with cetacean range. *Mar. Pollut. Bull.* 118: 115-166, *https://doi.org/10.1016/j.marpolbul.2017.02.026*)

Microplastics pose a threat to Mediterranean fin whales

The level of microplastics, as well as the toxicology of fin whale populations, were compared between the Gulf of California and the Pelagos Sanctuary in the Mediterranean Sea. Concentrations of microplastics in the Gulf of California ranged up to 0.14 items/m^3, while the Mediterranean had levels several times higher (up to 9.67 items/m^3, mean: 0.31 $\pm$ 1.17 items/m^3). Furthermore, phthalate and organochlorine contaminant levels, as well as biomarker responses, were significantly higher in Mediterranean fin whales. There was a clear overlap between areas with fin whales feeding and microplastic high density in the Ligurian and Sardinian seas. The authors conclude that "Mediterranean fin whales appear to be exposed to absorbed and constituent contaminants of plastic, as a result of direct and indirect ingestion of microplastic, macroplastic and contaminated prey. These results represent a warning for the vulnerable Mediterranean fin whale population". See Table 1 for biomarker and contaminant values.

(SOURCE: Fossi, M.C., Marsili, L., Baini, M., Giannetti, M., Coppola, D., Guerranti, C., Caliani, I., Minutoli, R., Lauriano, G., Finoia, M.G., Rubegni, F., Panigada, S., Bérubé, M., Urbán Ramírez, J., and Panti, C. 2016. Fin whales and microplastics: The Mediterranean Sea and the Sea of Cortez scenarios. *Environ. Poll.* 209: 68-78)

Plastic debris in whale protected area

Modelling of ocean currents with field data confirmed that the Pelagos Sanctuary, a Specially Protected Area of Mediterranean Importance, suffers heavy impacts from micro- and macro-plastics. The most abundant polymer was polyethylene, suggesting fragmentation of larger packaging as the primary source. There was a large overlap between marine litter hotspots and fin whale feeding habitat. This is an important contribution for risk assessment of fin whale exposure to microplastics.

(SOURCE: Fossi, M.C., Romeo, T., Baini, M., Panti, C., Marsili, L., Campani, T., Canese, S., Galgani, F., Druon, J.-N., Airoldi, S., Taddei, S., Fattorini, M., Brandini, C., and Lapucci, C. 2017. Plastic debris occurrence, convergence areas and fin whales feeding ground in the Mediterranean Marine Protected Area Pelagos Sanctuary: A modelling approach. *Front. Mar. Sci* 4: 167, *https://doi.org/10.3389/fmars.2017.00167*)

High sea surface microplastic densities in northern Adriatic Sea

Seventeen trawls over a 20-month period revealed abundant microplastics in the Slovenian part of the northern Adriatic. The average concentration was 406 x 10^3 particles/km^2, equivalent to 5.41 particles/m^3. Most of the analysed particles were polyethylene. This is amongst the highest concentrations reported in the Mediterranean, further corroborating the Mediterranean as one of the world's marine litter hotspots.

(SOURCE: Gajšt, T., Bizjak, T., Palatinus, A., Liubartseva, S., and Kržan, A. 2016. Sea surface microplastics in Slovenian part of the Northern Adriatic. *Mar. Pollut. Bull*. 113:392-399, *https://doi.org/10.1016/j.marpolbul.2016.10.031*)

Fishing activity and merchant ships associated with macro-litter in Spain

The Mediterranean Sea region produces the highest amounts of municipal waste per person per year in the world. Marine litter densities are more than 100,000 items/km^2 on the seafloor close to metropolitan areas (mass occasionally greater than that of megafauna) and the fourth highest concentration of floating debris in the world. This study revealed increasing densities in the Gulf of Alicante (Spain) from the open sea to the coast. By weight, 76% was plastic, metal and glass. Fishing activity was identified as being the source of nearly 30% of this litter. Overall, likely sources were merchant ships in open waters and recreational and fishing vessels in coastal waters. The latter reflects 1) the practice of discarding old or damaged gear and tackle overboard and 2) unintentional losses due to snagging, especially on rocky grounds closer to shore. This type of debris poses an entanglement threat to cetaceans. The authors encourage 'marine retention programmes' on trawlers to reduce marine litter.

(SOURCE: García-Rivera, S., Sánchez Lizaso, J.L., and Bellido Millán, J.M. 2017. Composition, spatial distribution and sources of macro-marine litter on the Gulf of Alicante seafloor (Spanish Mediterranean). *Mar. Pollut. Bull.* 119: 110-118, *https://doi.org/10.1016/j.marpolbul.2017.06.022*)

Bulgarian Black Sea coast heavily polluted with litter

The Bulgarian Black Sea has received little attention regarding marine litter. The eight beaches studied along the Bulgarian coastline were classified as being highly polluted with litter. Artificial polymer materials made up nearly 85% of this material. Cigarette butts, followed by plastic caps/lids and cups, were the most abundant items. Litter densities were highest on urban beaches, indicating that recreational activities associated with tourists and campers were key sources. The data collected in this and other studies in European seas are important for the European Marine Strategy Framework Directive, designed to achieve or maintain 'Good Environmental Status' for all European seas by 2020. Marine litter is one of 11 'descriptors' considered for determining this status.

(SOURCE: Simeonova, A., Chuturkova, R., and Yaneva, V. 2017. Seasonal dynamics of marine litter along the Bulgarian Black Sea coast. *Mar. Pollut. Bull.* 119: 110-118, *https://doi.org/10.1016/j.marpolbul.2017.03.035*)

First marine litter study on the southeast Black Sea coast

Nine beaches along the Turkish southeast coast of the Black Sea yielded a mean density of 0.16 litter items/m^2 by number and 3.6 g/m^2 by weight. Plastic marine debris is known to be the most abundant litter category in Turkish waters and was also the most abundant along the southeast coast of the Black Sea, followed by Styrofoam and fabric. Although the values were at the lower end of the range reported from other regions, the authors identify the source as inappropriately stored or disposed-of wastes and underline the role of major rivers and streams that empty into the Black Sea.

(SOURCE: Terzi, Y. and Seyhan, K. 2017. Seasonal and spatial variations of marine litter on the south-eastern Black Sea coast. *Mar. Pollut. Bull.* 120: 154-158, *http://dx.doi.org/10.1016/j.marpolbul.2017.04.041*)

Ship strikes

Sperm whales at risk of ship strikes in northwest Mediterranean Sea

Collisions with large vessels may be a conservation issue for the endangered Mediterranean sperm whale population. Comparing the sightings of sperm whales with ship traffic density yielded maps of collision risk in relation to vessel speed. The calculations show that the whales were more at risk from merchant vessels along the French and Italian continental coasts, and by conventional ferries on the east side of the islands of Corsica and Sardinia in the Pelagos Sanctuary. The authors estimated that 74 animals could be at risk of being struck by ships during the summer months in the Pelagos Sanctuary. The authors also noted that 9% of photo-identified sperm whales had scars attributed to ship strikes. These results provide a basis for defining high-risk areas and initiating mitigation measures that encompass commercial vessels, leisure boats and naval boats. While enforced shipping lanes avoid areas of high whale density, observers to detect whales (with infra-red vision at night), early warning systems and training for ships' crews could also be mitigation measures to reduce ship strike risk.

(SOURCE: Di-Meglio, N., David, L., and Monestiez, P. In press. Sperm whale ship strikes in the Pelagos Sanctuary and adjacent waters: assessing and mapping collision risks in summer. *J. Cetacean Res. Manage.* In press)

Chemical pollution

Pyrethroid insecticide found in striped dolphins from the Alborán Sea

Insecticide pyrethroid levels were determined from the liver of striped dolphins in the Alborán Sea. Pyrethroids were detected in 87% of the specimens, with a mean total concentration of 300 µg/kg lipid weight. The bioaccumulation of these insecticides was unlike that of POPs: the concentration increased slightly from calves to juveniles, but there was little difference between juveniles and adults. These levels are a cause for concern, although their toxicological impact is currently unknown. See Table 2 for values.

(SOURCE: Aznar-Alemany, Ò., Giménez, J., de Stephanis, R., Eljarrat, E., and Barceló, D. 2017. Insecticide pyrethroids in liver of striped dolphin from the Mediterranean Sea. *Environ. Pollut.* 225: 346-353)

High heavy metal concentrations in the eastern Black Sea

The contamination of Black Sea waters, sediments and organisms with a wide range of pollutants has become a matter of great concern. The main metal pollution problem in the eastern Black Sea coast of Turkey is related to agricultural run-off, sewage effluents with deficient or no treatment, and river-borne wastes from mines. The levels of metals in a bivalve and snail species were significantly above tolerable levels. Due to the bioaccumulation potential of heavy metals, such high levels are a potential cause for concern for higher-level predators such as cetaceans.

(SOURCE: Baltas, H., Sirin, M., Dalgic, G., Bayrak, E.Y., and Akdeniz, A. 2017. Assessment of metal concentrations (Cu, Zn, and Pb) in seawater, sediment and biota samples in the coastal area of Eastern Black Sea, Turkey. *Mar. Pollut. Bull.* 122: 475-482, *http://dx.doi.org/10.1016/j.marpolbul.2017.06.059*)

Endocrine-disrupting chemicals found in fish off Sicily

Endocrine-disrupting chemicals can show harmful effects on the reproduction and development of aquatic animals by interfering with normal hormonal levels and processes. This study used an improved method to detect three such compounds in all samples of red mullet collected from two sites (characterised by different degrees of pollution) off Sicily. The similar levels in both sites point to background values attributable to the global distribution of these contaminants rather than a local source. The three pollutants belong to category 1 (clear evidence of endocrine-disrupting activity) of Endocrine Disruptor Chemicals. The levels were sufficiently high to prompt the researchers to point to a potential risk for the health of aquatic animals, the Mediterranean Sea ecosystem, and the local human population for whom red mullet is a food source. Red mullet is also a prey species for dolphins.

(SOURCE: Errico, S., Nicolucci, C., Migliaccio, M., Micale, V., Mita, D.G., and Diano, N. 2017. Analysis and occurrence of some phenol endocrine disruptors in two marine sites of the northern coast of Sicily (Italy). *Mar. Pollut. Bull.* 120: 68-74, *http:///dx.doi.org/10.016/j.marpolbul.2017.04.061*)

High levels of PCBs found in three Mediterranean cetaceans

PCB levels in bottlenose and striped dolphins in Europe were amongst the highest recorded levels in cetaceans globally, exceeding all known PCB toxicity thresholds for marine mammals. In the western Mediterranean Sea (1990–2009), PCB concentrations in striped dolphins showed a marked decline after 1990 and then stabilised from 2003 to 2008, but still consistently exceeded all mammalian toxicity thresholds. Although they were not as high as PCB levels in the UK and Ireland, levels in killer whales from the Strait of Gibraltar were also potentially toxic. PCBs can lead to immune system suppression and it was noted that, for example, distemper due to cetacean morbillivirus infection was frequently seen in Mediterranean striped dolphins, and various lesions were observed in bottlenose dolphins and killer whales. The Mediterranean Sea is a global PCB hotspot and most of its cetacean species have declined over decades. The authors state that "Without significant mitigation, PCBs will continue to drive population declines or suppress population recovery in Europe for many decades to come". Despite regulations and mitigation measures to reduce PCB pollution, their biomagnification in marine food webs continues to cause severe impacts amongst cetacean top predators in European seas. See Table 3 for values.

(SOURCE: Jepson, P.D., Deaville, R., Barber, J.L., Aguilar, À., Borrell, A., Murphy, S., Barry, J., Brownlow, A., Barnett, J., Berrow, S., Cunningham, A.A., Davison, N.J., ten Doeschate, M., Esteban, R., Ferreira, M., Foote, A.D., Genov, T., Giménez, J., Loveridge, J., Llavona, Á., Martin, V., Maxwell, D.L., Papachlimitzou, A., Penrose, R., Perkins, M.W., Smith, B., de Stephanis, R., Tregenza, N., Verborgh, P., Fernandez, A., and Law, R.J. 2016. PCB pollution continues to impact populations of orcas and other dolphins in European waters. *Sci. Rep.-UK* 6:18573)

Genetic analyses of skin samples reveal contamination hotspots

Skin samples of stranded specimens of four cetacean species (bottlenose, striped and Risso's dolphins, fin whales) were examined for genetic markers specific to contaminants of emerging concern. Animals from three basins (Ionian, Tyrrhenian and Adriatic) were sampled. Three of four markers tested showed higher expression in the samples collected from the Adriatic. The researchers highlighted the role freshly stranded specimens can play in determining the region from which individual cetaceans come and the pollution levels there.

(SOURCE: Mancia, A., Lunardi, D., and Abelli, L. 2018. The chronicles of the contaminated Mediterranean seas: A story told by the cetaceans' skin genes. *Mar. Pollut. Bull.* 127: 10-14, *https://doi.org/10.1016/j.marpolbul.2017.11.037*)

High heavy metal concentrations in human food (and dolphin prey) in the Aegean Sea

The levels of Hg, Cd, Pb, Cr, Cu and Zn were measured in four species of fish—annular seabream, common pandora, European hake and red mullet - along the Turkish coast of the Aegean Sea. In one of the two bays sampled, the levels of Cd and Pb were above the FAO's tolerable limits for three species, and the levels of Hg were at the maximum permitted limits for two species. Accordingly, the consumption of red mullet and common pandora in this area is potentially hazardous to human health due to Hg concentrations. Dolphins are also known to prey on these species.

(SOURCE: Pazi, I., Gonul, L.G., Kucuksezgin, F., Avaz, G., Tolun, L. Unluoglu, A., Karaaslan, Y., Gucver, S.M., Orhon, A.K., Siltu, E., and Olmuz, G. 2017. Potential risk assessment of metals in edible fish species for human consumption from the Eastern Aegean Sea. *Mar. Pollut. Bull.* 120: 409-413, *https://doi.org/10.1016/j.marpolbul.2017.05.004*)

Chemicals associated with plastics concentrated in sea turtles

Sea turtles (one leatherback, 12 loggerhead) stranded along the Sicilian coast were examined for phthalates, chemicals used in the plastics industry. The total concentrations of the four phthalates examined were high in all tissues. The levels in fat were comparable to those found in marine mammals, underlining that these chemicals leach from plastics and enter the food chain. This supports the potential of monitoring these substances as tracers for microplastic ingestion, and the

authors call for efforts to adopt a common plastics waste management policy amongst all Mediterranean countries.

(SOURCE: Savoca, D., Arculeo, M., Barreca, S., Buscemi, S., Caracappa, S., Gentile, A., Persichetti, M.F., and Pacem A. 2018. Chasing phthalates in tissues of marine turtles from the Mediterranean Sea. *Mar. Pollut. Bull*. 127: 165-169, *https://doi.org/10.1016/j.marpolbul.2017.11.069*)

Trace elements in Mediterranean striped dolphins

The examination of trace elements (Hg, Se, Cd, Cu, Zn, Fe, Mn and As) in seven specimens of striped dolphin stranded along the Israeli coast from 2006-2011 showed no change from an earlier series beginning in 2001. The Hg values were high (and higher than in other seas), but might reflect the relatively high natural background level of Hg in the Mediterranean. The pathology findings included meningoencephalitis, pneumonia and hepatitis (but no DMV). Striped dolphins have suffered four DMV epidemics (1990-1992, 2006-2008, 2011 and 2013) in this area. This suggests a prolonged DMV circulation in the Western Mediterranean along with an inadequate level of antiviral immunity. This compromised immunity may be caused or aggravated by pollutants. This would impact the health and conservation status of Mediterranean striped dolphins (currently listed as Vulnerable on the IUCN Red List), calling for continued monitoring of the concentrations of heavy metals and other pollutants in this species.

(SOURCE: Shoham-Frider, E., Goffman, O., Harlavan, Y., Kress, N., Morick, D., Roditi-Elasar, M., Shefer, E., and Kerem, D. 2016. Trace elements in striped dolphins (*Stenella coeruleoalba*) from the Eastern Mediterranean: A 10-years perspective. *Mar. Pollut. Bull*. 109: 624-632, *http://doi.org/10.1016/j.marpolbul.2016.05.021*)

Trace element levels in Mediterranean cetaceans as ecological indicators

See Table 4 for values measured in sperm whales and bottlenose dolphins.

(SOURCES: Monteiro, S.S., Torres, J., Ferreira, M., Marçalo, A., Nicolau, L., Vingada, J.V., and Eira, C. 2016. Ecological variables influencing trace element concentrations in bottlenose dolphins (*Tursiops truncatus*, Montagu 1821) stranded in continental Portugal. *Sci. Total Environ.* 544: 837-844; Squadrone, S., Brizio, P., Chiaravalle, E., and Abete, M.C. 2018. Sperm whales (*Physeter macrocephalus*), found stranded along the Adriatic coast (Southern Italy, Mediterranean Sea), as bioindicators of essential and non-essential trace elements in the environment. *Ecol. Indic.* 58: 418-425)

Pop levels higher in Mediterranean than in North Atlantic or Southern Hemisphere cetaceans

See Table 5 for values in three species of cetacean.

(SOURCE: Pinzone, M., Budzinski, H., Tasciotti, A., Ody, D., Lepoint, G., Schnitzler, J., Scholl, G., Thomé, J.-P., Tapie, N., Eppe, G., and Das, K. 2015. POPs in free-ranging pilot whales, sperm whales and fin whales from the Mediterranean Sea: Influence of biological and ecological factors. *Environ. Res.* 142: 185-196)

Disease and mortality events

General

Mass mortality of juvenile and newborn harbour porpoises in the Black Sea

The endemic harbour porpoise subspecies in the Black Sea has experienced several large-scale mortalities in the 21st century. In 2016, unusually large numbers of newborns and juveniles washed up on beaches along the Black Sea coasts of Bulgaria and Turkey (in Turkey: 7.2 individuals/km, with 150 individuals along one 22 km stretch in July alone). In total, 443 stranded cetaceans (435 of them harbour porpoises) were reported in Turkey (coastline length: 300 km), and 234 cetaceans (218 harbour porpoises) in Bulgaria (coastline length: 238 km). Most were newborns less than 70 cm long. Öztürk *et al.* estimate that thousands of juveniles died during this mortality event. Such successive high mortalities of young animals could be a serious impediment to the recovery of this endangered subspecies.

(SOURCES: Sanders, N. 2016. Mass mortality event of Black Sea harbour porpoises. IUCN - SSC Cetacean Specialist Group, *http://www.iucn-csg.org/index.php/2016/08/25/mass-mortality-event-of-black-sea-harbour-porpoises*; Öztürk, A.A., Tonay, A.M., Dede, A., Danyer, I., and Popov, D. 2017. Unusual mass mortality of harbour porpoises on the coast of the western Black Sea (Bulgaria and Turkey) in summer 2016. Abstract submitted to 31st European Cetacean Society Conference, Middlefart, Denmark)

Stranding rate of porpoises correlates with fish stock dynamics in the Azov Sea

In 1999-2014, harbour porpoise stranding rates were regularly monitored on the southern coast of the Azov Sea, particularly at the uninhabited abraded coast of the Tarkhan Cape. Specifically, the general trends and annual fluctuations in strandings were compared to the catch reports of the Azov Sea anchovy, an important prey for porpoises. The fluctuations in stranding rates correlated with the population dynamics of the anchovy stock. A cosine function, based on the data from 1999-2012, correctly predicted maximum strandings in 2013 and their substantial decline in 2014. The function worked particularly well when biases affecting carcass preservation, such as discovery rate and drift conditions,

were reduced. In certain environments and over established time periods, the cetacean stranding rate can be an indicator of population trends which may be verified by external factors, including the dynamics of prey stocks.

(SOURCE: Vishnyakova, K. and Gol'din, P. 2015. Cetacean stranding rate correlates with fish stock dynamics: Research of harbour porpoises in the Sea of Azov. *Mar. Biol.* 162: 359-366)

Harmful algal blooms (HABs)

First global integrated marine assessment: Black Sea

The upper layer of water (ca. 150 m) in the Black Sea supports unique marine, freshwater, brackish and relic species (approximately 5000). The deeper layers are saturated with hydrogen sulphide and largely devoid of multi-cellular invertebrates. The eastern sector is a recognised biodiversity hotspot. A UN report identifies invasion by alien species as a key threat to the Black Sea ecosystem, with two species being of particular importance. The first is an American filter-feeding comb jelly, which has led to the collapse of pelagic fish populations (26 commercial fish stocks) and caused a major shift in the marine ecosystem (partially offset by the invasion of another, predatory comb jelly). The second is algae that produce harmful algal blooms and can further deplete the oxygen in the water. Temperature increases at the surface mixing with cold intermediate water layers have further accelerated species shifts. Critical status has been recognised for 13 out of 37 benthic habitats, including the neritic water column, coastal lagoons, estuaries and deltas. These developments, along with illegal fishing (gillnet entanglement), pose the greatest threats to the three cetacean species inhabiting the Black Sea, all of which are listed as Endangered or Vulnerable on the IUCN Red List.

(SOURCE: Inniss, L. and Simcock, A. (Joint coordinators); Rice, J. (Lead member of 14 contributors). 2016. The first global integrated marine assessment: World ocean assessment I. *United Nations, Chapter 36A:* p. 16-18, *http://www.un.org/Depts/los/global_reporting/WOA_RPROC/Chapter_36A.pdf*)

Climate change

Climate change a 'double issue' in the Mediterranean Sea

Climate change is a particular issue for enclosed seas, where organisms cannot migrate to higher latitudes. The Mediterranean is doubly affected because it is increasingly being inhabited by (sub) tropical non-indigenous species ('tropicalisation'). Moreover, warm-water native species previously restricted to southern sectors are now establishing themselves in the colder northwest basin ('meridionalisation'). The authors report that 20 southern species have been found for the first time at Genoa, including zebra seabream, parrotfish and juvenile Indo-Pacific bluespotted cornetfish. The linear increase in the number of warm-water native species and the exponential increase in the number of non-indigenous species point to a tropicalisation (rather than a meridionalisation) even in the northern sectors of the Mediterranean basin. If the present seawater warming continues, the Mediterranean would undergo a generalised process of biotic homogenisation. Such major ecosystem changes probably ultimately affect the entire food web, including top predators such as cetaceans. The authors point to the need for sustained monitoring as "a major concern for scientists and environmental managers alike".

(SOURCE: Bianchi, C.N., Caroli, F., Guidetti, P., and Morri, C. 2018. Seawater warming at the northern reach for southern species: Gulf of Genoa, NW Mediterranean. *J. Mar. Biol. Assoc. UK* 98:1-12, doi:10.1017/S0025315417000819)

Climate change could reduce common dolphin habitat in the Alborán Sea

A special volume of the journal *Deep Sea Research Part II: Topical Studies in Oceanography* was devoted to Atlantic and Mediterranean megafauna. Papers addressed abundance, distribution and habitats; one paper highlighted climate change (see also Azzellino *et al.*, 2017, in this SOCER). Short-beaked common dolphin distribution and environmental variables recorded in the Alborán Sea were used to project the impacts of climate change via changes in sea surface temperatures on dolphin habitat. The authors conclude that increasing sea surface temperatures will lead to a decrease in common dolphin habitat.

(SOURCE: Cañadas, A. and Vázquez J.A. 2017. Common dolphins in the Alborán Sea: Facing a reduction in their suitable habitat due to an increase in sea surface temperature. *Deep Sea Res. Pt. II: Topic. Stud. Oceanogr.* 141: 306-318)

Noise impacts

Vessel traffic alters the behaviour of bottlenose dolphins and harbour porpoises in the Istanbul Strait

The Istanbul Strait is one of the busiest international waterways in the world. The effect of marine traffic, location and season on the behavioural transitions, behavioural budget and bout duration (average time in each behavioural state) of bottlenose dolphins was investigated and modelled. Marine vessels were the main driving force for behavioural transitions, leading to

significant changes in behavioural budget and bout durations. There was a significant decrease in socialising, surface-feeding and resting behaviour in the presence of boats, whilst diving behaviour increased. Moreover, dolphins spent less time surface-feeding, resting, socialising and diving once disrupted. The current level of vessel-dolphin interaction in this area (51% of observation time) was sufficient to significantly alter the dolphins' cumulative behavioural budget. Finally, speed and distance of vessels played a considerable role in the directional responses of dolphins. The authors argue for creating protected zones in order to mitigate vessel-dolphin interactions, because the population is already classified as 'at risk' and still lacks a species-specific conservation plan. In a second study, high-speed ferries and boats were identified as the major cause of disturbance. Accordingly, the authors recommend that the proposed protected zones (three different seasonally managed areas) should limit the speed and density of marine traffic. A third study on the endangered Black Sea harbour porpoise in the strait showed similar results: vessel presence, speed and distance affected behavioural bout length and swimming direction, but there was no significant cumulative (diurnal) behavioural budget change. Nonetheless, exposure to high-speed vessels resulted in a strong response, which could lead to porpoise displacement from large areas. Porpoise density was higher in areas with less traffic (northern strait) and lower in areas of high traffic (southern and central strait). The authors argue for species-specific conservation actions, especially in the northern sections of the strait, including vessel exclusion zones, enforced speed limits and the designation of specific channels for ferries.

(SOURCES: Bas, A.A., Christiansen, F., Öztürk, B., Öztürk A.A., Erdoğan, M.A., and Watson, L.J. 2017. Marine vessels alter the behaviour of bottlenose dolphins *Tursiops truncatus* in the Istanbul Strait, Turkey. *Endang. Species Res.* 34:1-14; Bas A.A., Öztürk A.A., and Öztürk B. 2015. Selection of critical habitats for bottlenose dolphins (*Tursiops truncatus*) based on behavioral data, in relation to marine traffic in the Istanbul Strait, Turkey. *Mar. Mamm. Sci.* 31: 979-997; Bas, A.A., Christiansen, F., Öztürk, A.A., Öztürk, B., and McIntosh, C. 2017. The effects of marine traffic on the behaviour of Black Sea harbour porpoises (*Phocoena phocoena relicta*) within the Istanbul Strait, Turkey. *PLoS ONE* 12(3): e0172970. doi:10.1371/journal.pone.0172970)

Lower cetacean abundance in areas of high vessel traffic in the western Mediterranean

Shipping vessel number and cetacean abundance, determined via line transect surveys, were examined in the western Mediterranean Sea region. In locations with cetacean sightings, shipping traffic was 20% lower compared to random locations where no sightings were made. Most cetacean species, common bottlenose dolphins excepted, were observed in locations with lower levels of vessel traffic. Line transects in the Pelagos Sanctuary found reduced abundances of fin whales and striped dolphins in areas with more vessel traffic in the southeast region, and of large whales in the western portion of the sanctuary, where there is more vessel traffic. In the central part of the sanctuary—with moderate vessel traffic yet important feeding habitat locations—there were minor differences in the abundance of species (specifically Cuvier's beaked whales, sperm whales, fin whales and striped dolphins). It is possible that feeding habitats are so important that cetaceans still use these areas despite boat disturbance.

(SOURCE: Campana, I., Crosti, R., Angeletti, D., Carosso, L., David, L., Di-Méglio, N., Moulins, A., Rosso, M., Tepsich, P., and Arcangeli, A. 2015. Cetacean response to summer maritime traffic in the Western Mediterranean Sea. *Mar. Environ. Res.* 109: 1-8)

Italy introduces monitoring scheme for marine mammal presence for seismic exploration

Anthropogenic noise (e.g. naval sonar, pile driving, geophysical surveys) has now been recognised as a threat to marine fauna. Current oil and gas industry and navy protocols, as well as other guidelines based on 'best practise' or precautionary approaches for civil and industrial activities, are not standardised. In 2015, the Italian Environmental Impact Assessment Commission issued new criteria for obtaining permits for oil and gas exploration. It mandated that seismic operators apply a standardised protocol to compare the presence of marine mammals before, during and after offshore seismic surveys (see *http://www.va.minambiente.it/it-IT*). It established a 60-day monitoring period using both visual and acoustic methods. The authors underline that this approach, if used internationally, would improve the study of far-reaching intense low-frequency noise. The collected data are to be stored and made public by the Italian Ministry of the Environment.

(SOURCE: Fossati, C., Mussi, B., Tizzi, R., Pavan, G., and Pace, D.S. 2017. Italy introduces pre and post operation monitoring phases for offshore seismic exploration activities. *Mar. Pollut. Bull.* 120: 376-378, *https://doi.org/10.1016/j.marpolbul.2017.05.017*)

Resident population of bottlenose dolphin affected by vessel noise

Vessel traffic is known to affect the resident bottlenose dolphin's distribution and habitat use in the Cres-Losinj archipelago (Croatia, Adriatic Sea, a Natura 2000 site). This study found that the acoustic behaviour of the population is also affected by vessel noise. Dolphins significantly changed their whistle structure at high levels of ambient noise and in the presence of boats. These waters are visited consistently by sensitive mother-calf groups. The researchers called for an improved understanding of the overall acoustic repertoire of bottlenose dolphins and for determining potential population-level changes in the presence of these disturbance factors.

(SOURCE: Gospic, N.R. and Picciulin, M. 2016. Changes in whistle structure of resident bottlenose dolphins in relation to underwater noise and boat traffic. *Mar. Pollut. Bull.* 105: 193-198, *https://doi.org/10.1016/j.marpolbul.2016.02.030*)

Underwater noise hotspots in the Mediterranean Sea and the extent of seismic surveying

A number of noise-producing activities might threaten cetaceans in the Mediterranean Sea, including coastal and offshore activities, seismic surveys, naval exercises and vessel traffic. Between 2005 and 2015, 1446 harbours, 228 oil/gas drilling platforms, 52 windfarm projects, 830 seismic exploration areas and a number of military exercise areas were identified. In July 2014, 7 million maritime vessel positions were recorded every 10 minutes. On average, there were 1500 vessels present in the area at any time, with the heaviest density of traffic in northern and western parts of the Mediterranean Sea and in Greek waters. The maximum and minimum areas where seismic surveys were being conducted were calculated: 27% of the surface of the Mediterranean (675,000 km^2) in 2013 and 3.8% (67,000 km^2) in 2005. Hotspots of underwater noise that overlapped key cetacean habitat included the Pelagos Sanctuary, the Strait of Sicily and the Hellenic Trench. The authors conclude that "these results provide strong evidence of multiple stressors acting on the marine environment and of the need for urgent management and conservation actions".

(SOURCE: Maglio, A., Pavan, G., Castellote, M., and Frey, S. 2016. *Overview of Noise Hotspots in the ACCOBAMS Area.* Report for the ACCOBAMS Secretariat)

Recommendations for reducing the impacts of seismic surveys and underwater noise in the eastern Mediterranean Sea

A workshop was held in Croatia on mitigating the impacts of underwater noise, particularly from seismic surveys, in the eastern Mediterranean Sea. The workshop was attended by 65 participants from 15 countries. Recommendations from the meeting included taking a precautionary approach to noise management; developing a 'noise budget' for eastern Mediterranean waters; considering potential cumulative or synergistic impacts on cetaceans, including the impacts of climate change; and assessing the effectiveness of mitigation measures and monitoring activities. Better communication and sharing of information was also suggested, in particular information on the distribution of sensitive species. Strategic Environmental Assessments should be conducted by governments and analysed before any locations are licensed to the oil and gas industry. The *Convention on Migratory Species (CMS) Guidelines on Environmental Impact Assessments for Marine Noise Generating Activities* should be incorporated into national legislation and species management plans. The number of seismic surveys should be limited and their timing should be planned to avoid key periods for sensitive species. Duplication of seismic surveys should be avoided and the use and development of the best-available quieting technologies (e.g. marine vibroseis) should be pursued. The lack of training of (and capacity for) marine mammal observers and acoustic monitoring staff on seismic survey vessels should be addressed. A global report should be prepared on the best available technology and environmental practises for the mitigation of underwater anthropogenic noise, and should be made available to all government agencies in the region. Education and awareness-raising of the need to reduce noise in the marine environment was also recommended. Finally, subsidies for the oil and gas industry should be removed and public funds should be spent in line with the objectives of the 2015 Paris Agreement on Climate Change, i.e. in a way to reduce greenhouse gas emissions.

(SOURCE: NRDC, OceanCare, DBU. 2017. *Mitigating the impact of underwater noise on marine biodiversity with specific focus on seismic surveys in the south eastern European waters in the Mediterranean Sea.* Workshop held November 22-23, 2017. Split, Croatia)

Overlap between cetaceans and shipping in the Pelagos Sanctuary

A spatial analysis was conducted of shipping and the distribution of striped and bottlenose dolphins and fin whales in the southern part of the Pelagos Sanctuary. Overlap with vessel traffic occurred for all three species, with the greatest degree of overlap for striped dolphins, followed by bottlenose dolphins, then fin whales. Importantly, despite their lower overlap with shipping, fin whales might be particularly vulnerable to this source of disturbance because the overlap was associated with productive feeding areas, and animals focusing on feeding might be less reactive to approaching vessels.

(SOURCE: Pennino, M.G., Arcangeli, A., Prado Fonseca, V., Campana, I., Pierce, G.J., Rotta, A., and Bellido, J.M. 2017 A spatially explicit risk assessment approach: Cetaceans and marine traffic in the Pelagos Sanctuary (Mediterranean Sea). *PLoS ONE* 12(6): e0179686, *https://doi.org/10.1371/journal.pone.0179686*)

Fin whales silent when seismic survey noise detected in the Ionian Sea

Acoustic recordings made in the Ionian Sea detected 20 Hz calls from fin whales and pulses from seismic survey airguns. Airgun pulses were recorded in four of the 10 analysed months and occurred daily between 25 November 2012 and 21 February 2013 - this period coincided with an absence of recorded fin whale calls. The daily airgun pulses led to an increase in low frequency background noise (below 50 Hz) of 10 dB. The received levels of airgun pulse noise indicated that the sound originated several hundreds of kilometres from the recording site. This suggests a significant impact from seismic surveys on fin whale vocalisations in this area.

(SOURCE: Sciacca, V., Viola, S., Pulvirenti, S., Riccobene, G., Caruso, F., De Domenico, E., and Pavan, G. 2017. Shipping noise and seismic airgun surveys in the Ionian Sea: Potential impact on Mediterranean fin whale. *Proceed. Mtgs Acoust.* 27, 040010: 1-10, *https://doi.org/10.1121/2.0000311*)

The potential impact of seismic surveys in the Mediterranean Sea

This review assessed sources of underwater noise that might pose a problem for cetaceans in the Mediterranean Sea. Potential sources included: 1) shipping traffic; 2) military exercises; 3) seismic surveys; 4) development projects, both coastal and offshore; and 5) marine tourism. Over the past 10 years, seismic surveys have increased in the southeast Mediterranean, especially in the Adriatic Sea and the Hellenic Trench. Concern about the impacts of underwater noise extends also to essential prey species such as zooplankton. However, the author notes that "the full extent of the impact of seismic surveys at the population level is mostly unknown, partially due to the lack of baseline knowledge about the abundance and distribution of [cetaceans]". A number of mitigation measures was recommended, including: 1) improved cetacean surveys; 2) the establishment of strandings detection programmes; 3) more research on the impacts of seismic surveys; 4) no-go zones for seismic surveys; 5) increased capacity in Mediterranean nations to conduct effective environmental impact assessments; 6) the use of new technologies, such as marine vibroseis; 7) better funding and training (e.g. for marine mammal observers on seismic survey vessels); and 8) improved communication amongst stakeholders.

(SOURCE: Štrbenac, A. 2017. *Overview of Underwater Anthropogenic Noise, Impacts on Marine Biodiversity and Mitigation Measures in the South-Eastern European Part of the Mediterranean, Focussing on Seismic Surveys*. Report from Stenella Consulting, Croatia, for OceanCare, Switzerland)

Comparing monitored and modelled noise levels in Italian waters as a strategy for planning future shipping traffic routes

Acoustic noise levels were measured in waters off Sicily and compared with the results of a model based on AIS data. The hydrophones were installed at a depth of over 2000 m, 25 km off Catania, Sicily. The measured values correlated well with the passage of ships tracked by AIS. This monitoring was requested by the EU Directive on Marine Strategy in an effort to achieve 'Good Environmental Status'. The data are essential in planning new routes for shipping traffic (as anticipated for the future 'European Motorways of the Sea'). They will also be helpful in elaborating mitigation measures for protected species that could be threatened by high noise levels at low frequencies; e.g. fin whales. Comparing noise distribution with animal density will help identify noise hotspots for the most sensitive species.

(SOURCE: Viola, S., Grammauta, R., Sciacca, V., Bellia, G., Beranzoli, L., Buscaino, G., Caruso, F., Chierici, F., Cuttone, G. D'Amico, A., De Luca, V., Embriaco, D., Favali, P., Giovanetti, G., Marinaro, G., Mazzola, S., Filiciotto, F., Pavan, G., Pellegrino, C., Pulvirenti, S., Simeone, F., Speziale, F., and Riccobene, G. 2017. Continuous monitoring of noise levels in the Gulf of Catania (Ionian Sea). Study of correlation with ship traffic. *Mar. Pollut. Bull.* 121: 97-103, *https://doi.org/10.1016/j.marpolbul.2017.05.040*)

Table 1.

Mean (± SD) values of plastics biomarkers and organochlorines in sampled fin whales. (Units: CYP1A1 = pmol/mg protein; CYP2B = pmol/mg protein; LPO = nmol TBARS/mg protein; MEHP = ng/g f.w.; HCB = ng/g l.b.; DDT = ng/g l.b.; PCB = ng/g l.b.; OC = ng/g l.b.)

	N	CYP1A1	CYP2B	LPO	MEHP	HCB	ΣDDT	ΣPCBs	ΣOC
Mediterranean	30	71.9 ± 25.9	41.5 ± 22.9	11.0 ± 6.4	54.8 ± 27.7	29.9 ± 12.0	10480 ± 7480	13330 ± 8550	23830 ± 15060
Gulf of California	10	61.4 ± 28.4	52.9 ± 23.4	6.7 ± 3.8	40.0 ± 23.2	38.5 ± 33.6	3110 ± 2250	8754 ± 6540	11900 ± 6760

Table 2.

Maximum insecticide pyrethroid values in the livers of striped dolphins from the Alborán Sea (µg/kg lipid weight)

Tetramethrin	Bifenthrin	Cyhalothrin	Permethrin	Deltamethrin	ΣPyrethroid
3400	36	18	1800	78	5200

Table 3.

Maximum PCB levels (ΣPCB mg/kg lipid)

Bottlenose dolphin		Striped dolphin	Killer whale
Strait of Gibraltar	Western Mediterranean	Western Mediterranean	Strait of Gibraltar
879.3	601.39	2668.64	857.92

Table 4.

Maximum trace element values recorded in cetaceans from the Mediterranean (mg/kg wet weight). Mercury levels in bottlenose dolphins were extremely high, although exceeded by levels in the Mediterranean and Adriatic Seas.

		n		Al	As	Cd	Cr	Cu	Fe	Hg	Mn	Mo	Ni	Pb	Se	Sn	V	Zn
Sperm whale	Italian coast, Adriatic Sea	3	Brain	2.73	0.73	0.06	0.02	3.35	56.57		0.56	0.02	0.04		9.14	0.23	0.02	16.5
			Muscle	7.05	5.54	0.03	0.05	0.56	198.2		1.02	0.01	0.03		3.10	0.01	0.06	48.5
			Liver	2.79	6.71	2.84	0.12	7.62	1554		1.16	0.30	0.17		94.0	0.60	0.03	53.5
			Kidney	11.36	1.75	2.60	0.14	1.97	235.6		1.48	0.03	0.06		6.40	0.18	0.05	13.5
Bottlenose dolphin	Portuguese coast,entrance of the Mediterranean	10	Muscle		2.72	0.31		3.46		3.14	4.65		1.93	0.22	2.03			24.2
			Liver		0.94	0.47		30.6		208	4.68		0.27	0.26	117			94.9
			Kidney		1.58	2.81		8.28		40.1	1.48		0.21	0.11	11.9			46.9

Table 5.

Persistent organic pollutants detected in Mediterranean cetaceans. Pollutant levels were higher than comparative populations in the North Atlantic and southern hemisphere. The levels of organic contaminants frequently exceeded an estimated 17 mg/kg lipid weight toxicity threshold.

		Contaminant concentrations in mg/kg lipid weight									Contaminant concentrations in µg/kg lipid weight				
	n	ΣPCBs	ΣICES7	ΣPBDE	DDE	DDD	DDT	ΣDDT	ΣHCH	HBCD	ΣPCDD	ΣPCDF	Σnon-ortho PCB	Σortho PCB	WHO-TEQ/g lipid weight
Long-finned pilot whale	49	103	68	1.76	165	6.09	3.86	185	0.095	0.401	0.12	0.3	3.7	3627	472
Sperm whale	43	68.5	45.9	0.78	147	7.63	9.77	170	0.33	0.214	0.13	0.74	12.0	4735	1833
Fin whale	70	25.07	17.98	1.19	19.2	2.32	0.80	26.70		0.043					

GLOBAL (2014-2018)

General

Whale-watching disturbance estimated to cause substantial decreases in whale energy intake

Considerable effort is being made to answer how short-term behavioural disturbance in marine mammals, including cetaceans, translates into impacts at the population level. The authors analysed interactions of northern minke whales with whale-watching vessels, combined with a stepwise modelling approach, to estimate energy budgets and the loss of energy intake because normal foraging and diving behaviour ceases or is altered. Whale-watching vessel presence resulted in an estimated overall decrease in energy intake of 42%, due to a decrease in feeding behaviour.

(SOURCE: Christiansen, F., Rasmussen, M.H., and Lusseau, D. 2013. Inferring activity budgets in wild animals to estimate the consequences of disturbances. *Behav. Ecol.* 24: 1415-1425)

Habitat degradation and hunting of large species associated with mammal extinction risk

A review of IUCN Red Listed mammal species to determine what common factors were associated with endangerment determined that "large and widely distributed mammals are affected by combinations of direct exploitation and threats associated with increasing landscape modification that go from logging to intense human land-use." On the other hand, "small, narrowly distributed species are affected by intensifying levels of landscape modification but are not directly exploited." Unsurprisingly the most endangered species were exposed to the greatest number of threats and it was suggested that "extinction risk is associated with the accumulation of external threats." Habitat loss and degradation were strongly associated with mammal extinction risk, and for large, widely distributed species (e.g. cetaceans), hunting was an additional factor that increased extinction risk.

(SOURCE: González-Suárez, M. and Revilla, E. 2014. Generalized drivers in the mammalian endangerment process. *PLoS ONE* 9(2): e90292. doi:10.1371/journal.pone.0090292)

Yangtze finless porpoise population rapidly declining

The most recent survey conducted in 2012 in the Yangtze River and two adjoining lakes in China showed that the population of this endangered species—the only freshwater finless porpoise in the world—has declined to a mere 1000 individuals. Compared with the 2006 survey, this represents an unsustainable 13.7% rate of annual decline. The species is projected to become extinct as early as 2025. This decline is attributed to human disturbance such as increasing shipping traffic and newly discovered illegal fishing practices, including traps that could affect the porpoises. This trend could be exacerbated by the drastic shrinking of many Yangtze River Basin lakes: from 1950 to 2010, the central and lower reaches of the Yangtze lost approximately two-thirds of their lakes due to increased land reclamation for agriculture and industrial development. Moreover, 32 individuals were found dead in early 2012 in Dongting and Poyang lakes, from electro-fishing, boat propellers, food shortages and poison. The recent extinction of the baiji in the same waters is a wake-up call to take

immediate and urgent action. The reputation and reason for existence of national and international cetacean conservation and management organizations, including the IWC, is at stake, as is the conscience and responsibility of humankind toward nature in general.

(SOURCES: News. 2013. *Mar. Pollut. Bull.* 71: 3; News. 2012. *Mar. Pollut. Bull.* 64: 460; News. 2012. *Mar. Pollut. Bull.* 64: 1081)

Vast quantities of dumped military ordnance pose an increasing threat

European countries have dumped more than 1 million tons of munitions in the Irish Sea, 168,000 tons in Danish waters, and 300,000 tons in the North Sea. After World War II, the US and European countries dumped another 300,000 tons of conventional and chemical munitions into the sea. An estimated 150 individual dump sites spread from Iceland to Gibraltar. In the US, more than 400 dump sites are located in the Pacific, Atlantic and Gulf of Mexico. The integrity of this military ordnance, especially of incendiary and chemical weapons, has been compromised after decades in seawater. With our increasing use of the ocean bed for fishing, sand and gravel extraction, offshore oil and wind energy production, diving and so on—coupled with the further deterioration and leakage of toxic substances—this material poses an increasing threat to marine and human life.

(SOURCE: Morton, B. 2013. Bombs away! *Mar. Pollut. Bull.* 73: 1-2)

The global state of the oceans

A special issue of *Marine Pollution Bulletin* was devoted to a synthesis of two workshops held by the International Programme on the State of the Ocean (IPSO; *www.stateoftheocean.org*) in partnership with the International Union for Conservation of Nature (IUCN; *www.iucn.org*). The verdict: "[H]uman activities have led to intense multiple stressors acting together in many marine ecosystems. Most notably these are arising from overexploitation of biotic resources, climate change effects forming the so-called 'deadly trio' (ocean warming, acidification and hypoxia/anoxia) and pollution". The authors call for a "rapid adoption of a holistic approach to sustainable management of all activities that impinge on marine ecosystems". With regard to marine fisheries, several solutions are presented, including addressing the weaknesses and gaps in ocean governance via United Nations General Assembly resolutions. The most ambitious and promising approach is a structural overhaul of the system. This would include creating a new global infrastructure to coordinate, ensure consistency and accountability, and supervise, sanction and enforce. One step would be to create a U.N. Department for Oceans and Law of the Sea, and to negotiate a new agreement under UNCLOS to protect and preserve marine life in areas beyond national jurisdictions.

(SOURCE: Rogers, A.D. (ed.) 2013. The global state of the ocean: interactions between stresses, impacts and some potential solutions. Synthesis papers from the International Programme on the State of the Ocean 2011 and 2012 workshops. *Mar. Pollut. Bull.* 74: 491-551)

Extinction hotspot locations determined by analysing the paleontological record

The paleontological record (for the past 23 million years) was investigated to examine patterns of extinction for marine species. Six major marine taxonomic groups (bivalves, gastropods, scleractinian corals, echinoids, sharks, and mammals) were analysed due to their occurrence in the fossil record. The extinction risk was higher in tropical ecosystems. Mammals had the highest extinction risk and the extinction rates were highest in the Indo-Pacific, tropical south Pacific, and east Asia, followed by the north Atlantic, Indian Ocean and sub-Antarctic islands. These regions of high intrinsic extinction rates are currently facing strong impacts from anthropogenic activities, raising further concern regarding the extinction of marine mammals here.

(SOURCE: Finnegan, S., Anderson, S.C., Harnik, P.G., Simpson, C., Tittensor, D.P., Byrnes, J.E., Finkel, Z.V., Lindberg, D.R., Liow, L.H., Lockwood, R., Lotze, H.K., McClain, C.R., McGuire, J.L., O'Dea, A., and Pandolfi, J.M. 2015. Paleontological baselines for evaluating extinction risk in the modern oceans. *Science* 348: 567-570)

First evidence that marine protected areas work for marine mammals

The survival rate of a Hector's dolphin population increased after a marine mammal sanctuary was established to reduce gillnet mortality. Photo-identification surveys catalogued 462 individuals. Survival rates modelled before and after the sanctuary was created showed there was a 90% probability that survival improved after implementing the sanctuary, with estimates of mean survival probability increasing by 5.4%. This improvement in survival corresponds to a 6% increase in mean annual population growth. Clearly, MPAs can be effective for marine mammals. Estimating demographic parameters in marine mammals requires many years of data to achieve sufficient precision to detect biologically meaningful change. Therefore, MPAs should be established with a commitment to long-term monitoring.

(SOURCE: Gormley, A.M., Slooten, E., Dawson, S.M., Barker, R.J., Rayment, W., du Fresne, S., and Bräger, S. 2012. First evidence that marine protected areas can work for marine mammals. *J. Appl. Ecol.* 49: 474-480)

Patterns of marine species loss in the oceans

The authors argue that marine defaunation started much later in marine systems than terrestrial and freshwater systems. Despite this, humans have decreased the abundance of both large (e.g. baleen whales) and small (e.g. anchovies) marine species. Although marine ecosystems have fared slightly better than terrestrial ecosystems, with fewer marine extinctions—at least extinctions that are known—anthropogenic impacts on marine animals are increasing. The authors warn that the current rates of marine species loss "may be the prelude to a major extinction pulse… as the footprint of human ocean use widens". They recommend a system of MPAs and careful management of connecting ocean corridors. They note that "current trends in ocean use suggest that habitat destruction is likely to become an increasingly dominant threat to ocean wildlife over the next 150 years".

(SOURCE: McCauley, D.J., Pinksy, M., Palumbi, S.R., Estes, J.A., Joyce, F.H., and Warner, R.R. 2015. Marine defaunation: animal loss in the global ocean. *Science* 347: 247. doi: 10.1126/science.1255641)

Key research questions of global importance for cetacean conservation

A workshop at the 18th Biennial Conference on the Biology of Marine Mammals developed a list of urgent research questions, whose lack of answers are obstructing cetacean conservation. Examples of these research questions include:

- How do we better monitor cetaceans, human activities (e.g. industry, fisheries and tourism) and their interactions?
- What can be done to further engage industry and support communities (including indigenous societies) to develop and undertake cetacean-sustainable activities?
- How will current and predicted environmental changes (including climate change and anthropogenic pollution) affect cetacean ranges, habitat use, health, including through changes in the distributions of human activities (e.g. increase in Arctic shipping and drilling)?
- At what point do sub-lethal impacts compromise the viability of a cetacean population?
- How do we quantify multiple, cumulative, and synergistic impacts? To what degree are cetaceans able to habituate, cope, tolerate, or adapt? Does removing certain stressors increase resilience to those that remain?

The questions provide a road map for conservation research necessary to help manage and protect cetaceans.

(SOURCE: Parsons, E.C.M., Baulch, S., Bechshoft, T., Bellazzi, G., Bouchet, P., Cosentino, A.M., Godard-Codding, C.A.J., Gulland, F., Hoffmann-Kuhnt, M., Hoyt, E., Livermore, S., MacLeod, C.D., Matrai, E., Munger, L., Ochiai, M., Peyman, A., Recalde-Salas, A., Regnery, R., Rojas-Bracho, L., Salgado-Kent, C.P., Slooten, E., Wang, J.Y., Wilson, S.C., Wright, A.J, Young, S., Zwamborn, E., and Sutherland, W.J. 2015. Key research questions of global importance for cetacean conservation. *Endang. Spec. Res.* 27: 113-118)

Key research questions of global importance for marine species conservation

A workshop at the 3rd International Marine Conservation Congress developed a list of urgent research questions that would aid marine conservation globally. Some examples of these research questions include:

Climate change

- What attributes of species (e.g. tropical or temperate, sessile or motile) make them particularly sensitive to stressors attributable to climate change?

Disease

- Which strategies can be used to mitigate and manage the effects of the spread of existing and emergence of new marine pathogens?

Noise

- To what extent and in which ways does anthropogenic noise affect marine fauna at the population level, particularly species that depend heavily upon sound, and how do impacts accrue over time and space?

Shipping

- How can the negative impacts of shipping on marine species and ecosystems (e.g. disturbance to sensitive habitat areas, output of CO_2 and black carbon, underwater noise, and the release of other pollutants during construction and operations) be reduced and public awareness of such impacts be elevated?

Chemical pollution and marine debris

- How should novel and emerging marine contaminants be regulated even if their impacts and conservation implications are not fully understood?

Bycatch

- How can the impacts of bycatch from legal and illegal, unreported, and unregulated (IUU) fisheries be reduced to a level that will allow the reversal of declining trends of affected species?

Cumulative impacts

- What are the best ways to estimate, evaluate, and manage cumulative impacts and multiple anthropogenic stressors in the marine environment?

(SOURCE: Parsons, E.C.M., Favaro, B., Draheim, M., McCarthy, J.B., Aguirre, A.A., Bauer, A.L., Blight, L.K., Cigliano, J.A., Coleman, M.A., Côté, I.M., Fletcher, S., Foley, M.M., Jefferson, R., Jones, M.C., Kelaher, B.P., Lundquist, C.J., Nelson, A., Patterson, K., Walsh, L., Wright, A.J., and Sutherland, W.J. 2014. 71 important questions for the conservation of marine biodiversity. *Conserv. Biol.* 28: 1206-1214)

Whales help shape marine ecosystems

Whales once played a significant role in shaping marine ecosystems due to their large populations and high energy demands; the authors refer to them as 'ecosystem engineers'. These roles included—beyond being important predators and prey—promoting plankton growth by moving nutrients from depth to the surface (where plankton grows) and from feeding areas to calving areas. Moreover, whales shift carbon to the deep sea when they die and their carcasses serve as a habitat for many specialized invertebrates. The decline in overall whale numbers (by 66-90%) from commercial whaling probably altered the structure and function of the oceans. The authors conclude that, as whale populations increase, many of these structures and functions may be restored.

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

Risk of extinction for marine organisms as high as for terrestrial species

It has long been thought that human activities have had less impact in the marine than in the terrestrial environment. This is in part because only 19-24 of 850 recorded extinctions involved marine species. A new study of global extinction risk, however, reveals that this is a misconception, partly due to the different proportion of species that have been assessed by the IUCN. Correcting for this disproportion and focusing on species for which sufficient taxonomic data and conservation assessments are available shows that one in every four or five marine species is at a heightened risk of extinction. This is the same value as for land-living plants and animals.

(SOURCES: Webb, T.J. and Mindel, B.L. 2015. Global patterns of extinction risk in marine and non-marine systems. *Curr. Biol.* 25: 506-511; News: *Mar. Pollut. Bull.* 92:7)

Pollution and ocean acidification

On one hand, pollutants and eutrophication promote ocean acidification. On the other, ocean acidification increases the toxicity of heavy metals and reduces the degradation of organic pollutants. This paper reflects a wider attempt to understand how various threats can act synergistically, i.e. can multiply the impacts of individual threats beyond a mere additive accumulation of threats. This information is relevant to cetaceans because increasing the bioavailability of heavy metals and other pollutants would mean higher concentrations in their tissues, and strengthened acidification would lead to a decline of various shell-producing plankton species at the base of their food web.

(SOURCE: Zeng, X., Chen, Xijuan, and Zhuang, J. 2015. The positive relationship between ocean acidification and pollution. *Mar. Pollut. Bull.* 91: 14-21)

Only a third of global fisheries are biologically healthy

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

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

Whale diet responds to, and whale skin reflects, variable ocean conditions

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

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

Sperm whales reduce foraging and time at surface in response to research 'tagging' vessel

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

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

Current marine protected areas poorly represent biodiversity

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

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

Cetaceans help determine the 'state of the cetacean environment'

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

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

Disturbance during pregnancy could lead to loss of gray whale calves

The actual effects of anthropogenic disturbance are often hard to quantify, but there has been some progress with estimating the bioenergetic impacts of such disturbances. A model was created for a female gray whale over a two-year reproductive cycle with three disturbance scenarios. The authors reported that a 4% energetic loss during the year of pregnancy would result in the female not producing a calf. During lactation if the female experienced a 37% energetic loss, the female would wean the calf early, with the calf having a lower-than-average body mass. If the female experienced

a 30-35% energy loss pre-pregnancy, she would be unable to become pregnant, and a 40-42% energy loss could lead to female mortality. The study found that energy loss due to disturbance could lower reproductive success and even cause mortality, with reduced reproductive rates after just a small energy loss (4%) during the year of pregnancy. In short, 10 days of lost foraging opportunities, due to disturbance, from e.g. noise or climate-related effects, could result in an unsuccessful pregnancy/loss of a calf.

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

Monitoring whale health via drones

A small hexacopter drone was used to collect the blow from humpback whales off the east coast of the USA. Genetic analysis of the blow samples allowed identification of an array of microbes, identifying the normal microbial flora of the whale respiratory tract. No known respiratory pathogens were detected. This new technique allows the non-invasive monitoring of the respiratory health of whales.

(SOURCE: Apprill, A., Miller, C.A., Moore, M.J., Durban, J.W., Fearnbach, H., and Barrett-Lennard, L.G. 2017. Extensive core microbiome in drone-captured whale blow supports a framework for health monitoring. *mSystems* 2: e00119-17, *https://doi.org/10.1128/mSystems.00119-17*)

Global threat maps for marine mammals

More than 1780 publications (published between 1991 and 2016) were reviewed to determine the threats to 121 marine mammal species. From these data, risk maps were produced and compared with mapped distributions of marine mammals. Almost all species were reported to be facing at least one threat. Bycatch had the greatest impact for the most species (112 species), followed by pollution (99 species), direct harvesting (89 species) and ship strikes (86 species). Threats such as urban development, tourism, directed catches and fishing affected more than 60 species. Threats were associated with more than 51% of marine mammal core habitat. Particular threat hotspots included the coastal waters of temperate and polar areas, notably the Baltic and Mediterranean Seas. Risk patterns for odontocetes and mysticetes were similar, with high-risk areas for both being concentrated on the east coasts of North America and Asia, with additional risk zones for mysticetes off the west coast of South America and off southern Australia. Humpback and sperm whales were exposed to the greatest area of risk, and common bottlenose dolphins were exposed to the highest diversity of risks. Species with restricted distributions had the greatest risks with respect to the proportion of their core habitat affected (e.g. Hector's, Heaviside's and Chilean dolphins, vaquita, franciscana and gray and North Atlantic right whales). The authors note that "human activities in coastal waters worldwide impose previously unrecognised levels of cumulative risk for most of marine mammal species". They also suggest that these risk maps might be useful for planning MPAs for marine mammals.

(SOURCE: Avila, I.C., Kaschner, K., and Dormann, C.F. 2018. Current global risks to marine mammals: Taking stock of the threats. *Biol. Conserv.* 221: 44-58)

Environmental changes and anthropogenic disturbance could have significant population-level effects

A model was constructed to investigate the effects of environmental changes and anthropogenic disturbances on the energetics of blue whales in the eastern North Pacific. The model predicted that unprecedented environmental changes (such as in 2005, when the annual California Current-induced upwelling was delayed by several months) affecting female reproductive success will cause a decline in recruitment rates (dropping from 95% to 69%), with reproductive failures increasing (aborted calf rate will increase from 2% to 26%). Modelling intense local disturbances (such as an exercise using naval sonar, seismic surveys or similar) revealed that if whales stayed in the disturbed location, the abortion rate for calves rose to 12.5% and the proportion of calves starving rose to 18.5%, with the recruitment rate dropping to 63%. Modelling a widespread but weak level of disturbance (such as from whale watching or shipping traffic) showed a small drop in recruitment rate (to 94%), partly because of a calf starvation rate of 0.2%, on average. This modelling exercise demonstrates the significant effect major environmental changes (from climate change, for example) or intense anthropogenic disturbances could have on threatened whale populations.

(SOURCE: Pirotta, E., Mangel, M., Costa, D.P., Mate, B., Goldbogen, J.A., Palacios, D.M., Hückstädt, L.A., McHuron, E.A., Schwarz, L., and New, L. 2018. A dynamic state model of migratory behavior and physiology to assess the consequences of environmental variation and anthropogenic disturbance on marine vertebrates. *Am. Nat.* 191(2): E40-E56, *https://doi.org/10.1086/695135*)

Habitat degradation

General

Pollution with faecal pathogens increasing in coastal waters

Much of the world's human population and our domesticated animals live along coastlines. Parasites, bacteria and viruses that are shed in the faeces of humans and animals enter coastal waters through sewage, storm-drains and as run-off. This is making contamination of coastal waters with terrestrially-derived faecal pathogens a chronic and increasingly global pollution problem. This threat is expected to increase as natural coastal habitats become degraded or replaced by human infrastructure. Climate change is also expected to exacerbate this problem, calling for reducing our 'faecal footprint'. This type of contamination has adverse effects on marine wildlife, including marine mammals.

(SOURCE: Shapiro, K. 2012. Climate and coastal habitat change: A recipe for a dirtier ocean. *Mar. Pollut. Bull.* 64: 1079-1080)

An evaluation of the environmental impacts of dredging on marine mammals

A review on the environmental impacts of dredging discussed the wide impacts this activity can have on the marine environment and marine mammals. While dredging vessels are slow, and thus make collisions with marine mammals unlikely, they produce broadband noise, mostly below 1 kHz. This has the potential to cause behavioural changes and mask communication calls, especially in baleen whales. For example, backhoe dredgers produce noise (bandwidth 3 Hz–20 kHz) at a source level of 179 dB re 1µPa @1m. Dredging produces sediment plumes, which may not physically affect cetaceans but could affect planktonic and benthic species. It could also affect important habitats such as sea grass beds by smothering them with sediment. Dredging can also liberate sequestered contaminants into the marine environment and cause short-term increases in nutrient availability. The great variability in dredging equipment implies variable impacts, which may also vary depending on the site being dredged. The authors conclude that the impacts on cetaceans are "most likely to be masking and short-term behavioural alterations and changes to prey availability".

(SOURCE: Todd, V.L.G., Todd, I.B., Gardiner, J.C., Morrin, E.C.N., MacPherson, N.A., DiMarzio, N.A., and Thomsen, F. 2014. A review of impacts of marine dredging activities on marine mammals. *ICES J. Mar. Sci.* 72: 328-340)

Landmark convention on ballast water entered into force in 2017

The IMO has crafted a convention that requires ships to manage their ballast water to remove, render harmless or avoid the uptake or discharge of aquatic organisms and pathogens with ballast water and sediment. The goal is to avoid the spread of invasive species, which is threatening "the ecological and economic well-being of the planet". These clear and robust new standards require all ships to carry a ballast water record book and an International Ballast Water Management Certificate. Most ships will have to install onboard systems to treat ballast water and eliminate unwanted organisms. The entry into force involved ratification by 30 States (total 52 contracting Parties), representing 35% of world merchant shipping tonnage. This is an important step forward in checking the spread of, amongst others, harmful algae that cause mass mortalities of marine organisms (e.g. fish kills), promote oxygen depletion, and affect all levels of the food chain, including cetaceans.

(SOURCE: The Maritime Executive. Ballast water convention to enter into force in 2017, *https://www.maritime-executive.com/article/ballast-water-convention-to-enter-into-force-in-2017#gs.nb0nIE8*)

Fisheries interactions

Entanglement in fishing gear is a cause of mortality and severe injury for several whale species

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

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

New insights into fishing gear entanglement of cetaceans

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

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

Ghost gear entanglement of cetaceans worldwide

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

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

The energetic costs of entanglement cause population-level impacts

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

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

Fisheries discards remain a gobal issue

A global marine fisheries bycatch reconstruction project estimated that fish discarded by commercial fisheries peaked at 18.8 million tons in 1989, declining afterward to current levels of less than 10 million tons/year. Most discards were generated by industrial (i.e. large-scale) fisheries. More recently, fleets operating in northwest Pacific and western central Pacific waters have generated the most discards (reflecting a shift from Atlantic waters). The fact that essentially marketable species are involved suggests "a combination of poor fishing practices and poor management procedures". The discards amount to approximately 10% of the world's marine fishery catches, pointing to a major, wasteful exploitation that potentially affects the entire marine ecosystem, including top predators such as cetaceans.

(SOURCE: Zeller, D., Cashion, T., Palomares, M., and Pauly, D. 2017. Global marine fisheries discards: A synthesis of reconstructed data. *Fish and Fisheries* 19: 30-39, *https://doi.org/10.1111/faf.12233*)

Marine debris

Marine debris: Pervasive in the sea and dominating the literature on marine pollution

Marine debris is such an intensifying threat that it is coming to dominate the publications in the field of marine pollution. A review of the literature as it pertains to cetaceans reveals that ingestion of debris has been documented in 48 (56% of) species. Rates of ingestion peaked at 31% in some populations. Debris-induced mortality rates of up to 22% of stranded animals were documented. Plastic constituted most of the debris ingested. There is a high prevalence of debris interactions, and the authors call upon cetacean stranding networks to collect and publish such data on a species level.

(SOURCE: Baulch, S. and Perry, C. 2014. Evaluating the impacts of marine debris on cetaceans. *Mar. Pollut. Bull.* 80: 210 - 221, *http://dx.doi.org/10.1016/j.marpolbul.2013.12.050*)

New approaches to detecting lost fishing gear

Derelict fishing gear (DFG) poses a threat to marine ecosystems (and safe navigation). It is a key item in the cetacean entanglement problem and requires a multi-disciplinary approach. A special journal issue was devoted to the early, at-sea detection of such gear, the goal being pre-emptive removal. Three disciplines are addressed: oceanography, remote sensing and marine debris. The main conclusions drawn in these disciplines are that 1) DFG concentrations can be modelled, substantially reducing the search area and improving at-sea detection efficiency; 2) the only known attempt to use unmanned aircraft systems, whose instruments can detect DFG poorly visible to the human eye, proved to be unsuccessful but provided information for future attempts; and 3) marine debris removal is much less costly than the long-term impacts of ghost fishing.

(SOURCE: McElwee, L., Morishige, C., and Donohue, M. (eds.) 2012. At-sea detection of derelict fishing gear. *Mar. Pollut. Bull.* 65: 1-75)

First study to show microplastics in a baleen whale

Although macroplastics have often been documented in the digestive tracts of whales, this is the first report of ingested microplastics. The intestines of a humpback whale stranded in the Netherlands contained several polymer types, including polyethylene, polypropylene, polyvinylchloride and nylon in varying particle shapes (sheets, fragments and threads). The specific effects of microplastics in cetaceans have not yet been studied, but the larger surface-to-volume ratio compared to macroplastics and the leaching of chemicals from plastics, as reported in other marine organisms, calls for better reporting of microplastic occurrence in whales and further research into potential impacts.

(SOURCE: Besseling, E.-, Foekema, E.M., Van Franeker, J.A., Leopold, M.F., Kühn, S., Bravo Rebolledo, E.L., Heße, E., Mielke, L., IJzer, J., Kamminga, P., and Koelmans, A.A. 2015. Microplastic in a macro filter feeder: humpback whale *Megaptera novaeangliae*. *Mar. Pollut. Bull.* 95: 248-252, *http://dx.doi.org/10.1016/j.marpolbul.2015.04.007*)

Plastic marine debris remains a growing issue

Numerous recent publications underline the increasing recognition of the threat that plastic debris poses in the marine environment. An overview of the impact of debris on marine life (Gall and Thompson) reports that 340 papers have been published on encounters between organisms and marine debris, involving 693 species. At least 17% of the species were listed as threatened or near threatened. One editorial (Moore) outlines the history of the problem and provides a 9-point list of issues that need to be clarified, including an initial report of efforts to recycle stranded marine debris. Another paper (Gonzalez Carman *et al.*) presents a range of legal and institutional tools, along with a framework and practical suggestions, to mitigate the effect of plastic pollution on marine species, using Argentina as an example. The entanglement and ingestion threat posed to cetaceans is outlined in detail in Baulch and Perry (2014) (see SC/65b/E01).

(SOURCES: Gall, S.C. and Thompson, R.C. 2015. The impact of debris on marine life. *Mar. Pollut. Bull.* 92: 170-179; Gonzalez Carman, V., Machain, N., and Campagna, C. 2015. Legal and institutional tools to mitigate plastic pollution affecting marine species: Argentina as a case study. *Mar. Pollut. Bull.* 92: 125-133; Moore, C.J. 2015. How much plastic is in the ocean? You tell me! *Mar. Pollut. Bull.* 92: 1-3)

Marine plastic debris could increase tenfold by 2025

The total amount of plastic waste produced by 192 coastal countries was calculated for the year 2010 to be 275 million metric tons. Of this, an estimated 4.8 to 12.7 million metric tons went into the ocean. The quality of waste treatment and population size of the respective country were the two major factors determining how much waste entered the oceans to become plastic marine debris. The researchers warned that "without waste management infrastructure improvements, the cumulative quantity of plastic waste available to enter the ocean from land is predicted to increase by an order of magnitude by 2025".

(SOURCE: Jambeck, J.R., Geyer, R., Wilcox, C., Siegler, T.R., Perryman, M., Andrady, A., Narayan, R., and Law, K.L. 2015. Plastic waste inputs from land into the ocean. *Science* 347: 768- 771)

Research priorities to address the problem of marine debris

A group of experts on the impacts of debris on marine species developed a list of urgent research questions to address the problem of marine plastics. Marine plastics are a major component of marine debris and have been highlighted as a substantive threat for cetaceans. Some examples of these research questions include:

- What are the impacts of plastic pollution on the physical condition of key marine habitats?
- What are the impacts of plastic pollution on trophic linkages?
- What are the species-level impacts of plastic pollution, and can they be quantified?
- What are the population-level impacts of plastic pollution, and can they be quantified?
- What are the impacts of wildlife entanglement?
- What, and where, are the main sources of plastic pollution entering the marine environment?
- What are the alternatives to plastic?

(SOURCE: Vegter, A.C., Barletta, M., Beck, C., Borrero, J., Burton, H., Campbell, M.L., Eriksen, M., Eriksson, C., Estrades, A., Gilardi, K., Hardesty, B.D., Ivar do Sul, J.A., Lavers, J.L., Lazar, B., Lebreton, L., Nichols, W.J., Ribic, C.A., Ryan, P.G., Schuyler, Q.A., Smith, S.D.A., Takada, H., Townsend, K.A., Wabnitz, C.C.C., Wilcox, C., Young, L., and Hamann, M. 2014. Global research priorities to mitigate plastic pollution impacts on marine wildlife. *Endang. Spec. Res.* 25: 225-247)

Microplastics: a new hot topic in marine research

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

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

Microplastics found in the intestines of a humpback whale

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

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

More plastic than fish in the world's oceans in the near future

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

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

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

According to an IUCN report, tire particles and the fibres from clothing made of synthetic materials may contribute up to

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

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

Marine debris recognised and addressed by highest international organisation

Marine debris has been recognised as a crucial issue by the UN Environment Assembly, which seeks by 2025 to "prevent and significantly reduce marine pollution of all kinds, in particular from land-based activities, including marine debris and microplastics". The recent actions related to this 'Sustainable Development Goal 14' include a 2017 commitment by Member States to the 'Our Ocean, Our Future: Call for Action' declaration, as well as the 'Group of 20 Action Plan on Marine Litter', also adopted in 2017. The UN Environment Assembly has, amongst eight other points of action, invited the "relevant international and national organizations and conventions…to increase their action to prevent and reduce marine litter and microplastics and their harmful effects and to coordinate where appropriate to achieve that end". The first meeting of the Ad Hoc Open-Ended Expert Group on Marine Litter and Microplastics will be held in late May 2018 in Nairobi, Kenya, and the ministers of all Member States are invited to submit position papers.

(SOURCE: Marine litter and microplastics. United Nations. UNEP/EA.3/Res.7. 2018)

Ship strikes

New method to help detect ship strikes as the cause of death in cetaceans

Recording the number of cetacean deaths due to non-natural causes is an important task at the IWC, and ship strikes are a key recognized threat. Examinations of 13 stranded cetaceans with sharp trauma from ship strikes showed that muscle samples from elsewhere on the carcass (i.e. not at the injury site) also revealed a series of relevant microscopic changes. This histopathological approach provides additional criteria to help determine ship strikes as the cause of death in animals that are in an advanced stage of decomposition or where access to the entire animal is limited.

(SOURCE: Sierra, E., *et al.* 2014. Histopathological muscle findings may be essential for a definitive diagnosis of suspected sharp trauma associated with ship strikes in stranded cetaceans. *PLoS One* 9 (2): 1-8: e88780)

Water layering in the summer increases collision risk from shipping in sperm whales

Stratification of water layers (especially in warm waters) can dramatically affect underwater sound transmission. A modelling exercise examined noise level exposure of sperm whales to an approaching merchant vessel (15 knots) and a fast ferry (37 knots) in Mediterranean waters. The model found that received levels of noise generally were low, but increased dramatically when vessels were in close proximity, and this was exacerbated in summer months when waters were stratified. Sperm whales were estimated to have just 28 seconds' warning of the approach of a fast ferry in summer (due to the sudden increase in sound level), making the ability to conduct an avoidance manoeuvre unlikely (70 seconds in winter). For a merchant vessel, the possible response time was 175 seconds in winter and 70 seconds in summer. To decrease collision likelihood, the authors recommended that shipping lanes avoid high densities of cetaceans, but "speed limitation in whale high density areas remains an obvious way to augment the vessel's ability to avoid a collision and is also efficient at providing the whale with enough time to escape an imminent collision".

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

The diving behaviour of blue whales in response to shipping increases the risk of ship strikes

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

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

Real time alerts for mariners might be a feasible way to avoid whale collisions

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

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

Mandatory ship reporting system for Atlantic right whales deemed successful

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

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

Chemical pollution

Sperm whales used to indicate global lead pollution

Heavy metals, including lead, are a key marine pollutant. Sperm whales were used as an indicator species to assess oceanic lead pollution globally. They are suitable because they are distributed worldwide, long-lived and positioned at the end of the food chain, where higher concentrations are expected due to bioaccumulation. Three hundred and thirty-seven (337) skin biopsies were collected from animals around the world, including 35 from the Atlantic. Lead concentrations in skin reflect recent exposure because the half-life of lead in soft tissues is only a few weeks or months. This was the first global toxicological dataset for lead in a marine mammal and confirmed that lead is widely distributed, with hotspots in some regions (e.g. Papua New Guinea, Bahamas, Australia). The authors expect lead concentrations in other organs to be higher than that found in skin.

(SOURCE: Savery, L.C., *et al.* 2014. Global assessment of oceanic lead pollution using sperm whales (*Physeter macrocephalus*) as an indicator species. *Mar. Pollut. Bull.* 79: 236-244)

Whale earplug reveals lifetime history of contaminant exposure

In a new approach, an earplug taken from a blue whale killed by a ship strike off Santa Barbara, California, revealed information about the lifetime profiles (i.e. from birth to death) of exposure to organic contaminants (pesticides and flame retardants) and mercury. There was a transfer of contaminants to this whale from its mother early in life and two distinct pulses of mercury contamination. The recognition that earplugs chronologically archive pollutant and hormone levels provides a new approach to measuring environmental stress. In this case, hormone levels revealed a doubling of stress over the animal's lifetime and enabled determination of the time to sexual maturity. Combined with similar studies on earplugs of museum samples, this increases the feasibility of accurately assessing anthropogenic impacts on scales ranging from an individual whale to the marine ecosystem.

(SOURCE: Trumble, S.J., Robinson, E.M., Berman-Kowalewski, M., Potter, C.W., and Usenko, S. 2013. Blue whale earplug reveals lifetime contaminant exposure and hormone profiles. *PNAS* 110: 16922-16926)

Pollutant levels in dolphin population can vary by land use and watershed

A study investigating contaminant levels in dolphins found major differences in burdens between dolphins inhabiting two adjacent watersheds. A population in a developed watershed exhibited higher PCBs and PBDEs levels than one inhabiting a watershed with predominant wetland. Thus, there can be major differences in contaminant signatures at the watershed

level, and land-use patterns in watersheds can affect contaminant levels in dolphin populations.

(SOURCE: Adams, J., Speakman, T., Zolman, E., Mitchum, E., Bossart, G., and Fair, P. 2014. The relationship between land use and emerging and legacy contaminants in an apex predator, the bottlenose dolphin (*Tursiops truncatus*), from two adjacent estuarine watersheds. *Environ. Res.* 135: 346-353)

Long-term concentrations of organic contaminants in marine mammals show mixed trends

Marine mammals bioaccumulate certain pollutants to high concentrations over their lifetimes, especially organic contaminants that are lipophilic. A worldwide analysis of the literature from 2008 to 2014 showed both upward and downward trends depending on the substance. Thus, some contaminants whose use has been regulated and restricted showed decreased amounts in tissues (e.g. organochlorine pesticides, PBDE, HBCD, butyltins). The trends for perfluorinated compounds are more mixed. For PCBs, whose use has been widely controlled since the 1980s, an earlier downward trend appears to have stalled; their concentrations in harbour porpoise in the UK, for example, remain at toxicologically significant levels. This raises concerns for killer whales and bottlenose dolphins, for example, due to their larger size and greater bioaccumulation potential. The authors caution that restrictions on certain brominated flame retardants mean that the use of other brominated, chlorinated and phosphorus flame retardants will increase. Moreover, new compounds—with currently unknown potential impact—are still being detected in marine mammal tissues. Finally, some 'legacy' organic pollutants such as DDT continue to exert effects, calling for further efforts to reduce their inputs.

(SOURCE: Law, R.J. 2014. An overview of time trends in organic contaminant concentrations in marine mammals: Going up or down? *Mar. Pollut. Bull.* 82: 7-10)

The movement of mercury through the oceans and anthropogenic inputs

A three-dimensional model simulated the movement of mercury through water and ocean systems, atmosphere, rivers, and oceans. Examining a time when anthropogenic activities had major impacts (e.g. during the 15th century), the model indicated that mercury remains in the water for an average of 2000 years before becoming embedded in sediment. The model predicted that mercury levels in the deep north Pacific "are a factor of 2-3 higher than in the deep north Atlantic Ocean", because the movement of oceanic waters transfer mercury from the north Atlantic to the north Pacific. Anthropogenic inputs of mercury result in levels 5-6 times higher than predicted natural levels.

(SOURCE: Zhang, Y., Jaeglé, L., and Thompson, L. 2014. Natural biogeochemical cycle of mercury in a global three-dimensional ocean tracer model. *Glob. Geochem. Cycles* 28: 553-70)

Flame retardants found in dolphin brain tissue at higher levels than expected

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

(SOURCE: Barón, E., Hauler, C., Gallistl, C., Giménez, J., Gauffier, P., Castillo, J.J., Fernández-Maldonado, C., de Stephanis, R., Vetter, W., Eljarrat, E., and Barcelo, D. 2015. Halogenated natural products in dolphins: Brain-blubber distribution and comparison with halogenated flame retardants. *Environ. Sci. Technol.* 49: 9073-9083)

Determining contaminant levels that impair marine mammal immune systems

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

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

Heavy metal pollution may promote skin fungus in cetaceans

Cetaceans, positioned at the top of the food chain, typically accumulate the highest level of toxic pollutants such as heavy metals. The most widely used non-invasive method to test cetaceans is to analyse skin samples. The authors used skin biopsies from 40 false killer whales mass-stranded on South Africa's Cape Peninsula. They report a link between the occurrence of fungus (128 species in 22 skin samples) and higher aluminium:selenium and aluminium:zinc ratios. The conclusion is that elevated levels of some toxic metals such as aluminium can compromise the immune response of cetaceans, rendering them susceptible to fungal invaders. This supports the approach of using cetacean skin to monitor the bioaccumulation of trace elements and provide an indication of animal and ecosystem health.

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

Radioactive contamination from Fukushima disaster detected in Japanese cetaceans

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

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

Marine mammal toxicology entering a new era

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

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

Disease and mortality events

Direct exploitation

Human consumption of cetaceans

Based on 900 sources of information, the authors of this study determined that people from at least 114 countries have consumed one or more of at least 87 marine mammal species. These include less well-known species such as the pygmy beaked whale, South Asian river dolphin, narwhal, Chilean dolphin, long-finned pilot whale and Burmeister's porpoise. Overall the historical review reveals an increase in the exploitation of small cetaceans, particularly coastal and estuarine species. Many are caught in conjunction with fishing activities, whereby 'non-targeted-deliberate' acquisition is cause for serious concern. A greater understanding of the underlying motivations is required to design and implement more effective conservation measures, especially because most takes are in countries with little or no assessment of marine mammal populations.

(SOURCES: News. 2012. *Mar. Pollut. Bull.* 64: 459-461; Robards, M.D. and Reeves, R.R. 2011. The global extent of marine mammal consumption by humans: 1970-2009. *Biol. Conserv.* 144: 2770-2786)

Stress

The sublethal effects of capture

A review of marine bycatch papers determined that there were many possible sublethal effects of capture (i.e. bycatch), even if animals are released alive. These include physiological disturbance, behavioural impairment, injury, reflex impairment, and effects on reproduction (such as miscarriages in dolphins), feeding, and growth for animals that survived a fisheries interaction. Some of these sublethal impacts could be short-term (e.g. acute stress response) or could be long-term or even delayed sublethal outcomes (e.g. reduction in growth or reproduction) and are thus "directly fitness-relevant and could have had population-level effects". The authors called for more research into the effects of capture stress on reproduction in particular. They note that to date the sublethal effects of bycatch have mostly been ignored, but they could have major conservation and management repercussions. This could certainly be the case for cetaceans that were captured either accidentally (in active and ghost fishing gear) or deliberately (for research purposes).

(SOURCE: Wilson, S.M., Raby, G.D., Burnett, N.J., Hinch, S.G., and Cooke, S.J. 2014. Looking beyond the mortality of bycatch: sublethal effects of incidental capture on marine animals. *Biol. Conserv.* 171: 61–72)

Harmful algal blooms (HABs)

Do some bottlenose dolphins have a genetic resistance to harmful algal bloom toxins?

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

(SOURCE: Cammen, K.M., Schultz, T.F., Rosel, P.E., and Wells, R.S. 2015. Genomewide investigation of adaptation to harmful algal blooms in common bottlenose dolphins (*Tursiops truncatus*). *Molec. Ecol.* 24: 4697-4710)

Elevated southern right whale calf mortality over last decade probably due to harmful algal blooms

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

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

Harmful algal blooms and climate change: An emerging issue

Of the 4000 known species of marine phytoplankton, about 300 have properties that make them harmful to humans (e.g. causing neurological disorders) and the marine environment (e.g. causing oxygen crises, fish kills). In a project sponsored by SCOR and IOC of UNESCO, experts are seeking to improve our understanding of, and promote cooperation/partnerships on, the issue of HABs and the role climate change may be playing. This project (GlobalHAB) will help coordinate research and promote communication between scientists and society. HABs have been identified as a threat to cetaceans by the Committee and are the topic of a pre-meeting at SC67a.

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

Toxic algal blooms on the rise in northern hemisphere

High-resolution sea-surface temperature records over the last three decades were used to model the trends in HABs in the North Atlantic and North Pacific Oceans. The model shows that increasing ocean temperatures have facilitated the expansion of two harmful dinoflagellates, *Alexandrium fundyense*, which produces saxitoxin (causing paralytic shellfish poison in humans) and *Dinophysis acuminata*, which produces okadaic acid (causing diarrheic shellfish poisoning in humans). The temperature effect meant increased growth rates of these organisms and increased durations of HAB events (bloom season). Beyond the human health threat, HABs also affect ecosystems (e.g. fish kills) and cetaceans. The authors predict that continued ocean warming will "promote the intensification and redistribution of these, and likely other HABs,

around the world".

(SOURCE: Gobler, C.J., Doherty, O.M., Hattenrath-Lehmann, T.K., Griffith, A.W., Kang, Y., and Litaker, R.W. 2017. Ocean warming since 1982 has expanded the niche of toxic algal blooms in the North Atlantic and North Pacific Oceans. *PNAS*. 201619575, *https://doi.org/10.1073/pnas.1619575114*)

Oil spills

Ecosystem impacts of the *Deepwater Horizon* oil spill

The *Deepwater Horizon* oil spill introduced over 518 million litres of oil into the Gulf of Mexico marine ecosystem. A wide range of impacts have been reported, including greater marsh erosion (due to an increase in 'oil-eating' bacteria and root damage); fewer acrobat ants and marsh periwinkles; increased mortality rates and slower growth in eastern oyster larvae; and fewer chicks and nests built by seaside sparrows. Gulf killifish showed genetic evidence of exposure to toxic chemicals, although population numbers did not change, while thousands of brown pelicans died (again, no change in population numbers). Paradoxically, shrimp populations increased in oiled areas. Oil sank to the sea floor over more than 3200 km^2, an area roughly the size of Rhode Island. Near the wellhead, patches of coral were apparently killed or damaged by the oil. The diversity of benthic invertebrates decreased up to 17 km from the centre of the spill. Impacts on dolphin health in Barataria Bay, Louisiana, were reported in SC/65b/E01. An analysis of stranding patterns during the unusual mortality event (UME) found the highest values ever recorded in Louisiana in 2010-11, with high levels in 2011 for both Mississippi and Alabama. Stranding rates on the coast of Florida and Texas were not elevated during this period. Mortalities were clustered with this UME, with increased strandings in northern Louisiana and Mississippi (Mar-May 2010); Barataria Bay, Louisiana (Aug 2010-Dec 2011); Mississippi and Alabama (2011); and multiple locations around the Gulf of Mexico in early 2013. The total ecosystem impact of the spill still needs to be ascertained, but was extensive. Note that the Gulf is also the world's largest eutrophication-related 'dead zone', underlining the cumulative threats of multiple sources of pollution.

(SOURCES: Cornwall, W. 2015. Five years after the *Deepwater Horizon* disaster, scars linger. *Science* 348: 22-29; Schwacke, L.H., Smith, C.R., Townsend, F.I., Wells, R.S., Hart, L.B., Balmer, B.C., Collier, T.K., De Guise, S., Fry, M.M., Guillette, Jr., L.J., Lamb, S.V., Lane, S.M., McFee, W.E., Place, N.J., Tumlin, M.C., Ylitalo, G.M., Zolman, E.S., and Rowles, T.K. 2014. Health of common bottlenose dolphins (*Tursiops truncatus*) in Barataria Bay, Louisiana, following the *Deepwater Horizon* oil spill. *Environ. Sci. Tech.* 48: 93-103; Venn-Watson, S., Garrison, L., Litz, J., Fougeres, E., Mase, B., Rappucci, G., Stratton, E., Carmichael, R., Odell, D., Shannon, D., Shippee, S., Smith, S., Staggs, L., Tumlin, M., Whitehead, H., and Rowles, T. 2015. Demographic clusters identified within the Northern Gulf of Mexico common bottlenose dolphin (*Tursiops truncates*) [sic] unusual mortality event: January 2010-June 2013. *PLOS One*: doi: 10.1371/journal.pone.0117248)

Comparison of the Gulf of Mexico mortality event to past mortality events

A study compared the number of dolphin strandings in the Gulf of Mexico UME to past mortality events. As of September 2014, more than 1000 mortalities had been reported (versus a maximum of 344 in a 1990 mortality event), and the event had lasted more than 48 months, compared to the previous longest event of 17 months (average UME event length = 6 months). Previous UMEs had been attributed to morbillivirus or brevetoxin exposure. Although this UME began before the *Deepwater Horizon* oil spill, the latter has been implicated in the former's persistence.

(SOURCE: Litz, J., Baran, M., Bowen-Stevens, S., Carmichael, R., Colegrove, K., Garrison, L.P., Fire, S.E., Fougeres, E.M., Hardy, R. Holmes, S., Jones, W., Mase-Guthrie, B.E., Odell, D.K., Rosel, P.E., Saliki, J.T., Shannon, D.K., Shippee, S.F., Smith, S.M., Stratton, E.M., Tumlin, M.C., Whitehead, H.R., Worthy, G.A.J., and Rowles, T.K. 2014. Review of historical unusual mortality events (UMEs) in the Gulf of Mexico (1990-2009): providing context for the multi-year northern Gulf of Mexico cetacean UME declared in 2010. *Disease Aq. Org.* 112: 161-175)

High calf mortality associated with *Deepwater Horizon* oil spill

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

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

Increased mortality and reduced calving rates in dolphins after *Deepwater Horizon* oil spill

After 47 months of monitoring 10 pregnant bottlenose dolphins exposed to the *Deepwater Horizon* oil spill, only 20% had produced calves (as compared to 83% in a comparison population). This lower calving rate was statistically significant. It was noted that 57% of the pregnant females that did not produce a calf showed signs of moderate to severe lung disease. In addition, the animals' survival rate was lower (86.8%) than the survival rates in comparable populations (e.g. 95.1% and 96.2%). The authors concluded that "evidence suggests that dolphin reproduction and survival is being impacted by chronic disease, indicating that the effects of the [*Deepwater Horizon*] oil spill have been long-lasting".

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

Bottlenose dolphin mortalities as a result of the *Deepwater Horizon* oil spill

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

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

***Deepwater Horizon* oil spill: An update**

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

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

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

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

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

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

Immune system responses in dolphins exposed to the *Deepwater Horizon* oil spill

To investigate the effect of the *Deepwater Horizon* oil spill on living common bottlenose dolphins in Barataria Bay, Louisiana, blood samples were analysed from live-captured animals. Potentially oil-exposed animals demonstrated an increase in T white blood cells (in 2011) and B white blood cells (in 2011 and 2013). Certain cytokine levels were notably different from levels in a control population (and perhaps indicative of bacterial infections by pathogens such as *Brucella* - one of the pathogens that was implicated in the high rate of young dolphin mortalities post-oil spill). The white blood cell responses were similar to "those documented in other species following exposure to oil or [polyaromatic hydrocarbons] and were most pronounced in [Barataria Bay in] 2011, at the place and time most affected by oil".

(SOURCE: De Guise, S., Levin, M., Gebhard, E., Jasperse, L., Hart, L.B., Smith, C.R., Venn-Watson, S., Townsend, F., Wells, R., Balmer, B., Zolman, E., Rowles, T., and Schwacke, L. 2017. Changes in immune functions in bottlenose dolphins in the northern Gulf of Mexico associated with the *Deepwater Horizon* oil spill. *Endang. Species Res.* 33: 291-303)

Oil-dispersant mix causes dolphin white blood cell suppression

The immunotoxicity of the oil released in the *Deepwater Horizon* oil spill and the chemical dispersant Corexit was examined by investigating dolphin white blood cell responses to exposure *in vitro*. Oil exposure caused a proliferation of white (T and B) blood cells, but exposure to the oil mixed with the dispersant led to a decrease. The authors conclude that "The immunosuppression of [lymphocyte cells] at environmentally relevant concentrations of oil and dispersant suggests that marine mammals may be unable to mount an adequate defence against xenobiotic threats following exposure to oil and dispersant, leaving them more susceptible to disease".

(SOURCE: White, N.A., Godard-Codding, C., Webb, S.J., Bossart, G.D., and Fair, P.A. 2017. Immunotoxic effects of in vitro exposure of dolphin lymphocytes to Louisiana sweet crude oil and Corexit™. *J. Appl. Toxicol.* 37: 676-682)

Climate change

Climate change predictions for the oceans

The most recent 2014 International Panel for Climate Change (IPCC) report deals with foreseen effects of climate change and allocates a level of confidence to the predictions therein. Many of the predictions are related to the ocean environment. The authors note that "Responding to climate-related risks involves decision-making in a changing world, with continuing uncertainty about the severity and timing of climate change", cautioning policy makers that decisions need to be made urgently even when many scientific factors remain uncertain.

(SOURCE: Field, F.B., *et al.* 2014. *Climate Change 2014: Impacts, Adaptation, and Vulnerability*. International Panel on Climate Change, Geneva)

Upwelling ceased in Weddell Sea polynya due to climate change

The Weddell Sea polynya, an area of open water the size of New Zealand, is formed by relatively warm salty water being pushed to the surface when passing over a ridge. It keeps the Weddell Sea ice free. Normally, after emitting heat, this upwelling water sinks to become a major source of Antarctic bottom water, and this movement is a major contribution to oceanic circulation. However, the polynya has recently been covered by a layer of low-density freshwater from melting glaciers and increased precipitation. The cessation of this upwelling has reduced the transport of heat, salt and ocean water

towards Antarctica, and will greatly impact ocean circulation as well as Antarctic productivity, a major habitat for Southern Hemisphere cetaceans.

(SOURCE: de Lavergne, C., Palter, J.B., Galbraith, E.D., Bernardello, R., and Marinov, I. 2014. Cessation of deep convection in the open Southern Ocean under anthropogenic climate change *Nat. Clim. Change.* doi:10.1038/nclimate2132)

Global atmospheric carbon dioxide levels reach 400ppm: Highest levels in human history

In February 2015, atmospheric carbon dioxide levels reached 400 ppm, the highest level recorded in human history. Levels have not been so high for at least 2 million years (23 million years according to other estimates). The levels were reported from 40 sampling sites at remote locations. Since the pre-industrial era, the atmospheric carbon dioxide level has risen by approximately 120 ppm, with half of that that rise occurring from 1980 onwards.

(SOURCES: Biello, D. 2015. CO2 levels for February eclipsed prehistoric highs. *Scient. Amer.*, March 5, *http://www.scientificamerican.com/article/co2-levels-for-february-eclipsed-prehistoric-highs*; NOAA. 2015. Trends in atmospheric carbon dioxide, *http://www.esrl.noaa.gov/gmd/ccgg/trends/global.html*; Franks, P.J., Royer, D.L., Beerling, D.J., Van de Water, P.K., Cantrill, D.J., Barbour, M.M., and Berry, J.A. 2014. New constraints on atmospheric CO_2 concentration for the Phanerozoic. *Geophys. Res. Lett.* 41: 4685-4694)

Global warming and anoxic events

While warming of ocean waters and ocean acidification have been widely discussed as two climate change impacts, ocean deoxygenation has gained less attention. Since the 1960s, the number of anoxic zones in coastal waters has doubled. Open ocean deoxygenation has also occurred, exacerbated by stratification of ocean waters due to warming and changing patterns of ocean circulation. In particular, there has been an extensive oxygen decline in the northeast Pacific in the tropical and subtropical oceans over the last 50 years. Excessive nutrient levels that lead to coastal anoxic events also worsen oceanic hypoxia by "increasing surface-layer production that ultimately fuels microbial respiration at depth". Intensified wind-driven upwelling, which is one effect of global warming, is also bringing low oxygen and low pH waters from the deep ocean to coastal regions, again exacerbating coastal anoxic events. This is having particular impact on the west coast of the US, coasts of Mexico and the Bay of Bengal. A second study examined existing 'dead zones' and predicted warming in these locations. The authors found that 94% of anoxic zones would likely experience at least a 2°C temperature increase by 2100. Various climate variables, including temperature, ocean acidification, sea-level rise, precipitation, wind, and storm patterns, will affect dead zones. Many of these factors are expected to work synergistically and promote hypoxia.

(SOURCES: Levin, L.A. and Breitburg, D.L. 2015. Linking coasts and seas to address ocean deoxygenation. *Nat. Clim. Change* 5: 401-403; Altieri, A.H. and Gedan, K.B. 2014. Climate change and dead zones. *Glob. Change Biol.* 21: 1395-1406)

The projected decrease in aerosol levels will greatly exacerbate Arctic warming

Aerosols play a part in modifying climate change, possibly reducing the effect of greenhouse-gas-induced warming by 1.3-2.2°C. This cooling effect is particularly prominent in the Arctic. Without this aerosol-linked cooling, the Arctic would be even warmer. Aerosol emissions are projected to decrease in coming decades. If greenhouse gas emissions continue as they are, the net effect will be an 8.3°C rise in Arctic temperatures by 2100. The authors warn that unless greenhouse gases are reduced drastically, Arctic warming will be more severe than expected.

(SOURCE: Najafi, M.R., Zwiers, F.W., and Gillett, N.P. 2015. Attribution of Arctic temperature change to greenhouse-gas and aerosol influences. *Nat. Clim. Change* 5: 246-249)

Loss of Antarctic ice is accelerating and irreversible

Floating ice sheets around Antarctica hold back ice on the land, like a fence (i.e. buttressing). If this sea ice is lost, land ice flows into the sea, adding to oceanic water volume and thus sea level. Eighteen years of satellite data revealed that average ice-shelf volume change accelerated from the decade 1994–2003 to the decade 2003–2012. Ice losses in the western Antarctic increased by approximately 70% over the past decade, and gains in eastern Antarctic ice shelves have now ceased. An 18% loss of thickness occurred for some ice shelves in the Amundsen and Bellingshausen regions in less than two decades. The authors state that "If the present climate forcing is sustained, we expect a drastic reduction in volume of the rapidly thinning ice shelves at decadal to century time scales, resulting in grounding-line retreat and potential ice-shelf collapse. Both of these processes further accelerate the loss of buttressing, with consequent increase of grounded-ice discharge and sea-level rise". A study in the Amundsen Sea Embayment of West Antarctica examined ice loss using four different methods. From 1992–2013, the ice mass loss was 83 ± 5 Gt/yr, with the rate accelerating at 6.1 ± 0.7 Gt/yr, but between 2003–2011, the mass loss was 102 ± 10 Gt/yr with an acceleration of 15.7 ± 4.0 Gt/yr. Thus the rate of ice loss was

not only accelerating, but the rate of acceleration was increasing. The authors conclude that "The comprehensive record, evaluated from multiple techniques, of mass loss in West Antarctica, produced here shows a tripling in mass loss in recent years". In eastern Antarctica the situation is also pessimistic. Surveys over the Totten glacier (90 x 22 miles) found two undersea troughs beneath the ice shelf, allowing warm, saline deep water to flow under the glacier and exacerbate the rate of melting and glacier flow. The Totten glacier holds back a catchment of ice that, if it were to flow into the sea, would on its own create a 3.5 m rise in sea level. The glacier is currently losing 150 km^3 of ice each year. A fourth study modelled ice loss patterns in the Antarctic assuming that carbon dioxide levels were returned to pre-industrial levels. The pattern of warming and heat uptake by Southern Ocean waters initially causes a slight recovery of ice extent, but then convection brings stored heat to the surface and causes "a substantial loss of sea ice". This lost ice does not recover even after 150 years at atmospheric carbon dioxide concentrations reduced to pre-industrial levels.

(SOURCES: Paolo, F.S., Fricker, H.A., and Padman, L. 2015. Volume loss from Antarctic ice shelves is accelerating. *Science* 348: 327-331; Sutterley, T.C., Velicogna, I., Rignot, E., Jeremie Mouginot, J., Flament, T., van den Broeke, M.R., vanWessem, J.M., and Reijmer, C.H. 2014. Mass loss of the Amundsen Sea Embayment of West Antarctica from four independent techniques. *Geophys. Res. Lett.* 41: 8421-8428; Greenbaum, J.S., Blankenship, D.D., Young, D.A., Richter, T.G., Roberts, J.L., Aitken, A.R.A., Legresy, B., Schroeder, D.M., Warner, R.C., van Ommen, T.D., and Siegert, M.J. 2015. Ocean access to a cavity beneath Totten Glacier in East Antarctica. *Nat. Geosci.* 8: 294-298; Ridley, J.K. and Hewitt, H.T. 2014. A mechanism for lack of sea ice reversibility in the Southern Ocean. *Geophys. Res. Lett.* 41: 8404-8410)

Antarctic ice sheets more vulnerable than previously thought

A three-dimensional modelling exercise has found that Antarctica's ice sheets may be more vulnerable to warming than previously thought. There are two new ways by which ice sheets might collapse: meltwater and rain can drain into crevasses in the ice, leading to vertical fractures, and/or the top of the sheets can break apart, leading to sheet collapse. The West Antarctic Ice Sheet could collapse much faster than previously predicted (in decades rather than centuries).

(SOURCE: Pollard, D., DeConto R.M., and Alley R.B. 2015. Potential Antarctic Ice Sheet retreat driven by hydrofracturing and ice cliff failure. *Earth Planet. Sci. Lett.* 412: 112-121)

Arctic sea ice is warming from below: An effect that will increase as ice is lost

Water temperatures measured at different depths and areas across the Arctic Ocean indicated that heat rose more quickly from areas above uneven areas of the seabed versus flatter seafloor. This rising of heat from certain locations could warm Arctic sea ice more quickly and result in even greater sea ice loss than expected. Shrinking Arctic sea ice would promote mixing, these warm water mixing hotspots would increase, and further melting would occur.

(SOURCE: Rippeth, T.P., Lincoln, B.J., Lenn, Y.-D., Mattias Green, J.A., Sundfjord, A., and Bacon, S. 2015. Tide-mediated warming of Arctic halocline by Atlantic heat fluxes over rough topography. *Nat. Geosci.* 8: 191-194)

Wind patterns and warm water upwelling exacerbate ice shelf loss in Antarctica

Hydrographic ocean data collected since 1975 show that, over the past 40 years, Circumpolar Deep Water (CDW) has warmed in all sectors around Antarctica. As a result, water flowing under Antarctic ice shelves has warmed in recent decades. Winds at the continental shelf break may also add to this process. This warm water is effectively melting the underside of ice sheets, undermining them and causing them to break up. In parts of Antarctica where warming and ice loss are occurring, CDW slopes upward to the shelf break, possibly as the result of wind-induced upwelling. In the Ross and Weddell Seas, where there is less shelf warming, CDW flows downwards, again possibly due to wind patterns. Thus, Antarctic winds can play a major role in promoting ice loss. Increased atmospheric warming and ozone depletion will probably intensify these winds. Future changes in wind patterns could, moreover, also subject the Ross and Weddell Seas to warm-water upwelling. The authors note that marine megafauna may have already experienced these warmer waters, notably in the Bellingshausen and Amundsen Seas, concluding that this warming will "lead to irreversible retreat of a portion of the West Antarctic Ice Sheet, which will have an impact on global sea level".

(SOURCE: Schmidtko, S., Heywood, K.J., Thompson, A.F., and Aoki, S. 2014. Multidecadal warming of Antarctic waters. *Nature* 346: 1227-1231)

Unprecedented rates of climate change reported

One of the concerns about observed climate change is its rapid rate and how that reduces the ability of ecosystems and human societies to adapt. The strong rate of increase was confirmed in a study that found that trends in greenhouse-gas and aerosol emissions are causing rates of change that "are unprecedented for at least the past 1,000 years". In particular, regional rates of change in Europe, North America and the Arctic are higher than the global average. The authors caution that "the world is now entering a regime where background rates of climate change will be well above historical averages

until at least mid-century" and "The accelerated rates of change noted here mean that impacts related to rates of change will intensify over the coming decades".

(SOURCE: Smith, S.J., Edmonds, J., Hartin, C.A., Mundra, A., and Calvin, K. 2015. Near-term acceleration in the rate of temperature change. *Nat. Clim. Change* 5: 333-336)

Extinction risk from climate change

A model estimating extinction rates from climate change predicted that the amount of climate change that has already occurred will ultimately cause 2.8% of species to go extinct. The international policy target of limiting global warming at present to 2°C will lead to 5.2% of species going extinct. However, current estimates predict that this policy target will be greatly exceeded. A 3°C level of warming will lead to 8.5% of species going extinct, and if the current 'business-as-usual' level of emissions is not reduced, it will lead to a 4.3°C rise and a 16% extinction rate. Extinction risks were highest in South America, Australia, and New Zealand and did not vary by taxonomic group. The author states "Extinction risks from climate change are expected not only to increase but to accelerate for every degree rise in global temperatures. The signal of climate change-induced extinctions will become increasingly apparent if we do not act now to limit future climate change".

(SOURCE: Urban, M.C. 2015. Accelerating extinction risk from climate change. *Science* 348: 571-573)

Loss of Arctic snowpack and record low level of winter sea ice

Spring snow depth in the Arctic was measured between 2009 and 2013 by airborne radar surveys and ground-truthed with surface measurements. These data were compared to 1954-1991 data from Soviet ice stations. Snow thickness had decreased by 37% in the western Arctic and by 56% in the Beaufort and Chukchi Seas. The lack of snow was considered to be due to later formation of Arctic sea ice, which reduces snow accumulation. As sea ice starts forming later each autumn, there is less time for snow to accumulate before winter sets in. In a second report, the National Snow and Ice Data Center wrote that the Arctic winter sea ice extent in February 2015 was the lowest since satellite measurements of the Arctic began in the 1970s: 50,200 miles^2 less than the previous record low in 2011.

(SOURCES: Webster, M.A., Rigor, I.G., Nghiem, S.V., Kurtz, N.T., Farrell, S.L., Perovich, D.K., and Sturm, M. 2014. Interdecadal changes in snow depth on Arctic sea ice. *J. Geophys. Res.: Oceans* 119: 5395-5406; Mooney, C. 2015. Arctic sea ice hit new low, data shows. *Wash. Post,* 20 March 2015: A3)

Failure to adapt fisheries management to climate change effects led to fish stock collapse

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

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

Longer ice-free seasons increase number of gray whale calves and El Niño influences breeding location

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

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

Predicted impacts of climate change on marine vertebrates

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

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

Temperature increases could reach levels not seen for 420 million years

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

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

Widespread movement of meltwater onto and across Antarctic ice shelves

Climate change exacerbating harmful algal blooms (HABs)

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

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

Record levels of carbon dioxide recorded

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

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

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

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

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

Arctic sea ice coverage reaches a record low

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

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

2016 was the hottest year on record

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

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

Larsen C ice shelf shows signs of imminent collapse

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

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

Collapse of the Western Antarctic ice sheet might be inevitable

As a result of climate change-related melting, warm seawater inundation underneath the ice sheet and shearing stresses, there are concerns that the Western Antarctic Ice Sheet will collapse. Satellite images indicate that there is currently a high level of seawater undermining the ice sheet, increasing this likelihood. At present, most moderate (and worst-case) climate change models predict the collapse of the ice sheet. This could lead to a 20 cm rise in sea level per decade by 2100, in addition to major associated Antarctic ecosystem changes.

(SOURCE: Hulbe. C. 2017. Is ice sheet collapse in West Antarctica unstoppable? *Science* 356: 910-911)

Climate change-induced reduction in krill biomass predicted

A study estimating the effects of ocean warming on krill biomass in the Scotia Sea (the northern part of the Antarctic Peninsula and adjacent areas to the northeast) noted considerable declines. In particular, krill biomass in the northern Scotia Sea could potentially decline by 40%. This would likely have impacts on Antarctic predators - for example, a decline in penguin abundance of 30% was predicted, and there was a high risk of these animals becoming depleted. The study also noted that if current krill fishing ceased immediately, the impacts on the krill population could be mitigated. Although in this model the impacts on mysticetes were slight in this particular region (there was an impact upon pinnipeds), this study nonetheless does project a decline in krill biomass and ecosystem change in at least part of the Southern Ocean because of climate change. This calls for an investigation of the impacts of krill biomass reduction in regions more critical for mysticetes.

(SOURCE: Klein, E.S., Hill, S.L., Hinke, J.T., Phillips, T., and Watters, G.M. 2018. Impacts of rising sea temperature on krill increase risks for predators in the Scotia Sea. *PLoS ONE* 13(1): e0191011, 1-21)

Major decrease in biological productivity predicted due to climate change

A new study predicted that fish populations may decline by as much as 20% globally and 60% in the North Atlantic due

to a decline in ocean mixing, a result of climate change. The model assumes a 'business-as-usual' scenario, i.e. carbon emissions continue at the same rate as present. In particular, a combination of changing winds and warmer upper waters in the Southern Ocean will cause more nutrients to sink into the deeper layer of the ocean and become trapped there, substantially decreasing the productivity of Antarctic waters. The authors suggest that these changes could mean that fisheries will be reduced for a thousand years or more. This will have major impacts on the prey base of cetaceans.

(SOURCE: Moore, J.K., Fu, W., Primeau, F., Britten, G.L., Lindsay, K., Long, M., Doney, S.C., Mahowald, N., Hoffman, F., and Randerson, J.T. 2018. Sustained climate warming drives declining marine biological productivity. *Science* 359: 1139-1143)

Record levels of atmospheric carbon dioxide levels recorded

Atmospheric carbon dioxide levels exceeded 410 ppm in March 2018, the highest levels ever recorded in human history. Predicted levels in carbon dioxide will likely exceed 412 ppm in May 2018, which is 47% higher than pre-industrial carbon dioxide levels.

(SOURCE: Scripps Institution of Oceanography. 2018. The Keeling curve, *https://scripps.ucsd.edu/programs/keelingcurve*)

Climate change predicted to increase nutrient pollution

Nutrient pollution (which in turn would result in ecosystem degradation and oxygen-deprived 'dead zones') is predicted to increase due to climate change-induced precipitation (which could increase nutrients in river systems by approximately 19% in the USA alone). To prevent this, the amount of nitrogen input into the environment (e.g. via fertilisers) would have to be reduced by a third (thereby affecting food production). In particular, greater precipitation will increase nutrient pollution in the waters of India, China and southeast Asia.

(SOURCE: Sinha, E., Michalak, A.M., and Balaji, V. 2017. Eutrophication will increase during the 21st century as a result of precipitation changes. *Science* 357: 405-408)

Noise impacts

Seismic survey playbacks lead to abnormal development in larvae

The impacts of underwater noise on cetaceans continues to be investigated, but noise impacts on prey and keystone species are less well understood. Recordings of seismic survey pulses were played back to scallop larvae (a component of zooplankton). Larvae exposed to these pulses exhibited significant developmental delays and half (46%) developed body abnormalities. The larvae were exposed to received levels of 160 dB re 1 µPa (rms). Accordingly, considering the source levels of seismic survey arrays, the zone of impact for such larvae could be "over hundreds of km-squared assuming spherical spreading of sound" around a seismic survey source. This study suggests that the impact of seismic surveys could extend to ecosystem productivity and larger components of marine ecosystems other than just cetaceans.

(SOURCE: Aguilar De Soto, N., *et al.* 2013. Anthropogenic noise causes body malformations and delays development in marine larvae. *Scient. Rep* 3: 2831; doi:10.1038/srep02831)

Cuvier's beaked whales respond to mid-frequency naval sonar at levels much lower than assumed

Two tagged Cuvier's beaked whales were exposed to playbacks of mid-frequency active naval sonar. The sound source started at 160dB re 1µPa when whales were 3.4-9.5 km away, and the source was "ramped up" by 3dB every 25 seconds to 210dB re 1µPa. The whales began to respond at received levels of 89 dB re 1µPa (rms) by ceasing to beat their tail flukes. One animal stopped echolocating, ceased foraging, and swam rapidly away from the source at a received level of 98 dB re 1µPa (rms). The avoidance response lasted for 1.6 hours. The other whale initiated a similar response at a received level of 127 dB re 1µPa (rms), and this response lasted for 1.7 hours, with an unusually deep dive profile lasting 7.6 hours after exposure. The authors noted that "current US management practices assume that significant behavior disruption almost never occurs at exposure levels this low"; therefore, significant impacts to beaked whales could occur at levels lower than previously thought, making current US mitigation guidelines for mid-frequency active sonar ineffective at preventing impacts to whales.

(SOURCE: DeRuiter, S.L., *et al.* 2013. First direct measurements of behavioural responses by Cuvier's beaked whales to mid-frequency active sonar. *Biol. Lett.* 9(4): 20130223)

Seismic surveys can alter the behaviour of fish and invertebrates

Air guns used in seismic surveys are a major source of anthropogenic noise and are known to affect cetaceans. Experiments involving two species of schooling fish (trevally and pink snapper) and southern reef squid revealed that fish and

invertebrates also react to this type of noise. The fish, for example, moved to the bottom and swam faster in more tight groups. The squid showed similar behaviour: alarm responses and changes in swimming patterns and vertical position. Accordingly, consideration should be given not only to the direct effect of air guns on cetaceans, but also indirect effects on their potential prey. The corresponding mitigation techniques need to be developed before beginning a seismic survey.

(SOURCE: Fewtrell, J.L. and McCauley, R.D. 2012. Impact of air gun noise on the behaviour of marine fish and squid. *Mar. Pollut. Bull.* 64: 984-993)

First study to show that baleen whales react to sonar noise

Tagged blue whales in the Southern California Bight showed behavioural responses to mid-frequency (1-10 kHz) sonar sound. Although the sound levels produced in the experiments were orders of magnitude below some military systems, the blue whales responded by stopping feeding, increasing swimming speed, and travelling away from the sound source. This is the first study to show that baleen whales respond to this type of mid-frequency sound, which is known to cause mass strandings of deep-diving toothed whales.

(SOURCE: Goldbogen, J.A., *et al.* 2013. Blue whales respond to simulated mid-frequency military sonar. *Proc. Roy. Soc. B*. 280: 20130657, *http://dx.doi.org/10.1098/rsbl.2013.022378*)

International Maritime Organization issues new guidelines for shipping noise

The IMO recently adopted guidelines to reduce underwater noise from commercial ships—the impact of such noise on cetaceans was a major motivation for these guidelines. Although these guidelines are voluntary, their development is a major step forward in recognising and mitigating underwater noise produced by shipping. They: recognise that shipping noise can have short- and long-term impacts on marine species, especially on cetaceans and other marine mammals; call for monitoring and measurement of shipping noise; note analytical models that could be used to determine effective quieting measures; provide guidance for designing quieter ships; provide further guidance for reducing noise emissions from existing ships, especially by minimising cavitation from ship propellers; and provide advice on shipboard operations that could minimise shipping noise production, e.g. polishing ship propellers to smooth the surface and remove fouling organisms.

(SOURCE: International Maritime Organization's Code on Noise Levels on Board Ships, 2014 edition. Available for purchase at *http://www.imo.org/Publications/Documents/Newsletters%20and%20Mailers/Mailers/I817E.PDF*)

How to tell if bubble lesions in stranded cetaceans are from sonar/decompression or decomposition

Gas bubble lesions and emboli have been identified as signs of possible sonar exposure or rapid decompression (e.g. being brought to the surface rapidly after being caught in deep-water nets) in cetacean carcasses. However, it is difficult to tell whether bubbles seen in the tissues of stranded carcasses are from decomposition or emboli/decompression. A review of bubble presence found more gas bubbles in tissues of animals that had rapidly decompressed (due to bycatch) compared to stranded animals. Another analysis of gas in bubbles of test animals found that emboli- and decompression-associated bubbles have similar gas compositions (70-80% nitrogen and 20-30% carbon dioxide). Moreover, bubbles associated with decomposition contain hydrogen, which could be used as an indicator of decomposition-associated bubbles. These are useful diagnostic tools for detecting sources of cetacean mortality from anthropogenic activities.

(SOURCES: de Quirós, Y.B., *et al.* 2013. Differentiation at autopsy between in vivo gas embolism and putrefaction using gas composition analysis. *Inter. J. Legal Med.* 127: 437–445; de Quirós, Y.B., *et al.* 2013. Compositional discrimination of decompression and decomposition gas bubbles in bycaught seals and dolphins. *PLoS ONE* 8(12): e83994. doi:10.1371/journal.pone.0083994)

Responses of dolphins to mid-frequency naval sonar

Responses of dolphins to mid-frequency active (MFA) sonar were recorded in the Southern California Bight from 2004 through 2008. Fifteen groups of common dolphins (five short-beaked, ten *Delphinus* sp.), nine Pacific white-sided dolphin groups, and two bottlenose dolphin groups displayed responses, including cessation or changes in vocalization rates, changes in behavioural state or direction of travel. Interestingly, 46% of groups not exposed to sonar also changed their behaviour, whereas 43% of focal groups exposed to sonar did not. Vocalisation intensity began to increase at peak sound pressure levels of 113.6 dB re: 1 µPa; behavioural changed began at values of 121.3 dB re: 1µPa. Vocalizations began to cease at peak sound pressure levels of 123 dB re: 1µPa (or 107-117 dB rms re: 1µPa). The authors note a caveat: "it is possible that more subtle behavioural responses occurred that were not recorded, and so this analysis could have underestimated the level of response". They suggested that "lack of response in some cases may indicate a tolerance of or habituation to MFA sonar by local populations", although they note that some responses occurred at lower received levels and some animals might be more sensitive to sonar. Behavioural responses by dolphins could occur when "the MFA sonar source could be up to or greater

than 100 km away". The authors also note that "at sonar received levels over about 147 dB Peak re: 1 µPa, dolphins were no longer present; this could indicate some avoidance of the area and would represent an additional behavioural response".

(SOURCE: Henderson, E.E., Smith, M.H., Gassmann, M., Wiggins, S.M., Douglas, A.B., and Hildebrand, J.A. 2014. Delphinid behavioral responses to incidental mid-frequency active sonar. *J. Acoust. Soc. Amer.* 136: 2003-2014)

Baird's beaked whale responses to simulated sonar at low received levels

A controlled exposure to simulated mid-frequency active sonar (at 3.5-4 kHz) was conducted on a tagged Baird's beaked whale, the first time the response of this species has been recorded. Within three minutes of sonar exposure onset, the tagged whale increased its swim speed and body movement and showed "unusual dive behavior for each of its next three dives". The animal responded at a received level of 127 dB re: 1µPa. The researchers conclude that for Baird's beaked whales there is "evidence of avoidance responses at relatively low received levels compared to those for many other species".

(SOURCE: Stimpert. A.K., Deruiter, S.L., Southall, B.L., Moretti, D.J., Falcone, E.A., Goldbogen, J.A., Friedlaender, A., Schorr, G.S, and Calambokidis, J. 2014. Acoustic and foraging behavior of a Baird's beaked whale, *Berardius bairdii*, exposed to simulated sonar. *Scient. Rep.* 4(7031). 8 pp.)

The strategies of whales for coping with noisier habitat may not work with anthropogenic sound sources

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

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

Harbour porpoises are affected by shipping more than previously predicted

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

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

A 'ramp-up' or 'soft start' of seismic survey arrays may be an effective mitigation method

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

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

Reviews on underwater noise impacts

Several reviews on underwater noise impacts have been produced in the past year. One addresses masking, i.e. underwater noise that can interfere with or 'smother' important acoustic behaviour and calls. A second addresses the evolution of

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

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

The full impact of seismic survey sounds in shallow waters may not be addressed by present mitigation measures

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

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

Vocalising louder in noisier environments may result in higher energetic costs

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

(SOURCE: Holt, M.M., Noren, D.P., Dunkin, R.C., and Williams, T.M. 2015.Vocal performance affects metabolic rate in dolphins: Implications for animals communicating in noisy environments. *J. Exper. Biol.* 218: 1647-1654)

Vessel threats to cetaceans: Speed = noise

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

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

Sperm whales stop feeding when exposed to low frequency active sonar

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

is one of the first studies to show an impact of low frequency active sonar on sperm whales. Moreover, the loss of energy from reduced feeding could have an impact on sperm whale health, and potentially reproduction, if exposure is sustained.

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

Impact of seal scarers on porpoises

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

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

Pingers could displace harbour porpoises from their habitat

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

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

Substantial behavioural responses of northern bottlenose whales to mid-frequency naval sonar even at low levels

Northern bottlenose whales were one of the most heavily hunted beaked whales, yet relatively little is known about the species. This study found that mid-frequency active sonar, at received levels of 107 dB re 1 µPa (1-2 kHz), caused a northern bottlenose whale to move "in an unusually straight course and then [to make] a near 180° turn away from the source, and [perform] the longest and deepest dive (94 min, 2339 m) recorded for this species". The behaviour of the whale was significantly different from normal for at least 7 hours after exposure and at a distance of 33-36 km from the sound source, when the tag monitoring the animal fell off. The bottlenose whale also did not produce echolocating clicks for this period, indicating that it had ceased foraging for a substantial period of time. Moreover, "a sharp decline in both acoustic and visual detections of conspecifics after exposure suggests other whales in the area responded similarly". This indicates that northern bottlenose whales have 'high sensitivity' to military sonar and their behaviour is heavily impacted, ceasing biologically important behaviours for long periods of time, after receiving only relatively low levels of mid-frequency active sonar.

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

Proposal for anthropogenic noise to be addressed through marpol or a new convention

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

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

Prototype alarms to prevent whale entanglement prove ineffective

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

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

Jet-propelled craft are quieter than propeller craft: Implications for whales

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

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

Porpoises affected by noise at lower levels than predicted

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

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

Seismic survey mitigation guidelines are still insufficient

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

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

Sperm whales stop resting and feeding when exposed to military sonar

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

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

A quieter alternative to seismic survey airguns?

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

(SOURCES: Duncan, A.J., Weilgart, L.S., Leaper, R., Jasny, M., and Livermore, S. 2017. A modelling comparison between received sound levels produced by a marine Vibroseis array and those from an airgun array for some typical seismic survey scenarios. *Mar. Pollut. Bull.* 119: 277-288)

Small, restricted populations may be more vulnerable to disturbance

Many mitigation measures assume that as noise levels increase, cetaceans will simply move to another location to avoid harm. However, some species have habitats that are very restricted. If they move away from this habitat, they may face even greater impacts. Displacement may increase stress and result in reduced ability to forage for species such as Cuvier's beaked whales or Maui's dolphins. Species such as western gray whales, however, may be so reliant upon foraging in their restricted feeding grounds that they stay within this habitat, despite being exposed to disturbance and noise, and potentially suffer health-reducing levels of disturbance. Mitigation measures should recognise that small, restricted populations may literally have "nowhere to go without experiencing harm" when it comes to disturbance. The authors also highlighted that mitigation measures often do not take into account that some species are more difficult to detect and that noise producers might assume their activities are not having an effect, because they are unable to detect the animals that are suffering impacts. The authors therefore suggested that "[m]itigation and monitoring plans should explicitly include estimation of cetacean detection probabilities, to ensure that as many animals as possible are detected and that true risks of harming animals that may never be seen are understood".

(SOURCE: Forney, K.A., Southall, B.L., Slooten, E., Dawson, S., Read, A.J., Baird, R.W., and Brownell, R.L Jr. 2017. Nowhere to go: noise impact assessments for marine mammal populations with high site fidelity. *Endang. Species Res*. 32: 391-413)

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

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

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

A need to standardise sound measurements for impact policy purposes

Studies that describe the impacts of noise, both in the terrestrial and aquatic environment, often portray sound levels in different ways. For example, sounds might be measured as 1) SPL RMS–the 'average height' of the sound wave over a specified time period; and 2) 'peak-to-peak' (the difference between the highest and lowest pressure deviations in a given time interval). Depending on how noise is measured, a given sound level may actually vary in practical terms by up to 12 dB. Most managers, environmental advocates and policy-makers are not trained in the physics of underwater sound and fail to realize that the decibel scale is not easily comparable for underwater versus above-water noise. (Editor's note: For example the 'loudness' of sound sources such as seismic survey air guns is often compared to the loudness of a Boeing 747 jet taking off, which is approximately 150 dB (at 25 m) in air. Importantly, however, this would be valued as 215.5 dB (re 1µPa) underwater because of the difference of reference values and the physical nature of water.) A new review on this issue presented marine mammal case studies that highlighted such discrepancies. In one example, two levels were given the same decibel value, although there was actually a 45 dB difference between them. The review called for standardising how sound levels are expressed, especially when dealing with noise impacts. In particular the frequency spectrum should be expressed (e.g. in a format such as '40 dB SPL_{max} re 1µPa (10-200 Hz)'). In the case study noted above, for example, the disparity was because measurements were made over different frequency ranges. (Editor's note: An analogy is trying to

count the number of birds in a wood—although the number of birds remains the same, one gets a very different value if counting at midday versus at midnight. The observation 'window' needs to be standardised.) Because noise-related damage is often related to the maximum amount of noise in an event, it is important to note the maximum sound level (SPL_{max}), rather than averaging sound levels over a lengthier period. Sound-related damage may also increase as a result of continuous exposure, so that the cumulative sound exposure level (SEL) is also important, with information on the sound duration. The background noise level in an animal's habitat might also be an important value when measuring impacts. (Editor's note: For example, a dolphin that inhabits waters near a noisy harbour with a high level of background noise might be affected differently by a passing boat than a dolphin in a quiet bay. This is also an issue when the responses of animals kept in captive settings are used to predict responses of animals in quieter wild settings.) Finally, as noise exposure may cause stress responses, noting the duration of a noise exposure, as well as the duration of subsequent quiet 'recovery' periods, is also important. An intense sound that is shortly followed by another intense sound might be more stressful than a sound that is followed by a long quiet period. This calls for standardising how noise levels are expressed in papers and developing improved regulations in order to efficiently manage the impacts of sounds on cetaceans (and other species).

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

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

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

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

Seismic survey sounds dramatically reduce reef fish abundance

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

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

Scientific echo-sounder alters pilot whale behaviour

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

(SOURCE: Quick, N., Scott-Hayward, L., Sadykova, D., Nowacek, D., and Read, A. 2016. Effects of a scientific echo sounder on the behavior of short-finned pilot whales (*Globicephala macrorhynchus*). *Can. J. Fish. Aquat. Sci*. 74: 716-726)

A new method to analyse behavioural changes in response to disturbance

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

(SOURCE: Seuront, L. and Cribb, N. 2017. Fractal analysis provides new insights into the complexity of marine mammal behavior: A review, two methods, their application to diving and surfacing patterns, and their relevance to marine mammal welfare assessment. *Mar. Mamm. Sci.* 33: 847-879)

Feeding behaviour of humpback whales significantly reduced during sonar exposure

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

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

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

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

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

Beaked whales respond to mid-frequency sonar up to 100 km away

The behaviour of tagged Cuvier's beaked whales was observed in response to mid-frequency military sonar exposure during naval exercises off the coast of southern California. During sonar-exposed deep dives, subsequent shallow dives and surface intervals were longer than normal. The longer interval between deep dives suggested disrupted foraging. Longer deep (foraging) dive intervals were noted even when the sonar sources were approximately 100 km away.

(SOURCE: Falcone, E.A., Schorr, G.S., Watwood, S.L., DeRuiter, S.L., Zerbini, A.N., Andrews, R.D., Morrissey, R.P., and Moretti, D.J. 2017 Diving behaviour of Cuvier's beaked whales exposed to two types of military sonar. *Roy. Soc. Open Sci.* 4: 170629, 1-21)

Harbour porpoises respond when exposed to a single seismic airgun

Tagged harbour porpoises were exposed to a single seismic airgun for one minute (at a distance of 0.42-0.69 km and sound exposure levels of 135-147 dB re 1 μPa^2) and their reactions recorded. Two animals demonstrated shorter and shallower dives (normal behaviour resumed after 17 hours) and one animal rapidly swam away from the sound source (normal diving/swimming behaviour resumed after 35 hours), avoiding the area of the sound source for six days. This study demonstrates a significant behavioural reaction by harbour porpoises to just a single seismic airgun (seismic surveys typically have an array of many airguns).

(SOURCE: van Beest, F.M., Teilmann, J., Hermannsen, L., Galatius, A., Mikkelsen, L., Sveegaard, S., Balle, J.D., Dietz, R., and Nabe-Nielsen, J. 2018 Fine-scale movement responses of free-ranging harbour porpoises to capture, tagging and short-term noise pulses from a single airgun. *Roy. Soc. Open Sci.* 5: 170110, 1-14, *http://dx.doi.org/10.1098/rsos.170110*)

'Ramp-up' may not be an effective mitigation measure for protecting cetaceans from military sonar

'Ramp-up' or 'soft start', a gradual increase in volume of an intense anthropogenic sound source, is a frequently touted mitigation measure for intense sound-producing activities, such as seismic surveys or military sonar exercises. The assumption is that the initial low sound level will warn cetaceans that there will be an acoustic event, so that they can move out of the area of impact. However, only a few studies have tested whether this indeed occurs. A study on the reaction of a tagged humpback whale to a ramp-up of mid-frequency sonar (1.3-2.0 kHz) found that there was some response to the ramped-up signal, but the whale was at times unresponsive to the low levels of sound during the soft start. It was suggested that naïve, non-feeding or more skittish animals (such as mothers with calves) might react more readily to the initial low levels of sound, making this method more effective for these classes of animals. Overall, however, "ramp-up may not be effective" as a mitigation measure for intense sound activities.

(SOURCE: Wensveen, P.J., Kvadsheim, P.H., Lam, F.-P. A., von Benda-Beckmann, A.M., Sivle, L.D., Visser, F., Curé, C., Tyack, P.L., and Miller, P.J.O. 2017. Lack of behavioural responses of humpback whales (*Megaptera novaeangliae*) indicate limited effectiveness of sonar mitigation. *J. Exp. Biol.* 220: 4150-4161. doi:10.1242/jeb.161232)

References

International Whaling Commission. 1998. Chairman's Report of the Forty-Ninth Annual Meeting. Appendix 7. IWC Resolution 1997-7. Resolution on environmental change and cetaceans. *Rep. Int. Whal. Comm.* 48:48-49.

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). 13 pp. [Paper available from the Office of this Journal].

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Appendix 1

Glossary

Species glossary

Atlantic white-sided dolphin	*Lagenorhynchus acutus*
Baiji	*Lipotes vexillifer*
Baird's beaked whale	*Berardius bairdii*
Beluga whale	*Delphinapterus leucas*
Blainville's beaked whale	*Mesoplodon densirostris*
Blue whale	*Balaenoptera musculus*
Bowhead whale	*Balaena mysticetus*
Bryde's whale	*Balaenoptera edeni*
Burmeister's porpoise	*Phocoena spinipinnis*
Burrunan dolphin	*Tursiops australis*
Chilean dolphin	*Cephalorhynchus eutropia*
Commerson's dolphins	*Cephalorhynchus commersonii*
Common bottlenose dolphin (Black Sea)	*Tursiops truncatus ponticus*
Common bottlenose dolphin	*Tursiops truncatus*
Common dolphin (short-beaked)	*Delphinus delphis*
Common minke whale	*Balaenoptera acutorostrata*
Cuvier's beaked whale	*Ziphius cavirostris*
Dall's porpoise	*Phocoenoides dalli*
Fin whale	*Balaenoptera physalus*
Finless porpoise	*Neophocaena phocaenoides*
Franciscana	*Pontoporia blainvillei*
Fraser's dolphin	*Lagenodelphis hosei*
Ganges river dolphin	*Platanista gangetica*
Gray whale	*Eschrichtius robustus*
Guiana dolphin	*Sotalia guianensis*
Harbour porpoise (Black Sea)	*Phocoena phocoena relicta*
Harbour porpoise	*Phocoena phocoena*
Heaviside's dolphin	*Cephalorhynchus heavisidii*
Hector's dolphin	*Cephalorhynchus hectori*
Humpback whale	*Megaptera novaeangliae*
Indian Ocean humpback dolphin	*Sousa plumbea*
Indo-Pacific bottlenose dolphin	*Tursiops aduncus*
Indo-Pacific humpback dolphin	*Sousa chinensis*
Killer whale	*Orcinus orca*
Long-beaked common dolphin	*Delphinus capensis*
Long-finned pilot whale	*Globicephala melas*
Maui's dolphin	*Cephalorhynchus hectori maui*
Narwhal	*Monodon monoceros*
North Atlantic right whale	*Eubalaena glacialis*
Northern bottlenose whale	*Hyperoodon ampullatus*
Omura's whale	*Balaenoptera omurai*
Pacific white-sided dolphin	*Lagenorhynchus obliquidens*
Pantropical spotted dolphins	*Stenella attenuata*
Pygmy beaked whale	*Mesoplodon peruvianus*
Pygmy sperm whale	*Kogia breviceps*
Risso's dolphin	*Grampus griseus*
Rough-toothed dolphin	*Steno bredanensis*
Short-beaked common dolphin	*Delphinus delphis*
Short-finned pilot whale	*Globicephala macrorhynchus*
South Asian river dolphin	*Platanista gangetica*

Southern right whale	*Eubalaena australis*
Sperm whale	*Physeter macrocephalus*
Spinner dolphin	*Stenella longirostris*
Striped dolphin	*Stenella coeruleoalba*
Vaquita	*Phocoena sinus*
White-beaked dolphin	*Lagenorhynchus albirostris*
Harp seal	*Pagophilus groenlandicus*
Leatherback sea turtle	*Dermochelys coriacea*
Loggerhead sea turtle	*Caretta caretta*
Brown pelican	*Pelecanus occidenatlis*
Seaside sparrow	*Ammodramus maritimus*
Short-tailed shearwater	*Puffinus tenuirostris*
Annular seabream	*Diplodis annularis*
Atlantic herring	*Clupeus harengus*
Black Sea (Azov Sea) anchovy	*Engraulis encrasicolus*
Black Sea shad	*Alosa maeotica*
Black Sea turbot	*Scophthalmus maeoticus*
Capelin	*Mallotus villosus*
Cod	*Gadus morhua*
Common Pandora	*Pagellus erythrinus*
Eastern oyster	*Crassostrea virginica*
European hake	*Merluccius merluccius*
European sturgeon	*Huso huso*
Guitarfish	*Family Rhinobatidae*
Gulf killifish	*Fundulus grandis*
Hatchetfishes	*Polyipnus* spp.
Humboldt squid	*Dosidicus gigas*
Indo-Pacific bluespotted cornetfish	*Fistularia commersonii*
King crab	*Paralomis birsteini*
Krill	*Euphausia* spp.
Lesser spotted dogfish	*Scyliorhinus canicula*
Mullet	*Liza klunzingeri*
Parrotfish	*Sparisoma cretense*
Pink snapper	*Pagrus auratus*
Red mullet	*Mullus barbatus*
Sandeels	*Family Ammodytidae*
Southern reef squid	*Sepioteuthis australis*
Trevally	*Pseudocaranx dentex*
Turbot	*Psetta maeotica*
Yellowtail fish	*Seriola lalandi*
Zebra seabream	*Diplodus cervinus*
Acrobat ant	*Crematogaster pilosa*
Antarctic krill	*Euphausia superba*
Comb jelly (filter-feeding)	*Mnemiopsis leidyi*
Comb jelly (predatory)	*Beroe ovata*
Marsh periwinkle	*Littoraria irrorata*

Heavy metals

Al	*Aluminium*
As	*Arsenic*
Cd	*Cadmium*
Cr	*Chromium*
Cu	*Copper*
Fe	*Iron*
Hg	*Mercury*
Mn	*Manganese*
Mo	*Molybdenum*
Ni	*Nickel*
Pb	*Lead*
Se	*Selenium*
Sn	*Tin*
V	*Vanadium*
Zn	*Zinc*

Glossary of terms

Abraded:	Abrasion is the mechanical scraping of a rock surface by friction between rocks and moving particles during their transport by wind, glacier, waves, gravity, running water or erosion. An abraded coastline is formed by this action.
ACCOBAMS:	Agreement on the Conservation of Cetaceans in the Black Sea, Mediterranean Sea and Contiguous Atlantic Area.
Aerosol:	A suspension of solid or liquid particles in a gas; includes both the particles and the suspending gas, which is usually air.
AIS:	Automatic Identification System (automatic vessel-tracking system).
Anoxia:	Absence of oxygen.
Anthropogenic:	Human in origin.
Benthic:	Of or related to the bottom level of the ocean, including the sediment or ocean floor.
Benthic-pelagic coupling:	The cycling of nutrients between bottom sediments and the overlying water column.
Bifenthrin:	An insecticide in the pyrethroid family. It is highly toxic to aquatic organisms.
Bioaccumulation:	Increase in concentration of a pollutant within an organism over its lifetime, compared to background levels in its diet.
Bioavailability:	Quantity or fraction of an ingested dose that is absorbed.
Biomagnification:	Increase in concentration of a contaminant from one link in a food chain to another. Pollutant levels in top predators are highest.
Biomarker:	A biological indicator, e.g. blood chemical levels, of health status or pollutant level.
Biomonitor:	Species used to track toxic chemical compounds, elements or their metabolites in the environment. These compounds are typically measured in the biomonitor's blood and urine.
Biosphere Reserves:	Areas comprising terrestrial, marine and coastal ecosystems that promote solutions reconciling the conservation of biodiversity with its sustainable use, managed by UNESCO.
Bivalve:	A class of marine and freshwater molluscs that have laterally compressed bodies enclosed by a shell consisting of two hinged parts, e.g. clam, oyster.
Bottom otter trawls:	A form of bottom trawl net that 'ploughs' up to 15 cm into the sea floor, using flat boards ('otter boards') to keep the mouth of the net open.
Bottom-up effects:	Effects of varying prey abundance on predator populations (see also top-down effects).
Bq:	Becquerel, the International System of Units unit of radioactivity, equal to one nuclear decay or other nuclear transformation per second.
Brevetoxin:	A class of dangerous neurotoxins produced during blooms (red tides) of certain algae.
Brucella:	Various species of bacteria that cause the disease brucellosis.
Butyltins:	A class of toxic chemicals commonly used in anti-fouling paints on ship hulls (as tributyltin or dibutyltin, a breakdown product of tributyltin).

Capture-recapture modelling:	Also called mark-recapture. A method of estimating a population's size by capturing, marking and releasing a sample of that population and then later recapturing another sample and counting the number of marked individuals within the sample.
Carcinogenicity:	Ability or tendency to cause cancer.
CBD Aichi Target:	The Conservation on Biological Diversity's biodiversity targets, as determined at the Tenth Conference of the Parties in 2010, in Nagoya, Japan (Aichi Prefecture) - see *https://www.cbd.int/sp/targets/*.
CCAMLR:	Convention for the Conservation of Antarctic Marine Living Resources.
Chlorophyll-a:	A specific form of chlorophyll used in photosynthesis, which absorbs most energy from violet-blue and orange-red light. This photosynthetic pigment is essential for photosynthesis in some marine phytoplankton.
Comb jelly:	A free-swimming representative of the invertebrate phylum Ctenophora.
Cyhalothrin:	An insecticide in the pyrethroid family.
CYP1A1:	Also referred to as cytochrome P450 1A, a gene whose expression serves as a biomarker for plastics exposure.
CYP2B:	Also referred to as cytochrome P450 2B, a gene whose expression serves as a biomarker for plastics exposure.
Cytokine:	Any of a number of substances, such as interferon, interleukin, and growth factors, that are secreted by certain cells of the immune system and have an effect on other cells.
Data logger:	An electronic device that records data over time or across locations.
dB:	Decibel—a logarithmic measure of sound pressure level.
DDD:	The organochlorine dichlorodiphenyldichloroethane, a breakdown product of the pesticide.
DDT.DDE:	The organochlorine dichlorodiphenyldichloroethylene, a breakdown product of the pesticide.
DDT.DDT:	The organochlorine pesticide dichlorodiphenyltrichloroethane, which tends to accumulate in the ecosystem and in the blubber and certain internal organs of cetaceans.
Dead zone:	Areas of hypoxia and eutrophication.
Defaunation:	The loss of wildlife from ecological communities.
Deltamethrin:	An insecticide in the pyrethroid family.
Depredation:	In ecology, when animals feed on anthropogenically available resources, such as dolphins taking fish on lines or elephants eating crops.
Diatom:	Common type of phytoplankton, a one-celled alga encased in a silica cell wall. The species *Pseudo-nitzschia australis* produces domoic acid, which poisons mammals, causing paralysis and reproductive failure.
Dinoflagellate:	A large group of unicellular algae belonging to the phytoplankton.
Dioxin:	Toxic organic chemicals that can accumulate in the blubber of cetaceans. These chemicals are carcinogenic and can cause reproductive defects.
Diurnal:	Of or during the day (versus nocturnal, of or during the night).
DMV:	Dolphin morbillivirus.
Domoic acid:	See diatom—also responsible for amnesic shellfish poisoning.
Echinoids:	Seastars and sea urchins.
EEZ:	Exclusive Economic Zone.
Emboli:	Plural of embolus, which is any detached, traveling mass (solid, liquid, or gaseous) in blood vessels that is carried by circulation. Emboli are capable of clogging arteries at a site distant from their point of origin.
Endemic:	Native or restricted to a certain country, area or region.
Endocrine disruptor:	The endocrine system is a system of ductless glands producing hormones that control and moderate metabolic processes in the body. Chemicals that mimic these hormones or otherwise interfere with their activity are known as endocrine disruptors.
Epizootic:	A disease outbreak in non-human animals, equivalent to an epidemic in human populations.
Estuarine:	Related to estuaries or river mouths.
Euphausiid:	Of the family Euphausiidae, to which krill belong (may also include the single species found in the family Bentheuphausiidae).
Eutrophication:	Input of nutrients into an aquatic system, typically associated with excessive plant growth and oxygen depletion.

FAO:	Food and Agriculture Organization of the United Nations, an intergovernmental organization with 194 Member Nations.
Fractal:	A rough or fragmented geometric shape that can be split into parts, each of which is (at least approximately) a reduced-size copy of the whole.
Gastropods:	Snails.
Gyre:	Large system of rotating ocean currents.
HBB:	Hexabromobenzene, a halogenated flame retardant.
HBCD:	Hexabromocyclododecane, a brominated flame retardant.
HCB:	Hexachlorobenzene, an organochloride compound.
HCH:	Hexachlorocyclohexane, a polyhalogenated compound.
Hexacopter:	An unmanned helicopter (drone) with six rotors.
Hypoxia:	Low levels of dissolved oxygen.
Hz:	Hertz, a measure of sound frequency (pitch), in wave cycles per second (kHz=1000 Hertz).
IMO:	International Maritime Organisation.
In utero:	In the womb; before birth.
Indicator species:	Species that can provide information on ecological changes and give early warning signals regarding ecosystem processes due to their sensitive reactions to them. They can also be called sentinel species.
IOC:	Intergovernmental Oceanographic Commission of UNESCO.
IPIECA:	The global oil and gas industry association for environmental and social issues.
IUCN:	International Union for Conservation of Nature.
J:	Joule, a unit of energy.
Keystone species:	A species with a disproportionately large effect on its ecosystem relative to its abundance.
kN:	A kilonewton. The newton is the International System of Units unit of force. One thousand newtons is a kilonewton.
Lindane:	Also known as *gamma*-hexachlorocyclohexane, (γ-HCH), gammaxene, and Gammallin, lindane is an organochlorine chemical variant of HCH, which has been used both as an agricultural insecticide and as a pharmaceutical treatment for lice and scabies.
Lipid weight:	A basis of measurement whereby concentrations of a substance are compared to the lipid (fat) content of a material.
Lipophilic:	Capable of dissolving in lipids (fats); having an affinity for lipids.
LPO:	Lipid peroxidation, the oxidative degradation of *lipids*. It is the process in which free radicals 'steal' electrons from the *lipids* in cell membranes, resulting in cell damage.
Lymphocyte cells:	Small white blood cells that play a large role in defending the body against disease. Lymphocytes are responsible for immune responses. There are two main types of lymphocytes, B cells and T cells.
Marginal sea:	A smaller sea on the boundary of a larger one.
MEHP:	Monoethylhexylphthalate, a metabolite of the most common phthalate in the environment.
Meningoencephalitis:	Inflammation of the membranes of the brain and the adjoining cerebral tissue.
MeO-PBDE:	Methyloxidated polybrominated diphenyl ether.
Microplastics:	Plastic particles 0.3-5 mm in diameter, often the result of larger plastic pieces breaking down over time.
Minamata disease:	A group of physical and physiological symptoms arising from mercury poisoning.
Mirex:	A synthetic organochlorine insecticide, typically used against ants.
Mobulid:	The family Mobulidae, which includes manta rays and devil fish.
Morbillivirus:	A family of viruses that are typically highly infectious and pathogenic—the family includes measles, dog distemper and dolphin morbillivirus. A number of cetacean mass mortality events have been associated with viruses from this family.
MPA:	Marine Protected Area.
Mutagenicity:	Ability or capability of producing genetic mutations.
MW:	Megawatt.
NASA:	National Aeronautics and Space Agency of the US Government.
Natura 2000:	A network of core breeding and resting sites for rare and threatened species, and some rare natural habitat types that are protected in their own right, under the European Commission.
Neritic:	Relating to the shallow part of the sea near a coast and overlying the continental shelf.

Newton:	The International System of Units unit of force.
nm:	Nautical mile.
nmol:	Nanomole (equivalent to 10^{-9} moles).
NOAA:	National Oceanic and Atmospheric Administration of the US Government.
NP:	Nonylphenol, a group of organic compounds typically used in manufacturing, among other things, antioxidants, lubricating oil additives, and detergents.
OC:	Organochlorine compound.
OCP:	Organochlorine pesticide.
Organochlorine:	Organic compound that contains chlorine. Many are toxic and used as pesticides. Most of these compounds persist in the environment (are not biodegradable) and also tend to accumulate in fatty tissue (e.g. blubber) of cetaceans and other marine organisms.
Organohalogen:	Organic compounds that contain any halogen (i.e. fluorine, chlorine, bromine, or iodine).
Ortho and non-ortho PCBs:	Chemical variants of PCBs, relating to their toxicity.
PBDE:	Polybrominated diphenyl ether.
PCBs:	Polychlorinated biphenyls (209 different forms that contain differing numbers of chlorine atoms arranged in various positions on the aromatic rings) are industrial organochlorines that were manufactured to be used in electrical transformers and other applications. These man-made chemicals do not occur naturally and all traces reflect pollution.
PCDDs:	Polychlorinated dibenzo-p-dioxins.
PCDFs:	Polychlorinated dibenzofurans.
Pelagic:	Of or related to the open ocean.
Perfluorinated compounds:	A class of environmentally persistent molecules with fluorine atoms attached, used in many industrial applications including fire-fighting foams, pesticides and surface coatings.
Perinatal (perinate):	The period ranging from one month before to one month after birth (a foetus one month before and a newborn one month after birth).
Permethrin:	An insecticide (and skin medication for scabies and lice) in the pyrethroid family.
PET:	Polyethylene terephthalate, a plastic.
PFASs:	Per- and polyfluoroalkyl substances, which have many manufacturing and industrial applications because they are fire resistant and repel oil, stains, grease and water.
PFCs:	Perfluorinated compounds. A class of environmentally persistent molecules with fluorine atoms attached, used in many industrial applications including fire-fighting foams, pesticides and surface coatings.
Phthalate:	A class of substances added to plastics to increase their flexibility, transparency, durability, and longevity.
Phytoplankton:	Free-floating marine plants (versus zooplankton—free-floating marine animals).
pmol:	Picomole (equivalent to 10^{-12} moles).
Polyaromatic hydrocarbons:	Organic compounds containing only carbon and hydrogen, composed of multiple aromatic rings (organic rings in which the electrons are delocalized), found in coal and tar deposits.
Polyethylene, polypropylene, polyvinyl chloride:	Plastics.
POPs:	Persistent organic pollutants, organic compounds that are resistant to degradation and thus persist in the environment.
ppm:	Parts per million.
ppt:	Parts per thousand.
Primary production:	The synthesis of organic compounds from atmospheric or aqueous carbon dioxide, forming the foundation of any food web.
Pteropod:	Specialised free-swimming pelagic sea snails and sea slugs.
PVC:	Polyvinyl chloride, a plastic.
Pyrethroid:	An organic compound similar to the natural pyrethrins produced by flowers. Pyrethroids constitute the majority of commercial household insecticides.
Ramsar:	The Convention on Wetlands (also known as the Ramsar Convention).
Relic species:	A species more widespread or numerous in the past.
rms:	Root-mean-square. A measurement of sound pressure.

Salp:	A free-swimming tunicate (marine filter feeders with a water-filled, sac-like body structure and tubular openings, known as siphons, through which they draw in and expel water) with a transparent, barrel-shaped body.
Saxitoxin:	Neurotoxin found in marine dinoflagellates—the cause of paralytic shellfish poisoning.
Scleractinian corals:	Stony corals or hard corals.
SCOR:	Scientific Committee on Ocean Research of UNESCO.
SD:	Standard deviation.
SEL:	Sound exposure level.
Soundscape:	The level of natural and anthropogenic sound in the environment.
South Atlantic Gyre:	The subtropical gyre in the South Atlantic Ocean. In the southern portion of the gyre, northwesterly (or southeastward-flowing) winds drive eastward-flowing currents that are difficult to distinguish from the northern boundary of the Antarctic Circumpolar Current. Like other oceanic gyres, it collects vast amounts of floating debris.
SPL:	Sound pressure level. A measure of the intensity of sound, in decibels. SPL_{max} refers to maximum SPL.
Stratification:	Layering of the water column due to different water densities, as induced for example by temperature or salinity differences. Also layering that occurs in most sedimentary rocks and in those igneous rocks formed at the earth's surface.
Sympatric:	Occurring in the same geographical area, used with animals and plants.
TBARS:	Thiobarbituric acid reactive substances. The TBARS assay is one of the oldest laboratory measures of oxidative stress in serum or tissues. The assay measures the concentration of malondialdehyde produced due to degradation of unstable lipid peroxides.
TBT:	Tributyltin. A toxic chemical commonly used in anti-fouling paints on ship hulls.
TEQ:	Toxic equivalent.
Tetramethrin:	An insecticide in the pyrethroid family.
T-Hg:	Total mercury.
Top-down effects:	Mortalities of prey induced by predators (see also bottom-up effects).
T-PODs:	**T**iming **PO**rpoise **D**etector, an electronic device to record cetacean echolocation clicks.
Trammel nets:	Gill nets with three layers of netting tied together on a common floatline and common leadline, used to catch a wide variety of fishes.
Trap pot gear:	Submerged, three-dimensional wire or wood devices that permit fishery species to enter, but make escape extremely difficult or impossible.
UME:	Unusual mortality event, any set of related strandings that involves a greater number of animals than is typical for a certain time period.
UN:	United Nations.
UNCLOS:	United Nations Convention on the Law of the Sea.
UNESCO:	United Nations Education, Scientific and Cultural Organization.
Upwelling:	When seawater from depth rises to the surface, bringing nutrients with it; an area of high productivity.
Wet weight:	A basis of measurement whereby concentrations of a substance are calculated without the water being removed from the respective organism or sediment.
WHO:	World Health Organisation.
Wm^{-2}:	Watts per metre squared, a measure of irradiance from a light source such as the sun.
Xenobiotic:	Of or relating to substances, typically synthetic, that are foreign to the body or ecosystem.
Zooplankton:	Free-floating marine animals.
µg:	Microgram.
µPa:	Micropascal, a unit of pressure.

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