STATE OF THE CETACEAN ENVIRONMENT REPORT (SOCER) 2009

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INTRODUCTION

Several resolutions of the International Whaling Commission, including Resolutions 1997-7 and 1998-5, directed the Scientific Committee (SC) to provide regular updates on environmental matters that affect cetaceans. After submission of a prototype State of the Cetacean Environment Report (SOCER), Resolution 2000-7 welcomed the concept of the SOCER at the 52nd Annual Meeting in Adelaide, Australia, and "request[ed] the annual submission of this report to the Commission". The first full SOCER (SC/55/E7) was submitted in 2003 and focused on the Mediterranean and Black Seas and the Atlantic Ocean. Subsequent SOCERs have focused on the Pacific Ocean, the polar seas, and the Indian Ocean. This cycle has been continued, with each SOCER also including a Global section addressing information that applies generally to the cetacean environment. **SC/61/E1** (SOCER 2009) focuses once again on the Pacific Ocean, summarising key papers and articles that have been published from 2007 through 2009 to date.

PACIFIC OCEAN

Habitat protection/degradation

General

The impact of coastal development on small cetaceans

Coastal development, especially in densely populated areas, is a form of habitat degradation for small cetaceans. Hong Kong can serve as a case study because of the massive development there and because the city has addressed cetaceans (primarily the Indo-Pacific humpback dolphin) in environmental impact assessments more than anywhere else in the world. The mitigation measures used for large construction projects include bubble curtains, exclusion zones, ramping up of piling hammers, acoustic decoupling of noisy equipment, vessel speed limits, no dumping policies and curtains to hold back silt. One of the most important measures was to conduct surveys to monitor the density and behaviour of the animals in three phases: before, during and after the period of potential disturbance.

(SOURCE: Jefferson, T.A., Hung, S.K. and Würsig, B. 2009. Protecting small cetaceans from coastal development: Impact assessment and mitigation experience in Hong Kong. *Mar. Pol.* 33: 305-311)

New information about recently discovered small population of Indo-Pacific humpback dolphins

A recent survey of a newly discovered (2002) population of Indo-Pacific humpback dolphins in coastal waters of the eastern Taiwan Strait revealed an estimated 99 individuals. Their main distribution area is subject to extensive industrialization and habitat degradation and measures approximately 500 km². The assessment led to a categorization as 'Critically Endangered' according to IUCN Red List criteria. The continued existence of this population is unlikely without "*effective and precautionary* in situ *conservation effort*", a conclusion applicable to several very small populations of cetaceans.

(SOURCE: Wang, J.Y., Yang, S.C., Hung, S.K. and Jefferson, T.A. 2007. Distribution, abundance and conservation status of the eastern Taiwan Strait population on Indo-Pacific humpback dolphins, *Sousa chinensis*. *Mammalia*: 157-165)

Fisheries Interactions

Anthropogenic scarring in western gray whales

Contact with fishing gear and collisions with vessels are potentially serious factors influencing the survival chances of the critically endangered western gray whale. A multi-year (1995-2005) survey off Sakhalin Island, Russia, used photo-identification data to examine this threat based on visible scarring. Twenty percent of the 150 individuals had detectable scarring, of which 19% reflected at least one previous entanglement, and 2% indicated survival of at least one vessel collision. These are considered to be minimum estimates and point to trap nets as being the anthropogenic interaction leading to the most fatalities in this population.

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(SOURCE: Bradford, A.L., Weller, D.W., Ivashchenko, Y.V., Burdin, A.M. and Brownell Jr., R.L. 2009. Anthropogenic scarring of western gray whale (*Eschrichtius robustus*). *Mar. Mamm. Sci.* 25: 161-175)

Dolphin bycatch in New Zealand

A 2001-2005 study that examined short-beaked common dolphin bycatch during trawling for jack mackerel identified geographical area as the greatest influence on bycatch risk. Fishing depth, total winch time and light conditions were also major risk factors. Identifying risk factors is an important first step in reducing bycatch, and the authors noted the need for early exploratory data analysis and the creation of a well-designed database. Moreover, bycatch cannot be considered in isolation but rather as one of a number of non-natural sources of mortality.

(SOURCE: Du Fresne, S.P., Grant, A.R., Norden, W.S. and Pierre, J.P. 2007. Factors affecting cetacean bycatch in a New Zealand trawl fishery. *DOC Research & Development Series* 282: Department of Conservation, Wellington. 18 pp.)

Bycatch of common dolphins in Southern Australia

Bycatch of short-beaked common dolphins by the large purse-seine fishery in South Australia has led to serious concerns over the long-term viability of local dolphin populations. Fishermen reported only a small percentage of the actual encirclements and mortalities. After establishment of a Code of Practise (CoP) that included a number of avoidance and release strategies, the rates of encirclement and mortality dropped by 87% and 97%, respectively. The average response time of fishermen to encirclement also decreased by 77%, and the proportion of encircled animals that subsequently died fell from 21% to 5%. Improvements to the CoP could make this fishery a 'best practise' example. This overall management issue has become complicated by the discovery of a marked genetic differentiation between dolphins from South Australia and Tasmania, suggesting a minimum of two genetic populations here. This situation has implications for conservation management strategies here and elsewhere: wide-ranging species with seemingly uniform distributions can actually show unexpected degrees of genetic differentiation, calling for better identifying population boundaries.

(SOURCE: Hamer, D.J., Ward, T.M. and McGarvey, R. 2008. Measurement, management and mitigation of operational interactions between the South Australian sardine fishery and short-beaked common dolphins (*Delphinus delphis*). *Biologic. Conserv.* 141: 2865-2878; Bilgmann, K., Möller, L.M., Harcourt, R.G., Gales, R. and Beheregaray, L.B. 2008. Common dolphins subject to fisheries impacts in Southern Australia are genetically differentiated: implications for conservation. *Anim. Conserv.* 11: 518-528)

Entanglements of marine mammals and seabirds along the US Pacific coast

The entanglement databases of seven organizations operating along the US west coast documented 454 entanglements involving 31 bird and nine marine mammal species between 2001 and 2005. One sperm whale was killed in monofilament netting and one humpback whale in crab pot and line, with a second humpback being successfully disentangled from crab pots and fishing line. The entanglement materials were mostly fishing related; the recovered specimens represent an unknown proportion of entangled animals that die at sea. The entanglement frequency during these years points to a persistent problem.

(SOURCE: Moore, E., Lyday, S., Roletto, J., Litle, K., Parrish, J.K., Nevins, H., Harvey, J., Mortenson, J., Greig, D., Piazza, M., Hermance, A., Lee, D., Adams, D., Allen, S. and Kell, S. 2009. Entanglements of marine mammals and seabirds in central California and the north-west coast of the United States 2001-2005. *Mar. Poll. Bull.*, in press, available online 2 April 2009)

The vaquita – last ditch effort to help world's most endangered marine mammal

The population of the vaquita or Gulf of California harbour porpoise, known to science only since 1958, has fallen from a historical population estimated in the low thousands to 567 in 1991 to probably 150 today. Every year about 20-30 vaquitas get caught in gillnets and drown. The Government of Mexico has initiated a new plan that will buy fishing boats, create new jobs for fishers, replace gillnets with other gear, and provide compensation to stay out of core vaquita habitat. This is a step in the direction scientists have called for: "*immediate action, not more data*".

(SOURCE: Morell, V. 2008. Can the vaquita be saved? *Science* 321: 676)

Entanglement of humpback whales in Alaska

Entanglement of humpback whales in fishing gear is a potentially significant source of serious injury and mortality. A two-year study in Alaska that examined the caudal peduncles of whales for scars revealed that most animals (71%) had been non-lethally entangled at some time in their lives. The annual rate of scar acquisition was considered to be a more powerful measure of contemporary entanglement rates. This value was 8% between 2003 and 2004.

(SOURCE: Neilson, J.L., Straley, J.M., Gabriele, C.M. and Hills, S. 2009. Non-lethal entanglement of humpback whales (*Megaptera novaeangliae*) in fishing gear in northern Southeast Alaska. *J. Biogeog.* 36: 452-464)

Strategy to promote recovery of endangered Hector's dolphin in New Zealand

The populations of New Zealand's endemic Hector's dolphin (ca. 8000 individuals) have declined to 27% of the 1970 size and are predicted to continue declining. Two management strategies have been proposed to promote recovery: 1) expanding the current two protected areas into four strategically-sited areas and 2) reducing fishery mortality to levels approaching zero. The call for urgent action is supported by the considerations that, at rates of current decline, future management efforts will become increasingly expensive, logistically difficult and likely to fail.

(SOURCE: Slooten, E. 2007. Conservation management in the face of uncertainty: Effectiveness of four options for managing Hector's dolphin bycatch. *Endang. Spec. Res.* 3: 169-179)

Sperm whales attracted to longline fishing

Sperm whales are the largest marine mammals that take advantage of human fishing activities (by removing fish from lines), and such depredation may be increasing. The whales are apparently attracted to the fishery operations by acoustic cues, and this study indicated that the whales interrupt their normal activities and approach boats due to the sound (i.e., cavitation) created by changing propeller speeds in certain phases of fishing (rather than hydraulic or fishing gear noise). Such research is an important step in identifying the sounds that promote these undesirable encounters. Management strategies such as reducing the detection range of these cues and producing 'false cues' might reduce the attraction.

(SOURCE: Thode, A., Straley, J., Tiemann, C.O. and O'Connell, V. 2007. Observations of potential acoustic cues that attract sperm whales to longline fishing in the Gulf of Alaska. *J. Acoust. Soc. Am.* 122: 1265-1277)

Dolphin populations fail to recover after fishery threat reduced

In the eastern tropical Pacific, the abundances of eastern spinner and northeastern pantropical spotted dolphins were reduced to an estimated one-third and one-fifth of pre-fishery levels, respectively, by the late 1990s. They were determined to be 'depleted' in 2002. Two studies examined why the populations have failed to recover at the rate expected after the halting of massive direct mortalities during yellowfin tuna fishing ('fishing on dolphins'). Surveys carried out here by the US National Oceanic and Atmospheric Administration between 1987 and 2003 showed that the fishery continues to have population-level effects (impact on calf survival and/or birth rates, at least in the spotted dolphins) beyond the direct effects of bycatch. These results underline that ceasing highly damaging fishing practices, or replacing them with less harmful approaches ('fishing on logs', chasing and encircling but later releasing dolphins), does not necessarily guarantee rapid recovery of affected dolphin species.

(SOURCE: Wade, P.R., Watters, G.M., Gerrodette, T. and Reilly, S.B. 2007. Depletion of spotted and spinner dolphins in the eastern tropical Pacific: Modelling hypotheses for their lack of recovery. *Mar. Ecol. Prog. Ser.* 343: 1-14; Cramer, K.L., Perryman, W.L. and Gerrodette, T. 2008. Declines in reproductive output in two dolphin populations depleted by the yellowfin tuna purse-seine fishery. *Mar. Ecol. Prog. Ser.* 369: 273-285)

Limits to bycatch mortality of small cetaceans in Canada's Pacific region

In British Columbia, small cetaceans are bycaught in salmon gillnet fisheries. To determine whether these mortalities exceed sustainable levels, calculations were done for three species (Pacific white-sided dolphins, Dall's porpoises and harbour porpoises). Based on minimum abundance estimates and maximum rates of population increase, and factoring in uncertainty, the results showed that estimated bycatch in 2004 and 2005 exceeded only the most precautionary limits and only for the two porpoise species. Future priority should focus on better determining species-specific entanglement rates. Canada's management objective is to maintain favourable conservation status of cetacean populations, and harbour porpoises in these waters are a species of 'Special Concern' because they are considered to be highly sensitive to human activities.

(SOURCE: Williams, R., Hall, A. and Winship, A. 2008. Potential limits to anthropogenic mortality of small cetaceans in coastal waters of British Columbia. *Can. J. Fish. Aquat. Sci.* 65: 1867-1878)

Marine Debris

Marine debris collection in Korea

Nearly half of the 115,000 tons of marine debris generated each year in Korea (Ministry of Maritime Affairs and Fisheries) is sea-based, i.e., Styrofoam from aquaculture and ropes from fishing vessels and aquaculture. Using a fund generated from provinces contributing to the land-based marine debris inflow into coastal waters, the city of Incheon established an incentive program that pays fishermen to collect marine debris and bring it back to port. The city has thus purchased a total of 18,000 tons of debris during the period 2002-2007 (at US$5.00 per 40 litre bag). Beyond tackling the prevention of debris, such innovative programs are a positive step forward: they save the government money, involve local residents, and reduce a pervasive form of marine pollution that is known to affect cetaceans.

(SOURCE: Cho, D-O. 2009. The incentive program for fishermen to collect marine debris in Korea. *Mar. Poll. Bull.* 58: 415-417)

Floating marine debris in southern Chile

Floating marine debris (FMD) impacts marine wildlife by entanglement, ingestion and transport of encrusting fauna. Relatively high abundances of FMD (1-250 items/km) were detected by ship surveys in southern Chile (2002-2005). Eighty percent of the FMD was Styrofoam, plastic bags and plastic fragments. Most of this material originated from the intensive mussel and salmon mariculture industry here. These coastal waters are home to at least one threatened dolphin species, the Chilean dolphin.

(SOURCE: Hinojosa, I. A. and Thiel, M. 2009. Floating marine debris in fjords, gulfs and channels of southern Chile. *Mar. Poll. Bull.* 58: 341-350)

Chemical pollution

Numerous publications documented cetacean contaminant levels from the Pacific Ocean between 2006 and 2009. Maximum recorded butyltin levels are summarised for the Pacific in Table 1; Table 2 summarises maximum trace element levels; Table 3 summarises maximum fluorinated hydrocarbon concentrations; and Table 4 summarises maximum organic contaminant levels.

Persistent organic pollutants may be a risk for Southern Resident killer whales

Researchers measured persistent organic pollutant (POP) levels in Chinook salmon to investigate the consumption of these contaminants by Northern and Southern Resident killer whales on the Pacific coast of North America. It was estimated that killer whales consume up to 1.248 µg PCB day^{-1}; 0.085 HCH day^{-1}; 0.489 DDT day^{-1}; 0.674 µg PBDE day^{-1}; 0.055 µg PCDD day^{-1}; and 0.078 µg PCDF day^{-1}. Canadian guidelines for maximum contaminant concentrations to be consumed by mammalian wildlife were close to, or exceeded by, salmon from the Deschutes and Lower Fraser Rivers for PCBs and salmon from the Duwamish River for DDT. The conclusion was "*that the endangered southern resident killer whales are exposed to much higher concentrations of* [POPs] *than their northern counterparts through the consumption of more* [POP]*-contaminated Chinook salmon, and may increase their consumption of salmon in order to compensate for the reduced lipid content observed in southerly Chinook*".

(SOURCE: Cullon, D.L., Yunker, M.B., Alleyne, C., Dangerfield, N.J., O'Neill, S., Whiticar, M.J. and Ross, P.S. 2009. Persistent organic pollutants in Chinook salmon (*Oncorhynchus tshawytscha*): implications for resident killer whales. *Environ. Toxicol. Chem.* 28: 148-161)

High mercury levels in cetacean meat on sale for human consumption in South Korea

Cetacean meat on sale for human consumption in South Korea was tested for mercury contamination. Levels of mercury up to 41 µg. g^{-1} (wet weight) were detected in red meat (muscle tissue) and up to 156 µg. g^{-1} (wet weight) in liver. All samples were higher than Japanese health regulation limits for mercury contamination in marine foods and all but Cuvier's beaked whale and harbour porpoise meat were above Korean regulation safety limits. The researchers concluded: "*men and women who plan to have children, in addition to pregnant women and developing children, should restrict their consumption of Hg-contaminated products from odontocetes*". Bottlenose dolphin, false killer whale and killer whale tissues were the most heavily contaminated. Moreover, the analysed J-stock North Pacific common minke whale meat had mercury levels twice as high as J-stock or O-stock meat for sale in Japan.

(SOURCE: Endo, T., Ma, Y.U, Baker, C.S., Funahashi, N., Lavery, S., Dalebout, M.L., Lukoschek, V. and Haraguchi, K. 2007. Contamination level of mercury in red meat products from cetaceans available from South Korea markets. *Mar. Poll. Bull.* 54: 669–677)

Increasing contaminant levels in melon-headed whales and high contaminant transfer rates to calves

Concentrations of fluorinated hydrocarbons, polybrominated diphenyl ethers (PBDEs) and organochlorine compounds were determined in the tissues of 48 melon-headed whales stranded in Japan in 1982, 2001-2002, and 2006 (see also Table 4). Concentrations of the main fluorinated compounds increased tenfold between 1982 and 2002 (PFOS and PFOSA, although the latter declined between 2002 and 2006). Two other compound classes (PFNA and PFDA) increased significantly from 2001/2002 to 2006. Concentrations of PCBs, DDT, and HCB decreased between 1982 and 2002/2006. However, levels of chlordane and PBDEs increased, suggesting more recent inputs of these contaminants into the environment. Contaminant levels were also compared between two pregnant whales and their foetuses: the amount of fluorinated hydrocarbons transferred to the foetuses was much higher than of PCBs or brominated hydrocarbons. Approximately 85% of a mother's body burden of contaminants was estimated to be transferred to the offspring during gestation and lactation. These studies suggest increasing fluorinated and brominated hydrocarbon contamination in Japanese coastal waters, and the high level of placental transfer of these hydrocarbons has implications for neonate cetacean health.

(SOURCES: Hart, K., Kannan, K., Isobe, T., Takahashi, S., Yamada, T.K., Miyazaki, N. and Tanabe, S. 2008. Time trends and transplacental transfer of perfluorinated compounds in melon-headed whales stranded along the Japanese Coast in 1982, 2001/2002, and 2006. *Environ. Sci. Technol.* 42: 7132–7137; Kajiwara, N., Kamikawa, S., Amano, M., Hayano, A., Yamada, T.K., Miyazaki, N. and Tanabe, S. 2008. Polybrominated diphenyl ethers (PBDEs) and organochlorines in melon-headed whales, *Peponocephala electra*, mass stranded along the Japanese coasts: maternal transfer and temporal trend. *Environ. Pollut.* 15: 106-114)

Killer whales may face life-long risk from persistent organic pollutants

Models were developed to examine POP-related health risks in killer whales. Modelled PCB concentrations in the Northern and Southern Resident killer whales of the Pacific coast of North America responded slowly to declines in environmental pollutant loads, especially in adult males. Projections suggest that the Northern Resident population could fall below current guidelines for maximum contaminant concentrations to be consumed by mammalian wildlife by 2030 while the Southern Residents, listed as endangered under the US Endangered Species Act, may not do so until at least 2063. The use of models provides managers with benchmarks against which the effectiveness of contaminant mitigation can be measured. The results of these models provide little confidence that simple consumption guidelines afford protection to long-lived animals such as killer whales.

(SOURCE: Hickie, B.E., Ross, P.S., MacDonald, R.W. and Ford, J.K.B. 2007. Killer whales (*Orcinus orca*) face protracted health risks associated with lifetime exposure to PCBs. *Environ. Sci. Technol.* 41: 6613-6619)

Trace element-contaminated prey consumption may be a risk for Hong Kong dolphins and porpoises

Stomach contents of finless porpoises and Indo-Pacific humpback dolphins from Hong Kong waters were analyzed for trace element and organochlorine contamination. A risk assessment of the impact of consuming contaminated prey was conducted using a model incorporating contaminant dose guidelines for terrestrial mammals and humans. For trace elements, when using the terrestrial mammal guidelines only, arsenic was considered a risk, but most arsenic in marine fish is in a low toxicity organic form, suggesting the risk is low. However, when using human health guidelines, there was a risk from cadmium, chromium, copper, nickel and mercury. For PCBs, humpback dolphins had concentrations of up to 2.1 $\mu g\ g^{-1}$; finless porpoises up to 0.29 $\mu g\ g^{-1}$. Finless porpoises were considered to be at lower risk than humpback dolphins from consuming PCBs in their diet (using terrestrial mammal guidelines); the situation with humpback dolphins warranted further investigation. The researchers did not incorporate PCB bioaccumulation into their model.

(SOURCES: Hung, C.L.H., Lau, R.K.F., Lam, J.C.W., Jefferson, T.A., Hung, S.K., Lam, M.H.W. and Lam P.K.S. 2007. Risk assessment of trace elements in the stomach contents of Indo-Pacific humpback dolphins and finless porpoises in Hong Kong waters. *Chemosphere* 66: 1175-1182; Hung, C.L.H., Xu, Y., Lam, J.C.W., Jefferson, T.A., Hung, S.K., Yeung, L.W.Y., Lam, M.H.W., O'Toole, D.K. and Lam P.K.S. 2006. An assessment of the risks associated with polychlorinated biphenyls found in the stomach contents of stranded Indo-Pacific humpback dolphins (*Sousa chinensis*) and finless porpoises (*Neophocaena phocaenoides*) from Hong Kong waters. *Chemosphere* 63:845-852)

First report of the flame retardant HBCD in marine mammals in Southeast Asia

Environmental contamination by brominated flame retardants (BFRs) has become a serious concern (due to, *inter alia*, persistence, bioaccumulation, and possible adverse effects on humans and wildlife). Hexabromocyclododecanes (HBCDs) are intensively used as BFRs, with an annual consumption of 22,000 metric tons (in thermal insulation foam and furniture upholstery). This first report of HBCD contamination in marine mammals detected the chemical in blubber samples of all finless porpoises and Indo-Pacific humpback dolphins collected from the South China Sea between 1990 and 2001. Values were higher in the humpback dolphins (31-380 ng/g lipid weight) than in the finless porpoises (4.7-55 ng/g lipid weight), which was attributed to habitat (estuarine, industrial zone in the former, more ocean-influenced waters in the latter). Overall, values tended to increase from 1990 to 2001.

(SOURCE: Isobe, T., Ramu, K., Kajiwara, N., Takahashi, S., Lam, P.K,S., Jefferson, T.A., Zhou, K. and Tanabe, S. 2007. Isomer specific determination of hexabromocyclododecanes (HBCDs) in small cetaceans from the South China Sea – levels and temporal variation. *Mar. Poll. Bull.* 54: 1139-1145)

Metal toxicity associated with kidney damage and bone malformations in South Australian dolphins

In South Australia, significantly more cadmium, copper, and zinc in the liver were observed in dolphins with evidence of advanced kidney damage. Metal and selenium concentrations in the liver were similar in groups with various degrees of bone malformation. Two dolphins had high metal burdens, kidney damage and evidence of bone malformations, indicating possible severe and prolonged metal toxicity. Another dolphin showed some renal damage, but had no other symptoms; this was unlikely to be caused by metal toxicity. Multiple metal toxicity symptoms should be examined together in order to distinguish metal toxicity from unrelated conditions.

(SOURCE: Lavery, T.J., Kemper, C.M., Sanderson, K., Schultz, C.G., Coyle, P., Mitchell, J.G. and Seuront, L. 2009. Heavy metal toxicity of kidney and bone tissues in South Australian adult bottlenose dolphins (*Tursiops aduncus*). *Mar. Environ. Res.* 67: 1-7)

Organochlorine contaminants and enzyme expression

Cytochrome P450 (CYP) enzymes assist in metabolising (neutralising) substances such as environmental pollutants and carcinogens. DNA sequences from CYPs isolated from minke whale liver were examined to determine if organochlorine contaminants (OCs) affected their expression. The livers of 19 mature males were collected during JARPN II. Statistical analyses showed no significant correlation between CYP expression and OC levels, suggesting that either these contaminants do not alter CYP expression or the levels in minke whale liver are not sufficient to alter expression.

(SOURCE: Niimi, S., Kim, E-U., Iwata, H., Watanabe, M.X., Yasunaga, G., Fujise, Y. and Tanabe, S. 2007. Identification and hepatic expression profiles of cytochrome P450 1-4 isozymes in common minke whales (*Balaenoptera acutorostrata*). *Comp. Biochem. Physiol.* Part B 147: 667-681)

New polybrominated compounds identified in Australian marine mammals

Australian marine mammals are bioaccumulating elevated concentrations of a range of polybrominated natural products. One natural form (2,2'-diMeO-BB 80) was found in the blubber of selected marine mammal samples at concentrations of 200-1800 ng g^{-1} lipid weight, which represents the highest concentration reported for this compound in environmental samples. Three novel polybrominated dimethoxybiphenyls (PBDMBs) were identified in the same samples. These may represent either new or transformed natural products. In either case, the environmental relevance of natural and related PBDMBs needs to be investigated in more detail.

(SOURCE: Vetter, W., Turek, C., Marsh, G. and Gaus, C. 2008. Identification and quantification of new polybrominated dimethoxybiphenyls (PBDMBs) in marine mammals from Australia. *Chemosphere* 73: 580-586)

Disease and mortality events

General

High prevalence of skin lesions in bottlenose dolphins off California

A photo-identification study in a 500 km² area off Santa Monica, California, between 1997 and 2007 revealed that of 637 bottlenose dolphins examined for skin lesions, 79% showed at least one type of lesion. Offshore animals showed more lesions than coastal animals. Lesions can be a sign of disease and may be related to anthropogenic factors, making their high presence a cause of concern.

(SOURCE: Bearzi, M., Rapoport, S., Chau, J. and Saylan, C. 2009. Skin lesions and physical deformities of coastal and offshore common bottlenose dolphins (*Tursiops truncatus*) in Santa Monica Bay and adjacent areas, California. *Ambio* 38: 66-71)

Harmful Algal Blooms (HABs)

Unusual marine mammal mortality event off California correlated to toxic algal bloom

An unusual stranding event of marine mammals off California in 2002 included both inshore and offshore foraging cetaceans: long-beaked common dolphins, short-beaked common dolphins, bottlenose dolphins and gray whales. A correlation in time was established between this event and blooms of marine algae (diatoms) of the genus *Pseudo-nitzschia*, which produce the neurotoxin domoic acid. This toxin is known to cause death in marine birds, sea lions and humans (amnesic shellfish poisoning). This provides further evidence that harmful algal blooms pose a threat to cetaceans. Such blooms have been linked to anthropogenic effects, specifically to eutrophication.

(SOURCE: Torres de la Riva, G., Kreuder-Johnson, C., Gulland, F.M.D., Langlois, G.W., Heyning, J.E., Rowles, T.K. and Mazet, J.A.K. 2009. Association of an unusual marine mammal mortality event with *Pseudo-nitzschia* spp. blooms along the southern California coastline. *J. Wildlife Diseases.* 45: 109-121)

Ship strikes

Ship-strike rates of large whales off the coast of Washington State

Records (1980-2006; n = 130) of large whale strandings in Washington State, USA, revealed that seven species had evidence of ship strikes. Of these, fin whales had the highest rate (five ante-mortem strikes and two possible post-mortem strikes) – six of these strikes occurred during 2002-2006. Six gray whales also presented 'possible ship strike' injuries, although these animals are more abundant in the area than fin whales. There was one possible ship strike of a humpback whale despite an abundance of these animals occurring in shipping lanes. There were species-specific differences in ship-strike rates, suggesting some species may be more vulnerable to ship strikes than others.

(SOURCE: Douglas, A.B., Calambokidis, J., Raverty, S., Jeffries, S.J., Lambourn D.M. and Norman, S.A. 2008. Incidence of ship strikes of large whales in Washington State. *J. Mar. Biol. Assoc. UK* 88: 1121-1132)

Oil spills

Transient killer whale group may go extinct

Killer whales were photographed in oil after the 1989 'Exxon Valdez' oil spill, but preliminary damage assessments were inconclusive. Photo-identification methods used to monitor two killer whale populations for five years before the spill were continued for 16 years afterward. The AB resident pod and the AT1 transient group suffered losses of 33 and 41%, respectively, in the year following the spill. By 2005, the AB pod had not recovered to pre-spill numbers and its rate of increase was significantly less than that of other resident pods. The AT1 group continued to decline and is now listed as depleted under the US Marine Mammal Protection Act. The simultaneous losses of large numbers of individuals from two (ecologically) separate groups and the absence of other obvious perturbations strengthens the link between the mortalities, lack of recovery, and the oil spill. "*It is clear that resident killer whale pods, even under optimal conditions, may take decades to recover from the impacts of an oil spill or other disturbance, particularly if reproductive females and/or juvenile females are lost… The outlook for the AT1 Group is bleak and the group will likely go extinct within the next several decades*".

(SOURCE: Matkin, C.O., Saulitis, E.L., Ellis, G.M., Olesiuk, P. and Rice, S.D. 2008. On-going population-level impacts on killer whales *Orcinus orca* following the 'Exxon Valdez' oil spill in Prince William Sound, Alaska. *Mar. Ecol. Prog. Ser.* 356: 269-281)

Disease

Infection by *Toxoplasma* in a striped dolphin from Costa Rica

A stranded striped dolphin on the Pacific coast of Costa Rica, which later died, was diagnosed with severe meningoencephalomyelitis, and the sporozoan *Toxoplasma gondii* was isolated from the brain. The mechanism of infection of this potentially lethal parasite remains unknown, with one explanation being that oocysts of the sporozoan are washed from land into the sea via runoff contaminated by cat excrement. Although the prevalence of *T. gondii* in bottlenose dolphins from the USA is very high, this is the first report from this species.

(SOURCE: Dubey, J.P., Morales, J.A., Sundar, N., Velmurugan, G.V., Gonzales-Barrientos, C.R., Hernández-Mora, G. and Su, C. 2007. Isolation and genetic characterization of *Toxoplasma gondii* from striped dolphin (*Stenella coeruleoalba*) from Costa Rica. *J. Parasitol.* 93: 710-711)

<u>High rate of *Brucella*-linked fatalities in Costa Rican striped dolphins</u>

Between August 2004 and April 2007, 10 striped dolphins live-stranded on the Pacific coast of Costa Rica, and all displayed "*swimming problems compatible with neurologic disorders*" and died within 48 hours. All animals tested positive for *Brucella* antibodies and the six dolphins examined in detail demonstrated the presence of *Brucella* bacteria in multiple organs. A pregnant animal and her foetus demonstrated that this pathogen can be passed to unborn offspring. The animals examined had encephalitis, specifically non-suppurative meningitis. The authors expressed concerns about zoonotic infection, particularly in people who handled the infected animals, and noted that in Costa Rica "*other stranded dolphins have been transferred to privately owned swimming pools or to slaughter for use as a food source for humans and domestic animals*."

(SOURCE: Hernández-Mora, G., González-Barrientos, R., Morales, J.A., Chaves-Olarte, E., Guzmán-Verri, C., Baquero-Calvo, E., De-Miguel, M.J., Marín, C.M., Blasco, J.M. and Moreno, E. 2008. Neurobrucellosis in stranded dolphins, Costa Rica. *Emerg. Infect. Dis.* 14: 1430-1433)

<u>Possible *Brucella* infection in dolphins from Solomon Islands</u>

Antibodies to the bacterium *Brucella* were found in serum samples of 53% of the 58 Indo-Pacific bottlenose dolphins tested from Solomon Islands. *Brucella* bacteria species are the causative agent of brucellosis, a serious debilitating disease in humans and an important cause of abortion and sterility in domestic animals. The host range for *Brucella* spp. has recently expanded to include marine mammals, including cetaceans, around Europe and North and South America as well as the Arctic Sea. This is a first report from Pacific waters.

(SOURCE: Tachibana, M., Watanabe, K., Kim, S., Omata, Y., Murata, K., Hammond, T. and Watarai, M. 2006. Antibodies to *Brucella* spp. in Pacific bottlenose dolphins from the Solomon Islands. *J. Wildlife Sci.* 42: 412-414)

<u>Aspergillosis fungus infection in stranded melon-headed whale</u>

A melon-headed whale calf stranded in the Philippines and was diagnosed with lung lesions containing a fungal infection; the animal later died. The cause of death was respiratory failure due to severe bronchopneumonia caused by *Aspergillus fumigatus* infection. Such fungal mycoses are primarily seen in immunosuppressed hosts. This is the first report of fungal respiratory disease in any marine mammal in the Philippines.

(SOURCE: Torno, C.S., Buccat, M.C. and Masangkay, J.S. 2008. Aspergillosis in a melon-headed whale (*Peponocephala electra*). *Philipp. J. Vet. Med.* 45: 49-57)

Direct exploitation

<u>Genetic methods suggested as tool to better document illegal takes of rare whales in Micronesia</u>

IUU fishing is known to occur on marine megafauna such as cetaceans in the tropical Indo-Pacific. A rare ginkgo-toothed beaked whale, first described in 1958 and known from less than 30 specimens, was found frozen on a longline vessel in Guam after being taken in Micronesian waters. Taking such an animal is currently not prohibited by law in Micronesia, but the importation to Guam represented a contravention of CITES and the US Marine Mammal Protection Act. Molecular monitoring could be a powerful and relatively inexpensive tool to address this threat to rare cetaceans.

(SOURCE: Dalebout, M.L., Robertson, K.M., Chivers, S.J. and Samuels, A. 2008. DNA identification and the impact of illegal, unregulated, and unreported (IUU) fishing on rare whales in Micronesian waters. *Micronesica* 40: 139-147)

<u>Historical overexploitation during illegal whaling in the North Pacific</u>

Information on historical catches of whales is crucial to helping determine former population sizes and understand current recovery trends. This collection of 18 formerly secret internal reports by Soviet scientists (available for the first time in English translation) documents dramatic declines in abundance, disappearances of whales from previously populous feeding and breeding grounds, and a decline in the average size and age of animals in the catch. The most affected species were the North Pacific right whale (the most critically endangered population of large whales in the world) and sperm whale.

(SOURCE: Ivashchenko, Y.V., Clapham, P.J. and Brownell Jr., R.L. (eds) 2007. Scientific reports of Soviet whaling expeditions in the North Pacific, 1955-1978. *NOAA Technical Memorandum NMFS-AFSC-175*: 1-81)

Efforts to assess the impact of live captures of bottlenose dolphins in Solomon Islands

Live captures and export of Indo-Pacific bottlenose dolphins from Solomon Islands began in 2003. The IUCN Global Plan of Action for the Conservation of Cetaceans states that small cetaceans should not be captured unless their population has been assessed and shown capable of sustaining the removals. An IUCN workshop was convened to examine a range of topics, from management goals and assessment options to cultural and other local considerations. At the current permitted level of exports (100 individuals per year), the population would have to be at least 5,000 to 10,000 individuals, but the population is in fact estimated to be well below 5,000. The near-shore distribution of this population makes it particularly vulnerable to exploitation and other anthropogenic threats.

(SOURCE: Reeves, R.R. and Brownell, R.L., Jr. (eds). 2009. Indo-Pacific bottlenose dolphin assessment workshop report: Solomon Islands case study of *Tursiops aduncus*. *Occasional Paper of the Species Survival Commission*, No. 40, IUCN, Gland, Switzerland. 53 pp.)

Climate change

Northern Pacific climate alters offspring sex ratio in northern elephant seals

In northern elephant seals, where foraging resources are partitioned by sex, warmer sea surface temperature anomalies reduce or disperse prey resources for gestating females in the North Pacific Ocean. Such conditions favour the production of male offspring. Anthropogenic global warming is predicted to warm the North Pacific, which could alter basin-scale productivity, increase nutritional stress and alter sex ratios in mammalian populations where foraging resources are partitioned by sex. This warrants examining a potential effect in cetaceans.

(SOURCE: Lee, D.E. and Sydeman, W.J. 2009. North Pacific climate mediates offspring sex ratio in Northern elephant seals. *J. Mamm.* 90: 1-8)

Noise impacts

Sonar

U.S. Navy limits use of low-frequency active sonar

Under an agreement between the US Navy and conservation organizations, the Navy will restrict the use of its Surveillance Towed Array Sensor System (SURTASS) Low Frequency Active (LFA) sonar to defined military training areas in the North Pacific Ocean. The LFA signal can sometimes be detected across entire ocean basins and has the potential to disrupt whale behaviour hundreds of miles away. The agreement includes other protective measures such as seasonal and coastal exclusions.

(SOURCE: News. 2008. *Mar. Poll. Bull.* 56: 1678–1679)

Seismic surveys

Seismic survey mitigation and monitoring off Sakhalin Island

This paper summarised the results of the mitigation and monitoring program for western gray whales during a 3-D seismic survey by Exxon Neftegas Limited, conducted during 17 August – 9 September 2001 off Sakhalin Island, Russia (see entries below). Existing mitigation and monitoring practices for seismic surveys were evaluated to identify ‘best practices’ and two buffer zones were established: a 1 km ‘safety’ buffer (whose intent was to avoid injury) prevented exposures to levels of sound greater than 180 dB re 1 µPa (rms) and a 4-5 km ‘feeding’ buffer (whose intent was to avoid displacement from feeding areas) was established to prevent exposures greater than 163 dB re 1 µPa (rms). Trained marine mammal observers monitored whales within these buffers. Additional measures included: 1) rescheduling the program to avoid the spring arrival of migrating whales; 2) reducing the survey area by 19% to avoid waters less than 20 m deep (feeding whales concentrate here); 3) reducing the number and total volume of air guns by about half relative to initial plans; and 4) using ‘ramp-up’ or ‘soft-start’ procedures. This program provided new information about underwater sound propagation and gray whale responses during exposure to seismic surveys. The authors concluded that “[subsequent] *research in 2002-2005 suggested no biologically significant or population level impacts of the 2001 seismic survey*”.

(SOURCE: Johnson, S.R., Richardson, W.J., Yazvenko, S.B., Blokhin, S.A., Gailey, G., Jenkerson, M.R., Meier, S.K., Melton, H.R., Newcomer, M.W., Perlov, A.S., Rutenko, S.A., Würsig, B., Martin, C.R. and Egging, D.E. 2007. A western gray whale mitigation and monitoring program for a 3-D seismic survey, Sakhalin Island, Russia. *Environ. Monit. Assess.* 134: 1-19)

<u>Behavioural changes in gray whales in response to 3-D seismic surveys</u>

Land-based surveys (using scan sampling and surveyor's theodolites) were used to monitor western gray whale behaviour during seismic survey operations off Sakhalin Island. None of the whales were exposed to received levels greater than 163 dB re 1 μPa (rms) (see entry above). The seismic survey had no statistically detectable effect on individual or group numbers, nor did it affect nearly half (6 of 11) of the measures for movement and behaviour (including linearity of movement, changes in swimming speed, mean direction of movement, number of blows per surfacing, surface blow rate or time at the surface). However, other variables were significantly affected and "*these results…indicated that gray whales increased their speed, changed directions less, moved further from shore, and stayed underwater longer between respirations when estimated received sound energy from the seismic survey increased*".

(SOURCE: Gailey, G., Würsig, B. and McDonald, T.L. 2007. Abundance, behavior, and movement patterns of western gray whales in relation to a 3-D seismic survey, Northeast Sakhalin Island, Russia. *Environ. Monit. Assess.* 134: 75-91)

<u>Gray whales off Sakhalin Island shift distribution in response to seismic surveys</u>

In an analysis of the impacts of 3-D seismic surveys on the distribution of western gray whales feeding off Sakhalin Island, models predicting distribution were developed and aerial surveys of actual whale distribution were conducted. The surveys indicated a significant shift in distribution during seismic surveys into areas that received lower levels of sound, although whales appeared to remain in the overall region. This shift occurred despite all animals being beyond the established 4 km exclusion zone, and thus being exposed to received levels of noise under 163 dB re 1 μPa (rms). Another study on feeding activity in the region found no observable change in feeding in response to seismic surveys.

(SOURCE; Yazvenko, S.B., McDonald, T.L., Blokhin S.A., Johnson, S.R., Meier, S.K., Melton H.R.,. Newcomer, M.W., Nielson R.M., Vladimirov, V.L. and Wainwright, P.W. 2007. Distribution and abundance of western gray whales during a seismic survey near Sakhalin Island, Russia. *Environ. Monit. Assess.* 134: 45-73; Yazvenko, S.B., McDonald, T.L., Blokhin S.A., Johnson, S.R., Melton H.R.,. Newcomer, M.W., Nielson, R.M. and Wainwright, P.W. 2007. Feeding of western gray whales during a seismic survey near Sakhalin Island, Russia. *Environ. Monit. Assess.* 134: 93-106)

Shipping

<u>Humpback whales increase feeding call rate in the presence of increased vessel noise</u>

In Glacier Bay, Alaska, humpback whale feeding calls during conditions of high vessel noise and lower background noise were compared for differences in acoustic structure, use, and organization using 'information theoretic measures'. High vessel noise was associated with an increased rate and repetitiveness of calls and a decrease in information transmission in vocalisations. Such analyses can help determine the effects of vessel noise on humpback whale communication. This approach "*may also be adapted for wider application to many species where environmental noise is thought to be a problem*".

(SOURCE: Doyle, L.R., McCowan, B., Hanser, S.F., Chyba, C., Bucci, T. and Blue, J.E. 2008. Applicability of information theory to the quantification of responses to anthropogenic noise by southeast Alaskan humpback whales. *Entropy* 10: 33-46)

<u>Killer whales vocalise louder when boat noise increases</u>

As boat numbers increased around killer whales in Puget Sound, and the noise level to which the animals were exposed also increased, the whales increased the source level of their calls, presumably to overcome the masking effects of this noise. The researchers noted that "*increasing vocal output to compensate for noise might have energetic costs, lead to increased stress levels, or degrade communication among individuals which could affect their activity budget. At some level, background noise could also completely impede the use of calls by killer whales for communicative functions*."

(SOURCE: Holt, M.M., Noren, D.P., Veirs, V., Emmons, C.K. and Veirs, S. 2009. Speaking up: Killer whale (*Orcinus orca*) increase their call amplitude in response to vessel noise. *J. Acoust. Soc. Am.*125: 27-32)

GLOBAL

General

<u>Marine mammals more threatened than land mammals</u>

A comprehensive review of the conservation status and distribution of the world's mammals compiled data on all 5487 known species, including marine mammals. The researchers noted that "[c]*ompared with land species, threat levels are higher among marine mammals, driven by different processes (accidental mortality and pollution, rather than habitat loss), and are spatially distinct (peaking in northern oceans, rather than in Southeast Asia)*". Marine mammals also comprise a disproportionate number of the poorly known species. This combination – greater threats and fewer data – emphasises the priority marine mammals, including cetaceans, warrant from international conservation policy.

(SOURCE: Schipper, J. plus 129 additional authors. 2008. The status of the world's land and marine mammals: Diversity, threat, and knowledge. *Science* 322: 225-230)

Marine mammal conservation

Despite protective legislation in many countries, marine mammal conservation efforts have achieved mixed results: some species show signs of recovery following centuries of exploitation, whereas others have perished or are in steep decline. The authors assert that to "*avoid or at least to minimize further losses, human societies must be willing to assess and alter their values and activities that compete with, or otherwise contribute to, the demise of marine mammals and marine ecosystems*". They further conclude that conservation must become a fundamental construct of the daily lives of global citizens. They list the requirements for achieving effective conservation: "*a clear vision of future conservation goals and the roles of societies in achieving them, long-term planning and commitment of funding/resources, rigorous science to resolve critical uncertainties, precautionary protection of habitats and ecosystems in the face of such uncertainty, and an interdisciplinary, comprehensive approach to conservation that engages the social sciences and humanities to elevate the value of conservation over short-term economic gain and many other competing values*". They conclude that "*Without the social will to make such changes, the future for marine mammals looks bleak*".

(SOURCE: Reynolds, J.E. III, Marsh, H. and Ragen, T.J. 2009. Marine mammal conservation. *Endang. Species Res.* 7: 23-29)

Habitat protection/degradation

General

The effect of multiple anthropogenic stressors in marine systems

A key issue in (eco)toxicology concerns the combined impact of two or more stressors on organisms, with the three theoretical effects being antagonistic (lower than the sum of the individual components), additive, or synergistic (greater than the sum of the individual components). This synthesis of 171 studies showed that, overall, the combined effect of two stressors was synergistic, and that adding a third stressor doubled the number of synergistic interactions. This suggests that, in nature, where more than two stressors almost always exist, such synergies may be quite common.

(SOURCE: Crain, C.M., Kroeker, K. and Halpern, B.S. 2008. Interactive and cumulative effects of multiple human stressors in marine systems. *Ecol. Letts.* 11: doi 10.111/j.1461- 0248.2008.01253.x)

Spreading dead zones

'Dead zones' – areas of hypoxia and eutrophication – have spread exponentially since the 1960s and have serious consequences for ecosystem functioning. Dead zones have now been reported from more than 400 systems, affecting a total area of more than 245,000 square kilometres, and are probably a key stressor on marine ecosystems. The authors state that 'dead zones' "*now rank with overfishing, habitat loss, and harmful algal blooms as major global environmental problems*."

(SOURCE: Diaz, R.J. and Rosenberg, R. 2008. Spreading dead zones and consequences for marine ecosystems. *Science* 321: 926-929)

Guidance on model use when trying to identify important habitat

Habitat modelling can help define and manage marine protected areas (MPAs) or to predict the impact of climate change on species distribution. This study compared the predictive accuracy of two model types: presence-only models and presence-absence models. Absence data is difficult and expensive to verify for cetaceans, which spend considerable time underwater. Nevertheless, presence-absence methods are recommended for modelling cetacean distribution because they more accurately reflect complex habitat. However, the use of some presence-only techniques could be useful when extensive surveys are not feasible. This method also allows the use of opportunistic data sets (e.g., collected by recreational or whale-watching vessels) or the merging of data from different surveys.

(SOURCE: Praca, E., Gannier, A., Das, K. and Laran, S. 2009. Modelling the habitat suitability of cetaceans: Example of the sperm whale in the northwestern Mediterranean Sea. *Deep-Sea Research I* 56: 648–657)

<u>Whales no longer entangled in submarine cables</u>

Before the 1960s, at least 16 whales (primarily deep-diving sperm whales) were reported entangled in submarine telecommunication cables. These reports ceased by the 1960s due to major changes in submarine cable design, deployment, and maintenance, as well as advances in marine surveying. Modern cable has characteristics that minimize entanglement risk, and is commonly buried below the seabed. Better marine surveys allow for accurate cable placement in areas where entanglement is most likely (e.g., sperm whale habitat). This is an excellent example of advances in technology minimizing and even eliminating a source of risk for a deep-diving cetacean.

(SOURCE: Wood, M.P. and Carter, L. 2008. Whale entanglements with submarine telecommunication cables. *IEEE J. Oceanic Engineer.* 33: 445-450)

Fisheries Interactions

<u>Management reform may prevent fisheries collapse</u>

A global database of fisheries institutions and catch statistics in 11,135 fisheries from 1950 to 2003 was examined to determine whether catch shares (individual rights to fish, versus industry-wide quotas) could slow or prevent fisheries collapse. By 2003, the fraction of fisheries using catch shares that had collapsed was about half that of other fisheries. However, a blanket endorsement of catch shares was not expressed. The analysis looked at only one type of catch shares (individual transferable quotas) and catch shares are only one aspect of management reform that must include additional economic and social changes. Nevertheless, catch shares may help prevent not only the loss of commercial fisheries, but also the depletion of the prey base for marine predators, including cetaceans.

(SOURCE: Costello, C., Gaines, S.D. and Lynham, J. 2008. Can catch shares prevent fisheries collapse? *Science* 321: 1678-1681)

<u>The impact of whale predation on fisheries</u>

Certain governments have called for a cull of whales to protect economically important fish stocks. Using fisheries data available from the scientific literature, various databases, and input during regional stakeholder workshops, ecosystem models were developed to examine the potential increase in biomass of commercially important fish that would result from a reduction in whale abundance, focusing on northwest African and Caribbean ecosystems. This focus was due to increasing calls for whale culling in these regions. The authors determined that for "*a wide range of assumptions about whale abundance, feeding rates, and fish biomass, even a complete eradication of baleen whales in these tropical areas does not lead to any appreciable increase in the biomass of commercially exploited fish*". They concluded that the 'whales eat fish' paradigm distracts developing regions from addressing the real problems facing their fisheries; e.g., overexploitation of their marine resources by distant-water fishing fleets. The authors stated that "*it is important to recognize that the goal of ecosystem-based management is to manage the whole system for long-term sustainability rather than modifying particular trophic levels in an attempt to maximize fishery yield*".

(SOURCE: Gerber, L.R., Morissette, L., Kaschner, K. and Pauly, D. 2009. Should whales be culled to increase fishery yield? *Science* 323: 880-881)

<u>Fisheries management less effective when a single-species approach is taken</u>

This paper reviewed information available from observer programs, estimates, statutes, and regulations for bycatch of marine mammals and other taxa in US fisheries. The USA has a large fishing region, diverse fisheries (with consequent diverse bycatch), and domestic legislation that commits significant resources to bycatch reduction and can therefore be considered a good proxy for an 'ideal' domestic regulatory regime to reduce bycatch. However, taxon-specific legislation (e.g., the U.S. Marine Mammal Protection Act) has generally led to a single-taxon approach to regulation, "*resulting in more expensive and potentially less effective management than if overlapping problems were addressed together*". Although important progress has been made toward reducing bycatch here, the taxon-specific approach and the lack of perspective on cumulative impacts has reduced the effectiveness of regulation. One recommendation is to extend the approach used for marine mammals to other taxa (e.g., sea turtles and seabirds). While this may seem to divert resources from cetaceans, ultimately such a multi-species approach could have important benefits for them and their habitat, in the USA and elsewhere.

(SOURCE: Moore, J.E., Wallace, B.P., Lewison, R.L., Žydelis, R., Cox, T.M. and Crowder, L.B. 2009. *Mar. Pol.* 33: 435-451)

Marine Protected Areas

Habitat preference modelling can provide guidance to managers of protected areas

This study determined the distribution of several marine mammal species (harbour porpoises, minke whales, and harbour and grey seals) that regularly occur within a MPA established in Scotland to protect one species (bottlenose dolphins). The MPA protects not only the species for which it was designated, but also these other species. The species' distribution patterns were significantly related to environmental parameters and highlight locations for further research. Multi-species modelling can provide a biological basis for determining which specific areas within a MPA should be given highest conservation priority and for creating management zones within those areas.

(SOURCE: Bailey, H. and Thompson, P.M. 2009. Using marine mammal habitat modelling to identify priority conservation zones within a marine protected area. *Mar. Ecol. Prog. Ser.* 378: 279-287)

Chemical pollution

Mercury exposure alters genetic mechanisms in bottlenose dolphin cells

Methylmercury and PFOS are worldwide pollutants that biomagnify in the environment and are therefore found in relatively high concentrations in top marine mammal predators. Exposure of bottlenose dolphin cell cultures to these two compounds triggered cell stress, significantly altering their gene expression. Such alterations of normal cellular biology may lead to changes in the health of marine mammals.

(SOURCE: Mollenhauer, M.A.M., Carter, B.J., Peden-Adems, M.M., Bossart, G.D. and Fair, P.A. 2009. Gene expression changes in bottlenose dolphin, *Tursiops truncatus*, skin cells following exposure to methylmercury (MeHg) or perfluorooctane sulfonate (PFOS). *Aquat. Toxicol.* 91: 10-18)

Flame retardant recognized as emerging health risk for marine mammals

One commercial form of PBDE, Deca-BDE, has surpassed the concentrations of PCBs and DDT in some environments. This compound, which remains on the general market in North America but is slated to be banned in Europe, is accumulating in marine sediments. This is now recognized as a threat for marine organisms higher up the food chain, in particular because it breaks down into more persistent, more bioaccumulative, more toxic and more mobile compounds.

(SOURCE: Ross, P.S., Couillard, C.M., Ikonomou, M.G., Johannessen, S.C., Lebeuf, M., MacDonald, R.W. and Tomy, G.T. 2009. Large and growing environmental reservoirs of Deca-BDE present an emerging health risk for fish and marine mammals. *Mar. Poll. Bull.* 58: 7-10)

Disease and mortality events

Disease

Emerging diseases in marine mammals

Emerging and resurging diseases are apparently increasingly affecting marine mammals, including cetaceans. This is interpreted as reflecting a broad environmental distress syndrome involving, among other things, increases in tumours and infections, as well as anthropogenic and algal toxins that can harm both marine mammals and humans. Tracking marine organisms as sentinels helps evaluate aquatic ecosystems, identify damaging environmental trends, and focus public attention on ocean health issues.

(SOURCE: Bossart, G.D. 2007. Emerging diseases in marine mammals: From dolphins to manatees. *Microbe* 2: 544-549)

Brucella infection could cause population-level impacts in cetaceans

A stranded harbour porpoise off the west coast of Scotland was found with a large lesion on its testis; a smear test confirmed the cause to be *Brucella* spp. The animal was deemed to have died from encephalitis; due to the nature of microscopic lesions in the brain, the encephalitis was also believed to have been induced by *Brucella*. The authors concluded that "*The…pathology and* Brucella *spp. bacteria…within the testicle of this harbour porpoise adds to the evidence that* Brucella *spp. infections may be significant in sea mammal population dynamics via adverse effects on fertility*". The findings of this study are important, bearing in mind the high occurrence rate of *Brucella* infection and testicular lesions in baleen whale populations, such as common minke whales. This study indicates population level effects could result from such infection.

(SOURCES: Dagleish, M. P., Barley J., Finlayson, J., Reid, R.J. and Foster, G. 2008. *Brucella ceti* associated pathology in the testicle of a harbour porpoise (*Phocoena phocoena*). *J. Comp. Path.* 139: 54-59; Ohishi, K., Zenitani, R., Bando, T., Goto, Y., Uchida, K., Maruyama, T., Yamamoto, S., Miyazaki, N. and Fujise, Y. 2003. Pathological and serological evidence of *Brucella* infection in baleen whales (Mysticeti) in the western North Pacific. *Comp. Immunol. Microbiol. Infect. Dis.* 26: 125-136)

<u>New progress in distinguishing *Brucella* types in marine mammals</u>

Samples were taken from a range of marine mammals, including cetaceans: harbour porpoises, Atlantic white-sided dolphins, white-beaked dolphins, bottlenose dolphins, common dolphins, striped dolphins and minke whales. The *Brucella* species in the cetaceans and other marine mammals could be readily distinguished from those in terrestrial animals, and the cetacean *Brucella* strains fell into two groups, with either dolphins or porpoises as their preferred host. This is a step forward in better understanding the distribution, ecology and genetic relatedness of *Brucella* isolates from marine mammals.

(SOURCE: Dawson, C.E., Stubberfield, E.J., Perrett, L.L., King, A.C., Whatmore, A.M., Bashiruddin, J.B., Stack, J.A., and MacMillan, A.P. 2008. Phenotypic and molecular characterisation of *Brucella* isolates from marine mammals. *BMC Microbiol.* 8: 244)

<u>New method for identifying dolphin and porpoise morbilliviruses</u>

Morbilliviruses are some of the most devastating viruses known. In cetaceans, dolphin morbillivirus (DMV) and porpoise morbillivirus (PMV) cause serious respiratory and central nervous system disease. This ultimately leads to stranding and death and has been associated with mass mortalities. Compared to conventional methods, the new PCR-based approach described in this paper, used for identifying and differentiating infections caused by DMV and PMV, is cheaper, quicker, easier to scale up, less prone to cross-contamination, and has better limits of detection and specificity.

(SOURCE: Grant, R.J., Banyard, A.C., Barret, T. and Romero, C.H. 2009. Real-time RT-PCR assays for the rapid and differential detection of dolphin and porpoise morbilliviruses. *J. Virolog. Meths.* 156: 117-123)

<u>Contact with marine mammals poses health risks for humans</u>

In a survey of marine mammal workers, 50% of 483 respondents reported suffering an injury and 23% a skin rash or other reaction. Severe illnesses including tuberculosis, leptospirosis and brucellosis were also documented. Human contact with cetaceans during strandings or ‘swim-with-the-dolphin’ programs, particularly interactions with diseased animals, harbours a risk for transmission of infectious disease. This risk may increase if the marine environment deteriorates and if the incidence of disease increases. Another tuberculosis transmission (captive sea lions to humans) has also recently been reported.

(SOURCE: Hunt, T.D., Ziccardi, M.H., Gulland, F.M.D., Yochem, P.K., Hird, D.W., Rowles, T. and Mazet, J.A.K. 2008. Health risks for marine mammal workers. *Dis. Aquat. Org.* 81: 81-92; Kier, A., Klarenbeek, A., Mendelts, B., van Soolingen, D. and Koeter, G. 2008. Transmission of *Mycobacterium pinnipedii* to humans in a zoo with marine mammals. *Int. J. Tuberc. Lung Dis.* 12: 1469-1473)

<u>Zoonoses: Potential transmission of infectious disease between marine vertebrates and humans</u>

A special issue of the journal *Diseases of Aquatic Organisms* was devoted to the role of marine vertebrates, including cetaceans, as transmitters of infectious diseases to humans. Beyond risk to humans who directly consume marine mammals, various pathogens and animal hosts pose human health risks. For example, California sea lions, elephant seals and western gulls in the Channel Islands, California, harboured *Salmonella* bacteria to varying degrees, with the mammals showing higher rates than observed in other regions. A survey of 15 species each of marine mammals and seabirds, and 3 species of shark, along the northwest coast of the USA revealed a broad range of bacteria resistant to multiple antibiotics. *Brucella* and *Giardia* were the most commonly detected bacteria. Dolphins, porpoises, seals, gulls, eiders and one shark species also had potentially human-infecting *Giardia intestinalis* in their faeces. Gulls, which frequent wastewater and landfill trash sites, may be an important reservoir and transmitter for human-derived faecal pathogens in coastal areas. One study confirmed for the first time the presence of *Brucella* in the marine mammal population of the German North Sea (47 of 426 common seals, 2 of 298 harbour porpoises, 1 of 34 grey seals), primarily in the lung. Another provided the first report of a herpes simplex-like infection in a stranded bottlenose dolphin (Canary Islands). In all cases, the prevalence of diverse pathogens in marine ecosystems raises concerns about how diseases might be transmitted among different host species, including humans. The editor concluded that “*It is perhaps no surprise that human* *activities pose a greater threat to marine vertebrate health than vice versa, and that while the proximate concern may be the risk of humans acquiring infectious agents from marine vertebrates, the ultimate issues lie with the need to modify human activities on many scales*".

(SOURCE: Moore, M. (ed.) 2008. Marine vertebrate zoonoses. *Dis. Aquat. Org. Special 3* 81(1): 1-92)

<u>Lobomycosis in inshore and estuarine dolphins</u>

An increasing number of lobomycosis cases are being reported in humans and cetaceans, with confirmed reports in common bottlenose dolphins (Brazil, US Atlantic coast, Europe) and in the Guiana dolphin (Suriname). One case of dolphin-to-human transmission involving close contact with an aquarium attendant is known. The potential for zoonotic transmission of this disease, and its many poorly understood pathological and clinical aspects, call for further study.

(SOURCE: Paniz-Mondolfi, A.E. and Sander-Hoffmann, L.S. 2009. Lobomycosis in inshore and estuarine dolphins. *Emerg. Infect. Dis.* 15: 672)

<u>New method to determine immune status of bottlenose dolphins</u>

A new method (cELISA) has been developed to measure the serum immunoglobulin levels in bottlenose dolphins. Free-ranging animals had higher levels than two managed populations, probably due to the higher parasite load of the former. This approach may help evaluate the factors that potentially affect the health status of cetacean species in general and, ultimately, the health status of the marine ecosystem.

(SOURCE: Ruiz, C.L., Nollens, H.H., Venn-Watson, S., Green, L.G., Wells, R.S., Walsh, M.T., Nolan, E.C., McBain, J.F. and Jacobson, E.R. 2009. Baseline circulating immunoglobulin G levels in managed collection and free-ranging bottlenose dolphins (*Tursiops truncatus*). *Develop. Comp. Immunol.* 33: 449-455)

<u>Nocardiosis in marine mammals</u>

Ten cases of nocardiosis – a significant cause of mortality in marine mammals, caused by various species of *Nocardia* bacteria – were evaluated in marine mammals, including 10 cetacean individuals: Atlantic bottlenose dolphin, beluga whale and killer whale. The lung and thoracic lymph nodes were affected in 8 of the 10 individuals. Five *Nocardia* species were pathogenic in the cetaceans. Most aspects of this disease, such as the manner of transmission, the differences between cetaceans and pinnipeds, and the difference between captive and free-ranging animals, remain to be fully studied.

(SOURCE: St. Leger, J.A., Begeman, L., Fleetwood, M., Frasca Jr., S., Garner, M.M., Lair, S., Trembley, S., Linn, M.J. and Terio, K.A. 2009. Comparative pathology of nocardiosis in marine mammals. *Vet. Pathol.* 46: 299-308)

Stranding

<u>New method to estimate causes of mortality in marine mammals</u>

Stranding networks can help monitor the health of marine mammals. Based on case studies of California sea otters and Florida manatees, a new methodology was developed to extract even better information from stranding data. Specifically, a new statistical approach divides the total mortality rate into cause-specific mortality rates. This has potential use for population simulations, to identify changes in cause-specific mortality rates and to provide insights into mortality factors that limit species population growth over time and space. The approach would also be applicable to cetacean populations.

(SOURCE: Joly, D.O., Heisey, D.M., Samuel, M.D., Ribic, C.A., Thomas, N.J., Wright, S.D. and Wright, I.E. 2009. Estimated cause-specific mortality rates using recovered carcasses. *J. Wildlife Dis*. 45: 122-127)

Stress

<u>Small cetacean stress response could lead to higher mortality than expected</u>

A review of the pathology of bycaught, stranded, or captive small odontocetes found several similarities suggesting that this taxon can show general but extreme physiological stress responses to 'a perceived threat'. Pathologies included lesions such as band necrosis in cardiac and smooth muscles, injury to the intestinal mucosa, renal tube necrosis and muscle contraction in, and narrowing of the bronchi. Prolonging the alarm response triggering these pathological changes may result in widespread tissue injury. "*These observations may explain why 'sensitive' species die abruptly from handling or transportation, and why the mortality of highly stressed beach-stranded animals is very high*". This response would potentially lead to mortality in small odontocetes from chronic stress, or higher rates of mortality than expected from anthropogenic activities, such as fishery interactions.

(SOURCE: Cowan, D.F. and Curry, B.E. 2008. Histopathology of the alarm reaction in small odontocetes. *J. Comp. Path.* 139: 24-33)

Climate change

Worst case scenario predictions on climate change already achieved

The International Scientific Congress on Climate Change held in Copenhagen in March 2009 concluded that the current state of knowledge on climate change painted a grim picture: "*Recent observations confirm that, given high rates of observed emissions, the worst-case IPCC scenario trajectories (or even worse) are being realized. For many key parameters, the climate system is already moving beyond patterns of natural variability…These parameters include global mean surface temperature, sea-level rise, ocean acidification, and extreme climatic events. There is a significant risk that many of the trends will accelerate, leading to an increasing risk of abrupt or irreversible climatic shifts*".

(SOURCE: International Scientific Congress on Climate Change. 2009. Key science messages from the climate conference. 10-12 March 2009, Copenhagen, Denmark. Available from http://climatecongress.ku.dk/speakers/keymessagesandsummary.ppt. See also http://www.copenhagen climatecouncil.com)

Greenhouse gas emissions rise to record levels

Carbon dioxide emissions "*are rising faster than the worst-case scenario drawn up by the Intergovernmental Panel on Climate Change (IPCC)*". Carbon dioxide levels rose almost a full percentage point more than the IPCC predicted (3.5% versus 2.7%) for the period 2000-2007. China now ranks first among emitters of carbon dioxide, responsible for 21% of the world's emissions, up from 14% seven years ago. The USA is second, at 19%. India is fourth, but may soon overtake third place Russia. Other greenhouse gases, such as methane and nitrous oxide, also reached record high levels in 2007.

(SOURCES: News in Brief. 2008. Carbon dioxide emissions rise to record levels. *Nature* 455: 582; News in Brief. 2008. Greenhouse gases hit modern-day highs. *Nature* 456: 558-559)

Current status of polar sea ice

Sea-ice cover in the Arctic in 2008 did not break 2007's record of the smallest ice extent since satellite records began. There was 9.4% more ice at 2008's summer minimum than in 2007. However, the reduction over the Bering and Chukchi Seas may have already reached a 'tipping point'. A half dozen climate models, the best at predicting observed changes in sea ice to date, predict the complete loss of summer sea ice in the Arctic in about 30 years. In the Antarctic, modelling suggests that the sea ice/shelf could collapse relatively rapidly (in one to several thousand years). The rate at which small Antarctic ice shelves are melting is probably increasing dramatically. The West Antarctic ice sheet may begin to collapse when surrounding ocean temperatures warm by roughly 5ºC. More modelling work will be needed to predict if these scenarios will occur. Another study determined that warming in the Antarctic extends well beyond the Peninsula to cover most of West Antarctica, "*an area of warming much larger than previously reported*". This study found that surface warming trends were positive in both East and West Antarctica. Two separate modelling exercises looked at possible sea-level changes due to melting polar ice. One model showed that some coastal sites will see sea-level rises significantly higher (or, less commonly, lower) than previously predicted, with a greater sea-level rise in the oceans bordering North America and in the Indian Ocean than elsewhere. The other showed that sea-level rise generally may be lower than previously assumed, due to physical limitations of ice discharge from glaciers.

(SOURCES: News in Brief. 2008. Arctic ice shrinks less this year than last. *Nature* 455: 441; Kerr, R.A. 2009. Arctic summer sea ice could vanish soon but not suddenly. *Science* 323: 1655; Mitrovica, J.X., Gomez, N. and Clark, P.U. 2009. The sea-level fingerprint of West Antarctic collapse. *Science* 323: 753; Pollard, D. and DeConto, R.M. 2009. Modelling West Antarctic ice sheet growth and collapse through the past five million years. *Nature* 458: 329-333; Ray, G.C., Hufford, G.L., Krupnik, I.I. and Overland, J.E. 2008. Diminishing sea ice. *Science* 321: 1443-1444; Steig, E.J., Schneider, D.P., Rutherford, S.D., Mann, M.E., Comiso, J.C. and Shindell, D.T. 2009. *Nature* 457: 459-463)

New review of climate change and cetaceans

Climate change will potentially affect various cetacean species and populations, in particular those with a limited habitat range or that specialize in certain prey species (e.g., linkage between sea ice and krill). The IWC has addressed this issue in two workshops (1996, 2009). The challenges require innovative, large-scale, long-term and multinational response from scientists, conservation managers and decision makers. Moreover, the reactions to emerging developments and changes will need to be swifter.

(SOURCE: Simmonds, M. and Eliott, W.J. 2009. Climate change and cetaceans: Concerns and recent developments. *J. Mar. Biologic. Assoc. UK* 89: 203-210)

Species expansion, from the Pacific to the Atlantic via the Arctic, anticipated as warming continues

Global warming has already resulted in the northward expansion of several temperate marine species (including some cetaceans) into higher latitudes. As warming continues, North Pacific marine species (across all taxa) are expected to spread "*through the Bering Strait into a warmer Arctic Ocean and eventually into the temperate North Atlantic*". Because Pacific marine species tend to be larger and better competitors than their Atlantic counterparts, few Atlantic to Pacific migrations are expected. This suggests that the long-term prospects of Pacific cetaceans are less dire than those of Atlantic species.

(SOURCE: Vermeij, G.J. and Roopnarine, P.D. 2009. The coming Arctic invasion. *Science* 321: 780-781)

Ocean warming may decrease diversity of deep-water cetaceans

The open oceans comprise most of our biosphere. Based on long-term sighting data of deep-water cetaceans from the Atlantic, Pacific and Indian Oceans, seasonal and geographic changes in diversity are best predicted by sea-surface temperatures. Accordingly, the predicted response to ocean warming will be a decline of diversity across the tropics (and increases in higher latitudes). This approach indicates that the effects of global warming on cetaceans will go beyond species with restricted ranges and specialized habitat requirements (e.g., polar, inshore or riverine species).

(SOURCE: Whitehead, H., McGill, B. and Worm, B. 2008. Diversity of deep-water cetaceans in relation to temperature: Implications for ocean warming. *Ecol. Letts.* 11: 1198-1207)

Noise impacts

General

Ocean acidification will increase reach of noise pollution

Climate change may increase the threat posed to cetaceans (and other marine life) by marine noise. The predicted acidification of the ocean as the result of increasing carbon dioxide levels (and other atmospheric pollutants such as sulphur and nitrogen compounds) could potentially reduce sound absorption, i.e., sound will likely travel farther underwater. The 0.12 decrease in ocean pH that has already occurred has resulted in low- and mid-frequency sounds travelling 10-15% farther. Thus, anthropogenic noise is travelling farther, and in the future this effect will be exacerbated. The sound frequencies most greatly affected would be below 1 kHz, but there would be effects up to 10 kHz. By 2050, sound propagation up to 10 kHz would increase by at least 30% (but more likely up to 60%).

(SOURCE: Hester, K.C., Peltzer, E.T., Kirkwood, W.J. and Brewer, P.G. 2008. Unanticipated consequences of ocean acidification: A noisier ocean at lower pH. *Geophys. Res. Letts.* 35: L19601)

Great variability in sound transmission in water – distance of effect difficult to estimate

This study focused on the ability of dolphins to detect acoustic deterrent devices or 'pingers', but also found a great variability in sound propagation distance, which is not easily explained by acoustic models of sound spreading. Factors such as constructive and destructive interference and sound reflection from the surface and bottom substrates contributed to what was typically a 10-15 dB or more variation in sound levels. This calls for incorporating large margins of error when calculating sound impact distances or estimating sound levels at a distance in the marine environment.

(SOURCE: Shapiro, A.D., Tougaard, J., Jorgensen, P.B., Kyne, L.A., Balle, J.D., Bernardez, C., Fjalling, A., Karlsen, J. and Wahlberg, M. 2009. Transmission loss patterns from acoustic harassment and deterrent devices do not always follow geometrical spreading predictions. *Mar. Mamm. Sci.* 25: 53-67)

Anthropogenic noise exposure and stress in marine mammals

A workshop on the potential and likely consequences of noise-induced stress for individual marine mammals and their populations was held in Lanzarote, Canary Islands in June 2007. The results, published in the *International Journal of Comparative Psychology,* drew from the available information on human and animal physiology and psychology and considered the importance of context (including any previous stressor exposure) in assessing behavioural responses. The workshop noted that it is "*expected that exposure to noise can…lead to a physiological stress response in [marine mammal] species either directly or indirectly through annoyance, a secondary stressor*". They also noted that "*many consequences of exposure to noise can result in a cascade of secondary stressors…all with potential negative if not disastrous consequences*". Moreover, short exposures to stressors may result in long-term consequences, and acclimation to stressors cannot be assumed from behavioural reactions alone (e.g., failure to flee a stressor does not mean the animal has acclimated to it). The workshop concluded that "*it is reasonable to extrapolate information regarding stress responses in other species to marine mammals, because these responses are highly conserved among all species in which they have been examined to date. As a result, we determined that noise acts as a stressor to marine mammals*". Future research should focus on noise-induced stress responses, requiring careful study design.

(SOURCE: Wright, A.J. and Highfill, L. (eds.) 2007. Considerations of the effects of noise on marine mammals and other animals. *Int. J. Comp. Psychol.* 20(2-3): iii-viii, 89-316)

<u>The effectiveness and limits of using passive acoustic methods to detect beaked whales</u>

Due to the long, deep dives of beaked whales, visually detecting these acoustically vulnerable cetaceans when they are submerged is problematic. Likewise, poor weather and low visibility conditions reduce the effectiveness of visual monitoring. Passive acoustic monitoring (PAM) is often recommended to improve beaked whale detection under these conditions. An evaluation of PAM effectiveness determined that these whales might be detected during calm weather conditions, although detection probability reduces considerably with distance. An animal beyond 4 km would likely be detected only in conditions of unusually good sound transmission. Moreover, because diving beaked whales are often silent, a listening period of 140 minutes would be required to reliably detect animals. Therefore, PAM would be an effective mitigation measure only if the zone of impact of an anthropogenic noise source did not extend beyond 4 km, the activity was being conducted in calm weather and the vessel was stationary for at least 2 hours prior to the noise-producing activity.

(SOURCE: Zimmer, W.M., Harwood, J., Tyack, P.J., Johnson, M.P. and Madsen, P.T. 2008. Passive acoustic detection of deep-diving beaked whales. *J. Acoust. Soc. Am.* 124: 2823-2832)

Cetacean Hearing

<u>Finless porpoise utilize low frequency sounds – conservation implications</u>

Although porpoises are assumed to be high frequency hearing specialists (e.g. 100-150 kHz), researchers in China discovered that Yangtze river finless porpoise neonates produced low-frequency (2-3 kHz) pulsed sounds, and because "*the neonates emit low-frequency sounds more frequently when they are apart from the mother*" it was assumed that these are calls from the neonates to the mother. Although not discussed by the authors, these findings are important because lower frequency sounds may have greater impacts on this taxon than previously thought, particularly during a sensitive life stage. Of particular concern would be low frequency sounds such as shipping noise.

(SOURCE: Li, S., Wang, K., Wang, D., Dong, S. and Akamatsu, T. 2008. Simultaneous production of low- and high-frequency sounds by neonatal finless porpoises (L). *J. Acoust. Soc. Am.* 124: 716-718)

<u>Exposure to mid-frequency sounds and temporary threshold shift in a bottlenose dolphin</u>

An experiment was conducted on a bottlenose dolphin to determine the exposure levels from mid-frequency sounds (similar to active sonar pings) needed to cause temporary threshold shift (TTS), and to develop a model to predict TTS onset. The test subject was an 18-year-old, captive-born dolphin with a history of use in acoustic experiments – auditory evoked potential methodology was used. The results indicated that significant TTS occurred with longer but not shorter exposures. Higher source levels were required to induce TTS for shorter exposures. Recovery rates were relatively consistent but did show some indications that different exposure times may relate to different recovery rates. Some behavioural reactions, possibly indicative of aversive response to the stimulus, were observed. These results suggest that, as in terrestrial mammals, predicting bottlenose dolphin TTS is complicated.

(SOURCE: Mooney, T.A., Nachtigall, P.E., Breese, M., Vlachos, S. and Au, W.W.L. 2009. Predicting temporary threshold shifts in a bottlenose dolphin (*Tursiops truncatus*): The effects of noise level and duration. *J. Acoust. Soc. Am.* 125: 1816-1826)

Seismic Surveys

<u>Evaluation of seismic survey guidelines</u>

The United Kingdom's statutory conservation agency, the Joint Nature Conservation Committee (JNCC), developed guidelines in 1995 to minimise acoustic disturbance of marine mammals by oil and gas industry seismic surveys. These were the first national guidelines to be developed and have subsequently become the standard for international mitigation measures of seismic surveys. However, relatively few aspects of these measures have a firm scientific basis or proven efficacy. Existing guidelines do not offer adequate protection to marine mammals, given the complex propagation of airgun pulses; the difficulty of monitoring in particular the smaller, cryptic, and/or deep-diving species, such as beaked whales and porpoises; limitations in monitoring requirements; lack of baseline data; and other biological and acoustical complications or unknowns. Current guidelines offer a 'common sense' approach to noise mitigation, but in light of recent research and ongoing concerns, they should be updated, with broader measures needed to ensure adequate species protection and to address data gaps.

(SOURCE: Parsons, E.C.M., Dolman, S.J., Jasny, M., Rose, N.A., Simmonds, M.P. and Wright, A.J. 2009. A critique of the UK's JNCC seismic survey guidelines for minimising acoustic disturbance to marine mammals: Best practise? *Mar. Poll. Bull.* 58: 643-651)

<u>Testing the efficacy of the 'ramp-up' procedure as a mitigation measure for seismic surveys</u>

The 'ramp-up' or 'soft-start' is a standard mitigation measure used in seismic surveys. However, the efficacy this mitigation measure is poorly documented. A pod of 15 short-finned pilot whales was monitored before, during, and after a 30-min ramp-up procedure used in a 2-D seismic survey off Gabon. No change in behaviour was apparent during the initial period of the ramp-up. However, after 10 min, the nearest subgroup of animals turned sharply away from the airguns. After a subsequent period of milling, the group made a 180° change of course to travel in the opposite direction from the seismic vessel. This observation suggests that the whales initially demonstrated an avoidance response to the ramp-up. However, the movement away from the source was limited in time and space.

(SOURCE: Weir, C.R. 2008. Short-finned pilot whales (*Globicephala macrorhynchus*) respond to an airgun ramp-up procedure off Gabon. *Aquat. Mamm.* 34: 349-354)

Shipping

<u>Commercial vessels have the potential to affect whale communication</u>

This study suggested that, in certain areas characterized by relatively heavy commercial shipping traffic, vessel noise is at levels and within frequencies that warrant concern among managers regarding the ability of whales to maintain acoustic contact. Accordingly, the authors recommended "*the use of passive acoustic monitoring data to aid regional managers and maritime transport stakeholders in the development of proposals to the [International Maritime Organization], national regulatory agencies, and/or regional/local conventions to reroute and/or consolidate shipping traffic to minimize exposure of sensitive species to noise and risk of ship strike"*. They also recommended "*buffers for marine protected areas…with dimensions determined by the sensitivity of local species and local noise conditions)*". The concept of voluntary 'quiet zones' should be tested or implemented where appropriate. Finally, the authors recommended "*that future research explore the potential for using data from quasi-permanent, continuously recording passive acoustic monitoring systems to evaluate differences in ship noise profiles under different 'quieting' treatments*".

(SOURCE: Hatch, L., Clark, C., Merrick, R., Van Parijs, S., Ponirakis, D., Schwehr, K., Thompson, M. and Wiley, D. 2008. Characterizing the relative contributions of large vessels to total ocean noise fields: A case study using the Gerry E. Studds Stellwagen Bank National Marine Sanctuary. *Environ. Manage.* 42: 735-752)

<u>Exposure to boat noise reduces humpback whale singing behaviour</u>

A study on humpback whales in the Abrolhos Marine National Park in Brazil evaluated the responses of whales to boat traffic (e.g., whale-watching vessels) by measuring changes in male singing activity. The fluctuation in the number of singers over time was modelled in response to several variables, including exposure to boats, tide height and lunar phase. Boat traffic had an important negative effect on singing activity. Lunar phase and time of day also affected singing behaviour. The conclusion: adaptive management should aim at reducing the number of times whales are exposed to noise from each boat, which can improve the whale-watching experience and reduce the impact on male singing behaviour. It would also be "*important to address the need for enforcement of existing management guidelines, which clearly depends on political will and better prioritization of governmental resources*."

(SOURCE: Sousa-Lima, R.S. and Clark, C.W. 2008. Modeling the effect of boat traffic on the fluctuation of humpback whale singing activity in the Abrolhos National Marine Park, Brazil. *Canadian Acoustics* 36: 174-181)

Sonar

Review of strategies designed to reduce impact of military active sonar on marine mammals

Naval exercises, particularly those generating loud sounds such as sonar, are known to have an impact on at least certain cetacean species. The authors outline the three main standard methods to mitigate such impacts, namely planning the time and area for exercises, using certain operational procedures, and monitoring the animals to maintain an exclusion zone. The current shortcomings (e.g., mitigation during night-time and bad weather) are outlined and a call for improved international standards is made. The conclusion: the "*environmental duty of care*" does not need to come at the expense of navy training.

(SOURCE: Dolman, S.J., Weir, C.R. and Jasny, M. 2009. Comparative review of marine mammal guidance implemented during naval exercises. *Mar. Poll. Bull.* 59: 465-477)

Review of strandings associated with military active sonar use

Cetacean mass strandings associated with naval mid-frequency sonar use have mostly involved beaked whales, with common pathologies, although other cetacean species have also stranded coincident with naval exercises. Current mitigation measures have focused on preventing auditory damage (hearing loss), but the authors concluded that there are significant flaws with this approach. Behavioural responses, which occur at lower sound levels than those that cause hearing loss, may be more critical. The authors recommended revising current mitigation measures to address this. Moreover, important cetacean habitats should be avoided by naval vessels during training exercises using active sonar systems.

(SOURCE: Parsons, E.C.M., Dolman, S.J., Wright, A.J., Rose, N.A. and Burns, W.C.G. 2009. Navy sonar and cetaceans: Just how much does the gun need to smoke before we act? *Mar. Poll. Bull.* 56: 1248-1257)

Some cetacean responses to sonar may be anti-predator responses

Several recent reviews have examined the state of knowledge regarding impacts of anthropogenic noise on marine mammals. This newest review concludes that "*Although acute responses to intense sounds have generated considerable interest, the more significant risk to populations of marine mammals is likely to stem from less visible effects of chronic exposure*". One explanation for beaked whale mass strandings associated with sonar exercises is that the fundamental frequencies of the sonar signals are quite similar to the calls of killer whales (a beaked whale predator). "*In this case it may literally be more appropriate to call the response an anti-predator response rather than simple disturbance*". Anti-predator responses cost animals not only time and energy, but also lost opportunities. This review "*suggests the importance of some areas of research that have received less attention than observation of disturbance…The theories of predator risk and allostasis may help to provide a framework for progress in understanding the consequences to individuals and populations of disturbance caused by anthropogenic sound*".

(SOURCE: Tyack, P.L. 2008. Implications for marine mammals of large-scale changes in the marine acoustic environment. *J. Mammal.* 89: 549-558)

ACKNOWLEDGEMENTS

The editors would like once again 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 to obtain. The authors are especially grateful to the Government of Austria and Humane Society International for continuing to provide support for SOCER preparation, as requested by Resolution 2000-7. We also thank the IWC Scientific Committee for allotting funds for SOCER preparation in the 2009 SC budget.

Appendix 1

GLOSSARY

Species glossary

Atlantic white-sided dolphin	*Lagenorhynchus acutus*
Beluga whale	*Delphinapterus leucas*
Blainville's beaked whale	*Mesoplodon densirostris*
Common bottlenose dolphin	*Tursiops truncatus*
Common dolphin (long-beaked)	*Delphinus capensis*
Common dolphin (short-beaked)	*Delphinus delphis*
Common minke whale	*Balaenoptera acutorostrata*
Cuvier's beaked whale	*Ziphius cavirostris*
False killer whale	*Pseudorca crassidens*
Fin whale	*Balaenoptera physalus*
Ginkgo-toothed beaked whale	*Mesoplodon ginkgodens*
Gray whale	*Eschrichtius robustus*
Guiana dolphin	*Sotalia guianensis*
Harbour porpoise	*Phocoena phocoena*
Hector's dolphin	*Cephalorhynchus hectori*
Humpback whale	*Megaptera novaeangliae*
Indo-Pacific bottlenose dolphin	*Tursiops aduncus*
Indo-Pacific humpback dolphin	*Sousa chinensis*
Killer whale	*Orcinus orca*
Melon-headed whale	*Peponocephala electra*
North Pacific right whale	*Eubalaena japonica*
Pacific white-sided dolphin	*Lagenorhynchus obliquidens*
Pantropical spotted dolphin	*Stenella attenuata*
Risso's dolphin	*Grampus griseus*
Short-finned pilot whale	*Globicephala macrorhynchus*
Sperm whale	*Physeter macrocephalus*
Spinner dolphin	*Stenella longirostris*
Stejneger's beaked whale	*Mesoplodon stejnegeri*
Striped dolphin	*Stenella coeruleoalba*
Vaquita	*Phocoena sinus*
White-beaked dolphin	*Lagenorhynchus albirostris*
California sea lion	*Zalophus californianus*
Western gull	*Larus occidentalis*
Chinook salmon	*Oncorhynchus tshawytscha*
Jack mackerel	*Trachurus novaezelandiae*
Yellowfin tuna	*Thunnus albacares*

Element glossary

Ag	silver	Cu	copper	Pb	lead
As	arsenic	Fe	iron	Se	selenium
Cd	cadmium	Hg	mercury	Sn	tin
Co	cobalt	Mn	manganese	Zn	zinc
Cr	chromium	Ni	nickel		

Glossary of terms

2,2'-diMeO-BB 80: See PBDMB.

µg: Microgram.

Allostasis: This term refers to mechanisms that allow an organism to regain equilibrium in the face of external challenges; compare to 'homeostasis', which represents mechanisms to regain equilibrium in the face of internal changes.

Aquaculture: Finfish or shellfish farming.

BFR: Brominated flame retardant.

Bioaccumulation: Increase in concentration of a pollutant from the environment to the first organism in a food chain.

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

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

Brominated: Containing the element bromine.

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

cELISA: Competitive enzyme labeled immunosorbent assay.

Chlordane: A chlorinated hydrocarbon used as a pesticide.

CITES: Convention on International Trade in Endangered Species of Wild Fauna and Flora.

CoP: Code of Practise.

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

DBT: Dibutyltin. See butyltin.

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.

Diatom: Common type of phytoplankton, a one-celled alga encased in a silica cell wall. The species *Pseudo-nitzschia australis* produces domoic acid, which poisons mammals, causing paralysis and reproductive failure.

Dieldrin: A chlorinate hydrocarbon used as an insecticide.

Domoic acid: See diatom.

DPT: Diphenyltin is used in polymer manufacturing. See phenyltin.

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.

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

FMD: Floating marine debris.

Fluorinated: Containing the element fluorine.

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

HBCD: hexabromocyclododecane, a flame retardant

HCB: Hexachlorobenzene, an environmentally persistent organochlorine fungicide.

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

Hypoxia: Low oxygen levels.

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

IUCN: International Union for Conservation of Nature.

IUU: Illegal, unregulated, and unreported (used in reference to commercial fishing).

JARPN II: Japanese Whale Research Programme under Special Permit in the Western North Pacific – Phase II

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

Lobomycosis: A chronic fungal infection of the skin affecting humans in South America and two species of dolphins.

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.

MBT: Monobutyltin (see butyltin).

MeHg: Methyl mercury.

Milling: When a group of cetaceans circles in a small area or moves about haphazardly, sometimes seen when the group is foraging, but also a sign of impending direction change. Sometimes indicative of distress.

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

MPT: Monophenyltin. See phenyltin.

Neurotoxin: Any toxin acting on nerve cells.

Nocardiosis: An infectious bacterial disease typically affecting the lung and causing pneumonia and a high rate of mortality in humans (50%).

Oocyst: Thick-walled spore phase of certain sporozoans, such as *Toxoplasma*.

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.

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

PBDE: Polybrominated diphenyl ether(s), a widely used class of flame retardants in textiles, furniture upholstery and plastics.

PBDMB: Polybrominated dimethoxybiphenyls, brominated natural products of which the form 2,2'-dimethoxy-3,3',5,5'-tetrabromobiphenyl (2,2'-diMeO-BB 80) is the most commonly found in Queensland marine mammals.

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.

PCR: Polymerase chain reaction.

Perfluorinated compounds: A class of environmentally persistent molecules with fluorine atoms attached, used in many industrial applications including fire-fighting foams, pesticides and surface coatings. See PFOS.

PFNA: Perfluorononanoate.

PFDA: Perfluorodecanoate.

PFDoDA: Perfluorododecanoate.

PFOS: Perfluorooctane sulfonate.

PFOSA: Perfluorooctanesulfonamide.

PFUnDA: Perfluoroundecanoate.

Phenyltin: A class of organotin compounds that are used for a variety of industrial purposes, similar to butyltins and in some cases similarly toxic.

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

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

Sporozoan: Parasitic unicellular organisms of the class Sporozoa, often pathogenic, most of which reproduce sexually and asexually in alternate generations, often in different hosts, by means of spores.

TBT: Tributyltin. See butyltin.

TPT: Triphenyltin is used as an active component of antifungal paints and agricultural fungicides. See phenyltin.

Trophic level: Each level in a food chain, including decomposers, producers (photo- and chemo-synthesizers), and consumers.

Wet weight: See dry weight.

Zoonoses (plural): Singular, zoonosis. Infectious diseases that can be transmitted from vertebrate animals to humans or in the reverse direction.

Table 1: Maximum butyltin concentrations in cetacean tissues from the Pacific (µg.g^{-1})

Location	Species	Tissue	Weight	MBT	DBT	TBT	ΣBT	MPT	DPT	TPT	ΣPT	Reference
Thailand	Bryde's whale	blubber	wet	0.093	0.037	0.083	0.213	0.057	0.014	0.802	0.872	Harino *et al.*
		heart	wet	0.057	0.021	0.035	0.134	0.055	0.061	0.166	0.237	(2007)
		kidney	wet	0.080	0.039	0.054	0.162	0.019	0.025	0.081	0.106	
		liver	wet	0.063	0.036	0.071	0.147	<0.001	0.006	0.202	0.202	
		lung	wet	0.098	0.019	0.025	0.142	<0.001	<0.001	0.055	0.055	
		muscle	wet	0.049	0.021	0.028	0.098	0.021	0.007	0.035	0.041	
		stomach	wet	0.067	0.020	0.078	0.021	0.007	<0.001	0.250	0.250	
	False killer whale	blubber	wet	0.093	0.053	0.245	0.391	0.067	0.010	0.081	0.158	Harino *et al.*
		heart	wet	0.064	0.049	0.236	0.349	0.112	0.011	0.165	0.263	(2007)
		kidney	wet	0.273	0.129	0.299	0.408	0.096	0.014	0.310	0.366	
		liver	wet	0.916	2.870	1.071	4.86	0.549	0.028	0.592	1.14	
		lung	wet	0.636	0.033	0.115	0.784	0.027	0.014	0.008	0.043	
		muscle	wet	0.066	0.424	0.242	0.732	0.052	0.017	0.694	0.763	
		spleen	wet	0.038	0.032	0.138	0.208	0.011	0.007	0.023	0.041	
	Pygmy killer whale	blubber	wet	0.061	0.058	0.022	0.141	<0.001	0.007	0.406	0.413	Harino *et al.*
		muscle	wet	0.073	0.434	0.140	0.647	0.027	0.005	0.104	0.136	(2007)
	Short-finned pilot whale	blubber	wet	0.140	0.056	0.127	0.323	0.041	0.017	<0.001	0.058	Harino *et al.*
		heart	wet	0.042	0.041	0.132	0.215	0.034	0.012	0.015	0.061	(2007)
		liver	wet	0.148	0.244	0.154	0.546	0.037	0.013	0.016	0.063	
		muscle	wet	0.063	0.028	0.100	0.191	0.052	0.009	0.006	0.067	
	Sperm whale	blubber	wet	0.036	0.018	0.055	0.109	<0.001	0.011	0.402	0.413	Harino *et al.*
		liver	wet	0.033	0.133	0.139	0.285	0.045	0.011	0.050	0.106	(2007)
		muscle	wet	0.033	0.041	0.020	0.094	<0.001	0.008	0.269	0.277	
	Bottlenose dolphin	blubber	wet	0.026	0.009	0.004	0.038	<0.001	<0.001	0.007	0.007	Harino *et al.*
		heart	wet	0.022	0.012	0.018	0.045	<0.001	<0.001	0.010	0.010	(2008)
		kidney	wet	0.019	0.042	0.023	0.079	<0.001	<0.001	<0.001	<0.001	
		liver	wet	0.037	0.293	0.225	0.555	<0.001	<0.001	0.005	0.005	
		lung	wet	0.016	0.012	0.006	0.031	<0.001	<0.001	<0.001	<0.001	
		muscle	wet	0.014	0.009	0.009	0.031	<0.001	<0.001	0.003	0.003	
	Finless porpoise	blubber	wet	0.016	0.013	0.007	0.031	<0.001	<0.001	<0.001	<0.001	Harino *et al.*
		heart	wet	0.021	0.012	0.019	0.047	<0.001	<0.001	0.006	0.006	(2008)
		kidney	wet	0.016	0.009	0.009	0.034	<0.001	<0.001	0.002	0.002	
		liver	wet	0.027	0.073	0.031	0.122	<0.001	<0.001	<0.001	<0.001	
		lung	wet	0.019	0.014	0.004	0.037	<0.001	<0.001	0.006	0.006	
		muscle	wet	0.019	0.009	0.006	0.034	<0.001	<0.001	<0.001	<0.001	
	Long-beaked common	heart	wet	0.025	0.024	0.036	0.085	<0.001	0.002	0.009	0.011	Harino *et al.*
	common dolphin	kidney	wet	0.015	0.024	0.017	0.056	<0.001	<0.001	0.001	0.001	(2008)
		liver	wet	0.093	0.588	0.471	1.152	<0.001	<0.001	<0.001	<0.001	
		lung	wet	0.018	0.015	0.007	0.04	<0.001	<0.001	<0.001	<0.001	
		muscle	wet	0.016	0.013	0.033	0.062	<0.001	0.005	0.01	0.015	
	Indo-Pacific humpback	blubber	wet	0.009	0.006	0.002	0.017	<0.001	<0.001	0.062	0.062	Harino *et al.*
	dolphin	heart	wet	0.013	0.008	0.004	0.025	<0.001	<0.001	0.011	0.011	(2008)
		kidney	wet	0.016	0.016	0.005	0.037	<0.001	<0.001	0.004	0.004	
		liver	wet	0.023	0.127	0.015	0.165	<0.001	<0.001	<0.001	<0.001	
		lung	wet	0.010	0.006	0.001	0.017	<0.001	<0.001	<0.001	<0.001	
		muscle	wet	0.012	0.002	0.002	0.016	<0.001	<0.001	<0.001	<0.001	
	Spotted dolphin	blubber	wet	0.086	0.067	0.019	0.161	<0.001	0.015	0.015	0.018	Harino *et al.*
		heart	wet	0.088	0.022	0.025	0.133	<0.001	0.020	0.006	0.022	(2008)
		kidney	wet	0.101	0.346	0.033	0.480	<0.001	0.006	0.003	0.009	
		liver	wet	0.082	0.131	0.062	0.275	<0.001	0.005	0.002	0.005	
		lung	wet	0.048	0.041	0.012	0.095	<0.001	0.004	0.002	0.005	
		muscle	wet	0.051	0.030	0.022	0.095	<0.001	0.004	0.004	0.006	
	Spinner dolphin	blubber	wet	0.069	0.015	0.013	0.097	<0.001	0.005	0.004	0.009	Harino *et al.*
		heart	wet	0.066	0.018	0.034	0.118	<0.001	0.007	0.004	0.011	(2008)
		kidney	wet	0.057	0.024	0.032	0.113	<0.001	0.007	0.001	0.008	
		liver	wet	0.098	0.218	0.085	0.401	<0.001	0.007	0.002	0.009	
		lung	wet	0.059	0.016	0.014	0.089	<0.001	0.009	0.002	0.011	
		muscle	wet	0.046	0.020	0.030	0.096	<0.001	0.005	0.002	0.007	
	Striped dolphin	blubber	wet	0.116	0.026	0.015	0157	<0.001	0.017	0.014	0.018	Harino *et al.*
		heart	wet	0.066	0.027	0.043	0.136	<0.001	0.010	0.062	0.062	(2008)
		kidney	wet	0.105	0.032	0.042	0.179	<0.001	0.010	0.004	0.014	
		liver	wet	0.066	0.176	0.136	0.378	<0.001	0.019	0.007	0.019	
		lung	wet	0.046	0.019	0.018	0.083	<0.001	0.010	0.004	0.012	
		muscle	wet	0.036	0.015	0.028	0.079	<0.001	0.009	0.016	0.016	

(SOURCE: Harino, H., Ohji, M., Wattayakorn, G., Adulyanukosol, K., Arai, T. and Miyazaki, N. 2007. Accumulation of organotin compounds in tissues and organs of stranded whales along the coasts of Thailand. *Arch. Environ. Contam. Toxicol*. 53: 119–125; Harino, H., Ohji, M., Wattayakorn, G., Adulyanukosol, K., Arai, T. and Miyazaki, N. 2008. Accumulation of organotin compounds in tissues and organs of dolphins from the coasts of Thailand. *Arch. Environ. Contam. Toxicol.* 54: 145-153)

Table 2: Maximum trace element concentrations in cetacean tissues from the Western Pacific (µg g^{-1})

Location	Species	Tissue	Weight	Hg	Cd	Zn	Pb	As	Co	Cr	Cu	Fe	Mn	Ni	Se	Ag	Sn	Reference
New Zealand	Common dolphin	Blubber	Wet	1.7	0.19	100	-	1.7	<0.02	<0.1	4.5	26	0.11	0.71	20	<0.02	0.063	Stockin *et al.* (2007)
		Liver	Wet	110.0	21	73		0.32	<0.02	<0.1	14	250	4.8	<0.1	39	1.2	0.09	
		Kidney	Wet	8.1	52	37		0.13	0.031	<0.1	5.4	150	0.78	<0.1	6.4	0.033	0.05	
Northwest Pacific Ocean	Common minke whale	Muscle	Wet	0.43	-	-	-	-	-	-	-	-	-	-	-	-	-	Endo *et al.* (2007a)
	Cuvier's beaked whale	Muscle	Wet	0.43	-	-	-	-	-	-	-	-	-	-	-	-	-	
	Blainville's beaked whale	Muscle	Wet	3.30	-	-	-	-	-	-	-	-	-	-	-	-	-	
	Stejneger's beaked whale	Muscle	Wet	3.57	-	-	-	-	-	-	-	-	-	-	-	-	-	
	Harbour porpoise	Muscle	Wet	0.54	-	-	-	-	-	-	-	-	-	-	-	-	-	
	Finless porpoise	Muscle	Wet	1.81	-	-	-	-	-	-	-	-	-	-	-	-	-	
	Common dolphin	Muscle	Wet	1.89	-	-	-	-	-	-	-	-	-	-	-	-	-	
	Pacific white-sided dolphin	Muscle	Wet	1.61	-	-	-	-	-	-	-	-	-	-	-	-	-	
	Risso's dolphin	Muscle	Wet	1.85	-	-	-	-	-	-	-	-	-	-	-	-	-	
	Common bottlenose dolphin	Muscle	Wet	25.0	-	-	-	-	-	-	-	-	-	-	-	-	-	
	False killer whale	Muscle	Wet	41.0	-	-	-	-	-	-	-	-	-	-	-	-	-	
	Killer whale	Muscle	Wet	13.3	-	-	-	-	-	-	-	-	-	-	-	-	-	
Northern Japan	Killer whale	Liver	Wet	97.8	11.5	93.5	-	-	-	-	16.3	335	3.64	-	-	-	-	Endo *et al.* (2007b)
		Kidney	Wet	10.4	18.0	30.9	-	-	-	-	4.53	156	1.18	-	-	-	-	
		Muscle	Wet	1.46	-	38.6	-	-	-	-	1.95	178	0.27	-	-	-	-	
South Australia	Indo-Pacific bottlenose dolphin	Liver	Wet	2651	99.95	453	14.15	-	-	-	73.71	-	-	-	1188	-	-	Lavery *et al.* (2008) and (2009)
		Bone	Wet	-	0.33	-	16.00	-	-	-	-	-	-	-	-	-	-	
	Common bottlenose dolphin	Liver	Wet	772	20.00	68	0.11	-	-	-	85.04	-	-	-	253	-	-	Lavery *et al.* (2009)
		Bone	Wet	-	-	-	1.11	-	-	-	-	-	-	-	-	-	-	
	Common dolphin	Liver	Wet	165	10.92	175	0.13	-	-	-	71.18	-	-	-	63	-	-	Lavery *et al.* (2009)
		Bone	Wet	-	-	-	2.41	-	-	-	-	-	-	-	-	-	-	

(SOURCES: Stockin, K.A., Law R.J., Duignan, P.J., Jones, G.W., Porter, L., Mirimin, L., Meynier L., and Orams, M.B. 2007. Trace elements, PCBs and organochlorine pesticides in New Zealand common dolphins (*Delphinus* sp.). Sci. Total Environ. 387: 333–345; SOURCE: Endo, T., Ma, Y.U, Baker, C.S., Funahashi, N., Lavery, S., Dalebout, M.L., Lukoschek, V. and Haraguchi, K. 2007a. Contamination level of mercury in red meat products from cetaceans available from South Korea markets. *Mar. Poll. Bull.* 54: 669–677; Endo, T., Kimura, O., Hisamichi, Y., Minoshima, Y. and Haraguchi, K. 2007b. Age-dependent accumulation of heavy metals in a pod of killer whales (*Orcinus orca*) stranded in the northern area of Japan. *Chemosphere* 67: 51-59; Lavery, T.J., Butterfield, N., Kemper, C.M., Reid, R.J. and Sanderson, K. 2008. Metals and selenium in the liver and bone of three dolphin species from South Australia, 1988-2004. *Sci. Tot. Environ.* 390: 77-85; Lavery, T.J., Kemper, C.M., Sanderson, K., Schultz, C.G., Coyle, P., Mitchell, J.G. and Seuront, L. 2009. Heavy metal toxicity of kidney and bone tissues in South Australian adult bottlenose dolphins (*Tursiops aduncus*). *Mar. Environ. Res.* 67: 1-7)

Table 3. Maximum fluorinated hydrocarbon concentrations in cetacean tissues from the Pacific (ng g^{-1})

Location	Species	Tissue	Weight	PFOS	PFOSA	PFNA	PFDA	PFUnDA	PFDoDa	ΣPFC	Reference
Japan	Melon headed whales	Liver	Wet	117	111	20.9	20.5	101	22.8	215#	Hart *et al.* (2008)
Hong Kong	Indo-Pacific humpback dolphin	Liver	Wet	693	37.6	21.6	40.2	120	10.9	361#	Yeung *et al.* (2009)
	Finless porpoise	Liver	Wet	262	7.82	12.2	8.52	34.3	2.23	186#	

Highest mean value

(SOURCE: Hart, K., Kannan, K., Isobe, T., Takahashi, S., Yamada, T.K., Miyazaki, N. and Tanabe, S. 2008. Time trends and transplacental transfer of perfluorinated compounds in melon-headed whales stranded along the Japanese Coast in 1982, 2001/2002, and 2006. *Environ. Sci. Technol.* 42: 7132–7137; Yeung, L.W.Y., Miyake, Y., Wang, Y., Taniyasu, S., Yamashita, N. and Lam, P.K.S. 2009. Total fluorine, extractable organic fluorine, perfluorooctane sulfonate and other related fluorochemicals in liver of Indo-Pacific humpback dolphins (*Sousa chinensis*) and finless porpoises (*Neophocaena phocaenoides*) from South China. *Environ. Poll.* 157: 17-23)

Table 4. Maximum organic contaminant levels in cetacean tissues from the Pacific (µg.g^{-1})

Location	Species	Tissue	Weight	ΣHCH	HCB	DDE	DDD	*o,p'*-DDT	*p,p'*-DDT	ΣDDT	ΣPCB	Dieldrin	ΣPBDE	ΣChlordane	HP-epox	TCPMe	TCPMOH	Reference
USA	Killer whale	Blubber	lipid	1.30	1.60	-	-	-	-	160	180	-	15	14.0	-	-	-	Krahn *et al.* (2007)
Japan	Finless porpoise	Brain	wet	-	-	-	-	-	-	-	0.33	-	-	-	-	-	-	Kunisue *et al.* (2007)
	Striped dolphin	Brain	wet	-	-	-	-	-	-	-	0.62	-	-	-	-	-	-	Kunisue *et al.* (2007)
	Melon-headed whale	Blubber	lipid	0.43	0.51	-	-	-	-	73	34	-	0.51	6.9	0.23	0.092	0.36	Kajiwara *et al.* (2007)
		Brain	wet	-	-	-	-	-	-	-	0.16	-	-	-	-	-	-	Kunisue *et al.* (2007)
	Killer whale	Blubber	lipid	-	6.24	237	-	-	-	240	68.2	-	0.64	79.7	-	-	-	Haraguchi *et al.* (2009)
New Zealand	Common Dolphin	Blubber	lipid	0.004	0.13	3.9	0.14	0.32	0.14	4.43	1.634[1]	0.1	-	0.036		-	-	Stockin *et al.* (2007)

[1] 45 PCB congeners

(SOURCES: Haraguchi, K., Yohsuke Hisamichi, Y., Endo, T. 2009. Accumulation and mother-to-calf transfer of anthropogenic and natural organohalogens in killer whales (*Orcinus orca*) stranded on the Pacific coast of Japan. *Sci. Total Environ.*407: 2853–2859; Kajiwara, N., Kamikawa, S., Amano, M., Hayano, A., Yamada, T.K., Miyazaki, N. and Tanabe, S. 2008. Polybrominated diphenyl ethers (PBDEs) and organochlorines in melon-headed whales, *Peponocephala electra*, mass stranded along the Japanese coasts: maternal transfer and temporal trend. *Environ. Pollut.* 15: 106-114; Krahn, M.M., Hanson, M.B., Baird, R.W., Boyer, R.H., Burrows, D.G., Emmons, C.K., Ford, J.K.B., Jones, L.L., Noren, D.P., Ross, P.S., Schorr, G.S. and Collier, T.K. 2007. Persistent organic pollutants and stable isotopes in biopsy samples (2004/2006) from Southern Resident killer whales. *Mar. Pollut. Bull.* 54: 1903–1911; Kunisue, T. , Sakiyama, T., Yamada,T.K., Takahashi, S., and Tanabe, S. 2007. Occurrence of hydroxylated polychlorinated biphenyls in the brain of cetaceans stranded along the Japanese coast. *Mar. Pollut. Bull.* 54: 963–973; Stockin, K.A., Law R.J., Duignan, P.J., Jones, G.W., Porter, L., Mirimin, L., Meynier L., and Orams, M.B. 2007. Trace elements, PCBs and organochlorine pesticides in New Zealand common dolphins (*Delphinus* sp.). *Sci. Total Environ.* 387: 333-345)