Appendix 6

STATE OF THE CETACEAN ENVIRONMENT REPORT (SOCER) 2008

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INTRODUCTION

A prototype of the State of the Cetacean Environment Report (SOCER) was submitted to the International Whaling Commission Scientific Committee (SC) in 2000 in response to several resolutions from the Commission, including Resolutions 1997-7 and 1998-5, which directed the SC to provide regular updates on environmental matters that affect cetaceans. Resolution 2000-7 welcomed the concept of the SOCER at the 52nd Annual Meeting in Adelaide, Australia, and "*request[ed] the annual submission of this report to the Commission*". The first full SOCER (SC/55/E7) was submitted in 2003 and focused on the Mediterranean and Black Seas and the Atlantic Ocean. Subsequent SOCER's focused on the Pacific Ocean, the polar seas and the Indian Ocean, each also including a Global section, addressing information that applies generally to cetacean environments. SC/60/E1 (SOCER 2008) again focuses on the Atlantic Ocean, summarising key papers and articles that have been published from 2005 through 2008 to date.

LITERATURE ANALYSIS:

At SC/57, the Chair of the Scientific Committee requested the SOCER editors to determine what percentage of the cetacean literature was devoted to topics specifically related to habitat threats and conservation issues, versus topics addressing basic biology, ecology and evolution. For this analysis, the editors used a literature database maintained by David Janiger of the Natural History Museum of Los Angeles County (NHMLAC)[4]. For the year 2007, it contained 1389 document records from over 300 peer-reviewed journals, books, theses and technical reports[5], covering all aspects of marine mammal biology, evolution, ecology, habitats, conservation and policy. We believe this is a reasonably inclusive database of marine mammal literature (see SC/58/E1 for additional background).

All document records from the NHMLAC database that focused on pinnipeds or other marine animals – or on aspects of marine organisms, habitats or ecosystems not directly relevant to cetaceans – were deleted. The remaining 785 records[6] were then classified as follows:

- B ('basic biology'): Primary focus on basic biology (*e.g.* evolution, behaviour, physiology, anatomy, or taxonomy), ecology (*e.g.* distribution, habitat preference, habitat partitioning, or stock structure), or research techniques
- C ('conservation'): Primary focus on environmental threats, conservation, management, or policy

When a study presented basic biological or ecological information on a species and included a discussion on management implications only as a 'general framework' consideration, then it was typically categorised as 'basic biology'. If, however, management or conservation implications were the primary motivation for undertaking a study (even if including basic aspects of cetacean biology or ecology, *e.g.*, most studies on hearing), then the paper was generally categorised as 'conservation'.

Of the 785 document records examined for this analysis, 55.3% (n = 434) were focused on basic biology and 44.7% (n = 351) on conservation. This is almost certainly an underestimate of the number of studies undertaken to inform cetacean management or conservation policies, given the criteria noted above for categorising papers. The proportion of the database categorized as 'conservation' papers remained constant from 2006 to 2007. The total number of papers addressing cetacean issues increased, but this was likely attributable more to an expanded search effort by the NHMLAC database manager than to an increase in papers published.

Research in the marine sciences is characterized by an ongoing shift from basic scientific questions to understanding and managing complex ecosystems and their natural and anthropogenic perturbations. Based on the statistics presented here, in which almost half of all publications on cetaceans have a direct conservation focus, this shift is taking place in the field of cetacean research as well. Accordingly, the IWC is accurately reflecting the current trend in scientific endeavour with its focus on environmental and conservation matters.

ATLANTIC OCEAN

Habitat protection/degradation

General

Europe's "Marine Strategy": a flawed attempt?

The protection of regional seas and their marine inhabitants requires broad, internationally coordinated efforts. The author faults the European Commission's proposed "Marine Strategy" because European Union Member States would only be required to develop national environmental objectives and marine protection activity programmes. This would exclude key policy areas like the Common Fishery Policy. The Marine Strategy also has no

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Janiger searches every week for at least 35 keywords in *Zoological Records*, *Biological Abstracts*, and *Current Contents*. Once a month he also checks the leading publishers' websites for the same keywords.

[5] Contact the editors for a full list of the peer-reviewed publications, books, theses, and technical reports in the NHMLAC database. Most documents included in the analysis were subject to some level of peer review, but a small number were not necessarily peer-reviewed; *e.g.*, they appeared in a publication's 'news' section. There were several abstracts-only publications (from conferences or other sources – no full papers available) included in the NHMLAC database in 2007; none of these was included in the analysis. Full-paper proceedings, however, were included.

[6] Contact the editors for the full list of document records.

provisions for refining EU environmental law relevant to marine protection or to link EU-level action with international conventions for the protection of the oceans. However, the author lauds the ambitious goal of achieving good environmental status in European marine waters by 2021.

(SOURCE: Salomon, M. 2006. The European Commission proposal for a Marine Strategy: Lacking substance. *Mar. Pollut. Bull.* 52: 1328-1329)

Low-oxygen zones in intermediate depths expanding in tropical oceans

Oxygen-poor waters at intermediate depths (300-700m layer), known as oxygen-minimum zones (OMZs), occupy large volumes in eastern tropical oceans. Climate models reveal a vertical expansion of OMZs in the eastern tropical Atlantic (and equatorial Pacific) over the past 50 years: their thickness increased 85% from 370m in 1960 to 690m in 2006, and oxygen values decreased. These models also predict an expansion of OMZs under global warming conditions. The Atlantic may have the most potential for large increases in hypoxic areas. Reduced-oxygen areas will likely have dramatic consequences for ecosystems because key mobile macro-organisms will avoid or cannot survive in them.

(SOURCE: Stramma, L., Johnson, G.C., Sprintall, J. and Mohrholz, V. 2008. Expanding oxygen-minimum zones in the tropical oceans. *Science* 320: 655-658)

Fisheries Interactions

Strandings can reflect fisheries bycatch

When the winter gillnet fishery for spiny dogfish (*Squalus acanthias*) off the coast of North Carolina, USA, was limited due to management requirements, the number of observed bycaught common bottlenose dolphins (*Tursiops truncatus*) also declined. There was also a correlation between observed bycatch and the number of stranded animals displaying entanglement lesions. The authors conclude that monitoring strandings is a useful proxy for monitoring bycatch. This could allow the rapid enactment of management actions, before data from observers are collected. The authors suggest that "*observer coverage and stranding investigations can be used in concert for more effective fishery management*".

(SOURCE: Byrd, B.L., Hohn, A.A., Munden, F.H., Lovewell, G.N. and Lo Piccolo, R.E. 2008. Effects of commercial fishing regulations on stranding rates of bottlenose dolphin (*Tursiops truncatus*). *Fish. Bull.* 106: 72–81)

Factors affecting longline interaction on the US Atlantic coast

Long and short-finned pilot whales (*Globicephala macrorhynchus* and *G. melas*) and Risso's dolphins (*Grampus griseus*) are the two main species that interact with the US Atlantic coast longline fishery and "*pilot whale interactions were correlated with warm water temperatures, proximity to the shelf break, mainline lengths greater than 20 nautical miles, and damage to swordfish catch*". Like pilot whales, Risso's dolphin interactions were also correlated with mainline length, the shelf break and also bait type. As interactions with the longline fishery will also result in some level of bycatch, these factors influence bycatch rates. It was suggested that "*altering gear characteristics and fishery practices may mitigate incidental bycatch*", as well as reduce the amount of longline depredation.

(SOURCE: Garrison, L.P. 2007. Interactions between marine mammals and pelagic longline fishing gear in the US Atlantic Ocean between 1992 and 2004. *Fish. Bull.* 105: 408-417)

Iron oxide-treated nets decrease harbour porpoise bycatch rates in North Sea field test

Trials were conducted on monofilament nets impregnated with iron oxide (which theoretically would increase acoustic reflectivity). The treated nets were tested in the Danish North Sea bottom set gillnet fishery in 2000, against a control set of normal nets. There was significantly lower bycatch of harbour porpoises (*Phocoena phocoena*) in the treated nets (0 animals versus 8 in the control nets). Catches of four species of target fish were also analysed and only cod (*Gadus morhua*) catches were reduced (by approximately 30% in treated nets). Tests of the treated nets revealed that they did not have a greater acoustic signature. Instead, their increased 'stiffness' may explain the differences in catch rates.

(SOURCE: Larsen, F., Ole Ritzau Eigaard, O.R. and Tougaard, J. 2007. Reduction of harbour porpoise (*Phocoena phocoena*) bycatch by iron-oxide gillnets. *Fish. Res.* 85: 270–278)

Levels of cetacean bycatch estimated for the US

Levels of marine mammal bycatch in US fisheries (from 1990-1999) were assessed using levels of bycatch reported by onboard observers, taking into account total fishing effort for different gear types. The average annual cetacean bycatch for the US was estimated to be 3029 (± 316 SE). Most bycatch (84%) occurred in gill-net fisheries. A significant decline was reported over time, primarily reflecting declines in fishing effort or introduced cetacean conservation measures. For example, on the Atlantic coast, bycatch of Gulf of Maine harbour porpoises declined dramatically from 2900 in 1990 (accounting for 57% of cetacean bycatch in that year) to 332 in 1999 (19% of bycatch). Bycatch is likely underestimated due to a lack of observer schemes for all fisheries, bycaught animals falling out of nets and thus not being observed and a low level of reporting bycatch from fishermen (despite a legal requirement to do so). For example, in 1990, Gulf of Maine fishermen reported only 74 bycaught harbour porpoises versus 2900 estimated from the observer programme. Despite these estimated bycatch levels, it was emphasized that management measures do seem to reduce bycatch.

(SOURCE: Read, A.J., Drinker, P. and Northridge, S. 2006. Bycatch of marine mammals in U.S. and global fisheries. *Cons. Biol.* 20: 163-169)

Potentially unsustainable bycatch in Irish tuna fishery

Short-beaked common dolphins (*Delphinus delphis*) and striped dolphins (*Stenella coeruleoalba*) were the most commonly observed bycatch in Irish driftnet fisheries for tuna in 1996 (47.8% of 261 hauls were observed) and 1998 (2.2% of 819 hauls were observed), but other bycaught species included long-finned pilot whale, common bottlenose dolphin, Atlantic white-sided dolphin (*Lagenorhynchus acutus*), Risso's dolphin, minke whale (*Balaenoptera acutorostrata*) and sperm whale (*Physeter macrocephalus*). Extrapolating for the observed bycatch, the authors estimated that during the period 1990-2000 the fishery took approximately 11,723 short-beaked common and 12,635 striped dolphins. Catches of common dolphins likely represented 0.7 to 4.1% of the population. Based on the data from this study and bycatch rates for the French fleet the authors note that for the tuna fishery "*it is likely that removals exceeded 2% of local abundance estimates for striped dolphins and were likely to be unsustainable*".

(SOURCE: Rogan, E. and Mackey, M. 2007. Megafauna bycatch in drift nets for albacore tuna (*Thunnus alalunga*) in the NE Atlantic. *Fish. Res*. 86: 6-14)

Marine Debris

Plastic debris ingestion by a pygmy sperm whale and a rough-toothed dolphin

The forestomach of a severely emaciated, stranded adult rough-toothed dolphin (*Steno bredanensis*) off the coast of Brazil in 2001 contained two plastic bags and four pieces of sea sponge. The forestomach's mucosa was ulcerated. Solid waste was identified as a major pollutant in the region, leading to the suggestion that management measures should be taken to reduce the risk to cetaceans from marine debris "*such as legal mechanisms, enforcement and awareness campaigns*". Similarly, in 1993 a juvenile pygmy sperm whale (*Kogia breviceps*) washed up on the US Atlantic coast (New Jersey). At a rehabilitation facility, the emaciated animal appeared to have gas within its stomach, was unable to dive properly and occasionally regurgitated after eating. Examination of the stomach with an endoscope revealed an assortment of plastic scraps and a portion of Mylar balloon. These were extracted, and the animal eventually recovered and was released. The authors note increasing numbers of animals being reported consuming plastic debris and the propensity for pygmy sperm whales to swallow such debris. The study "*provides evidence on how* [plastic] *ingestion leads to debilitation and disease*".

(SOURCES: Oliveira de Meirelles, A.C. and Duarte do Rego Barros, H.M. 2007. Plastic debris ingested by a rough-toothed dolphin, *Steno bredanensis*, stranded alive in northeastern Brazil. *Biotemas* 20: 127-131; Stamper, A. M., Whitaker, B. R. and Schofield. T. D. 2006. Case study: morbidity in a pygmy sperm whale, *Kogia breviceps*, due to ocean-bourne plastic. *Mar. Mamm. Sci.* 22: 719-722)

Ship strikes

Ship strike lesions described in North Atlantic right whales to assist ship strike diagnosis

Ship strikes appeared to cause the death of 53% (n = 40) of the North Atlantic right whales (*Eubalaena glacialis*) necropsied between 1970 and December 2006. Injuries sustained were either 'sharp trauma', *e.g*., propeller lacerations, or 'blunt trauma', presumably from strikes by boat hulls. Four case studies were described: one animal survived the initial collision but died when its wounds reopened and became infected 14 years later. The three other carcasses showed lesions and fracturing patterns characteristic of ship strikes. The striking vessel was known for only one animal: a female carrying a near full-term foetus, struck by a US Navy Amphibious Assault Ship on 17 November 2004. A table of indicators associated with ship strikes was developed, for use by others to assist in diagnosing cause of death. The authors state that "*before this study, no detailed comparative analysis of trauma pathology that resulted from lethal interactions between vessels and right whales had been conducted*" and further note that their study and descriptions "*will enhance the present understanding of the impact of anthropogenic mortality on this critically endangered species*". As a practical suggestion, based on their findings, they posit that "*speed restrictions may be evaluated as a means of reducing vessel-whale collision fatalities*".

(SOURCE: Campbell-Malone, R., Barco, S.G., Daoust, P.-Y., Knowlton, A.R., McLellan, W.A., Rotstein, D.S. and Moore, M.J. 2008. Gross and histologic evidence of sharp and blunt trauma in North Atlantic right whales (*Eubalaena glacialis*) killed by vessels. *J. Zoo Wildl. Med.* 39: 37–55)

Measures proposed to reduce ship strike risk for North Atlantic right whales

The North Atlantic right whale is particularly susceptible to collisions with ships. Researchers investigated if the risk of ship strikes would be reduced if all vessels over 300 tonnes were limited to speeds of 10 knots (from April to July) and if either of two proposals was carried out: designating an area of critical habitat (an area to be avoided by shipping) and changing shipping channels into Boston Harbor. From 1999-2005, 75% of right whales sighted were in the proposed 'Area To Be Avoided', suggesting that reducing shipping traffic here could potentially reduce the risk of ship strike by 63%. Changing (narrowing) the shipping channels would have resulted in 77 of 196 whales using the area during 1999-2005 being physically separated from transiting ships, reducing the risk by an additional 11%, although the risk for animals transiting the new channel would be greater due to a higher ship density. The proposed changes could also reduce the ship strike risk for both fin (*Balaenoptera physalus*) and blue whales (*B. musculus*). As of July 2007, the ship traffic lanes have in fact been shifted.

(SOURCE: Merrick, R.L. and Cole, T.V.N. 2007. Evaluation of Northern right whale ship strike reduction measures in the Great South Channel of Massachusetts. NOAA Technical Memorandum NMFS-NE-202. National Marine Fisheries Service, Woods Hole, MA, USA; NOAA. 2008. "News" section, *Mar. Pollut. Bull.* 54: 1077).

Chemical pollution

Numerous publications documented cetacean contaminant levels from the Atlantic Ocean during 2005-2008. Maximum recorded trace element levels are summarised for the eastern Atlantic in Table 1; Table 2 summarises butyltins. Western Atlantic data for trace element concentrations are summarised in Table 3 and Table 4 summarises organic contaminant concentrations for species on both sides of the Atlantic.

Measurements of organochlorines in dead porpoises yield reliable values

A key question in studying contaminants in cetaceans is whether levels change after the animal dies. This study examines six freshly bycaught, dead harbour porpoises from the Bay of Fundy, Canada. It demonstrates that the levels of three organochlorine compounds – DLCs, PCB and tDDT – remained sufficiently stable over 48 hours after death to yield reliable results. Thus, bycaught harbour porpoises can be used as indicators of concentrations prior to death.

(SOURCE: Borrell, A., Aguilar, A., Zeljkovic, S. Brouwer, A. Besselink, H.T., Koopman, H. Read, A. and Reijnders, P.J.H. 2007. Post-mortem stability of blubber DLCs, PCB, and tDDT in by-caught harbour porpoises (*Phocoena phocoena*). *Mar. Pollut. Bull.* 54: 1663-1666)

PFAs found in cetaceans from the Faeroe Islands and Greenland

PFAs are used in textiles, upholstery and carpeting, as well as in the production of fire-fighting foams. Liver tissue from northern minke whales caught in aboriginal whaling operations in Greenland and from long-finned pilot whales caught in drive fisheries from the Faeroe Islands showed PFA levels higher in the latter than in the former. In general, PFOSA was the most abundant PFA. Although the authors did not note any ecotoxicological implications of their findings, this poses unknown risks to these cetaceans and to humans who consume them.

Maximum contaminant levels

Liver (µg.g^{-1} wet weight) PFOS: 0.065; PFOSA: 0.062

(SOURCE: Bossi, R., Riget, F.F., Dietz, R., Sonne, C., Fauser, P., Dam, M., Vorkamp, K. 2005. Preliminary screening of perfluorooctane sulfonate (PFOS) and other fluorochemicals in fish, birds and marine mammals from Greenland and the Faroe Islands. *Environ. Pollut.*136: 323-329)

High levels of mercury in dolphin blood in Florida, USA

Several studies in recent years have investigated trace element levels in the tissues of common bottlenose dolphins in Florida (see Table 3). Using non-lethal techniques, "*concentrations* [of Hg] *in both blood and skin were above the threshold at which detrimental effects are observed in other vertebrate species*" and thus may be of conservation concern.

(SOURCE: Bryan. C.E., Christopher S.J., Balmer, B.C. and Wells, R.S. 2007. Establishing baseline levels of trace elements in blood and skin of bottlenose dolphins in Sarasota Bay, Florida: implications for non-invasive monitoring. *Sci. Total Environ.* 388: 325–342)

Gasoline is a source of lead contamination in European cetaceans

A study comparing lead (Pb) concentrations and isotope levels in small cetaceans from the eastern Atlantic found levels of lead that were "*far lower than threshold value inducing toxic effects in humans*". The analysis of lead isotope levels revealed that some of the lead had an atmospheric source, and ratios suggested that alkyl lead used in gasoline has been the main source of contamination. See Table 1 for details on contaminant levels.

(SOURCE: Caurant, F., Aubail, A., Lahaye, V., Van Canneyt, O., Rogan, E., López, A., Addink, M., Churlaud, C., Robert, M. and Bustamante P. 2006. Lead contamination of small cetaceans in European waters – the use of stable isotopes for identifying the sources of lead exposure. *Mar. Environ. Res.* 62 131–148)

High levels of PBDEs and PFAs in common bottlenose dolphins on the US Atlantic coast

High levels of PBDEs were found in common bottlenose dolphins from the Atlantic coast of the US, whereby levels were significantly higher in dolphins from South Carolina than those from Florida. Moreover, adult males had significantly higher levels than adult females (males were twice as contaminated as females in Florida and 12 times as contaminated in South Carolina). Juveniles from S. Carolina also had higher levels of contaminants than adult females. The authors note that "*the levels of PBDEs in Charleston dolphins represent some of the highest measured in marine mammals*" and that these contaminants could pose a health risk to these dolphin populations. An analysis of common bottlenose dolphin blood plasma from several locations (Florida, S. Carolina, and New Jersey in the USA and Bermuda) identified eight PFAs, with PFOS the most common. Levels of PFAs were significantly higher in the samples from S. Carolina compared to those from Florida or Bermuda. PFA levels were positively correlated with age, but gender was not related to contaminant levels. The authors noted that "*concentrations reported in this study, particularly at Charleston, were generally greater than PFA concentrations reported previously for cetacean tissues and plasma*".

Maximum contaminant levels

Blubber (µg.g^{-1} lipid weight) ΣPBDE: 22.8

Blood plasma (µg.g^{-1} wet weight) PFOS: 3.073

(SOURCE: Fair, P.A., Mitchum, G. Hulsey, T.C., Adams, J., Zolman, E., McFee, W., Wirth, E. and Bossart, G.D. 2007. Polybrominated Diphenyl Ethers (PBDEs) in blubber of free-ranging bottlenose dolphins (*Tursiops truncatus*) from two southeast Atlantic estuarine areas. *Arch. Environ. Contam. Toxicol*. 53: 483-494; Houde, M., Wells, R.S. Fair, P.A., Bossart, G.D., Hohn, A.A., Rowles, T., Sweeney, J.C., Solomon, K.R. and Muir, D.C.G. 2005. Polyfluoroalkyl compounds in free-ranging bottlenose dolphins (*Tursiops truncatus*) from the Gulf of Mexico and the Atlantic Ocean. *Environ. Sci. Technol.* 39: 6591-6598)

Limited transfer of cadmium and mercury from mothers to calves in common dolphins

An analysis of trace element levels in common dolphin mother-calf pairs stranded on the coast of France discovered relatively low levels of Hg and Cd in calves compared to their mothers, suggesting that maternal transfer of these trace elements is low. However, "*hepatic Hg levels in foetuses increased with body length, and were also proportionate to maternal hepatic, renal and muscular Hg levels*"; thus, high levels of adult Hg contamination could have impacts on calf health. Levels of Se and Hg were correlated, suggesting that Se may have a role in detoxifying Hg in both adults and calves. See Table 1 for details on contaminant levels.

(SOURCE: Lahaye, V., Bustamante, P., Dabin, W., Churlaud, C. and Caurant, F. 2007. Trace element levels in foetus–mother pairs of short-beaked common dolphins (*Delphinus delphis*) stranded along the French coasts. *Environ. Internat.* 33: 1021–1028)

Decreasing levels of contamination in St Lawrence Estuary beluga whales

A review of 15 years' worth of organochlorine and other organic contaminant data from St Lawrence Estuary beluga whales (*Delphinapterus leucas*) showed that "*concentrations of most of the* [toxic chemicals] *examined had exponentially decreased by at least a factor of two…between 1987 and 2002*", including most PCBs, DDD and DDT. However, some chemicals did not decrease significantly (γ-HCH), probably because of continued use. No trends were noted in other chemicals (*e.g.*, TCPMe and TCPMOH). It was proposed that the declining trends in these organic contaminants were linked to less contaminated prey.

(SOURCE: Lebeuf, M., Noël, M., Trottier, S., Measures, L. 2007.Temporal trends (1987–2002) of persistent, bioaccumulative and toxic (PBT) chemicals in beluga whales (*Delphinapterus leucas*) from the St. Lawrence Estuary, Canada. *Sci. Total Environ.* 383: 216–231)

Workshop to investigate lack of recovery in the St Lawrence Estuary beluga whale population

The St Lawrence Estuary beluga whale population was severely depleted by commercial hunting. Its protected status since 1979 was not resulted in population recovery and there are concerns that high levels of contaminants (especially organochlorine and polyaromatic hydrocarbon contamination) may be causing reproductive and immune system depression. A workshop held 14-17 November 2005 concluded that an extensive necropsy programme has

"*documented lesions, anomalies such as cancer, opportunistic infections, and biomarkers such as DNA adducts suggesting toxic effects, possible endocrine disruption and immunosuppression due to contaminants*". However, ultimately the necropsy programme "*has not determined why this population is not recovering*". Integration of research data from various sources (*e.g.*, photo-identification and aerial surveys, necropsy findings) and freely accessible and shared data would assist with clarifying population-level effects. A research consortium was proposed, having three themes: (a) pathology and infectious diseases; (b) contaminants and their toxic effects; and (c) biology and demography. This proposed consortium could be an important model for other species or populations where there is concern about anthropogenic impacts. Its research results could have significant implications for other cetacean populations.

(SOURCE: Measures, L. 2007. *Proceedings of the workshop on the St. Lawrence Estuary beluga – review of carcass program.* 14-17 November 2005, Maurice Lamontagne Institute, Fisheries and Oceans Canada, Mont-Joli, Québec)

PCB mobilization from blubber and its health impacts

Knowledge of how contaminants are released from marine mammal blubber is essential to understanding the toxic potential for PCBs and other compounds. Levels of a PCB biomarker (cytochrome P4501A1, which is related to levels of hydroxylated PCBs in blood plasma) suggested that mobilized PCB concentrations were high in male dolphins and analysis of blubber biopsies found that fat cells (adipocytes) in their deep blubber layer were smaller. Adipocytes were smallest and biomarker levels highest in lactating pregnant females, suggesting a high level of mobilized contaminants. The authors summarised that "*during periods of lipid mobilization (as occurs during fasting, starvation…lactation, or any combination of these factors), stored blubber lipids…may be redistributed into the circulatory system, reaching target sites and undergoing bioactivation*". In terms of the risk posed to cetaceans, they conclude that "*the* [hydroxylated PCBs in the blood plasma] *may have the potential to interfere with…essential processes such as skeletal growth, development of the brain and inner ear, immune system function, maintenance of metabolic rate, fat metabolism, and sexual function*".

(SOURCE: Montie, E.W., Fair, P.A., Bossart, G.D., Mitchum, G.B., Houde, M., Muir, D.C.G., Letcher, R.J., McFee, W.E., Starczak, V.R., Stegeman, J.J., Hahn, M.E. 2008. Cytochrome P4501A1 expression, polychlorinated biphenyls and hydroxylated metabolites, and adipocyte size of bottlenose dolphins from the Southeast United States. *Aquat.Toxicol.* 86: 397–412)

Low levels of brominated compounds in dolphins

HBCD, a brominated flame retardant, was found in blubber and liver samples of Atlantic white-sided dolphins stranded between 1993 and 2004. Tests were made for three types of HBCD: α-HBCD was found in all samples, whilst *β*-HBCD and *γ*-HBCD were not detected in any. The authors noted that "*in general, concentrations of HBCDs were lower in these white-sided dolphins than in cetaceans from Western Europe*". A second study examining common bottlenose dolphins from Florida, stranded between 1991 and 2004, also found low levels of HBCDs. Like the first study, α-HBCD was most common, but *β*-HBCD and *γ*-HBCD were also detected, as was TBBPA (tetrabromobisphenol A), the first time this contaminant has been documented in US Atlantic coast dolphins. As with the first study, the second study's authors determined that HBCD levels in bottlenose dolphins "*were lower than the concentrations reported in other marine species from European countries*".

Maximum contaminant levels

α-HBCD (μg.g^{-1} lipid weight) blubber: 0.38; liver: 0.14

Total HBCDs (μg.g^{-1} lipid weight): 0.072

(SOURCE: Peck, A.M., Pugh. R.S., Moors, A., Ellisor, M.B., Porter, B.J., Becker, P.R. and Kucklick, J.R. 2008. Hexabromocyclododecane in white-sided dolphins: temporal trend and stereoisomer distribution in tissues. *Environ. Sci. Technol.* 42: 2650–2655; Johnson-Restrepo, B., Adams, D.H. and Kannan, K. 2008. Tetrabromobisphenol A (TBBPA) and hexabromocyclododecanes (HBCDs) in tissues of humans, dolphins, and sharks from the United States. *Chemosphere* 70: 1935–1944)

Dolphins and their prey carry site specific contaminant loads

A study investigating PCB and toxaphene levels in the prey species preferred by bottlenose dolphins discovered little difference in contamination levels amongst species, but did discover a significant difference in levels of contaminants amongst different estuaries. Fish were sampled from several dolphin-inhabited locations along the coasts of the US states of Georgia and Florida, and PCB levels were as much as an order of magnitude higher than fish sampled in New Jersey, Oregon or Alaska. A second study compared organochlorine contaminant levels amongst dolphins in these estuaries and, similarly to the fish, there were significant differences amongst the locations. Mean contaminant levels in dolphins from the Turtle/Brunswick River Estuary were an order of magnitude higher than in animals from Savannah River estuaries, 90km to the north. The PCB ratios in the dolphins mirrored those of their prey. This study supports the hypothesis that bottlenose dolphins off the US Atlantic coast are long-term residents in specific estuaries. The authors conclude that "*Knowledge of primary sources (i.e. contaminated prey) and the spatial extent of the contaminated environment* [is] *necessary for appropriate management actions to reduce exposure and thus risks associated with* [persistent organic pollutants]". See Table 4 for details on contaminant levels in the dolphins.

Maximum contaminant level

Fish (μg.g^{-1} lipid weight) ΣPCB: 3.1

(SOURCE: Pulster, E.L., Smalling, K.L. and Maruya, K.A. 2005. Polychlorinated biphenyls and toxaphene in preferred prey fish of coastal southeastern U.S. bottlenose dolphins (*Tursiops truncatus*). *Environ. Toxicol. Chem.* 24: 3128–3136; Pulster, E.L. and Maruya, K.A. 2008. Geographic specificity of Aroclor 1268 in bottlenose dolphins (*Tursiops truncatus*) frequenting the Turtle/Brunswick River Estuary, Georgia (USA). *Sci. Total Environ.* 393: 367-375)

Immune system suppression in relation to PCB contaminated minke whale tissue

Northern minke whale blubber was fed to sled dogs from western Greenland. A daily intake of 50-200g impaired the dogs' immune system. The authors noted that "*the study used exposure levels similar to those of Inuits*" and "*it is reasonable to infer that Inuits…suffer from similar decreased resistance to disease*" and warn about possible impacts to other top predators consuming cetacean tissues.

(SOURCE: Sonne, C., Dietz, R., Larsen, H.J.S., Loft, K.E., Kirkegaard, M., Letcher, R.J., Shahmiri, A. and Møller, P. 2006. Impairment of cellular immunity in West Greenland sledge dogs (*Canis familiaris*) dietary exposed to polluted minke whale (*Balaenoptera acutorostrata*) blubber. *Environ. Sci. Technol.* 40: 2056-2062)

Contaminant concentrations in the blood of common bottlenose dolphins on the US Atlantic coast

The levels of As, Mn and Se were significantly higher in dolphins from South Carolina compared to those from Florida, whilst the levels of Cu, THg and Zn were significantly higher in dolphins from Florida. Additional differences due to sex and age were attributed to different diets. The only positive age correlation was with THg in the S. Carolina population. This study provides the largest existing dataset for multiple trace elements in the blood of free-ranging bottlenose dolphins and is the first report on the concentrations of five contaminants in the blood of dolphins from the US's south Atlantic coast. Such studies provide baseline data for establishing possible correlations between contaminants and population declines, and blood concentrations may also be useful in comparing contaminant exposure of dolphins to that of humans and other mammals.

(SOURCE: Stavros, H.-C.W., Bossart, G.D., Hulsey, T.C. and Fair, P.A. 2008. Trace element concentrations in blood of free-ranging bottlenose dolphins (*Tursiops truncatus*): influence of age, sex and location. *Mar. Pollut. Bull.* 56: 348-379)

High calf mortality linked to PCB contamination in common bottlenose dolphins in Florida

A long-term study on organochlorine contamination in bottlenose dolphins in Florida determined that until sexual maturity was reached, both males and females exhibited similar PCB concentrations in blubber (15–50 $\mu g.g^{-1}$ lipid weight). After sexual maturity, male PCB concentrations increased with age (over 100 ppm on average, with a maximum of 860 $\mu g.g^{-1}$ lipid weight in a 43-year-old male). However, female contaminant concentrations decreased after the birth of their first calf and were much lower (less than 15 $\mu g.g^{-1}$ lipid weight). Concern was expressed over contaminant transfer to calves and it was noted that "*in primiparous females, PCB concentrations in blubber and plasma and the rates of first-born calf mortality were both high*". Only 50% of first-born calves survived their first year (compared to a survival rate of 70% for second and later-born calves).

(SOURCE: Wells, R.S.,Victoria Tornerob T.V., Borrell, A., Aguilar, A., Rowles, T.K., Rhinehart, H.L., Hofmann, S., Jarman, W.M., Hohn, A.A. and Sweeney, J.C. 2005. Integrating life-history and reproductive success data to examine potential relationships with organochlorine compounds for bottlenose dolphins (*Tursiops truncatus*) in Sarasota Bay, Florida. *Sci. Total Environ.* 349: 106– 119)

Chromium causes lung and testes cell damage - high levels a concern for North Atlantic right whales

Hexavalent chromium (Cr [VI]) is a toxic form of the trace element that can severely impact the health of organisms. The effects of Cr (VI) on cultured fibroblasts from North Atlantic right whale lung and testes tissues were examined. Increasing concentrations led to increasing levels of fibroblast mortality. Testes cells were significantly more sensitive than lung cells. This is a cause for concern as Cr (VI) has been shown to accumulate in testis tissue in humans and other mammals and thus could lower reproductive rates of contaminated animals. Increasing Cr (VI) concentrations also caused increasing amounts of chromosomal aberrations in tested cells, with no significant difference in the level of damage between cell types. Levels of Cr in right whales were determined by skin biopsy, assuming that Cr (VI) is the main form to which animals are exposed). The authors note that "*lung tissue levels in chromate workers with lung cancer ranged from 0.5 to 192 µg/g (wet weight) with a median level of 25 µg/g…the whale levels overlap this range… suggesting that* [the recorded contaminant levels] *are high*". The authors also noted that one Cr-exposed human who had contracted exposure-linked lung cancer had skin Cr levels much lower than the sampled right whales. The whales probably inhaled Cr issuing from coastal industrial cities and accumulated such high levels because of their large lung volumes. The authors conclude that "*these data support a hypothesis that chromium may be a concern for the health of the North Atlantic right whales*".

(SOURCE: Wise, J. P., Wise, S. S., Kraus, S., Shaffiey, F., Grau, M., Chen, T.L., Christopher Perkins, C., Thompson, W.D., Zheng, T., Zhang, Y., Romano, T., O'Hara, T. 2008. Hexavalent chromium is cytotoxic and genotoxic to the North Atlantic right whale (*Eubalaena glacialis*) lung and testes fibroblasts. *Mutat. Res*. 650: 30-38)

Disease and mortality events

Harmful Algal Blooms (HABs)

Brevetoxin exposure does not fully explain dolphin mortalities in Florida

Levels of brevetoxin (an algal toxin produced by the dinoflagellate *Karenia brevis*) were analysed in common bottlenose dolphin carcasses on the west coast of Florida. Eighty-four percent of carcasses recovered during *K. brevis* blooms tested positive for brevetoxin in stomach or excrement samples. Over 50% of carcasses examined outside of algal blooms also tested positive, but levels were considerably lower. Samples from the east coast of Florida, however, tested negative. Accordingly, "*dolphin carcasses not associated with large-scale mortality events can contain levels of brevetoxins comparable to carcasses stranding during such events*" and "*this finding suggests that* K. brevis *abundance and brevetoxin exposure are not the sole factors in determining the total effect of red tides on dolphins, and do not explain differences in dolphin mortality between populations*", although exposure to high levels of brevetoxin is likely to be a factor in these events.

Maximum levels

Stomach contents (ng PbTx-3 eq g^{-1}) brevetoxin: 2,896

(SOURCE: Fire, S. E., Fauquier, D., Flewelling, L.J., Henry, M., Naar, J., Pierce, R. and Wells R.S. 2007. Brevetoxin exposure in bottlenose dolphins (*Tursiops truncatus*) associated with *Karenia brevis* blooms in Sarasota Bay, Florida. *Mar. Biol.* 152: 827-834)

Disease

Diversity of antibiotic resistant bacteria found in US east coast bottlenose dolphins

Common bottlenose dolphins in the US states of Florida and South Carolina were screened for antibiotic-resistant bacteria. *E. coli* strains resistant to 6 of the 25 antibiotics tested were found. Penicillin resistance was most common, followed by cephalothin, ampicillin and amoxicillin resistance. This prevalence

of resistant bacteria was linked with urban development and ensuing decreases in water quality. Such bacteria presumably entered the local marine environment via discharged sewage, septic tanks or runoff. These "*may be serving as vectors for antibiotic resistant bacteria and quite possibly acting as vectors for dissemination into other environments*", which has implications for the health of the dolphins, associated marine species and also humans who may come into contact with these animals.

(SOURCE: Greig, T.W., Bemiss, J.A., Lyon, B.R., Bossart, G.D. and Fair, P.A. 2007. Prevalence and diversity of antibiotic resistant *Escherichia coli* in bottlenose dolphins (*Tursiops truncatus*) from the Indian River Lagoon, Florida and Charleston Harbor area, South Carolina. *Aquat. Mamm.* 33: 185-194)

Morbillivirus found in dolphin stranded on the German coast

In January 2007, a sub-adult white-beaked dolphin (*Lagenorhynchus albirostris*) was found stranded on the north coast of Germany. The animal presented signs of pneumonia and sections of the brain revealed the presence of morbillivirus antigens. Genetic analysis of tissues revealed the presence of morbillivirus material. The presence of the pathogen in white-beaked dolphins is a concern because "*these dolphins may play a role as a reservoir and vector for this morbillivirus, which is infectious for harbor porpoises, bottlenose dolphins, and other cetacean species*". Moreover, the "*reappearance of a morbillivirus represents a serious threat to susceptible marine mammals in northern European and American waters, with potentially devastating consequences and possibly the beginning of a new epidemic*".

(SOURCE: Wohlsein, P., Puff, C., Kreutzer, M., Siebert, U. and Baumgärtner, W. 2007. Distemper in a dolphin. *Emerg. Infect. Dis.* 13: 1959-1961)

Stranding

Baseline stranding data are useful for monitoring human-caused and natural mortality

Data from common bottlenose dolphin strandings (n = 302) in South Carolina from 1997 to 2003 were used to elucidate patterns in the species' seasonal distribution, reproductive cycles, migratory behaviour and negative interactions with human activity. A quarter of the strandings (an almost certain underestimation) displayed signs of rope entanglement, presumably resulting from interaction with lobster pot lines. Five animals showed signs of (trammel) net entanglement and six animals showed signs of boat strikes. The latter were juveniles and a subadult, echoing data from elsewhere suggesting inexperience plays a role in boat strikes in dolphins. The study demonstrated how useful, biological and conservation-related information can be gained from long-term stranding report programmes.

(SOURCE: McFee, W.E., Hopkins-Murphy, S.R. and Schwacke, L.H. 2006. Trends in bottlenose dolphin (*Tursiops truncatus*) strandings in South Carolina, USA, 1997-2003: implications for the Southern North Carolina and South Carolina Management Units. *J. Cet. Res. Manage*. 8: 195-201)

Sperm whale strandings in the North Sea linked to temperature anomalies

When migrating southwards from their feeding grounds, sperm whales normally travel to the west of the British isles, but sometimes swim into the shallow waters of the North Sea, which has been called a 'trap' for sperm whales, due to the difficulties they have navigating in this area. An analysis of sperm whale stranding events found that strandings were correlated with warm temperature anomalies, perhaps as the result of changes in the distribution of squid during these anomalies. Studies like these may prove useful in defining potential effects of climate change on cetaceans.

(SOURCE: Pierce, G.J., Santos, M.B., Smeenk, C., Saveliev, A. and Zuur, A.F. 2007. Historical trends in the incidence of strandings of sperm whales (*Physeter macrocephalus*) on North Sea coasts: An association with positive temperature anomalies. *Fish. Res.* 87: 219-228)

Climate change

A multiple variable analysis shows a possible regime shift in the Bay of Biscay

Long-term data from marine animal populations in the Bay of Biscay were collected in line transect surveys between 1974 and 2000 and fish abundance was derived from commercial fishery landings. Forty-four initial variables were used to describe the oceanic and atmospheric conditions. Inter-annual fluctuations for most seabird, cetacean and fish populations were significant. Cold-water species declined while two (Atlantic puffin [*Fratercula arctica*] and killer whale [*Orcinus orca*]) totally disappeared from the area. Warmer-water species increased. These demographic trends may reveal a regime shift for this part of the Atlantic Ocean. The multiple variable analysis suggests that the whole marine ecosystem is strongly affected by a limited number of physical parameters. The remaining variation corresponds to the impact of anthropogenic activities such as overfishing and oil spills (and to statistical error).

(SOURCE: Hemery, G., D'Amico, F., Castege, I., Dupont, B., D'Elbee, J., Lalanne, Y. and Mouches, C. 2008. Detecting the impact of oceano-climatic changes on marine ecosystems using a multivariate index: The case of the Bay of Biscay (North Atlantic-European Ocean). *Global Change Biol.* 14: 27-38)

Major climatic changes predicted for the Baltic Sea

Climate models predict major changes in the Baltic Sea by the late 21st century, including a major increase in freshwater input from increased precipitation and runoff. The average salinity of the Baltic may decrease by 8-50%. Moreover, westerly winds will increase in speed, with resulting increases in storm surges and wave heights. Models predict that the average temperature will increase from 1.9°C to 3.2°C. The extent of sea ice in the Baltic will also decrease by up to 77%, although it is unlikely to be ice-free in the winter. These changes could have major impacts on the marine ecosystem of this sea and hence on cetaceans.

(SOURCE: Meier, H.E.M. 2006. Baltic Sea climate in the late twenty-first century: a dynamical downscaling approach using two global models and two emission scenarios. *Clim. Dynam.* 27: 39 – 68)

Increasing sea surface temperatures lead to decreasing salmon condition

Condition of Atlantic salmon (*Salmo salar*) was found to be poor in years with high sea surface temperatures in the north Atlantic. These temperatures were correlated with depleted lipid supplies and thus impact reproductive capability. Over the past decade Atlantic salmon stocks have decreased by 11–14%; increasing temperatures may promote this decline. The authors suggested that sea surface temperature and condition of salmon year classes should be incorporated into fisheries models and "*conservation limits should be revised upwards conservatively*" to account for this new factor. The effects of climate

change on salmon, an important prey species for many marine mammals, or on other Atlantic fish stocks may have implications for cetacean prey availability.

(SOURCE: Todd, C.D., Hughes, S.L., Marshall, C.T., MacLean, J.C., Lonergan, M.E. and Biuw, E. M. 2008. Detrimental effects of recent ocean surface warming on growth condition of Atlantic salmon. *Global Change Biol.* 14: 958–970)

Noise impacts

General

Evidence of noise impacts on whale vocalisations

Right whales may shift call frequency to compensate for increased background noise. Right whales produce calls with a higher average fundamental frequency and call at a lower rate when they are in high background noise conditions, possibly in response to masking by low-frequency noise (*e.g.*, from shipping). Long-term changes have occurred within the known lifespan of individual whales, indicating that a behavioural change, rather than selective pressure, has resulted in the observed differences. The researchers concluded that "*given the observed behavioral response, the impacts on right whale communication need to be considered to determine what, if any, role increased noise may have on limiting reproduction and recovery of the species*".

(SOURCE: Parks, S. E., Clark, C. W. and Tyack, P. L. 2007. Short- and long-term changes in right whale calling behavior: The potential effects of noise on acoustic communication. *J. Acoust. Soc. Amer.* 122: 3725-3731)

Seismic surveys

Marine mammal reactions to seismic surveys in the northwest Atlantic

A monitoring programme during a seismic survey in the northwest Atlantic during 2003 observed marine mammals both visually and acoustically. No marine mammal incidents or adverse reactions were recorded. There was no correlation between visual and acoustical detections; neither method was redundant and using both methods increased the likelihood of obtaining a true indication of cetacean presence. Marine mammals appear to have avoided getting very close (<100 m) to the seismic array during operation, but the overall number of marine mammals within 1-2km did not change significantly when the seismic source was 'on' compared to 'off'. Larger and apparently less vocal groups were observed when the seismic source was active, although the results may be affected by potential sources of bias (such as the combination of data from toothed and baleen whales). The researchers noted that "*seismic surveying can apparently have a behavioral impact at a high level of statistical significance without visual observers reporting seeing fewer marine mammals*". In addition, some high-frequency energy content was detected in the otherwise lower-frequency seismic signal.

(SOURCE: Potter, J. R., Thillet, M., Douglas, C., Chitre, M.A., Doborzynski, Z. and Seekings, P.J. 2007. Visual and passive acoustic marine mammal observations and high-frequency seismic source characteristics recorded during a seismic survey. *IEEE J. Oceanic Engineer.* 32: 469-483)

Atlantic spotted dolphins show a greater reaction to seismic airguns than baleen whales in Angola

Marine mammals were observed from a seismic survey vessel off Angola between August 2004 and May 2005. The encounter rate for humpback and sperm whales did not differ significantly according to airgun operational status. However, encounters of Atlantic spotted dolphins (*Stenella frontalis*) occurred at a significantly greater distance from the airgun array when the guns were 'on'. Spotted dolphins approached the vessel only when the guns were off. There was no evidence for prolonged or large-scale displacement of animals from the region during the 10-month survey duration. Dolphins are generally perceived to be less sensitive to low frequency sound than baleen whales, but nevertheless showed a response greater than the two baleen whale species examined.

(SOURCE: Weir, C.R. 2008. Overt responses of humpback whales (*Megaptera novaeangliae*), sperm whales (*Physeter macrocephalus*), and Atlantic spotted dolphins (*Stenella frontalis*) to seismic exploration off Angola. *Aquat. Mamms.* 34: 71-83)

GLOBAL

Habitat protection/degradation

General

Wide-scale habitat degradation in the world's oceans

A multi-scale spatial model was developed to investigate how 17 human activities, and developments resulting from those activities (*e.g.*, shipping, bycatch, organic and nutrient pollution, ocean acidification and sea temperature change), affected 20 marine ecosystems. The model determined that no marine ecosystem was unaffected by human activities and nearly half (41%) were facing multiple stressors. Areas of high impact included the North Sea and Norwegian coastal waters, the eastern Caribbean and the US Atlantic coast, as well as the Mediterranean, Persian Gulf and Bering Seas. Only 3.7% of oceans faced 'low impacts' and these were predominantly polar areas with limited human access due to ice cover. However, the exercise did not include atmosphere-transported contaminants; population depletion as the result of illegal, unregulated or unreported fishing; or, for polar regions, possible ecosystem effects of global warming-induced ice loss or projected increases in human activities (*e.g.*, shipping and fishing), as ice loss allows greater human access. Other omitted factors included recreational fishing, aquaculture and coastal development. Long-lasting environmental impacts from past activities, *e.g.*, historical overfishing, were noted. In areas with multiple stressors, synergy may result in impacts more severe than predicted.

(SOURCE: Halpern, B.S., Walbride, S., Selkoe, K.A., Kappel, C.V., Micheli, F., D'Agrosa, C., Bruno, J.F., Casey, K.S., Ebert, C., Fox, H.E., Fujita, R., Heinemann, D., Lenihan, H.S., Madin, E.M.P., Perry, M.T., Selig, E.R., Spalding, M., Steneck. R. and Watson, R. 2008. A global map of human impact on marine ecosystems. *Science* 319: 948-952)

Large-scale 'iron fertilization' of the sea under scrutiny by the London Convention

A commercial company plans to 'fertilize' the sea about 600km west of the Galapagos Islands with nearly 100 tons of the iron-containing mineral haematite. The concept is designed to create phytoplankton blooms and thus control greenhouse gases and combat climate change. This attempt, which is also

designed to sell 'carbon credits', follows 12 earlier experiments and would ultimately affect an area as large as 10,000km². Although this approach does produce blooms, it remains unknown whether it permanently sequesters carbon. This, combined with potential side effects ranging from harmful algal blooms to oxygen depletion, has prompted the London Convention – the main treaty governing ocean dumping – to issue a statement of concern. It may call for further regulation under the terms of the treaty. The idea of using the world's seas as a site for large-scale experiments that dump industrial waste to achieve unproven goals has also attracted the interest of environmental groups and spawned a recent international symposium at Woods Hole Oceanographic Institution.

(SOURCES: Schrope, M. 2007. Treaty caution on plankton plans. *Nature ("News")* 447: 1039; The Ocean Iron Fertilization Symposium, 26-27 September 2007, Woods Hole Oceanographic Institution: presentations available as .pdfs at *http://www.whoi.edu/conference/OceanIronFertilization*.

Number of 'dead zones' due to oxygen deficiency increasing rapidly

The most recent research on oxygen crises in the seas has identified 415 eutrophic and hypoxic coastal systems worldwide. Of these, 169 are documented hypoxic areas, 233 are areas of concern and 13 are systems in recovery. The 169 documented areas represent a four-fold increase over the 44 areas reported in 1995 (only 10 documented cases in 1960). Two of the best known areas are the Gulf of Mexico (seasonal hypoxic zone measured 22,000 km² in 2002) and the Black Sea. Mass mortalities and 'dead zones' are related to eutrophication and represent the worst-case scenario for coastal biodiversity and ecosystem function. As such, they represent the severest form of habitat degradation.

(SOURCES: Selman, M., Greenhalgh, S. Diaz, R. and Sugg, Z. 2008. Eutrophication and hypoxia in coastal areas: a global assessment of the state of knowledge. *World Resources Institute, WRI Policy Note* 1: 1-6)

The first human-caused extinction of a cetacean species: the Yangtze River dolphin

An intensive 6-week visual and acoustic survey covering the entire historical range of the Yangtze River dolphin or baiji (*Lipotes vexillifer*) failed to find any evidence that this species survives. In the early to mid-1990s the population was estimated at less than 100 individuals; by the late 1990s, this had dropped to about 13 individuals. This dolphin was the sole representative of a separate family of mammals, making it the first extinction of an entire mammal family since 1500 C.E. and the first cetacean species to be driven to extinction by human activity (largely due to unsustainable bycatch in local fisheries and habitat degradation). This event should serve as a wake-up call for immediate and dramatic measures to prevent the extinction of other endangered cetaceans.

(SOURCE: Turvey, S.T., Pitman, R.L., Taylor, B.L., Barlow, J., Akamatsu, T., Barrett, L.A., Zhao, X., Reeves, R.R., Stewart, B.S., Wang, K., Wei, Z., Zhang, X, Pusser, L.T., Richlen, M., Brandon, J.R., Wang, D. 2007. First human-caused extinction of a cetacean species? *Biol. Lett.* 3: 537-540)

Chemical pollution

Evidence for heavy metal-initiated immune system suppression in bottlenose dolphins

To investigate the effect of toxic heavy metals on the common bottlenose dolphin immune system, white blood cells (phagocytes and lymphocytes) were placed in solutions of varying concentrations of Al, Cd, Cr, Hg and Pb. Hg caused programmed cell death at a concentration of $1mg.L^{-1}$, as did Cd at $10mg.L^{-1}$. Impaired lymphocyte function was reported after exposure to $1mg.L^{-1}$of Hg, $10mg.L^{-1}$of Cd and $50mg.L^{-1}$ of Pb. Decreased phagocyte function was also observed at $5mg.L^{-1}$of Hg, $50mg.L^{-1}$of Al and $10mg.L^{-1}$ of Cd. No effects were reported for any concentration of Cr. The researchers stated that "*these results support the hypothesis that exposure to these contaminants, particularly mercury and cadmium, could lead to a reduction in host resistance to disease in these animals*".

(SOURCE: Cámara Pellissó, S., Muñoz, M.J., Carballo, M., Sánchez-Vizcaíno, J.M. 2008. Determination of the immunotoxic potential of heavy metals on the functional activity of bottlenose dolphin leukocytes *in vitro*. *Vet. Immunol. Immunopath.*121: 189–198)

Differences in contaminant susceptibility between captive and free-ranging marine mammals

In a study of sea otter immune reactions, there was a significant difference in the impacts of contaminant mixtures on blood samples from captive sea otters versus blood samples from free-ranging otters. The authors considered that "*differences in* [contaminant] *susceptibility could be explained by the acute stress of capture, the chronic stress of captivity or nutritional differences*". The free-ranging samples came from otters that had been captured in the wild, sampled, tagged and then released. The capture process may subject animals to acute stress, whereas captive animals may experience a chronic type of stress. Stress hormones may modulate the immune system and this may influence the effects of contaminants. The authors note that "*this is the first report to demonstrate differences in susceptibility to toxicants between captive and free-ranging* [marine mammals]". This has many implications for the research methods used to investigate the impacts of contaminants on marine mammals and also highlights the need to study the possible synergistic effects of stress on contaminant susceptibility.

(SOURCE: Levin, M., Leibrecht, H., Chiharu Mori, C., Jessup, D., De Guise, S. 2007. Immunomodulatory effects of organochlorine mixtures upon *in vitro* exposure of peripheral blood leukocytes differ between free-ranging and captive southern sea otters (*Enhydra lutris*). *Vet. Immunol. Immunopath.*119: 269–277)

How PCBs may increase cetacean disease susceptibility

The reactions of bottlenose dolphin and beluga whale cells to (co-planar) PCBs demonstrated that cellular movement of Ca ions was affected. As Ca ions are important in phagocytosis, an essential immune system response, this provides information on how PCBs may be affecting the health of cetaceans. Moreover, the study found that mouse cells did not react in the same way as cetacean cells, demonstrating that toxicological tests on non-cetacean cells may be inappropriate proxies. This study shows that as a result of PCB influence on Ca mobilization, "*an animal's susceptibility to a variety of infections diseases may increase*".

(SOURCE: Levin, M., Morsey, B. and De Guise, S. 2007. Non-coplanar PCBs induce calcium mobilization in bottlenose dolphin and beluga whale, but not in mouse leukocytes. *J. Toxicol. Environ. Health A* 70: 1220–1231)

Synergistic effects of PCB mixtures and differences between species complicate pollution studies

Toxic equivalent (TEQ) calculations are designed to predict the cumulative toxicity of certain PCBs and dioxins. These typically give a toxicity multiplier value to different contaminants and multiply this value by the concentration of a contaminant; the toxicity of mixtures is calculated by summing these values. However, a new study on mouse and marine mammal cells has shown that this method is flawed. Marine mammal white blood cells (lymphocytes) were exposed to a variety of mixtures of PCBs and dioxin, with the constituent chemicals in differing ratios. The study discovered that PCBs and dioxin can sometimes act synergistically and sometimes antagonistically, to increase or decrease toxic effects and the observed toxicity did not follow what was predicted by TEQs. The responses shown by mouse cells (a typical test for immunotoxicity) were as expected based on TEQ values, but these results did not match the responses shown by dolphin tissues. The authors emphasise that "*the commonly used mouse model failed to predict the immunotoxicity due to* [organochlorines] *in the marine mammals tested*". Therefore TEQs may be an inaccurate predictor of organochlorine toxicity for cetaceans. The study also showed that organochlorines reduce lymphocyte function in dolphin cells and thus could increase the dolphins' susceptibility to disease.

(SOURCE: Mori, C., Morsey, B., Levin, M., Gorton, T.S. and De Guise, S. 2008. Effects of organochlorines, individually and in mixtures, on B-bell proliferation in marine mammals and mice. *J.Toxicol. Environ.Health A* 71: 266–275)

Climate change

Special journal issue on climate change and its impacts on marine mammals

A special edition of the journal *Ecological Applications* summarised predictions of how global warming will affect the Arctic. These include a large decrease in ice thickness and extent, with an accompanying sea level rise of tens of centimetres, changes that "*exceed the range of natural variability over the past 1000 years*". With sea ice loss and warmer temperatures, patterns of marine productivity in the Arctic will change, particularly at the ice edge. Animals will have to travel farther to forage. Warming temperatures could also introduce new diseases into the Arctic ecosystem. Although some sub-Arctic marine mammal species may benefit from climatic changes, Arctic species are likely to decline. Appropriate habitats will be limited to Canadian islands and parts of Siberia by mid-century, and even these may eventually become ice free in summer. Greenhouse gas emissions should be restricted, but management should also include reducing species and habitat losses resulting from other anthropogenic stressors. Practical measures might include efforts to stop habitat fragmentation; stronger management of fisheries; restrictions on shipping, oil and gas exploration or military activities; establishment of marine protected areas; cleaning up contaminated sites; vaccination programs; and curbs on hunting.

(SOURCE: Huntington, H.P. and Moore, S.E. (eds.) 2008. Arctic marine mammals and climate change. *Ecolog. Applic.* (*Suppl.*) 18: S1-S174)

Noise impacts

General

High levels of noise could impact harbour porpoises' ability to find prey

Studies conducted on distances at which harbour porpoises and bottlenose dolphins can detect prey via echolocation showed that the former, due to lower source levels, have shorter prey detection ranges than the latter. There was also a substantive decrease in the ability to detect prey in environments with high levels of background noise; the harbour porpoise, with its lower prey detection range, would be especially affected. The authors note that "*the limited echolocation detection range would make it difficult, if not impossible, for harbor porpoise to inhabit a noisy environment*". Therefore, increasing levels of anthropogenic noise could have a particularly strong impact on harbour porpoises, reducing their foraging efficiency.

(SOURCE: Au, W.W.L., Benoit-Bird, K.J. and Kastelein, R.A. 2007. Modeling the detection range of fish by echolocating bottlenose dolphins and harbor porpoises. *J. Acoust. Soc. Am.* 121: 3954–3962)

Two reviews on the impacts of anthropogenic sound sources on cetaceans

An updated review (the first since 1995) of cetacean acoustics research focused on behavioural (*e.g.*, changes in diving and surfacing), acoustic (*e.g.*, type and timing of vocalisations), and physiological (*e.g.*, hearing loss and stress) reactions. The literature review for the first two types of responses was exhaustive, while a thorough review of physiological consequences was beyond the scope of this paper. There has been significant progress in documenting cetacean response to noise sources, but received levels of sound are rarely measured empirically; the authors urge improvement in this regard. In addition, the effects of certain widespread sources of noise are poorly investigated, such as commercial sonars and depth finders. A second review of noise impacts on cetaceans summarised the current state of scientific knowledge; presented a list of cetacean strandings associated with anthropogenic noise sources; and discussed possible population-level, synergistic and cumulative impacts. The review also considered indirect effects of noise; management implications; and offered a discussion of mitigation shortcomings, possible solutions, and research recommendations.

(SOURCES: Nowacek, D.P., Thorne, L.H., Johnston, D.W. and Tyack, P.L. 2007. Responses of cetaceans to anthropogenic noise. *Mamm. Rev.* 37: 81–115; Weilgart, L.S. 2007. The impacts of anthropogenic ocean noise on cetaceans and implications for management. *Can. J. Zool.* 85: 1091-1116)

Development of noise exposure criteria for cetaceans

A review of available research data on marine mammal hearing capabilities and reactions to sound was used to develop a series of noise exposure criteria for management purposes. The authors estimated the noise levels that could cause physical, acoustic injury to cetaceans (*i.e.*, hearing loss). For most cetaceans, a sound pressure level of 230 dB re: 1µPa for single or multiple pulses was derived, primarily based on studies using captive cetaceans. The review also examined behavioural reactions, which for low-frequency-sensitive cetaceans showed "*an increasing probability of avoidance and other behavioural effects in the 120 to 160 dB re: 1µPa range*". For mid-frequency-sensitive cetaceans, "*[i]n some settings, individuals in the field showed behavioural responses with high severity scores to exposures from 90 to 120 dB re: 1µPa, while others failed to exhibit such responses for exposure [received levels] from 120 to 150 dB re: 1µPa*". The extrapolation of behavioural responses of captive animals to determine the reactions of free-ranging cetaceans was deemed problematic. For high-frequency specialists, reviewed data primarily concerned harbour porpoises, which "*are quite sensitive to a wide range of human sounds at low exposure [received levels] (~90 to 120 dB re: 1µPa)*"; "*[a]ll recorded exposures exceeding 140 dB re: 1µPa induced profound and sustained avoidance behaviour in wild harbour porpoises*". Importantly, some species may be particularly sensitive to acoustic disturbance (*e.g.*, beluga, bowhead whale, harbour porpoise), and the criteria do not account for effects such as masking, stress induction and non-auditory injuries (*e.g.*, gas bubble formation).

(SOURCE: Southall, B.L., Bowles, A.E., Ellison, W.T., Finneran, J.J., Gentry, R.L., Greene, C.R., Kastack, D., Ketten, D.R., Miller, J.H., Nachtigall, P.E., Richardson, W.J., Thomas, J.A. and Tyack. P.L. 2008. Marine mammal noise exposure criteria: initial scientific recommendations. *Aquat. Mamm*. 33: 411-521)

Sonar

Gas emboli found in beaked whale strandings in Taiwan coincident with naval exercises

An unusually high number of cetacean strandings occurred along the coast of Taiwan between 19 July and 13 August 2005. These strandings involved 13 dwarf sperm whales (*Kogia sima*), two pygmy sperm whales, two Longman's (*Indopacetus pacificus*) and two Blainville's beaked whales (*Mesoplodon densirostris*), two striped and one pantropical spotted dolphin (*Stenella attenuata*), and a short-finned pilot whale. Fifteen animals were examined post-mortem; three were fresh enough to allow pathological examination. The beaked whales "*had severe, diffuse vascular congestion and marked disseminated microvascular haemorrhages associated with widespread, round to oval cavitary lesions within vital organs, consistent with gas emboli*". Such gas emboli have been found in tissues of cetaceans that have stranded coincident with naval exercises. During this period, two sonar-utilizing naval exercises were undertaken by China (mid-July to late July in the East China Sea) and the USA (near Okinawa and Guam), although the latter was a considerable distance from Taiwan (>410 miles). No definitive causal relationship with naval sonar was established due to a lack of precise information on where and when sonar activity was conducted in Taiwanese and adjacent waters. The strandings occurred over a longer period of time and were more widespread than other atypical mass stranding events. It was hypothesized that "*if this mortality event was caused by exposure to high-intensity acoustic energy, it is possible that multiple acoustic sources (naval or otherwise) combined to produce the pattern of strandings observed*".

(SOURCES: Yang, W.C., Chou, L.S., Jepson, P.D., Brownell, R.L., Cowan, D., Chang, P.H., Chiou, H.I., Yao, C.J., Yamada, T.K., Chiu, J.T., Wang, P.J. and Fernández, A. 2008. Unusual cetacean mortality event in Taiwan, possibly linked to naval activities. *Vet. Record* 162: 184-186)

Seismic Surveys

Great variation in seismic survey guidelines

A review of international mitigation measures to reduce impacts to cetaceans from seismic surveys found much variety and inconsistency. For example, whilst several countries or regions include all marine mammal species within the mitigation measures, in others only large whale species are considered and there are no appropriate measures for dolphins, porpoises, or pinnipeds. Most regions required trained crew members to search for marine mammals within a zone of possible impact, but there was much variability as to what 'trained' entailed. Some regions required 'dedicated', 'qualified' or 'experienced' observers in 'sensitive' areas, although again definitions of these terms were often not provided. With respect to observers, "*a further concern is the lack of independence of MMOs* [marine mammal observers]. *This is most apparent where MMOs are crew members or otherwise employed directly by the seismic contractor, presenting a clear conflict of interest*". An exclusion zone around an operating seismic survey array is a standard mitigation measure, but these zones again vary widely, from 0.5 to 3km. Differing guidelines consider received levels from 160 to 190 dB re 1 µPa to be the critical threshold above which seismic surveys could cause impacts. The authors state that "*a further inefficiency of the existing mitigation methods is that the* [observer] *must visually observe the marine mammal entering the* [exclusion zone] *before mitigation can be requested. This does not adequately mitigate for deep-diving species such as sperm and beaked whales*". Another common mitigation measure is the 'soft start' or 'ramp-up', i.e., a gradual increase in airgun output. But guidelines lack consistent information on the nature of 'soft starts'. Poor consideration is given to the number or type of airgun arrays or the effect of water depth and oceanographic conditions. The authors state that "*a single standard* [exclusion zone] *value* [*i.e*., radius of impact] *for all seismic surveys regardless of airgun volume or water depth is inappropriate*". The impacts of weather on the ability to sight cetaceans are generally neglected and guidelines for surveys conducted at night are extremely variable. One critical observation is that "*relatively few aspects of current mitigation have a firm scientific basis and proven efficacy in the field*".

(SOURCE: Weir, C.R and Dolman, S.J. 2007. Comparative review of the regional marine mammal mitigation guidelines implemented during industrial seismic surveys, and guidance towards a worldwide standard. *J. Internat. Wildl. Law Policy*10: 1–27; see also Castellote, M. 2007. General review of protocols and guidelines for minimizing acoustic disturbance to marine mammals from seismic surveys. *J. Internat. Wildl. Law Policy*10: 273-288)

Aircraft

Aircraft cause 'distress' or 'defence' formation in sperm whales

During aerial surveys for cetaceans in the waters around Hawaii, circling aircraft reported a group of sperm whales changing their behaviour. The whales "*ceased forward movement, moved closer together in a parallel flank-to-flank formation…and formed a fan-shaped semi-circle with heads facing out and flukes toward the middle of the semi-circle. The bull was on the left outer edge of the semi-circle and the calf remained near the middle of the group*". One of the sperm whales was observed on its side with its mouth open. This was "*interpreted…as an agitation, distress, and/or defense reaction to our circling aircraft*". The authors state that "*although isolated occurrences of this type are probably not biologically significant, repeated or prolonged exposures to aircraft overflights have the potential to result in significant disturbance of biological functions, especially in important nursery, breeding or feeding areas*". They note that activities that might cause similar harassment of cetaceans include aircraft-based ecotourism flights, research surveys, oil and gas exploration development and military activities.

(SOURCE: Smultea, M.A., Mobley, J.R., Fertl, D. and Fulling, G.L. 2008. An unusual reaction and other observations of sperm whales near fixed-wing aircraft. *Gulf Carib. Res.* 20: 75-80)

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Appendix 1

GLOSSARY

Species glossary

Atlantic white-sided dolphin	*Lagenorhynchus acutus*
Baiji	*Lipotes vexillifer*
Beluga whale	*Delphinapterus leucas*
Blainville's beaked whale	*Mesoplodon densirostris*
Blue whale	*Balaenoptera musculus*
Common bottlenose dolphin	*Tursiops truncatus*
Short-beaked common dolphin	*Delphinus delphis*
Dwarf sperm whale	*Kogia sima*
Fin whale	*Balaenoptera physalus*
Franciscana	*Pontoporia blainvillei*
Harbour porpoise	*Phocoena phocoena*
Humpback whale	*Megaptera novaeangliae*
Killer whale	*Orcinus orca*
Long-finned pilot whale	*Globicephala melas*
Longman's beaked whale	*Indopacetus pacificus*
North Atlantic right whale	*Eubalaena glacialis*
Northern bottlenose whale	*Hyperoodon ampullatus*
Northern minke whale	*Balaenoptera acutorostrata*
Pantropical spotted dolphin	*Stenella attenuata*
Pygmy sperm whale	*Kogia breviceps*
Risso's dolphin	*Grampus griseus*
Rough-toothed dolphin	*Steno bredanensis*
Short-finned pilot whale	*Globicephala macrorhynchus*
Sperm whale	*Physeter macrocephalus*
Striped dolphin	*Stenella coeruleoalba*
White-beaked dolphin	*Lagenorhynchus albirostris*
Sea otter	*Enhydra lutris*
Domesticated dog	*Canis familiaris*
Atlantic puffin	*Fratercula arctica*
Atlantic salmon	*Salmo salar*
Bluefin tuna	*Thunnus thynnus*
Cod	*Gadus morhua*
Spiny dogfish	*Squalus acanthias*
Swordfish	*Xiphias gladius*

Element glossary

Al	aluminium
As	arsenic
Cd	cadmium
Co	cobalt
Cr	chromium
Cu	copper
Fe	iron
Hg (THg)	mercury (total mercury)
Mo	molybdenum
Mn	manganese
Ni	nickel
Pb	lead
Rb	rubidium
Se	selenium
Sr	strontium
V	vanadium
Zn	zinc

Glossary of terms

Adipocyte: A connective tissue cell that has differentiated and become specialized in the synthesis (manufacture) and storage of fat.

Antigen: Any substance that causes the immune system to produce antibodies against it. An antigen may be a foreign substance from the environment such as chemicals, bacteria, viruses, or pollen. An antigen may also be formed within the body, as with bacterial toxins or tissue cells.

Atypical mass stranding: A stranding of two or more animals, not a mother-calf pair, that occurs over an extended geographical area (in a relatively short period of time) instead of in a single location.

Biomarker: A biological indicator, *e.g.,* blood chemical levels, of health status or pollutant level.

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

Brominated: Containing the element bromine.

Butyltin: A toxic chemical commonly used in anti-fouling paints on ship hulls (as tributyltin or dibutyltin, a break-down product of tributyltin).

C.E.: Common Era, equivalent to A.D. (Anno Domini).

Congener: A term in chemistry that refers to one of many variants or configurations of a common chemical structure.

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

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

DDT: The organochlorine pesticide dichlorodiphenyltrichloroethane that tends to accumulate in the ecosystem and in the blubber and certain internal organs of cetaceans. DDT can have effects on the immune and reproductive systems and is a likely carcinogen.

Dioxin: Toxic organic chemicals that can accumulate in the blubber of cetaceans. These chemicals are carcinogenic and can cause reproductive defects.

DLC: Dioxin-like compound.

DMBP: Dimethyl bipyrrole.

Domoic acid: See diatom.

Dry weight: Dry weight, as opposed to wet weight, is a basis of measurement whereby concentrations of a substance are compared with dry content (*i.e.,* all water is removed) of a material.

Endocrine system: A system of ductless glands producing hormones that control and moderate metabolic processes in the body.

Endocrine disrupter: Any outside substance (chemical) that interferes with an organism's endocrine system.

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

Fluorinated: Containing the element fluorine.

HAB: Harmful algal bloom. Population explosion of certain phytoplankton species (algae) that produce toxic substances that can harm higher levels of the marine food chain and humans who consume contaminated seafood.

HBCD: Hexabromocyclododecane, a brominated flame retardant.

HCB: Hexachlorobenzene, an environmentally persistent organochlorine fungicide.

HCH: Hexachlorocyclohexane, a neurotoxic pesticide. The most well known HCH is lindane (γ-HCH), an environmentally persistent agricultural insecticide.

Hypoxic: Characterized by low oxygen levels.

Hz: Hertz, a measure of sound frequency (pitch), in wave cycles per second (kHz = 1000 Hertz).

Lipid weight: A basis of measurement whereby concentrations of a substance are compared to the lipid (fat) content of a material.

Lymphocyte: A class of white blood cells in lymph, involved in vertebrate immune system responses.

Masking: A phenomenon wherein the frequency and intensity of ambient noise covers up or 'masks' a biologically important signal, making it undetectable by a receiver.

µg: Microgram.

Morbillivirus: A family of viruses that are typically highly infectious and pathogenic – the family includes measles, dog distemper and dolphin morbillivirus. A number of mass mortality events have been associated with viruses from this family.

OCP: Organochlorine pesticide.

OMZ: Oxygen minimum zone.

Organochlorine: Organic compounds that contain chlorine. Many are toxic and used as pesticides. Most of these compounds persist in the environment (are not biodegradable) and also tend to accumulate in fatty tissue (*e.g.,* blubber) of cetaceans and other marine organisms.

Organotin: Organic chemicals containing tin.

Pathogen: A disease-causing agent (*e.g.,* bacterium, virus).

PBDE: Polybrominated diphenyl ether, a brominated flame retardant.

PCB: Polychlorinated biphenyls (209 different forms containing differing numbers of chlorine atoms arranged in various positions on the aromatic rings) are industrial organochlorines manufactured for use in electrical transformers and other applications. These man-made chemicals do not occur naturally and all traces reflect pollution. PCB (CB-154) is 2,2',4,4',5,5'- hexachlorobiphenyl, one of the most prevalent PCB congeners.

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. See PFA, PFOS and PFOSA.

PFA: Polyfluorinated alkyl compounds

PFOS: Perfluorooctane sulfonate.

PFOSA: Perfluorooctane sulphonamide

Phagocyte: A cell type that engulfs and consumes foreign material.

Phagocytosis: The process whereby foreign material is engulfed and consumed by phagocytes.

Phytoplankton: Free-floating marine plants (versus zooplankton – free-floating marine animals).

Sound pressure level: A measure of the intensity of sound, in decibels.

TCPMe: Trismethane, a persistent organochlorine structurally similar to the pesticide DDT and having endocrine-disrupting properties.

TCPMOH: Trismethanol, a persistent organochlorine structurally similar to the pesticide difocal and having endocrine-disrupting properties.

TBBPA: Tetrabromobisphenol A, a brominated flame retardant.

Vector: The agent that transfers pathogens between organisms (*e.g.,* the anopheles mosquito acts as a vector for the disease malaria by transmitting the malarial parasite plasmodium to humans).

Wet weight: See dry weight.

Table 1: Maximum trace element concentrations in cetacean tissues from the Eastern Atlantic (µg.g^{-1})

Location	Species	Tissue	Weight	Hg	Cd	Zn	Pb	Cu	Se	Reference
Danish coast	Harbour porpoise	Liver	wet	92.0	-	59.1	-	-	-	Strand et al. (2005)
S. North Sea		Liver	wet	32.8	-	154	-	-	-	Strand et al. (2005)
W. Greenland		Liver	wet	6.89	-	15.2	-	-	-	Strand et al. (2005)
Bay of Biscay		Liver	wet	65.5	-	-	-	-	-	Lahaye et al. (2007)
		Kidney	wet	-	5.12	-	-	-	-	Lahaye et al. (2007)
English		Liver	wet	40.0	-	-	-	-	-	Lahaye et al. (2007)
Channel		Kidney	wet	-	1.64	-	-	-	-	Lahaye et al. (2007)
Netherlands &		Liver	wet	139.4	-	-	-	-	-	Lahaye et al. (2007)
France		Kidney	wet	-	3.52	-	-	-	-	Lahaye et al. (2007)
East Scotland		Liver	wet	31.0	-	-	-	-	-	Lahaye et al. (2007)
		Kidney	wet	-	11.9	-	-	-	-	Lahaye et al. (2007)
Irish Sea		Liver	wet	165	-	-	-	-	-	Lahaye et al. (2007)
		Kidney	wet	-	1.66	-	-	-	-	Lahaye et al. (2007)
NW Scotland		Liver	wet	26.0	-	-	-	-	-	Lahaye et al. (2007)
		Kidney	wet	-	10.4	-	-	-	-	Lahaye et al. (2007)
S. Ireland		Liver	wet	54.9	-	-	-	-	-	Lahaye et al. (2007)
		Kidney	wet	-	3.19	-	-	-	-	Lahaye et al. (2007)
Bay of Biscay	Striped dolphin	Liver	wet	24.1	-	-	-	-	-	Lahaye et al. (2006)
		Kidney	wet	-	40.2	-	-	-	-	Lahaye et al. (2006)
Bay of Biscay	Short-beaked common dolphin	Liver	wet	38.9	1.16	47.5	-	32.4	18.3	Lahaye et al. (2007b)
		Kidney	wet	1.89	3.18	20.5	-	4.9	4.75	Lahaye et al. (2007b)
		Muscle	wet	0.88	-	-	-	-	-	Lahaye et al. (2007b)
France	Short-beaked common dolphin	Liver	wet	116.5	12.1	47.5	-	74.8	46.5	Lahaye et al. (2007b)
		Kidney	wet	6.29	28.8	35.1	-	3.8	6.56	Lahaye et al. (2007b)
		Muscle	wet	1.89	-	-	-	-	-	Lahaye et al. (2007b)
		Blood	wet	0.61	-	-	-	-	-	Lahaye et al. (2007b)
		Bone	dry	-	-	-	1.791	-	-	Caurant et al. (2006)
		Tooth	dry	-	-	-	3.329	-	-	Caurant et al. (2006)
France	Harbour porpoise	Bone	dry	-	-	-	0.619	-	-	Caurant et al. (2006)
		Tooth	dry	-	-	-	1.520	-	-	Caurant et al. (2006)
	Striped dolphin	Bone	dry	-	-	-	0.248	-	-	Caurant et al. (2006)
		Tooth	dry	-	-	-	0.248	-	-	Caurant et al. (2006)
Spain	Short-beaked common dolphin	Bone	dry	-	-	-	0.895	-	-	Caurant et al. (2006)
		Tooth	dry	-	-	-	1.371	-	-	Caurant et al. (2006)
	Striped dolphin	Bone	dry	-	-	-	0.887	-	-	Caurant et al. (2006)
		Tooth	dry	-	-	-	1.028	-	-	Caurant et al. (2006)
Holland	Striped dolphin	Bone	dry	-	-	-	1.437	-	-	Caurant et al. (2006)
		Tooth	dry	-	-	-	2.251	-	-	Caurant et al. (2006)
Ireland	Harbour porpoise	Bone	dry	-	-	-	0.458	-	-	Caurant et al. (2006)
		Tooth	dry	-	-	-	0.581	-	-	Caurant et al. (2006)

(SOURCES: Caurant, F., Aubail, A., Lahaye, V., Van Canneyt, O., Rogan, E., López, A., Addink, M., Churlaud, C., Robert, M. and Bustamante P. 2006. Lead contamination of small cetaceans in European waters – the use of stable isotopes for identifying the sources of lead exposure. *Mar. Environ. Res.* 62 131–148;
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Table 2: Maximum butyltin concentrations in cetacean tissues from the Eastern Atlantic (µg g^{-1})

Location	Species	Tissue	Weight	MBT	DBT	TBT	TPhT	ΣBT	Reference
Danish coast	Harbour porpoise	liver	wet	44	3689	871	62	4605	Strand et al. (2005)
S. North Sea		liver	wet	102	2328	521	26	2905	
W. Greenland		liver	wet	0.6	13	6.5	<3	18	

(SOURCE: Strand, J., Martin, T., Larsen, M. and Lockyer, C. 2005. Accumulation of organotin compounds and mercury in harbour porpoises (*Phocoena phocoena*) from the Danish waters and West Greenland. *Sci. Total Environ.* 350: 59-71)

Table 3: Maximum trace element concentrations in cetacean tissues from the Western Atlantic (µg g^{-1})

Location	Species	Tissue	Weight	Hg	Cd	Zn	Pb	Al	As	Co	Cr	Cu	Fe	Mn	Ni	Se	V	Mo	Rb	Sr	Reference
Bay of Fundy	North Atlantic right whale	Skin	wet	-	-	-	-	-	-	-	10.0	-	-	-	-	-	-	-	-	-	Wise et al. (2008)
S. Carolina	Bottlenose dolphin	Skin	dry	4.90	0.022	1471	1.00	157	4.40	1.60	2.20	2.40	1438	3.7	0.29	44.0	-	-	-	-	Stavros et al. (2007)
		Blood	wet*	573	-	3684	-	65.0	387	-	-	1212	804**	26.0	-	1349	-	-	-	-	Stavros et al. (2008)
Florida		Skin	dry	31.0	0.037	1586	0.65	7.40	1.50	0.71	1.70	2.30	565	0.96	0.57	32.0	-	-	-	-	Stavros et al. (2007)
Florida	Bottlenose dolphin	Skin	wet	6.39	0.004	249	0.087	2.06	0.885	-	0.454	1.33	-	0.138	-	9.64	0.018	0.016	1.76	0.25	Bryan et al. (2007)
		Blood	wet	1.77	-	3.75	0.007	0.003	0.140	-	-	1.50	-	-	-	-	-	0.002	0.786	0.123	Bryan et al. (2007)
		Blood	wet*	2751	-	4566	-	81.0	149	-	-	1329	872**	21.0	-	1005	-	-	-	-	Stavros et al. (2008)
		Liver	wet	240	-	-	-	-	-	-	-	-	-	-	-	90.7	-	-	-	-	Durden et al. (2007)
		Muscle	wet	47	-	-	-	-	-	-	-	-	-	-	-	16.1	-	-	-	-	Durden et al. (2007)
Brazil	Franciscana	Liver	dry	10.7#	1.5#	-	-	-	1.7#	-	-	-	-	-	-	11.1#	-	-	-	-	Seixas et al. (2007)
		Liver	wet	-	4.14	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Dorneles et al. (2007)

*µg L^{-1} **mg L^{-1} # Mean value

(SOURCES: Bryan. C.E., Christopher S.J., Balmer, B.C. and Wells, R.S. 2007. Establishing baseline levels of trace elements in blood and skin of bottlenose dolphins in Sarasota Bay, Florida: implications for non-invasive monitoring. *Sci. Total Environ.* 388: 325–342;
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Table 4: Maximum organic contaminant levels in cetacean tissues from the Atlantic (µg. g^{-1})

	Species	Tissue	Weight	ΣHCH	HCB	DDE	DDD	DDT	ΣDDT	ΣPCB	Dieldrin	ΣPBDE	ΣChlordane	TCPMe	TCPMOH	Reference
UK & Ireland	Killer whale	Blubber	wet	0.48	5.80	386	16.0	6.40	408.4	365	50.0	-	0.15	-	-	McHugh et al. (2007)
Norway	Killer whale	Blubber	lipid	-	-	11.65*	-	-	-	26.94*	-	0.475	6.56	-	-	Wolkers et al. (2007)
Greenland	Northern minke whale	Blubber	wet	0.02	0.028	-	-	-	0.595	1.72	0.094	0.063	0.296	-	-	Sonne et al. (2006)
'The Gully', Nova Scotia, Canada	Northern bottlenose whale	Blubber	lipid	-	-	-	-	-	21.57*	7.27*	-	-	-	-	-	Hooker et al. (2007)
Canary Islands	Common bottlenose dolphin	Blubber	wet	-	0.098	18.63	0.729	2.64	21.05	32.2	0.183	-	3.52	-	-	Carballo et al. (2008)
		Liver	wet	-	0.013	2.93	0.19	0.14	3.17	52.4	0.027	-	0.32	-	-	Carballo et al. (2008)
Massachusetts, USA	Atlantic white-sided dolphin	Blubber	wet	0.30	0.24	-	-	-	15.9	29.4	1.81	2.41	8.8	-	-	Tuerk et al. (2005)
	Rough-toothed dolphin	Blubber	wet	0.038	0.04	-	-	-	12.0	24.1	0.35	1.36	3.58	-	-	Tuerk et al. (2005)
	Common bottlenose dolphin	Blubber	wet	-	-	-	-	-	-	-	-	22.8	-	-	-	Fair et al. (2007)
Florida, USA	Common bottlenose dolphin	Blubber	lipid	-	-	-	-	-	-	-	-	4.50	-	-	-	Johnson-Restrepo et al. (2008)
Florida, USA	Common bottlenose dolphin	Blubber	lipid							860						Wells et al. (2005)
Florida, USA	Common bottlenose dolphin	Blubber	wet	-	-	-	-	-	5.52	66.9		0.52	2.83	-	-	Litz et al. (2007)
Eastern USA	Common bottlenose dolphin	Plasma	lipid wet	-	-	-	-	-	-	65# 0.308#	-	-	-	-	-	Houde et al. (2006)
		Blubber	lipid	-	-	-	-	-	-	124	-	-	-	-	-	Pulster and Maruya (2008)
Bermuda	Common bottlenose dolphin	Plasma	lipid	-	-	-	-	-	-	45.0	-	-	-	-	-	Houde et al. (2006)
Brazil	Costero	Blubber	lipid	0.061	0.40	-	-	-	150	79.0	0.34	-	1.1	0.46	0.38	Kajiwara et al. (2004)
	Fransciscana	Blubber	lipid	0.007	0.021	-	-	-	35	12.0	0.061	-	0.11	0.072	0.12	Kajiwara et al. (2004)
	Atlantic spotted dolphin	Blubber	lipid	0.050	0.084	-	-	-	48.0	60.0	0.39	-	0.69	0.55	0.21	Kajiwara et al. (2004)
	Long-beaked common dolphin	Blubber	lipid	0.024	0.032	-	-	-	11.0	17.0	0.20	-	0.20	0.082	0.097	Kajiwara et al. (2004)
Mauritius	Blainville's beaked whale	Blubber	lipid	0.041	0.085	-	-	-	2.70	1.50	0.021	-	0.069	0.003	0.006	Kajiwara et al. (2004)

* Mean value # Highest mean value

(SOURCES: Carballo, M., Arbelo, M., Espero, F., Mendez, M., de la Torre, A. and Muñoz, M.J. 2008. Organochlorine residues in the blubber and liver of bottlenose dolphins (*Tursiops truncatus*) stranded in the Canary Islands, North Atlantic Ocean. *Environ. Toxicol.* 23: 200–210;

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