STATE OF THE CETACEAN ENVIRONMENT REPORT (SOCER) 2006

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INTRODUCTION

The first edition 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 submission of the first SOCER at the 52nd Annual Meeting in Adelaide, Australia, and "request[ed] the annual submission of this report to the Commission". Previous SOCERs have focused on the Atlantic Ocean, the Mediterranean Sea, the Pacific Ocean and the Arctic and Southern Ocean (polar) regions. SC/58/E1 (SOCER 2006) focuses on the **Indian Ocean**, summarising key papers and articles that have been published in 2004, 2005, and to date in 2006. Information reported from this region was limited – most publications in this SOCER therefore focus on issues of global significance. The entries are organized under five major topics (habitat protection/degradation; chemical pollution; disease and mortality events; climate change; and noise impacts), and the entries are listed according to the last name of the first author, in alphabetical order.

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. To perform this analysis, the editors used a literature database[1] maintained by David Janiger of the Los Angeles Natural History Museum[2]. It contained 1024 document records from over 300 peer-reviewed journals, books, theses, and technical reports[3] for the year 2005, covering all aspects of marine mammal biology, evolution, ecology, habitats, conservation, and policy. We believe this is a reasonably inclusive database for peer-reviewed and technical publications on marine mammal-related topics in the literature; for example, searching 'Google Scholar' using the search term 'cetaceans' and '2005' yielded 1,830 hits, but many of these listings were abstracts from conference proceedings, popular science articles, web articles, obituaries, or otherwise not appropriate to include in the current analysis[4].

All document records from the Janiger database that were specifically focused on pinnipeds or other marine animals or were focused on aspects of marine organisms, habitats or ecosystems that were not directly relevant to cetaceans were deleted. The remaining 545 records[5] were then classified as follows:

- B ('basic biology'): Primarily focused 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

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[1] The Janiger database is not the sole source for SOCER entries. SOCER entries include articles and publications not listed in that database. The Janiger database is limited almost entirely to publications specifically addressing marine mammal biology, ecology, and policy – SOCER entries include publications addressing broader marine, coastal, and atmospheric science issues that have relevance to cetaceans.

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

[3] The full list of the peer-reviewed publications in the Janiger database (some books, all theses, and all technical reports have been omitted from this list, but were included in the analysis) is available on request from the editors. 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.

[4] We randomly selected approximately two dozen hits (of peer-reviewed articles only) from this Google Scholar search – all were present in the Janiger database. In other words, most peer-reviewed articles identified by Google Scholar were contained in the Janiger database as well, whereas the Janiger database contained only a few of the non-peer-reviewed document records listed in the Google Scholar search.

[5] The full list of document records is available on request from the editors.

- C (‘conservation’): Primarily focused 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 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 545 document records from 2005 examined for this analysis, 56.3% (n = 307) were focused on basic biology and 43.7% (n = 238) on conservation. This is almost certainly an underestimate of the number of studies in the database that were undertaken to inform management or conservation policies related to cetaceans, given the criteria noted above for categorising papers.

Over the last decade, scientific research in the field of marine sciences has undergone a paradigm shift. In response to an apparently deteriorating environment, research efforts have increasingly focused on topics related to describing, preserving, restoring and managing damaged systems and their inhabitants. This goes hand in hand with an increased urgency for collecting the relevant data, which is also reflected in the allocation of funds for conservation-oriented projects and programmes. Based on the statistics presented here, in which almost half of all publications on cetacean biology and ecology have a direct conservation focus, this paradigm shift is occurring in the field of cetacean research as well. Accordingly, the IWC is accurately reflecting the current trend in scientific endeavour by dealing with environmental and conservation matters.

INDIAN OCEAN

Habitat protection/degradation

High levels of marine debris in the Indian Ocean

A survey of 10 locations in the Indian Ocean revealed high levels of marine debris, with accumulation of durable rubbish being highest on the Christmas and Cocos Islands. Four decades ago, plastics were virtually unreported and insignificant on Indian Ocean shores. Now, even on mid-ocean islands, accumulation levels are high enough to be visible on a daily basis. This material not only poses the threat of ingestion and entanglement for cetaceans and other marine life, but in the Indian Ocean has also been identified as a means of transport for alien, invasive species to new regions, *e.g.*, to waters around Antarctica, the only marine realm from which exotic invaders are unknown.

(SOURCE: Barnes, D.K.A. 2005. Natural and plastic flotsam stranding in the Indian Ocean. In: *The Effects of Human Transport on Ecosystems: Cars, Boats and Trains.* Davenport, J. and Davenport, J.L. (eds). Dublin: Royal Irish Academy, pp. 193-205)

Beach debris in the Gulf of Oman

Marine debris is not only one of the most visible expressions of the negative impact of human activities, but it also represents a major threat of ingestion and entanglement by marine life, including cetaceans. Beach debris abundance and weight were estimated from surveys on 11 beaches of the Gulf of Oman along the Omani coast. Most debris, in terms of numbers, had a local origin and was associated with beach recreational activities, whereas fishing debris represented the largest proportion in terms of weight. Two recommendations were made: to install wind-resistant litter bins adjacent to prime recreational areas combined with an awareness campaign to help reduce the litter discarded by beach users and to provide fishing villages with specially designed industrial bins for discarded fishing gear.

(SOURCE: Claereboudt, M. R. 2004. Shore litter along sandy beaches of the Gulf of Oman. *Mar. Pollut. Bull.* 49: 770-777)

Shrimp farming releases chemicals into the marine environment

Shrimp farming has not only degraded coastal environments by dramatically reducing valuable mangrove forests, but has now been shown to be responsible for a significant input of chemicals. A study of 76 shrimp farms in Thailand, the world’s top shrimp producer, shows that 290 different chemical and biological products are in use in the industry. The average number of products per farm was 13. These included soil and water treatment compounds, fertilizers, pesticides, disinfectants, antibiotics, immunostimulants, and feed additives. Beyond the question of whether it is possible to efficiently use (*i.e.*, to understand and control) the combination of so many products in a shrimp farm, such inputs almost certainly have negative effects on adjacent ecosystems.

(SOURCE: Gräslund, S. Holmström, K. and Wahlström, A. 2005. A field survey of chemical and biological products used in shrimp farming. *Mar. Pollut. Bull.* 46: 81-90)

Madagascar creates protected seascapes

The government of Madagascar has brought one million hectares of wild landscapes and seascapes under protection. Within five years, 10% of the entire country is to have protected area status.

(SOURCE: Marine Pollution Bulletin News. 2005. Madagascar. *Mar. Pollut. Bull.* 52: 128)

Tsunami damage increased by coral destruction

Illegal removal of coral along Sri Lanka's coastline considerably increased the amount of destruction inflicted by the December 2004 tsunami. A map combining gaps in Sri Lanka's coral reefs and degree of wave inundation along the southwest coast showed that the tsunami reached significantly farther inland through the gaps, causing major fatalities. Interestingly, the reefs are sometimes in the best shape in front of hotels, where hotel owners maintain them for tourists. This is a forceful example for how (wilful) damage to one ecosystem has totally unexpected repercussions in another system, underlining the need for more comprehensive approaches in dealing with habitat degradation.

(SOURCE: Marris, E. 2005. Tsunami damage was enhanced by coral theft. *Nature* 436: 1071)

New form of marine pollution – microplastics

Plastics, as the chief component of marine debris, are a serious form of marine pollution. Plastics at sea eventually (over years to decades) undergo fragmentation, leading to microscopic particles, so-called 'microplastics'. New methods have been developed to reveal microplastics in the sea and show the prevalence of this material in the world's oceans. This study documents that microplastics are abundant at an Indian Ocean site (Singapore), both in beach sediments and in the ocean surface microlayer (50-60 µm) and subsurface layer (1m). The microplastics in the two ocean layers were composed of polyethylene, polypropylene and polystyrene. This material is ingested by marine organisms and probably serves as a transfer medium for toxic substances, including persistent man-made chemicals such as pesticides and polychlorinated biphenyls (PCBs).

(SOURCE: Ng, K.L. and Obbard, J.P. 2005. Prevalence of microplastics in Singapore's coastal marine environment. *Mar. Pollut. Bull.* in press)

Major decline in cetacean populations in the Arabian Gulf

In the United Arab Emirates (UAE), the estimates of cetacean abundance indicate a dramatic population decline of 71% between two surveys conducted in 1986 and 1999. The most common species found in the Arabian Gulf are the Indian Ocean (Indo-Pacific) bottlenose dolphin, the Indo-Pacific humpback dolphin, followed by the finless porpoise. At least two die-offs of marine mammals occurred in the 13 years between the surveys. The world conservation status of these three species is Data Deficient according to the IUCN. A coordinated series of protected areas is identified as the most promising approach for the long-term conservation of marine mammals here.

(SOURCE: Preen, A., 2004. Distribution, abundance and conservation status of dugongs and dolphins in the southern and western Arabian Gulf. *Biol. Conserv.* 118: 205-218)

Chemical pollution

Trace element contamination in western Malaysian fish and a high dietary intake of mercury

Trace element levels were analysed in fish from a variety of locations around the Malaysian coast, including the coast adjacent to the Indian Ocean. An evaluation was also conducted on likely human intakes of mercury based on the levels detected in fish species. Forty-eight percent of fish, if consumed, would exceed human health safety levels. The high dietary dose of mercury through consuming contaminated fish species would therefore pose a similar toxicological risk to cetaceans that might be consuming contaminated fish from the Malaysian coast.

Maximum contaminant levels

Liver/muscle (μg.g^{-1} dry weight) Ag: 0.7/0.024; Ba: 3.91/2.1; Bi: 0.113/0.039; Cd: 47.9/0.366; Co: 2.34/0.122; Cr: 2.1/0.9; Cs: 0.09/0.22; Cu: 28.9/4.63; Ga: 0.469/0.104; Hg: 2.23/0.35; Mn: 17.9/1.45; Mo: 14.4/1.13; Pb: 1.2/0.149; Rb: 4.11/6.51; Sb: 0.06/0.03; Se: 12/3.5; Sn: 1.75/0.4; Sr: 56.8/39.4; Tl: 0.04/0.028; V: 5.4/0.21; Zn: 216/53.9

(SOURCE: Agusa, T., Kunito, T., Yasunaga, G., Iwata, H., Subramanian, A., Ismael, A. and Tanabe, S. 2005. Concentrations of trace elements in marine fish and its risk assessment in Malaysia. *Mar. Pollut. Bull.* 51: 896-911)

Low organochlorine levels in bivalves in peninsular Malaysia

The levels of organochlorine compounds in cockles and mussels in four aquaculture areas in Malaysia were well within the range of the Maximum Residue Level designated in the Food Act. Human consumption of these shellfish therefore poses a very low risk of organochlorine contamination. The somewhat higher levels detected in cockles may reflect their habitat and close contact with the sediment. Organochlorine compounds persist and remain bound to sediment for 2-10 years. The results indicate little presence of banned pesticides in the tissues of these two bivalves.

(SOURCE: Ang, C.W., Mazlin, N.M., Heng, L.Y., Ismail, B.S. and Salmijah, S. 2005. Study on organochlorine compounds in cockles, *Anadara granosa* and mussels, *Perna viridis* from aquaculture sites in peninsular Malaysia. 2005. *Bull. Environ. Contam. Toxicol.* 75: 170-174)

High lead levels in a major river opening into the Bay of Bengal

The Ganga River opens into the Bay of Bengal, India, and therefore represents a major source of pollution affecting marine life there, including cetaceans. Water and sediment samples were collected from three permanent monitoring stations along the Ganga River in West Bengal and examined for lead, a heavy metal. Lead was detected in 74% of the water and 63% of the sediment samples. Values increased downstream versus upstream, and concentrations were considerably higher in sediment than in water. The lead concentrations in 83% of the samples far exceeded the permissible primary drinking water quality standards prescribed by the US Environmental Protection Agency. In India, only about 10% of the municipal sewage is treated by wastewater treatment plants.

(SOURCE: Dutta, S., Kole, R.K., Ghosh, S., Nath, D. and Vass, K.K. 2005. Impact assessment of lead on water quality of the River Ganga in West Bengal, India. *Bull. Environ. Contam. Toxicol*. 75: 1012-1019)

Crude oil spills along coast are persistent in Arabian Gulf

Between 6 and 8 million barrels of crude oil were spilled into the Arabian Gulf after the 1991 war. Its fate has been a question of major concern in recent years. A natural experiment along the Saudi Arabian coast revealed that, contrary to expectations, biological processes of oil elimination (microbial mats composed of cyanobacteria and associated microorganisms) were less effective than normal physical factors such as evaporation, photo-oxidation and water-washing. For some compounds, microbial mat ecosystems apparently even had the effect of preserving hydrocarbons by hindering direct exposure to the atmosphere and seawater. This means that crude oil remains in the ecosystem longer than previously thought, subjecting marine organisms in general to chronic, long-term exposure.

(SOURCE: Garcia de Oteyza, T. and Grimalt, J.O. 2006. GC and GC-MS characterization of crude oil transformation in sediments and microbial mat samples after the 1991 oil spill in the Saudi Arabian Gulf coast. *Environ. Pollut.* 139: 523-531)

Toxic chemicals used in anti-fouling paints contaminate marine invertebrate

Organotins – organic chemicals containing tin – are used as additives in anti-fouling paints. One such compound, tributyltin (TBT), is one of the most toxic substances to be deliberately introduced into marine environments by humans. TBT has several detrimental effects on non-target species, including larval mortality, malformations and growth retardations in invertebrates, along with (as a hormone disruptor) an impact on the reproductive system in a variety of invertebrates, fishes and mammals. Its use on marine structures to prevent attachment and overgrowth by organisms is not controlled in India. A study conducted on an edible oyster in Dona Paula Bay in India showed fairly high levels of TBT and its degradation product, DBT (dibutyltin). The contamination of oysters may be correlated with the intensity of shipping traffic, pointing to a potential for long-term chronic effects.

Maximum contaminant levels

Oyster tissue ($ng.g^{-1}$ dry weight) TBT: 368

(SOURCE: Garg, A. and Bhosle, N.B. 2005. Butyltin compounds in the oyster, *Saccostrea cuculata*, from the west coast of India. *Bull. Environ. Contam. Toxicol.* 75: 982-988)

Pesticides in India

Because the ocean is the final repository for most pollutants, there is a need to monitor pesticide levels in relevant coastal waters. Currently, approximately 145 pesticides are registered for use in India, and the country's production is about 85,000 metric tonnes. Although the consumption of pesticides in India is relatively low (only 3.75% of global consumption), non-judicious use has led to comparatively high contamination of food with pesticide residues, with a series of negative health consequences including human deaths from poisonings. The coastal waters of India should be monitored for these pesticides.

(SOURCE: Gupta, P.K. 2005. Pesticide exposure—Indian scene. *Toxicology* 198: 83–90)

Dioxins and dioxin-like substances contaminate Sri Lankan marine organisms

Preservation of Sri Lanka's coastal systems is important for protecting rare and sensitive organisms, including cetaceans, and the health of coastal fisheries. Few data on toxic organic pollutants are available from developing countries in Asia, including Sri Lanka. This study examines the levels of dioxins and dioxin-like substances in six species of fish and one crab species from Sri Lankan coastal areas. The data highlight the extensive contamination in the Kelani River, which runs through the most densely populated areas and various industrial localities in Sri Lanka. All the samples were contaminated with dioxins, suggesting that the study area is one of the dioxin contamination sources for humans and wildlife. Contamination of fish with these compounds, which bioaccumulate, is a public health concern.

(SOURCE: Guruge, K.S. and Tanabe, S. 2004. Polychlorinated dibenzo-p-dioxins, dibenzofurans and dioxin-like biphenyls in biota from Sri Lankan coast. *Mar. Pollut. Bull. Baseline* 48: 986-1008)

Chlorinated and brominated organic contaminants in east Indian Irrawaddy dolphins

Levels of a variety of organochlorine pesticides, PCBs, and brominated flame retardants were reported from Irrawaddy dolphins from Chilika Lake, Bay of Bengal, India. Levels of pesticides (*e.g.*, DDT and HCH) were higher than PCB levels, which could be explained by inputs from agricultural areas adjacent to the lake. Generally the contaminant levels were lower than, for example, levels detected in Ganges river dolphins or coastal animals from Asia.

Maximum contaminant levels

Blubber ($\mu g.g^{-1}$ lipid weight) ΣPCB: 0.39; ΣDDT: 10.0; ΣChlordane: 0.041; ΣHCH: 1.2; HCB: 0.017; TCPMe: 0.018; TCPMOH: 0.13; ΣPBDE: 0.018

(SOURCE: Kannan, K., Ramu, K., Kajiwara, N., Sinha, R.K. and Tanabe, S. 2005. Organochlorine pesticides, polychlorinated biphenyls, and polybrominated diphenyl ethers in Irrawaddy dolphins from India. *Arch. Environ. Contam. Toxicol.* 49: 415-420)

DDT and PCB contamination in dolphins from the Bay of Bengal, India

Blubber samples from Indo-Pacific humpback dolphins, spinner dolphins and bottlenose dolphins from the Bay of Bengal were analysed for organochlorine contaminant levels. Elevated levels of DDT were found, which might be explained by the fact that although DDT use in agriculture was banned in India in 1989, it still has widespread use there as a control for malarial mosquitoes. PCB contamination in the specimens may result from ship breaking yards and the dumping of derelict electronic equipment. It was concluded that "[o]dontocete species from the southeast coast of India have levels of PCBs in their blubber tissue that may be regarded as of significant concern" (p. 896).

Maximum contaminant levels

Blubber (µg.g^{-1} wet weight) ΣPCB: 1.22; ΣDDT: 23.3; HCH: 0.765

(SOURCE: Karuppiah, S., Subramanian, A. and Obbard, J.P. 2005. Organochlorine residues in odontocete species from the southeast coast of India. *Chemosphere* 60: 891-897)

<u>Open dumping sites in Asian developing countries a source of persistent organic pollutants (POPs)</u>

The overall ability of POPs to undergo long-range transport underlines that their continued use in Asian developing countries may contaminate other parts of the globe, even relatively pristine areas such as the Arctic and Antarctic, clearly affecting marine organisms including cetaceans. The effects of dumping large amounts of municipal wastes in open dumping sites were examined by collecting soil samples at sites in Cambodia, Vietnam and India (Chennai). Among the POPs at the dumping sites, the dominant contaminants were DDT, PCBs and HCHs. Residue levels were hundreds to thousands of times higher than those in general soils, implying possible risks to human health in the local communities. The pattern in India (Chennai) revealed higher levels of HCHs than DDT (PCBs > HCHs > DDT > CHLs > HCB). The difference in such patterns indicates more extensive use of HCHs in India compared with Cambodia and Vietnam. The presence of DDT indicated ongoing use.

(SOURCE: Minh, N. H., Minh, T. B., Kajiwara, N., Kunisue, T., Subramanian, A., Iwata, H., Tana, T. S., Baburajendran, R., Karuppiah, S., Viet, P. H., Tuyen, B. C. and Tanabe. S. 2006. Contamination by persistent organic pollutants in dumping sites of Asian developing countries: implication of emerging pollution sources. *Arch. Environ. Contam. Toxicol*. 50: 474-481)

<u>PCBs increase with latitude in coastal Pacific and Asian cetaceans</u>

PCBs were examined in the blubber of 10 species of adult male toothed whales from several locations in the North Pacific Ocean and along coastal waters of Japan, Hong Kong, the Philippines and India. Total PCB concentrations in cetaceans from temperate and colder waters were higher than those in cetaceans from tropical regions. The estimated concentrations in the blubber of some cetacean species exceeded the levels associated with immunosuppression in harbour seals.

Maximum contaminant levels

Blubber (µg.g^{-1} wet weight) ∑PCB: 50 (Indo-Pacific hump-backed dolphin, Hong Kong); 3 (spinner dolphin, Bay of Bengal, India)

(SOURCE: Minh, T.B., Nakata, H., Watanabe, M., Tanabe, S., Miyazaki, N., Jefferson, T.A., Prudente, M., and Subramanian, A. 2000. Isomer-specific accumulation and toxic assessment of polychlorinated biphenyls, including coplanar congeners, in cetaceans from the North Pacific and Asian coastal waters. *Arch. Environ. Contam. Toxicol.* 39: 398-410)

<u>Heavy metals in the Arabian Gulf and Gulf of Oman</u>

As a shallow, semi-enclosed sea with very high evaporation rates and poor flushing, contaminants undergo less dilution and slower dispersion in the Arabian Gulf than in open marine systems. The heavy metal contents of fish, various bivalves and sediment collected in Bahrain, Oman, Qatar and the United Arab Emirates were generally not remarkable, although hot spots were noted for certain metals in two countries (Cu, Hg Pb, Zn – Bahrain; As, Co, Cr, NI – east coast of UAE). Total mercury levels in a top predator fish (the orange spotted grouper) posed no threat to human health. Very high levels of cadmium in the livers of some fish from southern Oman and very high arsenic concentrations in certain bivalves were attributed to natural origins rather than anthropogenic contamination.

(SOURCE: de Mora, S., Fowler, S.W., Wyse, E. and Azemard, S. 2004. Distribution of heavy metals in marine bivalves, fish and coastal sediments in the Gulf and Gulf of Oman. *Mar. Pollut. Bull.* 49: 410–424)

<u>Organochlorine compounds along the coast of Pakistan reflect continued use of DDT</u>

Chlorinated pesticides, including hexachlorobenzene (HCB) and PCBs, were analysed in different fishes from five sites along the Karachi coast. This coastline stretches 135 km and is polluted due to the shipping industry and toxic effluents from a number of industries. This is severely affecting the mangrove forests and marine life in this area. DDT application has not ceased in Pakistan and continues to be used in conjunction with other organochlorine pesticides. The concentrations of DDT in every fish from all locations were relatively high (up to 87.62 µg ΣDDT.g^{-1} in one fish specimen), but still lower than those reported from highly contaminated coastal areas of the world. As opposed to the general situation in the world's oceans, the concentration of DDT was higher than that of its metabolites, probably due to the Karachi sites' closeness to places of origin or application. As might be expected, the levels in the fishes were lower than those reported by other authors in marine mammal top predators such as bottlenose dolphins, Indo-Pacific humpback dolphins, and finless porpoises in the region.

Maximum contaminant levels

Fish muscle (µg.g^{-1} lipid weight) dieldrin: 5.48; ΣHCH: 3.09; DDE: 23.78; DDD: 36.36; DDT: 27.47; HCB: 1.12; ΣPCB: 63.33

(SOURCE: Munshi, A.B., Detlef, S.-B., Schneider, R. and Zuberi R. 2004. Organochlorine concentrations in various fish from different locations at Karachi Coast. *Mar. Pollut. Bull.* 49: 597-601)

Heavy metals in coastal areas of Pakistan

Coastal areas accommodate well over 60% of the industries in Karachi, Pakistan, including more than 6000 different industrial units directly discharging 300 million gallons of industrial effluents and domestic sewage per day into the sea. The concentrations of ten metals (Mn, Cu, Ni, Zn, Mg, Fe, Cr, Pb, Co and Cd) were measured in sediment collected from three sites. The sediments were not highly contaminated, although the levels of certain metals were high at each site. The authors attribute this to dilution and dispersion by strong wave action, tides and current along the coast, which may have implications for local coastal cetaceans and other marine animals.

(SOURCE: Qari, R., Siddiqui, S.A. and Qureshi, N.A. 2005. A comparative study of heavy metal concentrations in surficial sediments from coastal areas of Karachi, Pakistan. *Mar. Pollut. Bull. Baseline* 50: 583-608)

Sites contaminated with heavy metals in southwestern India

The green mussel is often used as a bio-indicator of pollution levels. Mussels at 28 sites from the coastal waters of Karnataka, southwest India, were analysed for trace element concentrations (Cd, Cr, Cu, Fe, Mn, Ni, Pb, and Zn). Generally, the levels of these elements would not cause concern; however, levels of cadmium, chromium and lead were high near industrial areas, a situation attributed to anthropogenic contamination.

Maximum contaminant levels

Mussels (µg.g^{-1} wet weight) Pb: 1.95; Cd: 3.48; Cr: 0.46

(SOURCE: Sasikumar, G., Krishnakumar P.K, and G.S. Bhat, G.S. 2006. Monitoring trace metal contaminants in green mussel, *Perna viridis* from the coastal waters of Karnataka, southwest coast of India. *Arch. Environ. Contam. Toxicol.*: in press)

Crude oil in biota and sediments in Arabian Gulf

The composition and distribution of crude oil compounds in fish, bivalves and sediments from four countries in the Arabian Gulf were examined. Levels of petroleum hydrocarbons were relatively low in sediments and in the various seafood species. Oil pollution continues to be a problem in specific areas, such as at an oil refinery in Bahrain where chronic pollution occurs. Relatively high concentrations were found in oysters at an Abu Dhabi and United Arab Emirates site, and this was attributed to a past major oil spill and to as yet unknown, more recent pollution. Regular monitoring and more detailed analyses are recommended to determine the sources and possible dumping activities.

(SOURCE: Tolosa, I., de Mora, S.J., Fowler, S.W., Villeneuve, J.-P., Bartocci, J. and Cattini, C. 2005. Aliphatic and aromatic hydrocarbons in marine biota and coastal sediments from the Gulf and the Gulf of Oman. *Mar. Pollut. Bull.* 50: 1619-1633)

Climate Change

Climate change impacts in the Indian Ocean region

Climate change, specifically global warming, is having initial impacts in the Indian Ocean region and could affect the habitat of several cetacean species, including endangered river dolphins. This change is evident in receding glaciers and higher temperatures. Rivers originating in Nepal's mountains, for example, contribute about 70% to the pre-monsoon flow of the Ganges River, which snakes through India and Bangladesh. Asian rivers, including the Yangtze and Yellow rivers in China, the Indus in Pakistan, the Brahmaputra in Bangladesh and Burma's Irrawaddy will also be affected. Specifically, about 67% of the nearly 12,124 square miles of Himalayan glaciers are receding. In the long run, as the ice retreats, glacial runoffs in summer and river flows will also go down, leading to severe water shortages. Sixty researchers who met with policymakers in Johannesburg reported that, in Africa, temperatures have risen 1°C in the past century and could rise another 2-3°C by 2025. The author notes that the conservation concern is that "changes in biodiversity could directly affect fisheries, agriculture and tourism".

(SOURCES: Cherry, M. 2005. Ministers agree to act on warnings of soaring temperatures in Africa. *Nature* 437 (255): 1217 [News] AND Reuters:
http://www.cnn.com/2005/TECH/science/09/09/himalayan.glaciers.reut/index.html)

General

Fishery management concerns within the EEZs of small island developing states

Small island states in the Indian Ocean (AIO SIDS or Atlantic and Indian Ocean Small Island Developing States) are highly dependent on coastal and marine resources. While the Maldives and Seychelles show increasing recent fish catches, those of certain other islands are stagnating, suggesting that stocks are being fully exploited (no reduction in fishing effort). Fees from licensing of foreign fishing vessels in the EEZs of AIO SIDS can make up a significant proportion of national revenue, but these states often experience problems in regulating activities in this zone. Catches of non-target, endangered species, especially of turtles, dolphins and dugongs, are cause for concern, as are other non-selective and destructive fishing practices.

(SOURCE: UNEP. 2005. *Atlantic and Indian Oceans, Environmental Outlook. Special Edition for the Mauritius International Meeting for the 10-year Review of the Barbados Programme of Action for the Sustainable Development of Small Island Developing States.* 76pp.)

GLOBAL

Habitat protection/degradation

Multiple stressors in a marine ecosystem – a framework for evaluation

A review on multiple stressors on the marine environment discusses the need to look at multiple indicators of environmental degradation; *e.g.*, chemical indicators, changes in food availability, and predator-prey relationships. The review suggests using 'sentinel species' (*e.g.*, apex predators such as cetaceans) as possible indicators of the health of an ecosystem facing multiple stressors. A framework is then suggested for evaluating environmental degradation. After generally characterizing the study system, exposure to stressors should be assessed, using direct indicators of exposure (such as stress proteins), direct indicators of effects (such as immune dysfunction), and/or indirect indicators of effects (such as reproductive rates). When assessing potential causes of these effects, the review points out the extreme difficulty of determining causation in marine ecosystems: rigorous testing of hypotheses or designing of experiments to distinguish different stressors is not possible. An epidemiological approach is suggested, using a series of criteria to narrow causal possibilities; for example, researchers can examine the strength of an association, wherein a large proportion of individuals are affected in the exposed (stressed) versus reference areas, or the magnitude of an effect is high in a few individuals. Another example: researchers can examine time order or temporality, wherein the probable cause precedes the effect in time and also the effect decreases when the probable cause is decreased or removed. The framework may be especially valuable when attempting to establish whether stressors are problems for cetaceans. The report emphasised that using multiple lines of evidence helps to avoid problems with false negatives; false negatives increase the likelihood that damaging stressors will be overlooked in management decisions.

(SOURCE: Adams, S.M. 2005. Assessing the cause and effect of multiple stressors on marine systems. *Mar. Pollut. Bull.* 51: 649-657)

Sequential exploitation is increasing problems with overfishing

Sequential exploitation or "the spatially expanding depletion of harvest species" (p. 1557) has been identified as one of the problems that is exacerbating fisheries overexploitation, and thus depletion of potential prey species for cetaceans. When local fish stocks are depleted, fishing vessels move into other regions where there is typically less governance or concern for these newly exploited fish stocks. Many of these new fisheries are on the high seas or in the waters of foreign nations. For example, in the sea urchin fishery in Japan, after local stocks declined, sea urchins were harvested farther a field, including on the coast of Maine, USA. This new sea urchin fishery expanded after technological advances, unfettered by appropriate management, led to the decimation of apex predators of sea urchins. This led to rapid and unregulated harvests of Maine sea urchins for the Japanese sushi market. "The emergence of specialized export markets for hitherto unexploited stocks is almost always a surprise to managers" and "the resource may vanish before the problem is even noted" (p. 1558). Marine Protected Areas are often too small and too far apart to counter this pattern of sequential exploitation. The researchers noted that even the largest Marine Protected Area in the world "is too small to maintain stocks of marine mammals…that migrate across its boundaries" (p. 1558). The authors suggested that regulating institutions must be developed before a resource is at risk, and that "[g]lobal, regional and national bodies need to monitor trade and resource trends" (p. 1558). They also highlight local governance of resources as vital to ensure conservation of stocks.

(SOURCE: Berkes, F., Hughes, T.P., Steneck, R.S., Wilson, J.A., Bellwood, D.R., Crona, B., Folke, C., Gunderson, L.H., Leslie, H.M., Norberg, J., Nyström, M., Olsson, P., Österblom, H., Scheffer, M. and Worm, B. 2006. Globalization, roving bandits, and marine resources. *Science* 311: 1557-1558)

Deep-sea fish species heavily depleted and endangered

The prey base and associated ecosystems of deep-sea foraging cetaceans may be threatened by deep-sea directed fisheries and bycatch. Studies on several large, long-lived deep-sea fish species on the North Atlantic continental slope determined that although there were no substantial commercial fisheries for, or even bycatch of, these species before the 1970s, all species showed a decline of 89-98% (between 1974 and 1994). Moreover, an evaluation of two of these species, for which there was a longer dataset, showed a decline of 99.7-100% over three generations. Generally the declines occurred in a period of just one generation. The mean size of catch also declined 25-57%. The researchers noted that scientific investigation lags behind the collapse of deep-sea fisheries. They urged the pro-active establishment of deep-sea protected areas (p. 29).

(SOURCE: Devine, J.A., Baker, K.D. and Haedrich, R.L. 2006. Deep sea fishes qualify as endangered. *Nature* 349: 29 [Brief Communications])

Marine wind farms – proliferation outpacing research

Construction of coastal and offshore marine wind farm foundations can produce noise levels up to 260 dB re 1 μPa, and cable-laying can produce noise levels up to 178 dB re 1 μPa. Such noise may impact acoustically sensitive fish or marine mammals. When in operation, these wind farms add 80-110 dB re 1 μPa (0.001-0.4 kHz) to ambient noise levels in the submarine environment, which might impact marine mammals with low frequency hearing (such as baleen whales). There may also be indirect effects on cetacean prey distribution, changing patterns of prey habitat use. As fossil fuel stocks dwindle, there is an increasing push for renewable energy sources such as wind farms. Additional impacts of marine wind farms could include changes in coastal benthic marine environments as the result of sea bed disturbance, and the removal, or suspension, of sediments. "There is an urgent need to consider the ecological effects of the large increase in [wind farms] in the coastal zone" (p. 612); however, there is a lack of knowledge of their impacts, and research into this issue is not keeping up with the very rapid pace of wind farm planning and deployment.

(SOURCE: Gill, A.B. 2005. Offshore renewable energy: ecological implications of generating electricity in the coastal zone. *J. Appl. Ecol.* 42: 605-615)

New marine contaminant – oestrogens

Oestrogens are increasingly becoming a problem in the marine environment. Hormones (both natural and synthetic) can be used as growth promoters in livestock and poultry, and they enter aquatic ecosystems via agricultural runoff. Runoff from agricultural land fertilized with poultry manure can have oestrogen concentrations of up to 500ng.l^{-1}. Oestrogens used in contraceptive pills also enter into wastewater systems. Many organic pollutants (*e.g.*, DDT) also have oestrogen-mimicking effects, along with compounds such as alkylphenol polyethoxylates (APEOs) which are used in agriculture and industry (*e.g.*, paper pulp and paint manufacture). Particularly high levels of APEOs are used in Asia. These oestrogens may bioaccumulate in marine organisms and could result in major reproductive dysfunction in marine species. Effects in fish include the production of oocytes (egg-producing cells) in male testes (an effect referred to as ovotestis or 'intersex') and other forms of abnormal gonad growth, such as testes with oviducts. Abnormal reproductive systems have also been observed in various invertebrates, including crustaceans. The effects of these excess oestrogens in the marine environment have not been assessed for marine mammals, but may warrant research. Impaired reproduction in cetacean prey species may represent a form of habitat degradation and may further deplete stocks of fish or crustaceans.

(SOURCE: Langston, W.J., Burt, G.R., Chesman, B.S. and Vane, C.H. 2005. Partitioning, bioavailability and effects of oestrogens and xeno-oestrogens in the aquatic environment. *J. Mar. Biol. Assoc. UK*: 85: 1-31)

Monitoring only one response of dolphins to powerboats may miss effects

An experiment was designed to test the response of Indo-Pacific bottlenose dolphins to the approach of a 5.6m, 90hp powerboat. There was a significant change in dolphin behaviour (travelling behaviour typically shifted to milling behaviour) and direction of travel changed, with the original direction of travel resuming after the powerboat had passed. However, there was no significant change in echolocation click or whistle production, *i.e.*, acoustic behaviour was not affected. Therefore, acoustic monitoring of animals alone to determine impacts from boat traffic may not detect behavioural changes.

(SOURCE: Lemon, M., Lynch, T.P., Cato, D.H. and Harcourt, R.G. 2005. Response of travelling bottlenose dolphins (*Tursiops aduncus*) to experimental approaches by a powerboat in Jervis Bay, New South Wales, Australia. *Biol. Conserv.* 127: 363-372)

Frequent changes in dolphin group behaviour in response to powerboats and jet skis

This study on the behaviour of common bottlenose dolphins off Hilton Head Island, South Carolina, found that the size of dolphin groups was significantly larger in the presence of boats, compared to periods with no boat traffic. Moreover, dolphin group sizes were significantly larger when several boats, as opposed to single vessels, were present. Inter-animal distance (group cohesion) was not affected by boat traffic, but distance between dolphins and boats did have a significant effect; the closer the boats, the greater the likelihood that animals would change their movement direction or behaviour. Animals also responded differently to different types of boats, with the largest proportion affected by powerboats (55%). Jet skis elicited even greater changes: 67% of dolphin groups changed behaviour and/or direction. When jet skis were present most dolphin groups submerged and did not reappear at the surface. Larger vessels only resulted in a change in behaviour in 11% of the groups. Moreover, shrimp boats always caused animals to change direction to follow the vessels to feed. These results argued for "[s]tricter regulations and enforcement…on human activities in coastal waters and on boating activities, particularly commercial dolphin-watching boats and jet skis" (p. 139).

(SOURCE: Mattson, M.C., Thomas, J.A. and St. Aubin. D. 2005. The effect of boat activity on the behaviour of bottlenose dolphins (*Tursiops truncatus*) in waters surrounding Hilton Head Island, South Carolina. *Aquatic Mammals* 31: 133-140)

Acidifying the oceans – impacts on marine ecosystems

Increasing acidification of the oceans is an emerging potential threat to marine habitats and organisms. An increase in anthropogenic, atmospheric carbon dioxide is causing an increase in the dissolution of carbon dioxide in the oceans, which results in the formation of carbonic acid. This increase in acidity then affects the concentration of carbonate in the world's oceans, which in turn is an essential nutrient for many marine organisms, including plankton species that utilize calcium carbonate to form shells, crustaceans, molluscs, and corals. It was estimated that at the current rate of acidification, surface waters of the Southern Ocean will start to become depleted of biologically available calcium carbonate by 2050, and the whole of the Southern Ocean and sub-Arctic Pacific Ocean will be affected by 2100. The researchers conclude that "[c]hanges in [Antarctic] seawater chemistry that will occur by the end of the century could well alter the structure and biodiversity of polar ecosystems, with impacts on multiple trophic levels" (p. 285).

(SOURCE: Orr, J.C., Fabry, V.J., Aumont, O., Bopp, L., Doney, S.C., Feely, R.A., Gnanadesikan, A., Gruber, N., Ishida, A., Joos, F., Key, R.M., Lindsay, K., Maier-Reimer, E., Matear, R., Monfray, P., Mouchet, A. and Naijar, R.G. 2005. Anthropogenic ocean acidification over the twenty-first century and its impact on calcifying organisms. *Nature* 437: 681-686)

<u>Shellfish aquaculture displaced bottlenose dolphins</u>

Since 1993 a pearl oyster shellfish aquaculture site has been operating in Shark Bay, Australia. Researchers calculated that bottlenose dolphins (*Tursiops* sp.) utilised the leased area of the aquaculture site only 0.36% of the time. The aquaculture company requested an extension on their lease so that they could farm oysters in deeper water, an area that dolphins used 10.6% of the time. Despite being denied the use of this latter area, the aquaculture site used the site illegally in 1999, until they were evicted from it by government officials. Dolphin sightings decreased significantly when the aquaculture operation moved into this extension area. The distance between the dolphins and the normal aquaculture site did not increase when the farm started culturing oysters, but the distance between dolphins and the site did increase when the oyster farm occupied the extension area. Moreover, dolphins moved around the oyster farm area, *i.e.*, the presence of the oyster farm denied them access to this area of habitat. "Detailed movement patterns around the confirmed oyster farm provided the strongest evidence that dolphins are displaced by shellfish aquaculture" (p. 525). This is the first study to report loss of cetacean habitat as the result of shellfish aquaculture.

(SOURCE: Watson-Capps, J.J. and Mann, J. 2005. The effects of aquaculture on bottlenose dolphins (*Tursiops* sp.) ranging in Shark Bay, Western Australia. *Biol. Conserv.* 124: 519-526)

<u>Sub-tropical marine predator hotspots threatened</u>

Hotspots in marine predator diversity (primarily tuna and billfish, but also cetaceans) were found in sub-tropical regions that were related to thermal fronts, dissolved oxygen levels and temperature (a temperature of approximately 25ºC was considered to be the optimal for diversity). The richness of diversity for some predators was also associated with foraminifera (zooplankton) diversity. Hotspot areas included the eastern tropical Pacific, the US mid-Atlantic coast, some coastal areas of the east African coast, the eastern coast of Australia and Sri Lanka. However, over the past 50 years diversity in these hotspots has decreased from 10% to 50% as the result of over-fishing and climatic effects such as El Niño-Southern Oscillation events. The researchers suggested that data on these hotspot areas could be used to develop marine protected areas for large marine predators (which includes species such as cetaceans).

(SOURCE: Worm, B., Sandow, M., Oschlies, A., Lotze, H.K. and Myers, R.A. 2005 Global patterns of predator diversity in the open oceans. *Science* 309: 1365-1369)

Chemical pollution

<u>Faster initial rate of DDT (versus PCB) transfer from dolphin mothers to calves</u>

A lactating female short-beaked common dolphin and her calf were by-caught in fishing gear in the Mediterranean and an analysis of the level of organochlorines in both mother and calf was made. DDT levels in the calf were 3.4 times higher than in the mother, and total body burden was also higher in the calf, although the calf was only halfway through the lactation period. This suggests a high initial transfer of DDT from mother to calf during early lactation. PCB levels in the calf were 1.9 times higher than in the mother, and the calf's total body burden was lower than the mother's, suggesting that DDT is transferred to the calf faster than PCB. Nearly all of a first-time mother's body burden of organochlorines is apparently transferred to her calf; considering the high contamination level in many dolphins, this has serious toxicological implications for calf development, health, and mortality. The rapid transfer of DDT would also likely have a toxicological impact on new-borns.

(SOURCE: Borrell, A. and Aguilar, A. 2005. Mother-calf transfer of organochlorine compounds in the common dolphin (*Delphinus delphis*). *Bull. Environ. Contam. Toxicol.* 75: 149-156)

Thyroid damage linked to pollutants in harbour porpoises

A study on the thyroid tissue of 57 harbour porpoises from the North (Danish, German, Norwegian coast) and Baltic Seas (German coast) and Icelandic coasts noted a high rate of inter-follicular fibrosis in thyroids from German and Norwegian animals (30% and 38% of connective tissues, respectively). Moreover, analysis of the incidence of inter-follicular fibrosis and contaminants showed a relationship between PCBs, PBDE, DDE, DDT and toxaphene levels and fibrosis. This "supports the hypothesis of a contaminant-induced thyroid fibrosis in harbour porpoises raising the question of the long-term viability in highly polluted areas." This study adds more evidence to the threat of endocrine system damage by contaminants.

(SOURCE: Das, K., Vossen, A., Tolley, K., Víkingsson, G., Thron, K., Müller, G., Baumgärtner, W. and Siebert, U. 2006. Interfollicular fibrosis in the thyroid of the harbour porpoise: an endocrine disruption? *Arch. Environ. Contam. Toxicol.*: in press)

Effects of consumption of mercury-contaminated cetacean meat in laboratory rats

Laboratory rats were fed whale meat (false killer and minke whale) every day for a week (a dose of 0.5g per kg of body weight per day). The whale meat contained a total mercury concentration of up to 81µg.g^{-1} and a methyl mercury concentration of 13.4µg.g^{-1} (equivalent to a human consumption of 210g of whale meat per 60kg of body weight per week). After the last dose, elevated levels of mercury were found in the liver, kidney, red blood cells, and brain (cerebral cortex and medulla oblongata). No increased levels of mercury were detected in blood serum, but certain blood chemistry factors were altered (glutamic pyruvic transaminase and inorganic phosphorous increased and blood urea nitrogen decreased). The elevated mercury levels were greater than levels that have been associated with infertility in humans consuming mercury-contaminated seafood, and would be likely to cause foetal neurological damage in pregnant women. It was concluded that "[t]he occasional consumption of red meat from small cetaceans, therefore, could pose a health problem" (p. 1069). Although this study was primarily concerned with the impacts of eating cetacean meat on humans, toxicological impacts might also be expected on small cetacean-consuming marine mammals such as killer whales.

(SOURCE: Endo, T., Hotta, Y., Haraguchi, K. and Sakata. M. 2005. Distribution and toxicity of mercury in rats after oral administration of mercury-contaminated whale meat marketed for human consumption. *Chemosphere* 61: 1069-1073)

Sperm whales as global indicators of pollution

A 5-year world-wide survey of sperm whale contaminant loads has been completed. A total of 424 sperm whales were biopsied, with DDT as the most common pollutant, followed by PCBs. The survey also looked at the cytochrome biomarker, CYP1A1, and found that coastal animals in the Sea of Cortez, off the west coast of Mexico and Baja California, had double the levels of this biomarker compared to mid-Pacific animals, which was attributed to the effects of agricultural runoff. A biomarker hotspot was found off the Galápagos Islands but the reasons for this were unknown. Moreover, skin mercury levels were higher in the coastal wasters of the Sea of Cortez and the Galápagos compared to elsewhere in the Pacific.

(SOURCE: Ferber, D. 2005. Sperm whales bear testimony to worldwide pollution. *Science* 309: 1166 [News of the week])

Brominated contaminant found in cetacean market products

Researchers investigated levels of halogenated dimethyl bipyrroles (HDBPs) in market-sold cetacean products (northern minke whales, O and J stock, Bryde's and sei whale, common bottlenose, striped, rough-toothed and pantropical spotted dolphin, false killer whale, short-finned pilot whale, Baird's beaked whale and Dall's porpoise). The HDBPs were a substantial proportion of the organohalogen load of the samples tested, *i.e.*, up to 37% of the total organohalogen body burden in Dall's porpoise, down to 8.9% of the body burden in northern minke whales. HDBPs are thought to be naturally occurring, and have a different contaminant distribution pattern to anthropogenic contaminants, *e.g.*, Baird's beaked whales in the

Pacific were more contaminated than animals in the Sea of Japan. The researchers warned that "the consumption of HDBPs by Japanese individuals could be an exposure/health risk"; thus, there may also be risks to the health of the contaminated cetaceans, or predators of contaminated cetaceans.

Maximum values

HDBP ($\mu g.g^{-1}$ lipid weight) O stock northern minke whale: 1.24; J stock northern minke whale: 1.02; Bryde's whale: 0.09; sei whale: 0.03; common bottlenose dolphin: 40.7; short-finned pilot whale: 18.0; striped dolphin: 27.9; Baird's beaked whale: 7.0; Dall's porpoise: 5.71; false killer whale: 18.1; rough-toothed dolphin 8.62; pantropical spotted dolphin: 23.1

(SOURCE: Haraguchi, K., Hisamichi Y. and Endo, T. 2006. Bioaccumulation of naturally occurring mixed halogenated dimethyl bipyrroles in whale and dolphin products on the Japanese market. *Arch. Environ. Contam. Toxicol.*: in press)

<u>Tumour found in bottlenose dolphin associated with PCB contamination</u>

A large lymphoma (cancer) was found in a common bottlenose dolphin stranded on Gran Canaria, Canary Islands. High levels of organochlorines and polyaromatic hydrocarbons (PAHs) were found in the dolphin, which have been implicated with white blood (T) cell immunosuppression, which in turn has been associated with immunoblastic lymphomas such as the one discovered. It was suggested "[h]igh concentrations of PCBs 153, 180, 138 and 187 found in the liver may have been associated with the [tumour]" (p. 242).

Maximum contaminant levels

Liver ($\mu g.g^{-1}$ lipid weight) ΣDDT: 3.6; PCB138: 8.9; PCB153: 15.4; PCB180: 13.4; PCB187: 8.4; ΣPCB: 52.4; ($\mu g.g^{-1}$ lipid weight; blubber): ΣDDT: 15.6; PCB138: 1.65; PCB153: 2.89; PCB180: 3.1; PCB187: 2.14; ΣPCB: 10.97.

(SOURCE: Jaber, J.R., Pérez, J., Carballo, M., Arbelo, M., Espinosa de los Monteros, A., Herráez, P., Muñoz, J., Andrada, M., Rodríguez, F. and Fernández, A. 2005.Hepatosplenic large cell immunoblastic lymphoma in a bottlenose dolphin (*Tursiops truncatus*) with high levels of Polychlorinated Biphenyl Congeners. *J. Comp. Path.* 132: 242-247)

<u>Synergistic effects of PCB mixtures and differences between species complicate pollution studies</u>

The effects of several PCB congeners and a dioxin on phagocytosis (the envelopment of pathogens by white blood cells, an essential immune system response to combat disease) and on white blood cell production were recorded in marine mammals and mice. Cetacean species tested included killer and beluga whales and Commerson's, common bottlenose, and Pacific white-sided dolphins. Certain PCB congeners seemed to have a major effect on phagocytosis rates. In Commerson's dolphins, one congener (with or without the dioxin) reduced phagocytosis by 50-57%, whereas some other mixtures *increased* phagocytosis rates. For white-sided dolphins, certain congener mixtures decreased phagocytosis by 66-69%, and for killer whales, certain mixtures caused a 124-155% *increase* in phagocytosis. Toxic equivalent (TEQ) calculations, which are designed to predict the cumulative toxicity of certain PCBs and dioxins, failed to predict the phagocytosis suppression caused by the mixed contaminants. Tests on laboratory mice similarly failed to predict responses. As with phagocytosis, the examination of effects on white blood cell count showed that exposure to PCBs generally caused a reduction, but mixtures of different congeners and dioxin had different effects. The results suggested that there were synergistic effects of contaminants on white blood cell production, *i.e.* most mixtures had a greater effect on reductions than single congeners, but some mixtures led to lesser impacts (certain congeners perhaps acted to reduce impacts). TEQ calculations assume that toxic effects are additive – this study suggested that this is not always the case and, as with the phagocytosis study, TEQs could not accurately predict actual responses. Different reductions in white blood cell counts were also attributable to species differences. Killer whales, bottlenose dolphins, and mice showed the greatest reductions and therefore may be more vulnerable to contaminant-induced immune system suppression, making them more susceptible to diseases as the result of pollution exposure. Both of these studies show that the effects of pollutants on marine mammal immune systems are more complex than previously thought. This has implications for studies on single or a small number of cetacean species that are then used as models for other species, and also suggests that certain cetacean species are more vulnerable to contaminants. Generally, these "results are a cause for concern for wild marine mammals, which are exposed to [organochlorines] as well as other contaminants, since they may be at risk to normally non-threatening diseases as their immune systems may not be functioning at optimal levels" (Levin *et al.*, p. 653).

(SOURCES: Levin, M., Morsey, B., Mori, C., Nambiar, P.R. and De Guise, S. 2005. PCBs and TCDD, alone and in mixtures, modulate marine mammal but not B6C3F1 mouse leukocyte phagocytosis. *J. Toxicol. Environ. Health A* 68: 635-656 AND Mori, C., Morsey, B., Levin, M., Nambiar, P.R., De Guise, S. 2006. Immunomodulatory effects of in vitro exposure to organochlorines on T-cell proliferation in marine mammals and mice. *J. Toxicol. Environ. Health A* 69: 283-302)

Possible biomarker for contamination and DNA damage in mature female cetaceans

Levels of a possible biomarker of DNA damage (8-hydroxy-2'-deoxyguanosine or 8-OHdG) were determined in the liver and kidneys of stranded and by-caught Taiwan cetaceans. The levels of 8-OHdG did not appear to be related to the general health of the cetaceans, but there was a correlation with PCB levels in the livers of females. However, there was not a similar correlation with DDE. Also, in adult females, coplanar PCBs (as used in TEQ evaluations) were correlated with 8-OHdG. There were no significant correlations when males or immature females were considered. In summary, 8-OHdG may be a useful biomarker for DNA damage, PCBs and TEQs in the liver of mature female cetaceans. Moreover, PCBs in the liver of mature female cetaceans may cause DNA damage, and potentially have carcinogenic and mutagenic effects.

(SOURCE: Li, C.S., Wu, K.Y., Chang-Chien, G.P., Chou, C.C. 2005. Analysis of oxidative DNA damage 8-hydroxy-2'-deoxyguanosine as a biomarker of exposures to persistent pollutants for marine mammals. *Environ. Sci. Tech.* 39: 2455-2460)

New brominated contaminant found in relatively high quantities in marine mammal tissues

A novel polybrominated biphenyl compound (2,2'-dimethoxy-3,3',5,5'-tetrabromodiphenyl) has been discovered in cetacean products being sold for human consumption (Baird's beaked whale, striped dolphin, common bottlenose dolphin and northern minke whale tissues). The researchers note that the source of this contaminant may be anthropogenic – a by-product of the production of a livestock drug treatment – but it is probably also produced by natural sources, *i.e.*, produced by marine microorganisms. Concentrations of this contaminant were higher than many other polybrominated contaminants in the samples tested. This issue requires further attention, particularly regarding the impact of this novel compound on high trophic level species, such as cetaceans.

Maximum value

Striped dolphin cooked liver tissue (ng.g^{-1} lipid weight): 800

(SOURCE: Marsh, G., Athanasiadou, M., Athanassiadis, I., Bergman, A., Endo, T. and Haraguchi, K. 2005. Identification, quantification, and synthesis of a novel dimethoxylated polybrominated biphenyl in marine mammals caught off the coast of Japan. *Environ. Sci. Technol.* 39: 8684-8690)

Rate of transformation of PCBs and PBDEs by whale metabolic systems

An experiment examined the proportion of various PCB and brominated flame retardant congeners that were metabolized and transformed by metabolic processes in beluga whales. Generally PCBs that were more highly chlorinated were not transformed. Degree of transformation was also very different from that of rat metabolic transformation, suggesting that laboratory rats may not be a good proxy for studies on contamination in cetaceans. It was suggested that "the formation of potentially toxic oxidative PCB and PBDE products (metabolites), in addition to the parent pollutants, may be contributing to contaminant-related stress effects on the health of [cetaceans]" (p. 87). Therefore to fully investigate the total body burden of pollutants, scientists should also look at levels of PCB and PBDE metabolites (which typically is not done in cetacean ecotoxicological studies), not just the parent PCB and PBDE contaminants.

Proportion of PCBs metabolised: CB15: 100%; CB77: 93%; CB31: 29%; CB26: 25%; CB52: 13%; CB101: 0%; CB105: 0%. Proportion of PBDEs metabolised: BDE15: 100%; BDE28: 11%; BDE47: 5%.

(SOURCE: McKinney, M.A., De Guise, S., Martineau, D., Béland, P., Arukwe, A., and Letcher, R.J. 2006. Biotransformation of polybrominated diphenyl ethers and polychlorinated biphenyls in beluga whale (*Delphinapterus leucas*) and rat mammalian model using an in vitro hepatic microsomal assay. *Aquat. Toxicol.* 77: 87-97)

New pollutant in marine mammals – synthetic musks

Levels of two synthetic musks used in perfume production (AHTN and HHCB) were found in finless porpoises from the coast of Japan. Although AHTN levels were low, HHCB was found in the blubber of all the finless porpoises tested, including notable levels in a porpoise foetus (26 $ng.g^{-1}$). Concentrations were highest in blubber tissue, followed by kidney tissue, suggesting a contaminant accumulation pattern similar to PCBs and organochlorines. Synthetic musk was also found in sharks, suggesting that this contaminant accumulates in top predators. Although the toxicological effects of this contaminant are unknown, this study adds yet another contaminant found in cetacean tissues.

Maximum contaminant levels

Blubber ($ng.g^{-1}$ wet weight) HHCB: 149; AHTN: 9.6

(SOURCE: Nakata, H. 2005. Occurrence of synthetic musk fragrances in marine mammals and sharks from Japanese coastal waters. *Environ. Sci. Tech*. 39: 3430-3434)

New class of pollutants in marine mammals

At regular intervals, potentially problematic new chemical pollutants are being identified in marine ecosystems. One such new class is halogenated naphthols. Although no direct sources of these chemicals are documented, they have now been reported in the livers of stranded white-sided dolphins on the eastern coast of Canada. Data on toxicity are lacking, although the structure of these chemicals is related to compounds that exhibit toxicity similar to PCBs. More data are needed to assess their contribution to global marine pollution and whether they should be classified as POPs in the framework of the UNEP-backed Stockholm Convention on Persistent Organic Pollutants.

(SOURCE: Saint-Louis, R. and Pelletier, E. 2005. Unsuspected organic pollutants in marine mammals: halogenated naphthols. *Mar. Pollut. Bull.* 50: 889-903)

Biomagnification of brominated flame retardants in harbour porpoises

Harbour porpoises had levels of brominated flame retardants approximately 20 times greater than their herring prey. The level of biomagnification varied according to the specific chemical congener, from no biomagnification to approximately 40 times the level in prey species. These results showed that, at least for brominated flame retardants, there are congener-specific patterns of biomagnification – some congeners may even exceed expected levels of biomagnification.

(SOURCE: Veltman, K., Hendricks, J., Huijbregts, M., Leonards, P., van den Heuvel-Greve, M. and Vethaak, D. 2005. Accumulation of organochlorines and brominated flame retardants in estuarine and marine food chains: field measurements and model calculations. *Mar. Pollut. Bull.* 50: 1085-1102)

Global survey of perfluorinated acids in oceans

Perfluorinated compounds (PFCs) have emerged as a new class of global environmental pollutants. They have been reported in tissues of marine organisms, and this study examines data collected from water sampled during several international research cruises around the world. The goal is to better detect sources and pathways of these compounds into the oceans. This required first developing a reliable and highly sensitive analytical method (sub-parts-per trillion = ng/l, and parts-per-quadrillion = pg/l). PFOA was the major component detected in oceanic waters, followed by PFOS.

Maximum contaminant levels

Liver, harbour porpoise, North Sea ($ng.g^{-1}$ wet weight) PFOS: 395, PFOA <62

Liver, whales, seals, dolphins, porpoise, North Sea ($ng.g^{-1}$ wet weight) PFOS: 821, PFOA <62

Coastal and open waters, Tokyo Bay ($pg.l^{-1}$) PFOS: 57,700, PFHS: 5600, PFNA: 71,000, PFOA: 192,000

(SOURCE: Yamashita, N., Kannan, K, Taniyasu, S., Horii, Y., Petrick, G. and Gamo, T. 2005. A global survey of perfluorinated acids in oceans. *Mar. Pollut. Bull.* 51: 658-667 – Liver values cited from Van de Vijver *et al*. (2003))

<u>Butyltin and arsenic contaminants transferred from a porpoise mother to her foetus</u>

An analysis of butyltin and arsenic contamination in a female Dall's porpoise and her 6-month-old foetus showed that the foetus had acquired detectable levels of both contaminants, presumably passed from the mother across the placenta. The average foetal butyltin contamination level was 25 times lower than in the mother, while the mother had higher levels of arsenic compounds in her liver. The distribution of butyltins in the foetus was different than in the mother, with the mother showing more accumulation in the liver, and the proportions of specific types of butyltin were also different, with tributyltin predominating in the mother and dibutyltin predominating in the foetus. However, the proportions of differing organic forms of arsenic (*e.g*., arsenobetaine, arsenocholine) were similar in both mother and foetus. There may be developmental impacts of such contaminant transfer between mothers and calves. This is the first report of the transfer of butyltin contaminants across a cetacean placenta.

(SOURCES: Yang, J. and Miyazaki, N. 2006. Transplacental transfer of butyltins to fetus of Dall's porpoises (*Phocoenoides dalli*). *Chemosphere* 63: 716-721 AND Kubota, R., Kunito, T., Fujihara, J., Tanabe, S., Yang, J. and Miyazaki, N. 2005. Placental transfer of arsenic to fetus of Dall's porpoises (*Phocoenoides dalli*). *Mar. Pollut. Bull.* 51: 845-849)

<u>New pollutant found in European small cetaceans – HBCD</u>

A brominated flame retardant used in polystyrene foams (hexabromocyclododecane or HBCD) was found in the tissues of harbour porpoises and common dolphins from different European waters. The highest levels were found in harbour porpoises from western Scottish waters and the coastal Irish Sea. The predominant form of HBCD found in cetacean tissues was not the predominant form used industrially, so the possibility that mammalian metabolic systems can change the form of HBCD was investigated. Rats showed some transformation of the industrial form; from this, it was suggested that cetaceans could also transform this type of HBCD. HBCD has been reported to have neurotoxic effects in mammals and also has the ability to induce genetic recombination, which in turn can cause cancer. However, if cetaceans can metabolically transform HBCD, they may also be reducing its toxicity. This new class of contaminant in cetaceans may have toxicological impacts and warrants further investigation.

Contaminant levels

Northwest Scotland samples ($\mu g.g^{-1}$ lipid weight): 5.1 (median); 9.7 (range maximum)

(SOURCE: Zegers, B.N., Mets, A., Van Bommel, R., Minkenberg, C., Hamers, T., Kamstra, J.H., pierce, G.J., and Boon, J.P. 2005. Levels of hexabromocyclododecane in harbor porpoise and common dolphins from western European Seas, with evidence for stereoisomeric-specific biotransformation by cytochrome P450. *Environ. Sci. Technol.* 39: 2095-2100)

Disease and mortality events

<u>Two new cetacean viruses identified</u>

Two new poxviruses have been identified, one from the skin of dolphins (Indo-Pacific bottlenose, common bottlenose, striped and rough-toothed dolphins) and the second from the skin of a bowhead whale. The viruses had some shared DNA and amino acid sequences with terrestrial poxviruses, including viruses found in domestic livestock.

(SOURCE: Bracht. A.J., Brudek, R.L. Ewing, R.Y., Manire, C.A., Burek, K.A., Rosa, C., Beckman, K.B., Maruniak, J.E. and Romero, C.H. 2006. Genetic identification of novel poxviruses of cetaceans and pinnipeds. *Arch. Virol.* 151: 423-438)

<u>Fish contaminated with algal toxins implicated in marine mammal mortality</u>

In 2004, 107 common bottlenose dolphins and 34 Florida manatees died in an unusual mortality event. High levels of brevetoxin, produced by the red tide algae *Karenia brevis*, in the stomachs of the animals suggested that poisoning resulted from ingestion of contaminated food. Dolphin stomach analysis found brevetoxin-contaminated plankton-feeding fish (predominantly menhaden), even though the algae was not present. This study shows that cetaceans and other marine mammals can accumulate lethal loads of algal toxins through the consumption of contaminated prey. This illustrates the risk that harmful algal blooms (HABs) and anthropogenic activities that can promote the formation of HABs can have on cetaceans.

(SOURCE: Flewelling, L.J., Naar, J.P., Abbott, J.P., Baden, D.G., Barros, N.B., Bossart, G.D., Bottein, M.-Y.D., Hammond, D.G., Haubold, E.M., Heil, C.A., Henry, M.S., Jacocks, H.M., Leighfield, T.A., Pierce, R.H., Pitchford, T.D., Rommel, S.A., Scott, P.S., Steidinger, K.A., Truby, E.W., Van Dolah, F.M. and Landsberg, J.H. 2005. Red tides and marine mammal mortalities. *Nature* 435: 755-756)

Nutrient enrichment increases toxin production by phytoplankton

Certain species of phytoplankton produce poisonous substances, and blooms of such algae (harmful algal blooms or HABs) can disrupt marine ecosystems and cause mortalities in fish and mammals, including humans. One such algal species is the dinoflagellate *Alexandrium tamarense*, which produces a suite of paralytic toxins that cause paralytic shellfish poisoning (PSP). A laboratory study has now shown that addition of the nutrients nitrate and phosphate increased the cell density of this species by 6-29% and the cellular toxic content by 20-76%. The implication is that nutrient-enriched waters not only promote algal blooms including HABs, but also increase their toxicity. Cetacean deaths have been attributed to HABs.

(SOURCE: Hu. H., Chen, W., Shi, Y. and Cong, W. 2005. Nitrate and phosphate supplementation to increase toxin production by the marine dinoflagellate *Alexandrium tamarense*. *Mar. Pollut. Bull.* in press)

Red tide events impact cetaceans

Based on new research on mass fatalities of endangered manatees in 2002 and bottlenose dolphins in 2004 in Florida, marine mammal deaths can be caused by the brevetoxins produced by red tides even after the lethal amounts of the toxins have dissipated. Fish (especially their internal organs) have been identified as the pathways that transfer brevetoxin up the food web.

(SOURCE: Marine Pollution Bulletin News. 2005. Red tide toxins linger on in food webs. *Mar. Pollut. Bull.* 50: 795)

Odontocete strandings coincide with acoustic dead zones

Coastal topography (*e.g*., gently sloping beaches) may have an effect on the reception of echolocation information, when echolocation is being used by odontocetes to navigate. Return echoes for echolocation signals were modelled for a section of coastline, revealing acoustic 'dead zones', *i.e*., areas where rebounding echolocation signals would be weakened and degraded. In three of the four scenarios, these acoustic dead zones were significantly associated with odontocete strandings (primarily of long-finned pilot whales). Therefore it may be possible to predict areas and locations with a high probability of odontocete strandings based on the acoustic properties resulting from coastline topography.

(SOURCE: Sundaram, B., Poje, A.C., Veit, R.R., Nganguia, H. 2006. Acoustical dead zones and the spatial aggregation of whale strandings. *J. Theoret. Biol.* 238: 764-770)

Sperm whale strandings linked to changes in sunspot activity

Researchers analysed sperm whale strandings in the North Sea from 1712 to 2003, and discovered a significant correlation with sunspot activity. Energy radiation from the sun is inversely related to the period length of sunspot activity. Ninety percent of sperm whale strandings in the North Sea were associated with sun spot periods that were shorter than normal, *i.e*., radiation output was greater than normal. The significant association between sunspot activity and sperm whale strandings might be the result of the effects that sunspot activity have on the earth's geomagnetic field. If sperm whales are able to detect the earth's magnetic field, and use this field for navigational purposes, changes in sunspot activity may impact their ability to navigate and cause increased stranding rates.

(SOURCE: Vanselow, K.H. and Ricklefs, K. 2005. Are solar activity and sperm whale *Physeter macrocephalus* strandings around the North Sea related? *J. Sea Res.* 53: 319-327)

Climate change

Climate change is warming the oceans

Since the 1950s, 84% of the additional heat trapped in the earth's system has entered the oceans, which has in turn led to thermal expansion of seawater, contributing to 25% of the sea level rise observed during this period. Increases in temperature in the top 700m of the ocean surface waters have been found to be correlated with increases in anthropogenic greenhouse gases. The impacts of this warming on marine ecology and circulation could be substantial.

(SOURCES: Antonov, J.I., Levitus. S, and Boyer, T.P. 2005. Thermosteric sea level rise, 1955–2003. *Geophys. Res. Lett.* 32: L12602; Barnett, T.P., Pierce, D.W., AchutaRao, K.M., Gleckner, P.J., Santer, B.D., Gregory, J.M. and Washington, W.M. 2005. Penetration of human-induced warming into the world's oceans. *Science* 309: 284-287; Hegerl, G.C. and Bindoff, N.L. 2005. Warming the world's oceans. *Science* 309: 254-255; AND Levitus. S., Antonov, J.I. and Boyer, T.P. 2005. Warming of the world ocean, 1955–2003. *Geophys. Res. Lett.* 32: L02604)

An increase in destructiveness of tropical cyclones may be linked to global warming

Hurricanes can have major impacts on cetaceans inhabiting coastal waters in tropical and sub-tropical waters, degrading their habitats. In the past 35 years there has been a major increase (57%) in the number of very powerful hurricanes (*i.e*., Category 4 and 5 tropical cyclones) in the Atlantic and Pacific Oceans. As surface water temperature is critical to the formation of tropical cyclones and the amount of energy they contain, several studies have suggested a link between rising global temperatures and cyclone power. Some debate exists about how much human activities are contributing to this pattern.

(SOURCES: Emanuel, K. 2005. Increasing destructiveness of tropical cyclones over the past 30 years. *Nature* 436: 686-688; Webster, P.J., Holland, G.J., Curry, J.A. and Chang, H.R., 2005. Changes in tropical cyclone number, duration and intensity in a warming environment. *Science* 309:1844-1846;*See also* Pielke, R.A. 2005. Are there trends in hurricane destruction? *Nature* 438: E11 [Brief Communications]; Landsea, C.W. 2005. Hurricanes and global warming. *Nature* 438: E11-E13 [Brief Communications]; Emanuel, K. 2005. Emanuel replies. *Nature* 438: E13 [Brief Communications]; AND Chan, J.C.L. 2006. Comment on 'Changes in tropical cyclone number, duration and intensity in a warming environment'. *Science* 311: 1713b [Technical Comment])

Increasing carbon dioxide causing increased water flow into the oceans

The amount of fresh water flowing into the oceans has been increasing. Increased rainfall over land, however, cannot account for this increase in freshwater flow. This study suggests that increased atmospheric carbon dioxide is causing plants to leave open their stomata (closable pores in the leaves) for shorter periods, leading to less water transpiring from plants, and less water being released into the atmosphere. This in turn increases water levels in the soil, leading to greater runoff. This could affect the amount of land-based pollution washed into the oceans (*i.e*., it could increase the amount of runoff) and also affect coastal hydrography and ecology.

(SOURCES: Gedney, N., Cox, P.M., Betts, R.A., Boucher, O., Huntingford, C. and Stott, P.A. 2006. Detection of a direct carbon dioxide effect in continental river runoff records. *Nature* 439: 835-838 AND Matthews, D. 2006. The water cycle freshens up. *Nature* 439: 793-794)

Climate change effects on fish recruitment worsened by overfishing

Significant decreases in age at sexual maturity and average size have been reported in many over-fished stocks worldwide. In Atlantic cod, the age at reproductive maturity has decreased by three years, from 10-11 to 7-8 over approximately the last five decades. Moreover, variability in recruitment rates in Atlantic cod is linked to climate: the spawning age in cod is strengthening the link between climate change and recruitment, *i.e*., younger spawning fish are more vulnerable to global warming-related extremes and uncertainty than larger, older spawning animals. This suggests a synergistic effect of overfishing and climate change that could significantly reduce overfished stocks even further, and hence impact cetacean prey species.

(SOURCE: Ottersen, G., Hjermann, D. Ø., and Stenseth, N.C. 2006. Changes in spawning stock structure strengthen the link between climate and recruitment in a heavily fished cod *(Gadus morhua)* stock. *Fisheries Oceanography* 15: 230-243)

Noise impacts

<u>Mitigation measures to reduce acoustic injury and mortality in naval 'ship shock' tests</u>

'Ship shock' tests involve detonations of explosives (*e.g.*, 10,000lb bombs) close to naval vessels to assess the structural integrity of new ship designs to 'combat conditions'. A review of mitigation measures (to protect marine mammals) actually employed during a series of ship shock tests was conducted. Various mitigation measures were used, including the establishment of 'safety' and 'buffer' zones, aerial surveys, and observers on board the vessel to be tested. In addition, a nearby vessel had a marine mammal observer and veterinarian on board, in case animals were injured. Detonations were delayed on three days due to marine mammal or turtle sightings, and completely postponed on one day due to numerous sightings. Detonations were also cancelled on two days due to weather conditions that would have made sighting cetaceans difficult. The large numbers of sightings in the test area suggest that had mitigation measures not been employed there would have been numerous animal deaths and injuries. The mitigation measures were considered effective "since no dead or injured [animals] were detected after the detonations" (p. 48). In evaluating the programme it was emphasised that "[e]xperienced and trained observers are crucial for detecting and tracking marine mammals" (p. 49). In terms of improving and increasing the effectiveness of mitigation measures, it was suggested that: (1) passive acoustic monitoring was largely ineffective, as it was both expensive and no animals were detected; (2) two survey planes be used instead of one to improve survey coverage; (3) the additional boat (with the veterinarian) should be better equipped, with additional observers and 25x binoculars, with a more active role in tracking and monitoring marine mammals; (4) post-detonation monitoring should be increased; and (5) surveys to assess possible test areas (to identify areas with the lowest density of marine mammals and turtles) should be conducted during the same season as future tests, using similar methodologies. The expense of dedicated surveys to determine a time and location of minimum marine mammal abundance is ultimately worthwhile because it reduces both the potential impacts and the number of extremely costly test delays. The mitigation measures examined in this study could serve as an example of appropriate measures for other high intensity noise-producing activities.

(SOURCE: Clarke, J.T. and Norman, S.A. 2005. Results and evaluation of US Navy shock trial environmental mitigation of marine mammals and sea turtles. *J. Cet. Res. Manage.* 7: 43-50)

<u>Sound causes gas bubble formation in supersaturated blood, liver, and kidney</u>

This study placed samples of bovine blood, liver, and kidney under pressure (equivalent to 40-70m in diving depth) and exposed them to low frequency sound pulses. Bovine tissues effectively supersaturated with gases (*e.g*., having high levels of dissolved nitrogen) all clearly showed the presence of bubbles or gas lesions after ensonification. This is further evidence that high intensity sound sources such as sonar can cause gas emboli syndrome in stranded cetaceans.

(SOURCE: Crum, L.A., Bailey, M.R., Guan, J., Hilmo, P.R., Kargl, S.G., Matula, T.J. and Sapozhnikov, O.A. 2005. Monitoring bubble growth in supersaturated blood and tissue *ex vivo* and the relevance to marine mammal bioeffects. *Acoust. Res. Lett. Online* 6: 214-220)

<u>Stranded beaked whales exhibit 'gas embolic syndrome'</u>

In January 2006, four beaked whales stranded in Almeria, on the southern coast of Spain. These animals had gas emboli in their tissues, as has been found in sonar-associated strandings (see below). Coincident naval exercises were not confirmed at the time of this news report.

(SOURCE: Dalton, R. 2006. More whale strandings are linked to sonar. *Nature* 440: 593 [News])

<u>The potential effects of pile-driving noise on cetaceans</u>

Pile driving is an activity associated with many forms of coastal development, including raising structures such as wind farms. The sound produced by pile driving can be substantial (*e.g*., 135 dB re 1 μPa up to 1km from a site). An analysis concentrating on bottlenose dolphins estimated that pile-driving noise could mask strong dolphin acoustic communications within 10 to 15km and weak communications up to 40km. The radius of masking effects was frequency dependent, for example 1.2km at 115 kHz and 6km at 50kHz.

(SOURCE: David, J.A. 2006. Likely sensitivity of bottlenose dolphins to pile-driving noise. *Water Environ. Jour.* 20: 48-54)

<u>New syndrome associated with sonar-related strandings</u>

One Gervais', one Blainville's, and eight Cuvier's beaked whales were stranded in the Canary Islands in September 2002 coincident with an international naval exercise. The stranded animals had congestion and bleeding within the ears, brain, jaw fat and kidneys and unusual gas bubble lesions and fat emboli in several organs, including the liver. It was noted that "[g]as and fat emboli can cause nervous and cardiovascular dysfunctions, respiratory distress, pain, and disorientation" (p. 453). The suggestion was that these lesions resulted from sonar exposure, eliciting changes in whale diving behaviour, *e.g.*, forcing animals to the surface, which could lead to formation of nitrogen bubbles in a manner similar to decompression sickness or 'the bends'. An alternative hypothesis was that the physical properties of sonar pulses actually caused bubbles to form in the tissues of the whales, as these tissues may hold higher than normal levels of (be 'supersaturated' with) dissolved nitrogen gas. In either case, the gas lesions and fat emboli syndrome are "apparently induced by exposure to mid-frequency sonar signals and particularly affect…deep, long-duration, repetition-diving species like [beaked whales]" (p. 446). The researchers emphasised the need to investigate the behavioural and physiological effects of sonar and how it causes these effects.

(SOURCE: Fernández, A., Edwards, J.F., Rodríguez, F., Espinosa del los Monteros, A., Herráez, P., Castro, P., Jaber, J.R., Martín, V. and Arbelo, M. 2005. "Gas and fat embolic syndrome" involving a mass stranding of beaked whales (family *Ziphiidae*) exposed to anthropogenic sonar signals. *Vet. Pathol.* 42: 446-457)

<u>Antibiotic treatment causes hearing loss in beluga whale</u>

Hearing tests on captive beluga whales demonstrated a 'severe' (90 dB) hearing loss in one beluga whale. Comparing differences between two individual animals, the only major difference in environmental exposures in the two animals was that one animal had been treated with antibiotics. It is possible that this drug treatment damaged sensitive cells in the whale's ears. This study demonstrates a risk of possible hearing damage when cetaceans are administered certain drugs. Also, it highlights a new problem in using captive animals in auditory studies; any animals treated with certain antibiotics may have hearing damage, and using these animals as proxies for the hearing abilities of wild cetaceans could produce erroneous results.

(SOURCE: Finneran, J.J., Carder, D.A., Dear, R., Belting, T., McBain, J., Dalton, L., Ridgway, S.H. 2005. Pure tone audiograms and possible aminoglycoside-induced hearing loss in belugas (*Delphinapterus leucas*). *J. Acoust. Soc. Am.* 117: 3936-3943)

<u>Report on North Carolina stranding event inconclusive</u>

On 15 and 16 January 2005, 33 short-finned pilot whales, two dwarf sperm whales and one northern minke whale stranded near Oregon Inlet and Cape Hatteras in North Carolina, USA. Coincident with this stranding event, naval activities were being conducted and concern was raised that this stranding event may have been caused by sonar exposure. A report on this stranding event published by the US National Marine Fisheries Service described necropsies on most of the stranded animals. The minke whale was emaciated and the cause of its stranding may have been unrelated to the others. The other stranded animals had a variety of conditions, including cranial infections and cardiovascular problems. Gas emboli, which have been associated with sonar-related strandings in beaked whales, were not found. Within the heads of animals there was some reddening of fats in the jaw, which might have been the result of haemorrhaging, but it might also have been an artefact of freezing samples. One animal had a subdural haemorrhage, *i.e.*, bleeding between the inner and outer membranes of brain, which is typically associated with severe brain injury following trauma. This was considered "likely [to have] occurred from thrashing on the beach post-stranding, although its occurrence prior to stranding cannot be excluded" (p. iii). Coincident with the stranding event, the US Navy was using mid-frequency sonar in the general region of the event and the report notes "the association between the naval sonar activity and the location and timing of the event could be a causal rather than a coincidental relationship" (p. iv). The report does not rule out the possibility that the strandings, and thus the subsequent mortality, were the result of cetaceans exhibiting a "behavorial avoidance of noise exposure" (p. iv). In conclusion, disease may have been a factor in the stranding of some of the whales, and due to a lack of definitive lesions, sonar could not be definitively attributed as a cause of the stranding; given the multiple species involved and the proximity of a naval exercise, sonar could not be ruled out as a contributor, possibly in addition to other factors, to the event.

(SOURCE: Hohn, A.A, Rotstein, D.S., Harms, C.A. and Southall, B.L. 2006. Report on marine mammal unusual mortality event UMESE0505Sp: Multi-species mass stranding of pilot whales (*Globicephala macrorhynchus*), minke whale (*Balaenoptera acutorostrata*), and dwarf sperm whales (*Kogia sima*) in North Carolina on 15-16 January 2005. NOAA Technical Memorandum NMFS-SEFSC-537. Southeast Fisheries Science Center, Beaufort, North Carolina. Available from: http://www.sefsc.noaa.gov/PDFdocs/Report_on_UMESE0501sp.pdf)

ICES ad hoc report on cetaceans considers sonar impacts a minor issue

An ad hoc special panel commissioned by the International Council on the Exploration of the Seas (ICES) reviewed the issue of acoustic impacts on marine mammals and fish. Some of the conclusions of the panel were that "[t]he use of high-intensity mid frequency sonar has led to the deaths of a number of cetaceans in some places" (p. 38), noting that beaked whales appear to be the most affected. The report identified 40 definitive sonar-related beaked whale deaths over a 9-year period, and compared this to 35 known beaked whale by-catches in US fisheries over a 6-year period. Several mid-frequency sonar stranding case studies were reviewed; for low frequency sonar, there was less information. The report stated that knowledge of sub-lethal and behavioural effects of sonar is "poor" and emphasised overall the major uncertainties and unknowns with respect to sonar and cetaceans and also the lack of research on the impacts of sonar on fish. The report noted that noise levels in the ocean are increasing and that impacts of noise on communication may affect the life history of cetaceans (including reproduction), stating that long-term impacts on populations "could be worse than direct killing" (p. 39). However, a main conclusion of the report was that it "appears that sonar is not a major current threat to marine mammal populations generally, nor will it ever be likely to form a major part of ocean noise. Sonar can place individual whales at risk, and has affected the local abundance of beaked whales" (p. 39). The report nevertheless pointed out that sonar deployment would probably increase in future and thus there was a need to continue to search for effective mitigation measures.

(SOURCE: International Council for the Exploration of the Sea. 2005. *Report of the ad-hoc group on impacts of sonar on cetaceans and fish (AGISC)* (2nd Edition). CM 2006/ACE. ICES, Copenhagen, Denmark)

Gas lesions reported in UK cetaceans

Pathological examinations found gas emboli, which have previously been associated with sonar-related strandings, in the livers of four Risso's dolphins, three short-beaked common dolphins, one harbour porpoise and one Blainville's beaked whale. From 5 to 90% of the liver volume contained these gas lesions. Other organs found with similar lesions included the kidneys, spleen, lymph nodes and thyroid gland. Lack of bacteria associated with the lesions did not support infection as a cause. Lesions were more prevalent in deep-diving species, but were also found in shallower-water species. The veterinarians and pathologists suspected "a decompression-related mechanism involving embolism of intestinal gas or de novo gas bubble (emboli) development derived from tissues supersaturated with nitrogen" (p. 291) to be the cause of the lesions. This increases the number of species associated with this type of lesion. The implications of this study are that sonar impacts are not limited to beaked whales or deep-diving species alone, and may be more widespread a problem than previously thought.

(SOURCE: Jepson, P.D., Deaville, R., Patterson, I.A.P., Pocknell, A.M., Ross, H.M., Baker, J.R., Howie, F.E., Reid, R.J., Colloff, A. and Cunningham, A.A. 2005. Acute and chronic gas bubble lesions in cetaceans stranded in the United Kingdom. *Vet. Pathol.* 42: 291-305)

Sound exposure duration increases temporary hearing loss in marine mammals

The sound pressure levels (SPL) at which temporary hearing loss (temporary threshold shift or TTS) is inflicted are frequently used as the standard levels at which marine mammals may be injured. A controlled exposure experiment on three individual seals, of three different species, found that the degree of TTS increased substantially when the duration of noise exposure was doubled. Indeed, the degree of effect was greater than increasing the sound pressure level by 15dB. This underlines the importance of considering both the sound pressure level and the duration of sound exposure when evaluating the effects of noise on marine mammals. It also stresses the use of sound exposure levels (SEL), which are a function of sound pressure level *and* duration, when assessing the effects of noise on marine mammal hearing.

(SOURCE: Kastak, D., Southall, B.L., Schusterman, R.J. and Reichmuth Kastak, C. 2005. Underwater temporary threshold shift in pinnipeds: effect of noise level and duration. *J. Acoust. Soc. Am.* 118: 3154-3163)

Differing reactions of different cetacean species to a noise source

Researchers compared the reactions of a striped dolphin and a harbour porpoise to an acoustic deterrent device (ADD) or 'pinger' (Dukane Netmark 1000; 9-15 kHz; 133-163 dB re 1 µPa). Although the porpoise showed a significant reaction, there was little change in the behaviour of the striped dolphin. This has several implications for cetacean conservation. The reaction of one cetacean species to a noise source is not necessarily representative of all species. Also, the efficacy or feasibility of pingers such as the type tested to reduce striped dolphin by-catch is thrown into doubt.

(SOURCE: Kastelein, R.A., Jennings, N., Verboom, W.C., de Haan, D. and Schooneman, N.M. 2006. Differences in the response of a striped dolphin (*Stenella coeruleoalba*) and a harbour porpoise (*Phocoena phocoena*) to an acoustic alarm. *Mar. Environ. Res.* 61: 363-378)

New measure for potential acoustic impacts on marine mammals: acoustic discomfort zone

As part of an evaluation of an acoustic system to help prevent ship collisions, an environmental impact assessment (EIA) was conducted, which also examined the effects on marine mammals. In determining safety zones, behavioural impacts (*e.g.*, avoidance and displacement) were used instead of physical impacts (*e.g.*, temporary threshold shift, which is commonly used as a mitigation standard). The concept of the 'acoustic discomfort threshold' was defined as "the boundary between areas that the animals generally occupy during the transmission of the sounds and the areas that they generally do not enter during transmission. The [sound pressure level in decibels] at this boundary is the discomfort threshold" (p. 21). This is an important measure because "[i]f animals are deterred from ecologically important areas to less favourable areas, this might affect the population size." The animals in the study (captive harbour seals) reacted to the test sound source by swimming away from the source into less-ensonified areas of the test tank, and a 107dB re 1 µPa discomfort threshold level was determined. The EIA for the system had assumed a 180dB (re 1 µPa) 'safe' level for marine mammals (*i.e*., 10dB lower than the level of assumed permanent hearing loss). Such a safe level would be over 10 million times louder than the 'discomfort' threshold determined in this study. The researchers noted that other sound sources would produce other discomfort thresholds and zones. This study provides a new method for assessing zones of impact on wild marine mammals that takes into account marine mammal behaviour and potential displacement from critical habitat, perhaps serving as a model for future noise impact assessments.

(SOURCE: Kastelein, R.A., van der Heul, S., Verboom, W.C., Triesscheijn, R.J.V. and Jennings, N.V. 2006. The influence of underwater data transmission sounds on the displacement behaviour of captive harbour seals (*Phoca vitulina*). *Mar. Environ. Res.* 61: 19-39)

A need to re-evaluate how to measure sound 'safety' levels

The difficulties of estimating harmful levels of noise to whales are complicated by the various differences in sound structure. An example is given of a brief, simple click by a sperm whale, which may produce a wave with amplitude similar to that of a sonar 'ping' and so would theoretically be considered nearly equal in terms of possible impacts on cetaceans. However, the click is at peak amplitude for only a brief moment, with most of the energy of the wave contained in this brief moment. Maximum amplitude is maintained longer by a sonar ping, with energy levels being consistently high. Therefore, the total amount of energy that an animal might be exposed to is greater for the sonar ping than for the whale click. Accordingly, 'energy flux density' should be used as a measurement when assessing the potential impact of sound sources: it takes into account the amount of energy delivered per unit area. The study concludes that current standards for safe sound source levels "are unsuited as a stand-alone mitigative measure for transient noise effects on marine mammals" (p. 3956).

(SOURCE: Madsen, P.T. 2005. Marine mammals and noise: problems with root mean square sound pressure levels. *J. Acoust. Soc. Am.* 117: 3952-3957)

The potential acoustic impacts of windfarms

The growing number of windfarms in coastal areas may have an impact on cetaceans, in particular because of the noise they make. The researchers considered four different zones around windfarms: the first was the area in which the noise was *detected*; the second the area in which the noise resulted in a behavioural or physiological *reaction* (*i.e*., disturbance or harassment); the third the area in which sounds cause *masking* and may prevent biologically important acoustic information from being transmitted; and finally a zone of *injury* (defined as being where animals begin to suffer temporary threshold shifts or TTS). Noise-producing activities associated with windfarms include initial pile driving during construction and actual operation. The researchers note that "the calculated ranges clearly indicate that pile-driving sounds are audible to all the marine mammals treated here at very long ranges of more than 100km, and possibly up to more than a thousand kilometers" (p. 289) and "pile driving operations have the potential to cause disruption of normal behavior in marine mammals over a very large area at ranges of many kilometers" (p. 289). Acoustic injury to cetaceans may occur within a radius of 2km of pile-driving activity. For operating wind turbines, which produce lower frequency sound, and sound levels lower than that of pile driving, there is a lack of studies on effects. Nonetheless, it was concluded that "there is no reason to believe that [bottlenose dolphins and harbour porpoises] can hear even the noisiest of the wind turbines in current use at a range of more than a few hundred meters" (p. 290). Baleen whales, however, which are low frequency specialists, "[they] may respond to noise from operating turbines at ranges up to a few kilometers in a quiet habitat" (p. 289), leading to greater effects. Although short-term displacement of cetaceans as the result of windfarm-associated noise may not be biologically significant, in some areas prolonged construction in multiple areas may have cumulative and long-term impacts.

(SOURCE: Madsen, P.T., Wahlberg, M., Tougaard, J., Lucke, K. and Tyack, P. 2006. Wind turbine underwater noise and marine mammals: implications of current knowledge and data needs. *Mar. Ecol. Prog. Series* 309: 279-295)

<u>Indo-Pacific bottlenose dolphins alter communications dependent on ambient noise levels</u>

The acoustic communications of three populations of Japanese Indo-Pacific bottlenose dolphins were studied in relation to levels of ambient noise in their respective environments. Animals inhabiting waters with less ambient noise produced a greater range of frequencies and with more modulation of frequencies. In comparison, animals inhabiting environments with higher levels of ambient noise showed decreased frequency modulation and tended to produce lower frequency whistles. It was suggested "that communication signals are adaptive and are selected to avoid the masking of signals and attenuation of higher frequency signals" (p. 541). This adaptation of acoustic communication may have an important role in avoiding one of the problems that marine noise poses for cetaceans: masking biologically important signals.

(SOURCE: Morisaka, T., Shinohara, M., Nakahara, F. and Akamatsu, T. 2005. Effects of ambient noise on the whistles of Indo-Pacific bottlenose dolphin populations. *J. Mammal.* 86: 541-546)

<u>Infant dolphin more sensitive to sound than adult</u>

Experiments investigating hearing sensitivities of captive cetaceans have been widely used to model and predict the possible effects of anthropogenic sounds on free-ranging cetaceans. Therefore, studies investigating the efficacy of this method are important for research on, and management of, noise- related impacts. A study investigating the hearing sensitivities of a stranded infant Risso's dolphin discovered that the young animal's hearing was more sensitive than a previously tested adult individual, *e.g*., detecting 100 kHz signals at a level nearly 60dB lower than the adult. The young dolphin also detected higher frequencies than the adult, suggesting age-related hearing loss and "probably underestimat[ing] the best hearing sensitivity for this species" (p. 4187). This emphasises that acoustic sensitivity data based on older and/or captive animals may be underestimating the potential impacts of anthropogenic sound.

(SOURCE: Nachtigall, P.E., Yuen, M.M.L., Mooney. T.A. and Taylor, K.A. 2005. Hearing measurements from a stranded infant Risso's dolphin, *Grampus griseus*. *J. Experiment. Biol.* 208: 4181-4188)

<u>Military sonar possible contributing factor to Hanalei Bay 'milling event'</u>

At approximately 0700hrs on 3 July 2004, about 150 melon-headed whales were observed in the shallow waters of Hanalei Bay, Kauai, Hawaii. These normally deep-water animals were in the bay for over 28 hours in what has been termed a 'milling event', *i.e*., multiple animals crowded into shallow water near shore, but not actually stranded on land. On 4 July at 0930hrs, the animals were herded out of the bay into deeper water by volunteers. Only one animal was known to have died (a calf), which was necropsied with no evidence of trauma or disease-related lesions observed. The possible cause of death may have been separation from the mother, *i.e*., dehydration and starvation. An analysis of environmental conditions, including bathymetry, oceanographic fronts and weather conditions, could find no link between these factors and the event. Moreover, there were no harmful algal blooms in the vicinity. However, the event was coincident with use of mid-frequency sonar by six naval vessels prior to the start of the biennial Rim of the Pacific (RIMPAC) naval exercise (US and Japan). The National Marine Fisheries report notes that "[p]ropagation modelling suggests that transmissions from sonar use during the July 3 exercise…may have been detectable at the mouth of the Bay" (p. 2). The report does not claim that the sonar activities were definitively the cause of the event, but the compilers state that they "consider the active sonar transmissions of July 2-3, 2004, a plausible, if not likely, contributing factor" (p. 2) to the event, although other factors may have also contributed.

(SOURCE: Southall, B.L., Braun, R., Gulland, F.M.D., Heard, A.D., Baird, R.W., Wilkin, S.M. and Rowles, T.K. 2006. Hawaiian melon-headed whale (*Peponocephala electra*) mass stranding event of July 3-4, 2004. NOAA Technical Memorandum NMFS-OPR-31, Office of Protected Resources, NOAA, Silver Spring, Maryland, http://www.nmfs.gov/pr/health/mmume/event2004jul.htm)

RELATED INFORMATION

Volcanoes cause temporary global cooling

Recent research shows that volcanic eruptions can cause major, but temporary cooling (due to aerosols ejected into the atmosphere cutting down heat levels hitting the earth surface), and can affect other climatic patterns such as rainfall and patterns of sea level rise. The major eruption of Mount Pinatubo in the Philippines in 1991 was largely responsible for a brief period of cooling in the early 1990s, decreases in ocean temperature and a 6mm drop in sea level within a year (due to thermal contraction). Volcanic events such as the Mount Pinatubo eruption have periodically masked global warming; when the effects of volcanic activity are taken into account, observed climatic trends are in closer agreement to those trends predicted by the effects of anthropogenic greenhouse gas production and global warming. This result highlights the global, short-term impacts that volcanic activity can have on climate, including ocean temperatures.

(SOURCE: Church, J.A., White, N.J. and Arblaster, J.M. 2005. Significant decadal-impact scale of volcanic eruptions on sea level and ocean heat content. *Nature* 438: 74-77)

2005 one of the warmest years on record

According to meteorologists, 2005 was the warmest, or the second warmest (after 1998) year on record. Nine of the ten warmest years recorded have occurred since 1995.

(SOURCE: Henson, R. 2005. The heat was on in 2005. *Nature* 438: 1062 [News])

Extinction risks are greater in large mammals

An analysis of extinction rates of animals noted that the impacts of environmental and intrinsic factors that could cause extinction to increase substantially in large mammals, a category to which most cetaceans clearly belong. Intrinsic factors that increase risk of extinction include low reproductive rates, gestation length, weaning age, low population densities and large geographic range sizes. They note that "the disadvantages of large size are greater than generally recognized, and future loss of large mammal biodiversity could be far more rapid than expected" (p. 1239). The researchers suggested that although small mammals may benefit from protected areas, large mammals would fare better from a more single species-oriented, large-scale conservation approach.

(SOURCE: Cardillo, M., Mace, G.M., Jones, K.E., Bielby, J., Bininda-Emonds, O.R.P., Sechrest, W., Orme, C.D.L. and Purvis, A. 2005. Multiple causes of high extinction risk in large mammal species. *Science* 309: 1239-1241)

High dosage of algal toxins in North Atlantic right whales

North Atlantic right whales are among the most highly endangered cetaceans in the world. SOCER attempts to report all new information related to this population. Levels of saxitoxin, the algal toxin that causes paralytic shellfish poisoning, were analysed in the North Atlantic right whale by examining faeces from actively feeding whales. The researchers estimated that the right whales were consuming dosages that would be considered lethal to humans (adjusted for weight). However, the sampled animals did not seem to be suffering from acute toxicity, although there may have been sub-lethal, chronic effects on the animals (*e.g.*, effects that might lead to reduced reproductive rates). Saxitoxin was also found in copepods, the primary prey of these feeding whales.

Maximum levels

Saxitoxin in faeces (µg equivalents g^{-1}, wet weight): 0.5

(SOURCE: Doucette, G.J., Cembella, A.D., Martin, J.L., Michaud, J., Cole, T.V.N. and Rolland, R.M. 2006. Paralytic shellfish poisoning (PSP) toxins in North Atlantic right whales *Eubalaena glacialis* and their zooplankton prey in the Bay of Fundy, Canada. *Mar. Ecol. Prog. Ser.* 306: 303-313)

<u>Lower atmosphere is warming – more evidence for global warming</u>

A major criticism of global warming has been that although the surface of the earth was warming, the lowest layer of the atmosphere (the troposphere) did not appear to be warming. However, several studies published over the past year have shown via reanalysis of satellite data that the troposphere is, in fact, warming at 0.12^{o}C-0.19^{o}C per decade.

(SOURCES: Mears, C.A. and Wenz, F.J. 2005. The effect of diurnal correction on satellite-derived lower tropospheric temperature. *Science* 309: 1548-1551 AND Santer, B.D., Wigley, T.M.L., Mears, C. , Wentz, F. J., Klein, S.A., Seidel, D.J., Taylor, K.E., Thorne, P.W., Wehner, M.F., Gleckler, P.J., Boyle, J.S., Collins, W.D., Dixon, K.W., Doutriaux, C., Free, M., Fu, Q., Hansen, J.E., Jones, G.S., Ruedy, R., Karl, T.R., Lanzante, J.R., Meehl, G.A., Ramaswamy, V., Russell, G. and Schmidt G.A. 2005. Amplification of surface temperature trends and variability in the tropical atmosphere. *Science* 309: 1551-1556).

<u>The end of the 20th century the warmest period in over a millennium</u>

An analysis of historical climate data from the northern hemisphere produced a timeline of climate over a period of 1200 years. The study showed a warming period between 890 AD and the 'Little Ice Age', which caused a cooling between 1580 and 1850. However, the warming observed in the latter part of the 20th century is the most significant period of warming throughout this historical timeline.

(SOURCE: Osborn, T.J. and Briffa, K.R. 2006. The spatial extent of 20th Century warmth in the context of the past 1200 years. *Science* 311: 841-844)

<u>Changes in thermohaline circulation – is it slowing down?</u>

Thermohaline circulation in the North Atlantic, *i.e*., warm waters of the Gulf Stream losing heat in the North Atlantic and the cooled waters sinking, is an important controller of both climate and oceanic circulation. This, for example, causes the climate of the eastern North Atlantic to be warmer than expected for the latitude. However, recent research is showing that the rate of thermohaline circulation in the North Atlantic is slowing. This slowing is believed to be due to increased outflows of low-density fresh water in the North Atlantic, resulting from global warming-induced ice melt. Research has shown that 50% more warm Gulf Stream surface water is being diverted back south than heading northwards, and overall thermohaline circulation in the region has slowed by 30%. The concern is "when a certain threshold is reached, the circulation may jump abruptly to a new state in which there is little to no heat flux to the north" (p. 566, Quadfasel, 2005). This would dramatically affect the climate in the North Atlantic, if not globally. Other studies suggest that increased salinity in northwards-moving water (due to increased evaporation) may counteract some of the effects of freshwater inflow, while yet others suggest that increasing temperatures indicate that northwards movement of warm water may have increased slightly since the 1970s, further complicating the situation. Nevertheless, any major climatic and oceanographic changes due to altered thermohaline circulation patterns are cause for considerable concern. For example, a shutdown of thermohaline circulation in the North Atlantic was predicted to halve the plankton biomass in the region and to cause a global decline of 20%, due to reduced surface nutrient concentrations. This would considerably impact marine ecosystems.

(SOURCES: Quadfasel, D. 2005. The Atlantic conveyor slows. *Nature* 438: 565-566 [News]; Kerr, R.A. 2005. Atlantic Climate Pacemaker for Millennia Past, Decades Hence? *Science* 309: 41-43 [Focus]; Kerr, R.A. 2005. Confronting the bogeyman of the climate system. *Science* 310: 432-433 [Focus]; Kerr, R.A. 2005. The Atlantic conveyor may have slowed, but don't panic yet. *Science* 310: 1403-1405 [Focus]; Schiermeier, Q. 2006. Sea change. *Nature* 439: 256-260 [News]; Bryden, H.L., Longworth, H.R. and Cunningham, S.A. 2005. Slowing of the Atlantic meridional overturning circulation at 25^{o}N. *Nature* 438: 655-657; Curry, R. and Mauritzen, C. 2005. Dilution of the Northern North Atlantic Ocean in recent decades. *Science* 308: 1772-1774; Hátún, H., Sandø, A.B., Drange, H., Hansen, B. Valdimarsson, H. 2005. Influence of the Atlantic subpolar gyre on the thermohaline circulation. *Science* 309: 1841-1844; AND Schmittner, A. 2005. Decline of the marine ecosystem caused by a reduction in the Atlantic overturning circulation. *Nature* 434: 628-633)

Population growth does not behave as expected – major management implications

A new analysis of population growth rates of nearly 2000 populations of species from various taxa may explain the lack of predicted recovery in some cetacean species and their prey after exploitation. This analysis examined insects, fish, birds and mammals and found that rates of population growth (per capita growth rate) are high at low population densities but, contrary to current thinking, growth rates decline rapidly as population size increases and then flatten out, which "produces a strongly concave relationship between a population's growth rate and its size" (p. 607). This research affects "our practical ability to make predictions about how…species respond to environmental change" (p. 609). Moreover, the researchers warn that if ecological parameters such as carrying capacity (K) and reproductive rate are based on the natural history data collected for animals in optimal environments, then the per capita growth rate will be over-estimated when the population is below K and thus "[t]his would have dangerous consequences in wildlife and fisheries management, because populations would recover from disturbances more slowly than predicted" (p. 609).

(SOURCE: Sibly, R.M., Barker, D., Denham. M.C., Hone, J. and Pagel, M. 2005. On the regulation of populations of mammals, birds, fish, and insects. *Science* 309: 607-610)

The ozone layer is recovering

Due to a worldwide decrease in the use and production of ozone-depleting chemicals (particularly chlorofluorocarbons or CFCs) there are signs of recovery in the ozone layer. The improvement may be traced to the Montreal Protocol of 1987, which banned many ozone-depleting substances. However, although showing signs of recovery, the ozone layer still is not, and may not ever be, comparable to its extent prior to the 1980s.

(SOURCE: Weatherhead, E.C. and Andersen, S.B. 2006. The search for signs of recovery of the ozone layer. *Nature* 441: 39-45)

ACKNOWLEDGEMENTS

The editors would like to offer heartfelt thanks to David Janiger for providing his database of recently published marine mammal papers and for supplying .pdf copies of papers that were difficult for us to obtain. Thanks also to Denise Cole and Chris Herbst for highlighting papers. The authors would especially like to thank the Government of Austria and Humane Society International for continuing to provide support for SOCER preparation, as requested by Resolution 2000-7.

Appendix 1

GLOSSARY

Species glossary

Baird's beaked whale	*Berardius bairdii*
Beluga whale	*Delphinapterus leucas*
Blainville's beaked whale	*Mesoplodon densirostris*
Bowhead whale	*Balaena mysticetus*
Bryde's whale	*Balaenoptera edeni*
Commerson's dolphin	*Cephalorhynchus commersonii*

Common bottlenose dolphin	*Tursiops truncatus*
Common dolphin	*Delphinus delphis*
Cuvier's beaked whale	*Ziphius cavirostris*
Dwarf sperm whale	*Kogia sima*
False killer whale	*Pseudorca crassidens*
Finless porpoise	*Neophocaena phocaenoides*
Gervais' beaked whale	*Mesoplodon europaeus*
Harbour porpoise	*Phocoena phocoena*
Indo-Pacific bottlenose dolphin	*Tursiops aduncus*
Indo-Pacific humpback dolphin	*Sousa chinensis*
Irrawaddy dolphin	*Orcaella brevirostris*
Killer whale	*Orcinus orca*
Long-finned pilot whale	*Globicephala melas*
Melon-headed whale	*Peponocephala electra*
Minke whale	*Balaenoptera acutorostrata*
Narwhal	*Monodon monoceros*
North Atlantic right whale	*Eubalaena glacialis*
Northern minke whale	*Balaenoptera acutorostrata*
Pacific white-sided dolphin	*Lagenorhynchus obliquidens*
Pantropical spotted dolphin	*Stenella attenuata*
Pygmy sperm whale	*Kogia breviceps*
Rough-toothed dolphin	*Steno bredanensis*
Sei whale	*Balaenoptera borealis*
Short-finned pilot whale	*Globicephala macrorhynchus*
Sperm whale	*Physeter macrocephalus*
Spinner dolphin	*Stenella longirostris*
Striped dolphin	*Stenella coeruleoalba*
Manatee	*Trichechus manatus latirostris*
Harbour seal	*Phoca vitulina*
Rat	*Rattus norvegicus*
Atlantic cod	*Gadus morhua*
Herring	*Clupea harengus*
Menhaden	*Brevoortia* spp
Orange-spotted grouper	*Epinephelus coioides*
Green mussel	*Perna viridis*
Cockles	*Anadara granosa*
Copepods	*Calanus glacialis* and *C. hyperboreus*
Oyster	*Saccostrea cuculata*
Sea urchin	*Loxechinus albus* and *Strongylocentrous* spp
Red tide algae	*Karenia brevis*

Element glossary

Ag	silver	Ga	gallium
Al	aluminium	Hg	mercury
As	arsenic	Mg	magnesium
Ba	barium	Mn	manganese
Bi	bismuth	Mo	molybdenum
Cd	cadmium	Ni	nickel
Co	cobalt	Pb	lead
Cr	chromium	Rb	rubidium
Cs	caesium	Sb	antimony
Cu	copper	Se	selenium
Fe	iron	Sn	tin

Sr	strontium	V	vanadium
Tl	thallium	Zn	zinc

<u>Glossary of terms</u>

Acoustic deterrent devices: also known as ADDs or 'pingers'. These devices are intended to produce moderate intensity sounds that either alert cetaceans to, or scare cetaceans away from, fishing nets to which the ADDs are attached. This is a by-catch mitigation technique that has become legally required for several fisheries due to high levels of cetacean by-catch.

AIO SIDS: Atlantic and Indian Ocean Small Island Developing States.

AHTN: 7-acetyl-1,1,3,4,4,6-hexamethyltetrahydeonapthalene, a synthetic musk used in fragrances.

Anti-fouling paint: Paint used to prevent accumulation of marine organisms, such as barnacles, on ship hulls. Repulsing chemicals such as butyltin are used to prevent organisms from settling.

Aquaculture: Finfish or shellfish farming

APEOs: Alkylphenol polyethoxylates, surfactants in commercial detergents.

Benthic: Referring to the ocean bottom.

Bioaccumulation: Increase in concentration of a contaminant in an organism's tissues (*e.g.,* blubber) over time, compared to the concentration of the contaminant in the environment.

Biomagnification: Increase in concentration of a contaminant from one link in a food chain to another.

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

Biota: All living things in an ecosystem.

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

Brominated: Containing the element bromine.

Butyltins: See TBT.

Carcinogenic: capable of causing cancer.

CFC: Chlorofluorocarbons.

CHL: Chlordane-related compound.

Chlordane: An organochlorine pesticide.

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

Copepods: Tiny crustaceans, the base of many marine food webs.

Coplanar: A flat configuration (said of a molecule) with rings in the same plane.

Cyanobacteria: Once known as blue-green algae, these organisms are not algae but bacteria, capable of photosynthesis.

Cytochrome: Proteins found in cells that carry out electron transport or catalyse cellular reactions.

dB: Decibel – a logarithmic measure of sound pressure level

DDD: The organochlorine dichlorodiphenyldichloroethane, a pesticide.

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

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

Dieldrin: A commercial pesticide.

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

Dioxin: A class of extremely toxic organochlorines, generally produced as a waste or by-product.

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.

Fibrosis: Formation of scar-like (fibrous) tissue. This can occur anywhere in the body.

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.

HCB: Hexachlorobenzene, an environmentally persistent organochlorine pesticide.

HCH: Hexochlorocyclohexane, an environmentally persistent organochlorine pesticide.

HDBPs: Halogenated dimethyl bipyrroles, environmentally persistent but naturally occurring organohalogens.

HHCB: 1,3,4,6,7,8-hexahydro-4,6,6,7,8,8-hexamethylcyclopenta[g]-2-benzopyran, a synthetic musk used in fragrances.

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

Immunostimulants: General immune system stimulants not particular to a specific disease or antigen. Resistance is increased by mobilizing ‘effector cells’, which act against all foreign particles, not just specific ones.

Immunosuppression: The suppression of the immune system or response, resulting in a greater susceptibility to disease.

K: Carrying capacity – the maximum number of organisms a habitat can support without detrimental effects.

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

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.

Mutagenic: Capable of causing genetic mutations.

ng: Nanogram.

nm: Nautical mile.

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.

Ozone: O_3, a molecule naturally occurring in the upper atmosphere that filters ultraviolet radiation.

PAHs: Polycyclic aromatic hydrocarbons.

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

PBDE: Polybrominated diphenyl ether, a brominated flame retardant.

PCB: 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.

PFCs/PFOs: Perfluorinated compounds or perfluorinated organochemicals, a class of environmentally persistent molecules with fluorine atoms attached, used in many industrial applications including fire-fighting foams, pesticides and surface coatings. See PFOA, PFOS, PFHS, and PFNA.

PFOA: Perfluorooctanoate.

PFOS: Perfluorooctane sulfonate.

PFHS: Perfluorohexane sulfonate.

PFNA: Perfluorononoate.

pg: Picogram.

Phagocytosis: a cell's ability to digest (remove) extracellular molecules.

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

POP: Persistent organic pollutant.

PSP: Paralytic shellfish poisoning. A potentially fatal illness in mammals, including humans, caused by the consumption of shellfish that have concentrated the poisonous substances produced by the phytoplankton they filter from the water.

PTS: Permanent threshold shift, or permanent hearing loss. A hearing threshold is the lowest possible sound pressure level at which a sound of a particular frequency can be detected by a receiver. PTS is not recoverable and occurs when there is permanent damage to the ear structures after exposure to a sound. See TTS.

Saxitoxin: Neurotoxin found in marine dinoflagellates – the cause of paralytic shellfish poisoning.

Sentinel 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 indicator species.

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

TBT: Tributyltin – a toxic chemical commonly used in anti-fouling paints on ship hulls (also DBT – dibutyltin, a break-down product of tributyltin – collectively butyltins).

TEQ: Toxic Equivalent. The overall toxicity or environmental threat posed by a set of closely related pollutants.

Thermohaline Circulation: The deepwater circulation of the oceans, which is primarily caused by differences in density (which are in turn dependent on salinity and temperature) between water bodies of different regions. This circulation system is important in distributing heat energy around the world.

Toxaphene: An insecticide containing over 670 chemicals.

Trophic level: Each level of consumption in a food chain.

Troposphere: Lowest layer of the atmosphere.

TTS: Temporary threshold shift, or temporary hearing loss. TTS is recoverable (hearing returns to normal after some period of time passes). See PTS.

Wet weight: See dry weight.