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The Conservation of British Cetaceans: A Review of the Threats and Protection Afforded to Whales, Dolphins, and Porpoises in UK Waters, Part 1

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EXECUTIVE SUMMARY

This review covers the established and emerging threats affecting cetaceans and makes a series of recommendations that should be urgently implemented if the policy makers in the UK truly plan to meet their conservation commitments and save the British whales and dolphins for generations to come.

1. THREATS TO UK CETACEANS

Evaluating the threats to cetaceans in the UK is problematic to say the least. Outside of, perhaps, entanglement in fishing gear,[3] there has been little research to evaluate the scale and impact of various threats to the cetacean populations that use UK waters. Rates of mortality due to certain factors could be broadly and very grossly estimated by the number of animals found stranded on beaches where a particular factor could be taken to be the cause of death (e.g., injuries present are consistent with entanglement in fishing gear, marine

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[3] *E.g.*, N.J.C. Tregenza *et al.*, *Harbour Porpoise* (Phocoena Phocoena L.) *By-Catch in Set Gillnets in the Celtic Sea*, 54 ICES J. of Marine Sci. 896 (1997); 47 N.J.C. Tregenza *et al.*, *Common Dolphin* Delphinus Delphis L., *Bycatch in Bottom Set Gill Nets in the Celtic Sea, in* Reports of the International Whaling Commission 835 (1997) [hereinafter 1997 Report]; 48 N.J.C. Tregenza *et al.*, *Common Dolphin* Delphinus Delphus *Bycatch in Pelagic Trawl and Other Fisheries in the North East Atlantic, in* Reports of the International Whaling Commission 453 (1998) [hereinafter 1998 Report].

litter, or due to boat-caused injuries). But these rates of mortality do not take into account killed or injured animals that did not wash up onto beaches, or did wash up, but were not found and reported to the relevant authorities. Nor do they take into account less obvious or cryptic factors, which may cause decreases in cetacean health, or increase the likelihood of mortality, but are not readily apparent (for example, chemical or biological pollutants, or stress caused by habitat degradation or noise).

In any event, the UK does not currently have thorough estimates of the number of cetaceans present in UK waters, trends in population sizes, or cetacean patterns of habitat use. These deficiencies add to the difficulty in determining the significance of the various threats that affect UK cetaceans. This is particularly compounded for some species such as common dolphins (*Delphinus delphis*), which may move great distances, following highly mobile prey, and may even cross national boundaries during their movements.

However, basic information exists for several issues which either may be (or are known to be) a significant threat to cetaceans in UK waters. These issues can be broadly divided into: directed takes, incidental takes, chemical and noise pollution, and habitat degradation.

1.1 Directed Takes

Directed takes refer to activities that are specifically directed towards the killing or capturing of cetaceans. There are many directed takes of cetaceans globally, including commercial hunts for whales, as well as hunts on an aboriginal/subsistence basis[4] (see Section 2.1.6, Part 2). For example, Norway presently conducts a commercial hunt of approximately 700 northern minke whales (*Balaenoptera acutorostrata*) in the North East Atlantic area, and the Norwegian government has stated that this quota will increase to more than 1,000 animals.

The governments of Japan and Iceland are also currently conducting lethal directed takes of cetaceans for "scientific" purposes, although to call these catches "scientific" is very misleading. These scientific takes are effectively commercial whaling in everything but name.[5] Directed takes can also take the form of culls, that is, killing cetaceans in the name of removing a potential competitor for fisheries resources.[6] The Norwegian government is

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[4] *See generally* C. Stroud, *The Ethics and Politics of Whaling, in* THE CONSERVATION OF WHALES AND DOLPHINS: SCIENCE AND PRACTICE 55–58 (M.P. Simmonds & J.D. Hutchinson eds., 1996); R.R. REEVES *ET AL.*, DOLPHINS, PORPOISES AND WHALES: 2002–2010 CONSERVATION ACTION PLAN FOR THE WORLD'S CETACEANS (2003).

[5] N.J. Gales *et al.*, *Japan's Whaling Plan under Scrutiny,* 435 NATURE 883–884 (2005).

[6] M. Earle, *Ecological Interactions Between Cetaceans and Fisheries, in* THE CONSERVATION OF WHALES AND DOLPHINS: SCIENCE AND PRACTICE 167–204 (M.P. Simmons & J.D. Hutchinson eds., 1996).

currently using the idea that minke whales compete with human fishermen over depleted fish stocks as another justification for hunting minke whales.[7]

Non-lethal takes for cetaceans can also occur, such as live captures of animals for aquariums and marine theme parks. Live captures can also cause depletion of wild populations of cetaceans,[8] and live captures in several parts of the world have become a conservation issue.[9]

The UK ceased whaling in 1963. Commercial whaling (see Section 2.1.6, Part 2) and directed capturing or killing cetaceans in UK waters—up to 200 nautical miles from the coastline—was made illegal under the 1981 Fisheries Act,[10] the Wildlife and Countryside Act (Section 2.4.1, Part 2), and the EU Habitats Directive (Section 2.3.1, Part 2).

Beyond 200 nautical miles from the UK coastline, cetaceans can be hunted, and at present, lethal takes of cetaceans in waters adjacent to the UK are primarily conducted by Norwegian whaling boats targeting northern minke whales. Concern has been expressed that Norwegian whaling operations may take minke whales that inhabit UK waters for part of the year, but whose movements and migrations take them into Norwegian whaling grounds at other times.[11]

However, there currently is no information regarding the migration patterns and routes of the minke whales in UK waters or their population structure. Nor are Norwegian whaling vessels required to give details of where they take their catch. Therefore, the impact of commercial whaling upon UK cetacean populations remains unknown.[12]

1.2 Incidental Takes

Incidental takes are those in which cetaceans are killed or injured accidentally, or as a result of activities that are not specifically targeting cetaceans. The main known source of incidental take in the UK is entanglement in fishing gear.

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[7] P.J. Corkeron, *Fishery Management and Culling,* 306 SCI. 1891(2004).

[8] The IUCN Cetacean Specialist Group states,

> Removal of live cetaceans from the wild, for captive display and/or research, is equivalent to incidental or deliberate killing, as the animals brought into captivity (or killed during capture operations) are no longer available to help maintain their natural populations. When unmanaged and undertaken without a rigorous program of research and monitoring, live-capture can become a serious threat to local cetacean populations.

REEVES, *supra* note 5, at 17.

[9] NAOMI A. ROSE *ET AL.*, THE CASE AGAINST MARINE MAMMALS IN CAPTIVITY 7 (3rd ed. 2006).

[10] The Fisheries Act (1981) amended the Whaling Industry (Regulations) Act (1934).

[11] E.C.M Parsons *et al.*, *Cetacean Conservation in Northwest Scotland: Perceived Threats to Cetaceans,* 13 EUR. RES. ON CETACEANS 128, 128 (1999).

[12] For more information on whaling, see Section 2.1.6.

In addition, entanglement and ingestion of marine litter and strikes by boat traffic are causes for concern.

1.2.1 Entanglement in Fishing Gear

Accidental entanglement of whales and dolphins in fishing gear is generally considered to be a major source of cetacean mortality worldwide.[13] This "bycatch" of cetaceans occurs in the UK[14] and is a major conservation issue: for example, levels of harbour porpoise (*Phocoena phocoena*) bycatch in gill nets in the Celtic[15] and North[16] Seas are thought to be unsustainable and causing a decline in porpoise populations in these areas. It is believed that the echolocation clicks of harbour porpoises are unable to detect monofilament (or multi-filament) gill nets; thus, porpoises swim into and become entangled in these types of net.

In addition to harbour porpoises, dolphin bycatch has been reported as the result of gill net[17] and trawl fishing.[18] In particular, high levels of common dolphin (*Delphinus delphis*) mortality have been reported in south-western UK waters.[19] During the winter of 2003/2004, more than 250 cetaceans were stranded on the beaches of south-western England showing signs of bycatch. Between November 2004 and April 2005, a further 119 cetaceans were reported. This mortality rate is likely a fraction of the actual mortality rate as many animals do not strand. Indeed, fishermen catching the animals may attempt to sink by-caught carcasses to avoid discovery. The main culprit for this particular bycatch issue is believed to be the pair trawl fishery for bass.

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[13] A.J. Read *et al.*, *Incidental Catches of Small Cetaceans, in* THE CONSERVATION OF WHALES AND DOLPHINS: SCIENCE AND PRACTICE 109–128 (M.P. Simmons & J.D. Hutchinson eds., 1996); A.J. READ *ET AL.*, BY-CATCHES OF MARINE MAMMALS IN US FISHERIES AND A FIRST ATTEMPT TO MEASURE THE MAGNITUDE OF GLOBAL MARINE MAMMAL BY-CATCH (2003); Y. Morizur *et al.*, *Bycatch and Discarding in Pelagic Trawl Fisheries, in* REPORT TO THE EUROPEAN COMMISSION DGXIV ON STUDY BIOECO/93/017 182 (1999); Y. Morizur *et al.*, *Incidental Catches of Marine-Mammals in Pelagic Trawl Fisheries of the Northeast Atlantic,* 41 FISHERIES RES. 297–307 (1999).

[14] J.R. Baker, *Causes of Mortality and Parasites in Incidental Lesions in Harbour Porpoises* (Phocoena Phocoena) *from British Waters*, 130 VETERINARY REC. 554–558, 569–572 (1992); J.K. Kirkwood *et al.*, *Entanglement in Fishing Gear and Other Causes of Death in Cetaceans Stranded on the Coasts of England and Wales,* 141 VETERINARY REC. 94–98 (1997).

[15] Tregenza, *supra* note 4.

[16] S.P. NORTHRIDGE & P.S. HAMMOND, ESTIMATION OF PORPOISE MORTALITY IN UK GILL AND TANGLE NET FISHERIES IN THE NORTH SEA AND WEST OF SCOTLAND (1999).

[17] 1997 REPORT, *supra* note 4.

[18] 1998 REPORT, *supra* note 4.

[19] T. Kuiken *et al.*, *Mass Mortality of Common Dolphins* (Delphinus Delphis) *in South-West England Due to Incidental Capture in Fishing Gear,* 134 VETERINARY REC. 81–89 (1995); T. Kuiken *et al.*, *PCBs Cause of Death and Body Condition in Harbour Porpoises* (Phocoena Phocoena) *From British Waters,* 24 AQUATIC TOXICOLOGY 13–28 (1994).

Assessing the full scale of the cetacean bycatch problem is difficult because not all fisheries have been properly monitored and assessed. Another problem in monitoring and dealing with the fisheries bycatch issue is that many of the fishing vessels operating in UK waters are owned and operated by foreign (often Spanish or French) nationals, but are registered to a UK port allowing them to fish in UK waters. These "flagships" rarely use the UK as a homeport and their movements are unpredictable. Consequently, it is difficult to assess levels of bycatch for these vessels or manage their activities.

Another issue that makes management of bycatch difficult is that cetaceans are not just entangled in "active" fishing gear, but also in discarded gear. Animals entangled in such "ghost" fishing nets are rarely documented,[20] and since the net is no longer in possession of fishermen, safe removal of animals entangled in discarded gear is not an option to reduce mortality rates.

Although fishing nets are typically associated with cetacean bycatch, other forms of fishing can also cause entanglements. In 1987, a minke whale was found entangled in a kreel (lobster pot) line in western Scotland. Additionally, these lines have been reported to have caused entanglement of other minke whales and even harbour porpoises in other areas.[21]

1.2.2 Marine Litter

The impacts of anthropogenic debris and litter upon marine life have become global causes of concern.[22] Around the world, an estimated one million birds and one hundred thousand marine mammals and sea turtles die each year either from entanglement in plastics or plastic ingestion.[23]

Entanglement in marine debris can result in the asphyxiation of cetaceans if they are unable to reach the surface or death from starvation or predation if entangled near the surface (these are incidental takes).[24]

Moreover, marine litter can also cause:[25]

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[20] T. Matsuoka *et al.*, *A Review of Ghost Fishing: Scientific Approaches to Evaluation and Solutions,* 71 FISHERIES SCI. 691–702 (2005).

[21] J. H. SHRIMPTON & E.C.M. PARSONS, CETACEAN CONSERVATION IN WEST SCOTLAND 85 (2000).

[22] *See* Robert H. Day & David G. Shaw, *Patterns in the Abundance of Pelagic Plastic and Tar in the North Pacific Ocean, 1976–1985*, 18 MARINE POLLUTION BULL. 311 (1987); José G.B. Derraik, *The Pollution of the Marine Environment by Plastic Debris: A Review*, 44 MARINE POLLUTION BULL. 842 (2002); David W. Laist, *Overview of the Biological Effects of Lost and Discarded Plastic Debris in the Marine Environment*, 18 MARINE POLLUTION BULL. 319 (1987); Douglas A. Wolfe, *Persistent Plastic and Debris in the Ocean: An International Problem of Ocean Disposal*, 18 MARINE POLLUTION BULL. 303 (1987).

[23] D.W. Laist, *Impacts of Marine Debris: Entanglement of Marine Life in Marine Debris Including a Comprehensive List of Species With Entanglement and Ingestion Records*, *in* MARINE DEBRIS: SOURCES, IMPACTS AND SOLUTIONS 99 (J.M. Coe & D.B. Rogers eds., 1997).

[24] *Id.*; Laist, *supra* note 23.

[25] Laist, *supra* note 23; Laist, *supra* note 24.

1. Reduced manoeuvrability—trailing debris creates drag, thus reducing the cetacean's ability to forage or avoid predators;
2. Physical trauma—debris may cut into the skin and other tissues of the entangled cetacean, particularly as it grows, causing significant debilitating wounds, which may also become infected; or
3. Reduced circulation—debris may become so tightly wrapped around a cetacean's appendage that growth of the appendage may be restricted, leading to deformities, or blood circulation to the appendage may be reduced or may even cease altogether.

The ingestion of marine debris by cetaceans has been documented in several species,[26] including the northern minke whales (*Balaenoptera acutorostrata*)[27] and harbour porpoises (*Phocoena phocoena*).[28] Such ingestion of marine litter could result in:[29]

1. Physical damage of the digestive tract—lacerations, ulcerations, and even piercing of the alimentary canal, which may cause starvation, or infection and septicaemia—the result of faecal waste spilling into the body cavity;
2. Mechanical blockages—preventing the passage of food materials through the digestive tract, ultimately leading to starvation;
3. Impaired foraging efficiency—as ingested, indigestible debris may cause a false sense of satiation or hamper the absorption of nutrients from the digestive system; or
4. The release of toxic pollutants—toxic chemical components of the ingested materials may leach out (e.g., toxic plasticisers) or ingested materials may be coated with toxic chemicals adhering to the surface of the debris.

The types of litter that pose the most threat to cetaceans include discarded fishing nets and net fragments ("ghost" nets; see Section 1.2.1), bags, plastic

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[26] N.B. Barros *et al.*, *Ingestion of Plastic Debris by Stranded Marine Mammals From Florida*, 1 PROC. OF SECOND INT'L CONF. ON MARINE DEBRIS 746 (1990); E. R. Secchi & S. Zarzur, *Plastic Debris Ingested by a Blainville's Beaked Whale,* Mesoplodon densirostris, *Washed Ashore in Brazil*, 25 AQUATIC MAMMALS 21 (1999); R.J. Tarpley & S. Marwitz, *Plastic Debris Ingestion by Cetaceans Along the Texas Coast: Two Case Reports,* 19 AQUATIC MAMMALS 93 (1993); William A. Walker & James M. Coe, *Survey of Marine Debris Ingestion by Odontocete Cetaceans*, 1 PROC. OF SECOND INT'L CONF. ON MARINE DEBRIS 747 (1990).

[27] Tarpley & Marwitz, *supra* note 27.

[28] Robin W. Baird & Sascha K. Hooker, *Ingestion of Plastic and Unusual Prey by a Juvenile Harbour Porpoise,* 40 MARINE POLLUTION BULL. 719 (2000); R.A. Kastelein & M. S. S. Lavaleije, *Foreign Bodies in the Stomach of a Female Harbour Porpoise* (Phocoena phocoena) *from the North Sea*, 18 AQUATIC MAMMALS 40, 40 (1992).

[29] Laist, *supra* note 23; Laist, *supra* note 24.

packing strips, synthetic ropes or line, and small objects that fragment, such as plastic cups.[30]

In the UK, relatively high rates of debris entanglement have been recorded at least for minke whales. Off the Isle of Mull, of the 74 identifiable minke whales recorded in a catalogue of individual animals, 12 per cent displayed evidence of accumulating marine litter.[31]

1.2.3 Ship Strikes

Marine shipping can also incidentally take cetaceans, killing or wounding them through collisions. Marine traffic collisions with cetaceans were first reported in the late 1800s, but their occurrence was rare until the 1950s. Since then, incidences have increased, and ship strikes are a major form of mortality for some whale species.[32] It is believed that this increase in ship strikes is not simply due to an increase in awareness of conservation and the need to report ship strikes, but also an increase in fast-travelling shipping traffic.[33]

In particular, high-speed ferries have been highlighted as problematic for cetaceans: five cetacean collisions with jetfoil ferries were reported in the sea of Japan;[34] at least nine ship-struck fin whales and other species were hit by ferries and other shipping in the Mediterranean, including high-speed vessels servicing Corsica, Sardinia, and Sicily;[35] and several sperm whales were struck and killed by high-speed ferries off the Canary Islands.[36] Indeed, the ship strike situation in the Canaries, with respect to collisions with high-speed ferries, is so dire that a model predicts that the local population of short-finned pilot whales (*Globicephala macrorhynchus*) was at risk of extirpation as the result boat strike mortalities.[37]

Whale-watching vessels have caused several cetacean mortalities through collisions[38] and can be a particular threat as they target areas of

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[30] Laist, *supra* note 23.

[31] A. Gill *et al.*, *Photographic and Strandings Data Highlighting the Problem of Marine Debris and Creel Rope Entanglement to Minke Whales* (Balaenoptera acutorostrata) *and Other Marinelife in Scottish Waters*, 14 EUR. RES. ON CETACEANS 173 (2000).

[32] Robert D. Kenney, *Scientific Correspondence Right Whale Mortality—A Correction and an Update*, 9 MARINE MAMMAL SCI. 445 (1993); Scott D. Kraus, *Rates and Potential Causes of Mortality in North Atlantic Right Whale (Eubalaena glacialis)*, 6 MARINE MAMMAL SCI. 278, 288 (1990); David W. Laist *et al.*, *Collisions Between Ships and Whales*, 17 MARINE MAMMAL SCI. 35 (2001).

[33] Laist, *supra* note 33.

[34] Y. Honma *et al.*, *Histological Observations on a Muscle Mass From a Large Marine Mammal Struck by a Jetfoil in the Sea of Japan*, 63 FISHERIES SCI. 587 (1997).

[35] G. Pesante *et al.*, *Evidence of Man-Made Injuries on Mediterranean Fin Whales*, 14 EUR. RES. ON CETACEANS 192 (2000).

[36] R. Leaper, *Summary of Data on Ship Strikes of Large Cetaceans from Progress Reports (1996–2000)* (July 2001) (*presented to the Int'l Whaling Comm'n Sci. Comm.*, 53d Meeting of the Int'l Whaling Comm'n, Paper SC/53/BC/WP8).

[37] N. Tregenza *et al.*, *Potential Impact of Fast Ferries on Whale Populations: A Simple Model with Examples from the Canary Islands*, 14 EUR. RES. ON CETACEANS 195 (2000).

[38] M.T. Weinrich, *A Review of Collisions between Whales and Whale Watch Boats* (June 2005) *(presented to the Scientific Comm.*, 57th Meeting of the Int'l Whaling Comm'n, Paper SC57/WW8).

high cetacean abundance. Four fin whales, four humpback whales, and three minke whales have been killed as the result of whale-watching boats. All these collisions occurred either in the St. Lawrence Estuary, Canada, or off the coast of Massachusetts (United States).[39] In particular, the trend for larger and faster whale-watching boats is an increasing concern. The use of such vessels may decrease the time available for operators (and whales) to take evasive action when an animal unexpectedly surfaces just ahead.[40] The impact of the collision will also be greater for faster (and larger) vessels, and it has been suggested that speeds over 13 knots are more likely to result in lethal collisions with cetaceans.[41]

Concerns over the increase in the number of high-speed whale-watching boats in parts of the UK led to suggestions being voiced at the 2003 meeting of the International Whaling Commission that speed restrictions (i.e., ten knots or less) be introduced in known areas of high whale abundance.[42] However, to date, there have been few conclusive reports of cetaceans being killed as the result of collisions with marine traffic in the UK; although on 11 July 2005, a northern minke whale (*Balaenoptera acutorostrata*) calf was reported to have been hit by a small speed boat near Portsoy Harbour in Banffshire, Scotland. Moreover, several small cetaceans have also been observed with badly cut dorsal fins, which may be attributed to propeller damage.[43]

1.3 Pollution

1.3.1 Chemical Pollution

A wide variety of anthropogenic (man-made) pollutants enter the marine ecosystem carried by rivers, run-off from land, sewage and waste discharges, and atmospheric inputs. Since cetaceans are long-lived top predators, they are susceptible to accumulating certain persistent pollutants over their long life span. Concentrations of pollutants, which may be relatively low in planktonic marine life, accumulate and magnify up the food chain with carnivorous fish usually containing higher levels than planktonic species, and marine mammals, which in turn consume these fish, showing even higher accumulated tissue levels.

The chemical pollutants that are the greatest concern to cetaceans include but are not limited to:[44] organohalogens, trace elements, polynuclear

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[39] Laist *et al.*, *supra* note 33.

[40] Weinrich, *supra* note 39.

[41] Laist, *supra* note 32.

[42] E.C.M. PARSONS & T. GAILLARD, CHARACTERISTICS OF HIGH-SPEED WHALEWATCHING VESSELS IN SCOTLAND (2003).

[43] Parsons *et al.*, *supra* note 12.

[44] P.W. Johnston *et al.*, *Cetaceans and Environmental Pollution: The Global Concerns*, *in* THE CONSERVATION OF WHALES AND DOLPHINS: SCIENCE AND PRACTICE 219 (M. Simmonds & J.D. Hutchinson eds.,

aromatic hydrocarbons (PAHs) and other hydrocarbons, radionuclides, and the organotins. In addition, biological pollutants, such as sewage pathogens and excess nutrients, are also of concern.

Cetaceans are exposed to a wide range of contaminants, and it is possible that many of these pollutants work synergistically—that is, the toxic effects of one form of pollutants may combine, or be exacerbated, due to the presence of another pollutant. Thus, the pollutants listed below should not be considered as having an impact on cetaceans in isolation, but rather impacting cetaceans as parts of a suite of stressors.

1.3.1.1 Organohalogens

The first evidence of halogenated hydrocarbon (i.e., organic compounds with elements such as chlorine and bromine attached) contamination in cetaceans was provided by a study on harbour porpoises from the east coast of Scotland, in which concentrations of organochlorine pesticides such as DDT and dieldrins were discovered.[45] There have subsequently been an increasing number of studies investigating cetacean contamination by organochlorines around the world, with an emphasis on organochlorine pesticides (such as DDT) and polychlorinated biphenyls (PCBs).[46] Cetaceans are particularly susceptible to these highly lipophilic (fat-soluble) compounds since they are long-lived, occupy a high trophic level, and a large proportion of their body (in particular their blubber layer) is fat.

In addition, cetaceans lack certain enzymes for the detoxification of organochlorines.[47] As a result, large organochlorine levels bio-accumulate in their blubber tissue. As mentioned above, the long lifespan of cetaceans also means that they accumulate organochlorines over a significant period of time, resulting in higher contaminant levels in older animals.[48]

This age-related accumulation of organoclorines, however, is slightly different in females. As organochlorines are lipophilic, females can pass

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1996); S.M. Tanabe *et al., Butyltin Contamination in Marine Mammals From North Pacific and Asian Coastal Waters*, 32 ENVT'L. SCI. & TECH. 193, 193–198 (1998).

[45] A.V. Holden & K. Marsden, *Organochlorine Pesticides in Seals and Porpoises*, 216 NATURE 1274, 1274–1276 (1967).

[46] P.J.H. Reijnders, *Organohalogen and Heavy Metal Contaminations in Cetaceans: Observed Effects, Potential Impact and Future Prospects*, *in* THE CONSERVATION OF WHALES AND DOLPHINS: SCIENCE AND PRACTICE 205 (M. Simmonds & J.D. Hutchinson eds., 1996); T. O'Shea, *Environmental Contaminants and Marine Mammals*, *in* BIOLOGY OF MARINE MAMMALS 485 (J.E. Reynolds III & S. Rommel eds., 1999); TOXICOLOGY OF MARINE MAMMALS (J.G. Vos *et al.* eds., 2003).

[47] S. Tanabe, *PCB Problems in the Future: Foresight from Current Knowledge*, 50 ENVT'L. POLLUTION 5 (1988); S. Tanabe *et al.*, *Capacity and Mode of PCB Metabolism in Small Cetaceans*, 4 MARINE MAMMAL SCI. 103 (1988).

[48] R. Wagemann & P.C.G. Muir, *Concentrations of Heavy Metals and Organochlorines in Marine Mammals of Northern Waters: Overview and Evaluation*, 1276 CAN. TECHNICAL REP. ON AQUATIC SCI. 1 (1984).

the contaminants onto their calves during pregnancy and via lactation.[49] As cetacean milk has particularly high lipid content and is consumed in large quantities during the initial, rapid development and growth of calves, large quantities of organochlorines can be transferred over a relatively short period of time. Indeed, a study on dolphin milk contamination in Hong Kong estimated that dolphin calves in that area would be receiving doses of organochlorines exceeding health limits that have been set for humans if they ingested more than a single drop of milk a day.[50] It has also been estimated that 80 per cent of an adult female's PCB and DDT burden is transferred to her first born calf.[51] Consequently, cetacean calves and adult males often have the highest contaminant loads in cetaceans.

Levels of organochlorine contamination in cetaceans are affected by the feeding behaviour of the species in question. For example, baleen whale tissues typically have lower contaminant concentrations than toothed whales and dolphins, as baleen whales feed at a lower trophic level.[52] Conversely, mammal-eating species of toothed whales have been found to have higher concentrations of contaminants.[53]

In addition, the proximity of animals to a pollutant source can also lead to higher contaminant levels. Coastal or estuarine animals near sources of pollutants may display higher contaminant levels than more oceanic or offshore species.[54]

Organochlorines cause a variety of effects in mammals, including, in the case of DDT, lethal poisoning by direct action on the mammalian nervous system.[55] In lower concentrations, organochlorines are known to be immuno-

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[49] S. Tanabe *et al.*, *Transplacental Transfer of PCBs and Chlorinated Hydrocarbon Pesticides from a Pregnant Striped Dolphin,* Stenella coeruleoalba*, to Her Fetus*, 46 AGRIC. & BIOLOGICAL CHEMISTRY 1249, 1254 (1982); A. Subramanian *et al.*, *Age and Size Trends and Male-Female Differences of PCBs and DDE in Dalli-Type Dall's Porpoises,* Phocoenoides dalli *of the North-Western North Pacific*, 1 PROC. NAT'L INST. OF POLAR RES. SYMP. ON POLAR BIOLOGY 205 (1987); V.G. Cockcroft *et al.*, *Organochlorines in Bottlenose Dolphins from the East Coast of Southern Africa*, 8 S. AFR. J. MARINE SCI. 207 (1989); R. Morris *et al.*, *Metals and Organochlorines in Dolphins and Porpoises of Cardigan Bay, West Wales*, 20 MARINE POLLUTION BULL. 512, 521 (1989).

[50] E.C.M. Parsons, *The Potential Impacts of Pollution on Humpback Dolphins—With a Case Study on the Hong Kong Population*, 30 AQUATIC MAMMALS 18, 23 (2004).

[51] V.G. Cockcroft *et al.*, *Organochlorines in Bottlenose Dolphins From the East Coast of Southern Africa*, 8 S. AFR. J. MARINE SCI. 207 (1989).

[52] T.J. O'Shea & R.L. Brownell, *Organochlorine and Metal Contaminants in Baleen Whales: A Review and Evaluation of Conservation Implications*, 154 SCI. TOTAL ENV'T 179, 185 (1994).

[53] W.M. Jarman *et al.*, *Levels of Organochlorine Compounds, Including PCDDs and PCDFs, in the Blubber of Cetaceans From the West Coast of North America*, 32 MARINE POLLUTION BULL. 426 (1996).

[54] Parsons, *supra* note 51, at 24; E.C.M. Parsons & H.M. Chan, *Organochlorine and Trace Metal Concentrations in Bottlenose Dolphins* (Tursiops Truncatus) *From the South China Sea*, 42 MARINE POLLUTION BULL. 780 (2001).

[55] DDT contamination of the brain has resulted in the death of various species of small mammal at relatively low concentrations: 17–34 μg.g^{-1} in shrews (*Blarina brevicauda*); 25 μg.g^{-1} in bats (*Myotis lucifugus*) and 45–50 μg.g^{-1} in laboratory rats and mice. W.E. Dale *et al.*, *Poisoning by DDT: Relation*

suppressive,[56] reducing the ability of the body to fight off infection and increasing mortality in viral,[57] bacterial,[58] and protozoan[59] infections. Immune system suppression has been documented in marine mammals exposed to organochlorine contamination,[60] including cetaceans.[61]

In addition to direct mortality and immuno-suppression, organochlorines can adversely affect cetacean populations by disrupting their reproductive systems. This is the result of the structure of many organochlorine molecules (i.e., they resemble the structure of many reproductive hormones). As a result, reproductive failure occurs in mammals[62] fed on a diet containing PCBs in relatively low[63] concentrations.[64] Other PCB-induced reproductive defects include altered menstrual cycles, embryo reabsorption, abortions,

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Between Clinical Signs and Concentration in Rat Brain, 142 SCI. 1475 (1963); W.J. Hayes, *Review of the Metabolism of Chlorinated Hydrocarbon Insecticides Especially in Mammals*, 5 ANN. REV. OF PHARMACOLOGY 27 (1965); G.L. Henderson & D.E. Woolley, *Studies on the Relative Insensitivity of the Immature Rat to the Neurotoxic Effects of 1,1,1,*-trichloro-*2,2,*-bis (p-chlorophenyl) ethane *(DDT)*, 170 J. PHARMACOLOGY & EXPERIMENTAL THERAPY 173 (1969); R. Gingell & L. Wallcave, *Species Differences in the Acute Toxicity and Tissue Distribution of DDT in Mice and Hamsters*, 28 TOXICOLOGY & APPLIED PHARMACOLOGY 385 (1974); L.J. Blus, *Short-Tailed Shrews: Toxicity and Residue Relationships of DDT, Dieldrin, and Endrin*, 7 ARCHIVES ENVTL. CONTAMINATION & TOXICOLOGY 83 (1978); D.R. Clarke *et al.*, *Insecticides Applied to a Nursery Colony of Little Brown Bats* (Myotis Lucifugus)*: Lethal Concentrations in Brain Tissues*, 59 J. MAMMALOGY 84, 84 (1978); D.R. Clarke, *Bats and Environmental Contaminants: A Review*, 235 U.S. FISHERIES & WILDLIFE SERVICE SPECIAL SCI. REP. WILDLIFE 1 (1981). Our knowledge of the lethal doses for DDT in larger mammals, notably cetaceans, is lacking.

[56] J.G. Vos & M.I. Luster, *Immune Alterations*, *in* HALOGENATED BIPHENYLS, TERPHENYLS, NAPTHALENES, DIBENZODIOXINS, AND RELATED PRODUCTS 295 (R.D. Kimborough & A.A. Jensen eds., 1989).

[57] L.D. Koller & J.E. Thigpen, *Reduction of Antibody to Pseudorabies Virus in Polychlorinated Biphenyl-Exposed Rabbits*, 34 AM. J. VETERINARY RES. 1605–1606 (1973); M. Friend & D.O. Trainer, *Experimental DDT–Duck Hepatitis Virus Interaction Studies*, 38 J. WILDLIFE MGMT. 887 (1974).

[58] A.W. Smith *et al.*, *Hazards of Disease Transfer From Marine Mammals to Land Mammals: A Review and Recent Findings*, 173 J. AM. VETERINARY MED. ASS'N 1131, 1131–1132 (1978); P.T. Thomas & R.D. Hinsdill, *Effect of Polychlorinated Biphenyls on the Immune Responses of Rhesus Monkeys and Mice*, 44 TOXICOLOLOGY & APPLIED PHARMACOLOGY 41 (1978).

[59] L.D. Loose *et al.*, *Impaired Host Resistance to Endotoxin and Malaria in Polychlorinated Biphenyl- and Hexachlorobenzene Treated Mice*, 20 INFECTIOUS IMMUNOLOGY 30, 30–31 (1978).

[60] R. Swart *et al.*, *Impairment of Immune Function in Harbour Seals* (Phoca Vitulina) *Feeding on Fish From Polluted Waters*, 23 AMBIO 155 (1994).

[61] G.P. Lahvis *et al.*, *Decreased Lymphocyte Responses in Free-ranging Bottlenose Dolphins* (Tursiops truncatus) *Are Associated With Increased Concentrations of PCBs and DDT in Peripheral Blood*, 103 ENVTL. HEALTH PERSPECTIVES 67 (1995); M. Levin *et al.*, *Specific Non-coplanar PCB-mediated Modulation of Bottlenose Dolphin and Beluga Whale Phagocytosis Upon In Vitro Exposure*, 67A J. TOXICOLOGY & ENVTL. HEALTH 1517, 1518–1519, 1530, 1533 (2004).

[62] *I.e.*, mink (*Mustela vison*) and rhesus monkeys (*Macaca mulatta*).

[63] 0.64 μg PCB.g^{-1} for mink and 2.5 μg PCB.g^{-1} rhesus monkeys.

[64] N.S. Platnow & L.H. Karstad, *Dietary Effects of Polychlorinated Biphenyls on Mink*, 37 Can. J. Comp. Med. 391, 391–400 (1973); J.R. Allen *et al.*, *Residual Effects of Short-Term, Low-Level Exposure of Nonhuman Primates to Polychlorinated Biphenyls*, 30 TOXICOLOGY & APPLIED PHARMACOLOGY 44 (1974); J.R. Allen & D.A. Barsotti, *The Effects of Transplacental and Mammary Movement of PCBs on Infant Rhesus Monkeys*, 6 TOXICOLOGY 331 (1976); D.A. Barsotti *et al.*, *Reproductive Dysfunction in Rhesus Monkeys Exposed to Low Levels of Polychlorinated Biphenyls*, 14 FOOD & COSMETIC TOXICOLOGY 99 (1976); R.J. Aulerich & R.K. Ringer, *Current Status of PCB Toxicity to Mink, and Effect on Their Reproduction*, 6 ARCHIVES ENVTL. CONTAMINATION & TOXICOLOGY 279 (1977); M.R. Bleavins *et al.*,

still-birth, impaired infant survival, low birth weights, and impaired growth.[65] However, the concentrations at which PCB-induced reproductive effects occurred varied between species.[66] For example, PCBs can seriously disrupt the mammalian reproductive system, although the concentrations at which this occurs will vary. Other documented effects of organohalogens include liver toxicity, skin damage, cancer promotion, behavioural changes, and "reduced intelligence."[67]

In marine mammals, organochlorines have been implicated with skeletal deformities,[68] lipid metabolism abnormalities in dolphins,[69] testosterone deficiencies in porpoises,[70] and reproductive abnormalities and failure in other marine mammal species.[71] Population level effects have also been linked to organochlorines, such as the decline of beluga whales (*Delphinapterus leucas*) in the St. Lawrence Estuary,[72] mass mortalities of seals in the northern Europe,[73] and cetaceans in the Mediterranean, the east coast of the

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Polychlorinated Biphenyls (Arochlors 1016 and 1242): Effects on Survival and Reproduction in Mink and Ferrets, 11 ARCHIVES ENVTL. CONTAMINATION & TOXICOLOGY 305 (1980); R.J. Aulerich *et al.*, S.J. Bursian, W.J. Breslin, B.A. Olson, & R.K. Ringer, *Toxicological Manifestations of 2,4,5,2′,4′,5′-, 2,3,4,2′,3′,6′-, and 3,4,5,3′,4′,5′-Hexachlorobiphenyl and Arochlor 1254 in Mink*, 15 J. TOXICOLOGY & ENVTL. HEALTH 63 (1985); J.E. Kihlström *et al.*, *Effects of PCB on the Reproduction of the Mink* (Mustela vison), 21 AMBIO 563 (1992).

[65] *Id.*

[66] For example, concentrations of PCBs four times higher than those causing effects in rhesus monkeys (*Macaca mulatta*) were required before reproductive abnormalities were induced in the related monkey species *Macaca fascicularis*. *Id.*

[67] S. Safe, *Polychlorinated Biphenyls (PCBs) and Polybrominated Biphenyls (PBBs): Biochemistry, Toxicology and Mechanisms of Action*, 13 CRC CRITICAL REVS. TOXICOLOGY 319 (1984).

[68] V.M. Zakharov & A.F. Yablokov, *Skull Asymmetry in the Baltic Grey Seal: Effects of Environmental Pollution*, 19 AMBIO 266 (1990).

[69] S. Kawai *et al.*, *Relationship Between Lipid Composition and Organochlorine Levels in the Tissues of Striped Dolphin*, 19 MARINE POLLUTION BULL. 129 (1988).

[70] A.N. Subramanian *et al.*, *Reduction in Testosterone Levels by PCBs and DDE in Dall's Porpoises of the North-Western North Pacific*, 18 MARINE POLLUTION BULL. 643, 644 (1987).

[71] R.L. Delong *et al.*, *Premature Births in California Seal Lions: Associations With High Organochlorine Pollutant Residue Levels*, 181 SCI. 1168 (1973); E. Helle *et al.*, *PCB Levels Correlated With Pathological Changes in Seal Uteri*, 5 AMBIO 261 (1976); J.C. Duinker *et al.*, *Organochlorides and Metals in Harbour Seals (Dutch Wadden Sea)*, 10 MARINE POLLUTION BULL. 360, 363–364 (1979); P.J.H. Reijnders, *Organochlorine and Heavy Medal Residues in Harbour Seals From the Wadden Sea and Their Possible Effects on Reproduction*, 14 NETH. J. OF SEA RES. 30, 46, 56–57 (1980); 3 G.B. FULLER & W.C. HOBSON, EFFECTS OF PCBS AND THE ENVIRONMENT 101 (J.S. Waid ed., 1986); P.J.H. Reijnders, *Reproductive Failure of Common Seals Feeding on Fish from Polluted Waters*, 324 NATURE 456, 456 (1986); J.R. Baker, *Pollution-Associated Uterine Lesions in Grey Seals From the Liverpool Bay Area of the Irish Sea*, 125 VETERINARY REC. 303 (1989); R.F. Addison, *Organochlorines and Marine Mammal Reproduction*, 46 CAN. J. OF FISHERIES & AQUATIC SCIS. 360 (1989).

[72] D. Martineau *et al.*, *Levels of Organochlorine Chemicals in Tissues of Beluga Whales* (Delphinapterus Leucas) *From the St. Lawrence Estuary, Quebec, Canada*, 16 ARCHIVES OF ENVT'L. CONTAMINATION & TOXICOLOGY 137(1987); D. Martineau *et al.*, *Pathology and Toxicology of Beluga Whales From the St. Lawrence Estuary, Quebec, Canada: Past, Present, and Future*, 154 SCI. OF TOTAL ENV'T 201 (1994).

[73] J. Harwood & P.J.H. Reijinders, *Seals, Sense and Sensibility*, NEW SCIENTIST, Oct. 15, 1988, at 28–29; A.J. Hall *et al.*, *Organocholorine Levels in Common Seals* (Phoca Vitulina) *Which Were Victims and Survivors of the 1988 Phocine Distemper Epizootic*, 115 SCI. OF TOTAL ENV'T 145 (1992).

United States, the Gulf of Mexico, and the North Sea.[74] Thus, organochlorine contamination is widely considered a major threat to cetacean populations in various regions of the world.

Numerous studies have been conducted in the UK to evaluate organochlorine levels in cetaceans.[75] Several of these UK animals have been reported with organochlorine levels equal to, or exceeding, those that have been reported to cause reproductive suppression[76] and immune system[77] changes in species of small cetaceans.[78] Some animals also have concentrations that have been considered to be a serious health risk to cetaceans.[79] Additionally, recent studies in the UK have discovered that animals with a disease- related death

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[74] J.R. Geraci, *Clinical Investigation of the 1987–88 Mass Mortality of Bottlenose Dolphins Along the U.S. Central and South Atlantic Coast* (1989) (unpublished report to the National Marine Fisheries Service and U.S. Navy, Office of Naval Research and the U.S. Marine Mammal Commission); A. Aguilar & J.A. Raga, *La Mortandad des Delfines en el Mediterraneo*, 25 POLITICA SCIENTIFICA 51 (1990); A. Aguilar & J.A. Raga, *The Striped Dolphin Epizootic in the Mediterranean Sea*, 22 AMBIO 524 (1993); A. Borrell & A. Aguilar, *Were PCB Levels Abnormally High in Striped Dolphins Affected by the Western Mediterranean Die-off?*, 5 EUR. RES. ON CETACEANS 88 (1991); M.P. Simmonds, *Cetacean Mass Mortalities and Their Potential Relationship With Pollution, in* PROCEEDINGS OF THE SYMPOSIUM, WHALES: BIOLOGY, THREATS, CONSERVATION 217 (Royal Acad. of Overseas Scis. ed., 1992).

[75] A.V. Holden & K. Marsden, *Organochlorine Pesticides in Seals and Porpoises*, 216 NATURE 1274 (1967); Morris *et al.*, *supra* note 49, at 512–513, 516, 518, 521; D.E. Wells & I. Echarri, *Determination of Individual Chlororbiphenyls (CBs), Including Non-Ortho, and Mono-Ortho Chloro Substituted CBs in Marine Mammals from Scottish Waters*, 47 INT'L J. OF ANALYTICAL CHEMISTRY 75 (1992); T. Kuiken *et al.*, *Adrenocortical Hyperplasia, Disease and Chlorinated Hydrocarbons in the Harbour Porpoise* (Phocoena phocoena), 26 MARINE POLLUTION BULL. 440 (1993); Kuiken *et al, supra* note 19; J.P. Boon *et al.*, *Concentration Dependent Changes of PCB Patterns in Five Species of Fish-Eating Mammals in Relation to Uptake from Food and Biotransformation Capacity*, 33 ARTICLES OF ENVT'L. CONTAMINATION & TOXICOLOGY 298 (1997); R.J. Law *et al.*, *Uptake of Organochlorines (Chlorobiphenyls, Dieldrin, Total PCB, and DDT) in Bottlenose Dolphins* (Tursiops truncatus) *from Cardigan Bay, West Wales*, 30 CHEMOSPHERE 547 (1995); R.J. Law *et al.*, *Metals and Organochlorines in Sperm Whales* (Physeter macrocephalus) *Stranded around the North Sea During the 1994/1995 Winter*, 32 MARINE POLLUTION BULL. 72 (1996); R.J. Law *et al.*, *Metals and Organochlorines in Tissues of Sperm Whales* (Physeter macrocephalus) *and Other Cetacean Species Exploiting Similar Diets*, 67 BULLETIN DE L'INSTITUTE ROYAL DES SCIENCES NATURELLES DE BELGIQUE BIOLOGIE 79 (1997); R.J. Law *et al.*, *Metals and Organochlorines in Tissues of a Blainville's Beaked Whale* (Mesoplodon densirostris) *and a Killer Whale* (Orcinus orca) *Stranded in the United Kingdom*, 34 MARINE POLLUTION BULL. 208 (1997); C. McKenzie *et al.*, *Concentrations and Patters of Organic Contaminants in Atlantic White-Sided Dolphins* (Lagenorhynchus acutus) *from Irish and Scottish Coastal Waters*, 98 ENVT'L. POLLUTION 15, 15–16 (1997); P.D. Jepson *et al.*, *Investigating Potential Associations Between Chronic Exposure to Polychlorinated Biphenyls and Infectious Disease Mortality in Harbour Porpoises from England and Wales*, 243/244 SCI. OF TOTAL ENV'T 339 (1999); R.J. Law *et al.*, *Metals and Organochlorines in Pelagic Cetaceans Stranded on the Coasts of England and Wales*, 42 MARINE POLLUTION BULL. 522 (2001); R.J. Law *et al.*, *Persistent Organohalogens Compounds in Marine Mammals Stranded or Bycaught in the UK*, 62 ORGANOHALOGEN COMPOUNDS 224 (2003); P.D. Jepson *et al.*, *Relationships between PCBs and Health Status in UK-Stranded Harbour Porpoises* (Phocoena phocoena), 24 ENVT'L. TOXICOLOGY & CHEMISTRY 238 (2005).

[76] Subramanian, *supra* note 70, at 644.

[77] Lahvis, *supra* note 61.

[78] Subramanian, *supra* note 70, at 645 (concentrations of 10–20 $\mu g.g^{-1}$).

[79] Wageman & Muir, *supra* note 48 (concentrations of 50–200 $\mu g.g^{-1}$).

have significantly higher organochlorine levels than animals dying through traumatic injury (e.g., bycatch).[80] This implies that organochlorine contamination, via immuno-suppressive effects, is perhaps resulting in increased cetacean disease-related mortality.

In addition to organochlorines, research in the UK[81] and adjacent waters[82] is also pointing to other classes of organohalogens—brominated fire retardants[83] and perflourinated organochemicals—as potential contaminants that could pose health risks to cetaceans, although documented effects of these classes of contaminants have yet to be published. Other emerging organic contaminants that may pose a risk to cetaceans, and thus warrant research and consideration, include short-chained chlorinated parrafins, phthalates, nonyphenol, tris (4-chlorophenyl) methane (TCPMe), tris (4-chlorophenyl) methanol (TCPMeOH), dioxins, and dibenzofurans.[84]

1.3.1.2 Trace Elements

Some trace elements, in small amounts, are essential nutrients required for healthy living. However, in excess, these elements can be toxic. In particular, so-called heavy metals, metallic trace elements with a high atomic number, such as mercury and cadmium, are particularly toxic to biological systems, even in relatively small amounts.

Trace elements are frequently the by-products of various industrial processes, such as cadmium waste from factories producing electric cells and batteries, or lead, which has been used as an additive in petrol for decades. These trace elements can enter the marine environment through atmospheric processes or via rivers and run-off from land. Unlike organohalogens, if ingested, trace elements tend to accumulate in protein-based tissues, such as muscle or the liver, rather than fat-based tissues, such as blubber. Like organochlorines (Section 1.3.1.1), trace elements accumulate with age and with trophic level,

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[80] Jepson *et al.*(1999), *supra* note 75; Jepson *et al.*(2005), *supra* note 75.

[81] J.P. Boon *et al.*, *Polybrominated Diphenyl Ether (PBDE) Flame Retardants in the North Sea Food Web*, 36 ENVTL. SCI. & TECH. 4025 (2002); R.J. Law *et al.*, *Polybrominated Diphenyl Ethers in the Blubber of Marine Mammals Stranded on the Coasts of England and Wales* (paper presented at the Third World Conference of the Society of the Environmental Toxicology and Chemistry, 2002); R.J. Law *et al.*, *Polybrominated Diphenylethers in the Blubber of Harbour Porpoises* (Phocoena phocoena L.) *Stranded on the Coasts of England and Wales*, 47 ORGANOHALOGEN COMPOUNDS 249 (2002); R.J. Law *et al.*, *Polybrominated Diphenylethers in Two Species of Top Marine Predators From England and Wales*, 46 CHEMOSPHERE 673, 673–675 (2002); R.J. Law *et al.*, *Levels and Trends of PBDEs and Other Brominated Flame Retardants in Wildlife*, 29 ENVTL. INT'L 757, 757–758 (2003); R.J. Law *et al.*, *Brominated Diphenyl Ethers in the Blubber of Twelve Species of Marine Mammals Stranded in the UK*, 50 MARINE POLLUTION BULL. 356 (2005).

[82] K.I. Van de Vijver *et al.*, *Perfluorinated Chemicals Infiltrate Ocean Waters: Link Between Exposure Levels and Stable Isotope Ratios in Marine Mammals*, 37 ENVT'L. SCI. &TECH. 5545 (2003).

[83] Polybrominated Diphenyl Ethers (PBDEs).

[84] M.P. Simmonds *et al.*, *A Note Concerning "Novel" Pollutants and Cetaceans* (2001) (paper presented to the Scientific Committee at the 53rd Meeting of the Int'l Whaling Comm'n).

and some can cross the placental barrier, causing high mercury burdens in young individuals.[85]

A trace element of particular concern with respect to its potential toxic effects is chromium, which, in some forms, is toxic and even carcinogenic.[86] Cadmium also has widespread toxic effects on the mammalian body, including depressed growth, kidney damage, cardiac enlargement, hypertension, foetal deformity, and cancer.[87] Kidney dysfunction has also been reported in cetaceans with elevated levels of cadmium.[88]

Lead encountered in cetacean tissues in the UK have been attributed to the use of "leaded" petrol[89] —the result of compound alkyl lead being added to petrol to act as an "anti-knocking" agent. The toxic effects of lead in mammals include anaemia, kidney damage, hypertension, cardiac disease, immunosuppression (through antibody inhibition), and neurological damage.[90]

Mercury is considered to be the trace element of greatest toxicological significance: mercury poisoning results in neurological damage and immunosuppression, and can cause foetal abnormalities in mammals.[91] Several industrialized countries have reported extremely high levels of mercury contamination in cetaceans, including Japan,[92] and the Mediterranean waters of southern Europe.[93] Indeed, it has been suggested that anthropogenic contaminants, including mercury, may have played a role in cetacean mass mortality events in the Mediterranean.[94] Specific toxic effects of mercury that have been

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[85] J.M. Andre *et al.*, *Mercury Contamination Levels and Distribution in Tissues and Organs of Delphinids* (Stenella attentata) *From the Eastern Tropical Pacific, in Relation to Biological and Ecological Factors*, 30 MARINE ENVT'L. RES. 14 (1990).

[86] R.A. Anderson, *Chromium*, *in* 1 TRACE METALS IN HUMAN AND ANIMAL NUTRITION (W. Mertz ed., 1987); J. Gauglhofer & V. Bianchi, *Chromium*, *in* TRACE METALS AND THEIR COMPOUNDS IN THE ENVIRONMENT (E. Merian ed., 1991).

[87] K. Kostial, *Cadmium*, *in* 2 TRACE ELEMENTS IN HUMAN AND ANIMAL NUTRITION (W. Mertz & E.J. Underwood eds., 5th ed., 1986); M. Stoeppler, *Cadmium*, *in* TRACE METALS AND THEIR COMPOUNDS IN THE ENVIRONMENT (E. Merian ed., 1991).

[88] Y. Fujise *et al.*, *Tissue Distribution of Heavy Metals in Dall's Porpoise in the Northwestern Pacific*, 19 MARINE POLLUTION BULL. 226 (1988).

[89] R.J. Law & J.A. Whinnet, *Polycylic Aromatic Hydrocarbons in Muscle Tissue of Harbour Porpoises* (Phocoena phocoena) *from UK Waters*, 24 MARINE POLLUTION BULL. 550 (1992).

[90] J. Quarterman, *Lead*, *in* 2 TRACE METALS IN HUMAN AND ANIMAL NUTRITION (W. Mertz & E.J. Underwood eds., 5th ed. 1986).

[91] T. Clarkson, *Mercury*, *in* 1 TRACE METALS IN HUMAN AND ANIMAL NUTRITION (W. Mertz ed., 1987); R. Von Burg & M.R. Greenwod, *Mercury*, *in* TRACE METALS AND THEIR COMPOUNDS IN THE ENVIRONMENT (E. Merian ed., 1991).

[92] For example, levels of 1600 μg.g^{-1} dry weight. K. Honda *et al.*, *Heavy Metal Concentrations in Muscle, Liver and Kidney Tissue of Striped Dolphin* Stenella coeruleoalba *and Their Variations With Body Length, Weight, Age and Sex*, 47 AGRIC. & BIOLOGICAL CHEMISTRY 1219–1228 (1983).

[93] For example, levels of 13,156 μg.g^{-1} dry weight. C. Leonzio *et al.*, *Heavy Metals and Selenium in Stranded Dolphins of the Northern Tyrrhenian (NW Mediterranean),* 119 SCI. OF TOTAL ENV'T 77–84 (1992).

[94] M.P. Simmonds, *Cetacean Mass Mortalities and Their Potential Relationship With Pollution*, *in* PROCEEDINGS OF THE SYMPOSIUM, WHALES: BIOLOGY, THREATS, CONSERVATION 217–245 (Royal Acad. of Overseas Scis. ed., 1991).

observed in cetaceans include various lesions and liver abnormalities, decreased nutritional state, and fatty degeneration.[95]

Several studies have been conducted in the UK to evaluate trace element concentrations in a variety of cetacean species.[96] Cadmium[97] and mercury[98] levels reported in some UK cetaceans are equivalent to levels that have been associated with chronic toxic effects in other cetacean populations.

Moreover, a study, which analysed trace element concentrations in UK harbour porpoises, discovered that animals that died from infectious diseases, as opposed to trauma-related deaths—such as bycatch—displayed significantly higher tissue concentrations of mercury, selenium, and zinc.[99] High zinc concentrations have also been linked to disease and emaciation in North Sea harbour porpoises.[100] In particular, animals that displayed ratios of mercury contamination much greater than selenium concentrations (which is believed

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[95] A.J. Rawson *et al.*, *Liver Abnormalities Associated With Chronic Mercury Accumulation in Stranded Atlantic Bottlenose Dolphins*, 25 ECOTOXICOLOGY & ENVTL. SAFETY 42–43 (1993); U. Siebert *et al.*, *Potential Relation Between Mercury Concentrations and Necropsy Findings in Cetaceans From German Waters of the North and Baltic Seas*, 38 MARINE POLLUTION BULL. 285–294 (1995).

[96] C.R. Falconer *et al.*, *Trace Metals in the Common Porpoise,* Phocoena phocoena, 8 MARINE ENVT'L. RES. 119–126 (1983); R. Morris *et al.*, *Metals and Organochlorines in Dolphins and Porpoises of Cardigan Bay, West Wales,* 20 MARINE POLLUTION BULL. 512–521 (1989); R.J. Law *et al.*, *Concentrations of Trace Metals in the Livers of Marine Mammals (Seals, Porpoises and Dolphins) From Waters around the British Isles*, 22 MARINE POLLUTION BULL. 183–190 (1991). R.J. Law *et al.*, *Trace Metals in the Livers of Marine Mammals from the Welsh coast and Irish Sea,* 24 MARINE POLLUTION BULL. 296–304 (1992). R.J. Law, *Metals in Marine Mammals, in* INTERPRETING ENVIRONMENTAL CONTAMINANTS IN WILDLIFE TISSUES 357–371 (N. Beyer *et al.* eds., 1996). R.J. Law *et al.*, *Metals and Organochlorines in Sperm Whales* (Physeter macrocephalus) *Stranded Around the North Sea During the 1994/1995 Winter*, 32 MARINE POLLUTION BULL. 72–77 (1996); R.J. Law *et al.*, *Sperm Whale Deaths in the North Sea: Science and Managemen*t, 67 (Suppl. 1) BULLETIN DE L'INSTITUTE ROYAL DES SCIENCES NATURELLES DE BELGIQUE BIOLOGIE 79–89 (1997); R.J. Law *et al.*, *Metals and Organochlorines in Tissues of a Blainville's Beaked Whale* (Mesoplodon densirostris*) and a Killer Whale* (Orcinus orca) *Stranded in the United Kingdom*, 34 MARINE POLLUTION BULL. 208–212 (1997); P.M. Bennett *et al.*, *Exposure to Heavy Metals and Infectious Disease Mortality in Harbour Porpoises from England and Wales*, 112 ENVTL. POLLUTION 35 (2001). R.J. Law *et al.*, *Metals and Organochlorines in Pelagic Cetaceans Stranded on the Coasts of England and Wales*, 42 MARINE POLLUTION BULL. 522–526 (2001).

[97] For example, cadmium concentrations in liver >20 μg.g^{-1} wet weight. Y. Fujise *et al.*, *Tissue Distribution of Heavy Metals in Dall's Porpoise in the Northwestern Pacific*, 19 MARINE POLLUTION BULL. 226–230 (1988).

[98] For example, mercury concentrations in liver >61 μg.g^{-1} wet weight. A.J. Rawson *et al.*, *Liver Abnormalities Associated with Chronic Mercury Accumulation in Stranded Atlantic Bottlenose Dolphins*, 25 ECOTOXICOLOGY & ENVTL. SAFETY 42–43 (1993). As a "rule of thumb" levels of 100–400 μg.g^{-1} wet weight of mercury in liver may present a threat to marine mammals. R. Wageman & P.C.G. Muir, *Concentrations of Heavy Metals and Organochlorines in Marine Mammals of Northern Waters: Overview and Evaluation*, 1276 CAN. TECHNICAL REP. ON AQUATIC SCIS. 1–97 (1984).

[99] *Id.*

[100] K. Das *et al.*, *Ecological and Pathological Factors Related To Trace Metal Concentrations in Harbour Porpoises* Phocoena phocoena *from the North Sea and Adjacent Areas*, 281 MARINE ECOLOGY PRESS SERIES 283–295 (2004).

to have a mercury detoxification effect in marine mammals)[101] were significantly more likely to have died from infectious diseases.[102] This implies that excess mercury levels resulted in immune-suppression and mortality through infectious disease in these UK harbour porpoises,[103] i.e., elevated trace element concentrations are potentially causing population level effects.

1.3.1.3 Butyltins

For over 30 years, oranotin compounds, primarily the butlyins, were used as anti-fouling treatments in paints applied to ship hulls, fish farm cages, and other marine structures. However, in the 1980s, it was discovered that butyltins which leach into the marine environment can have a variety of effects on marine species.[104] For example, growth retardation and deformity of sexual organs was recorded in marine invertebrates at relatively low[105] concentrations.[106] In addition, butyltins have been reported to have caused the disruption of mammalian immune systems,[107] including those of cetaceans.[108]

As a result of the toxicological impacts of butyltins on the marine environment, laws were introduced in the UK in 1986 to limit their use, followed by a Europe-wide ban, which was enacted in 1987 on boats under 25 metres. However, use of butyltin-based anti-fouling paints continued on most vessels larger than 25 metres until January 2003, when a world-wide ban on tributyltin-based anti-fouling paints was enacted by the International Maritime Organisation. The ban on butyltin use on small boats did, however, play a role in substantially decreasing tributyltin contamination in some coastal areas in the UK.[109]

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[101] R. Martoja & J.P. Berry, *Identification of Tiemannite as a Probable Product of Dimethylation of Mercury by Selenium in Cetaceans: A Complement to the Scheme of the Biological Cycle of Mercury*, 30 VIE ET MILIEU 7–10 (1980).

[102] P.M. Bennett *et al.*, *Exposure to Heavy Metals and Infectious Disease Mortality in Harbour Porpoises From England and Wales*, 112 ENVTL. POLLUTION 33–40 (2001).

[103] *Id.*

[104] K. Fent, *Ecotoxicology of Organotin Compounds*, 26 CRITICAL REVS. OF TOXICOLOGY 7–10, 30 (1996).

[105] For example, 10–20 $ng.L^{-1}$.

[106] P.E. Gibbs & G.W. Bryan, *Reproductive Failure in Population of Dog-Whelk Nucella lapillus Caused by Imposex Induced by Tributyltin From Antifouling Paints*, 66 J. OF MARINE BIOLOGICAL ASSOC. OF THE UK 767–777 (1986); I.F. Lawler & J.C. Aldrich, *The Sublethal Effects of Bis*(Tributyltin)*oxide on* Crassostrea gigas Spat, 18 MARINE POLLUTION BULL. 274–278 (1987).

[107] W. Seinen & M.I. Willems, *Toxicity of Organotin Compounds: I. Atrophy of Thymus and Thymus-dependent Lympoid Tissue In Rats Fed Di-N-Octytin Dichloride*, 35 TOXICOLOGY & APPLIED PHARMACOLOGY 63–75 (1976); J.G. Vos, *Toxicity of Bis(tri-n-butyltin)oxide in the Rat*, 75 TOXICOLOGY & APPLIED PHARMACOLOGY 387–408 (1984).

[108] K. Kannan & S. Tanabe, *Response to Comment on "Elevated Accumulation of Tributyltin and Its Breakdown Products in The Bottlenose Dolphin* (Tursiops truncatus) *Found Stranded along the U.S. Atlantic and Gulf Coasts*, 31 ENVT'L. SCI. & TECH. 3035–3036 (1997); H. Nakata *et al.*, *Evaluation of Mitogen-induced Responses in Marine Mammal and Human Lymphocytes by In-Vitro Exposure of Butyltins and Non-Ortho Coplanar PCBs*, 120 ENVT'L. POLLUTION 245–253 (2002).

[109] M.E. Waite *et al.*, *Reductions in TBT Concentrations in UK Estuaries Following Legislation in 1986 and 1987*, 32 MARINE ENVT'L. RES. 89–111 (1991).

Several cetacean populations have been discovered with high levels of butyltin contamination,[110] which have, in turn, been linked to chemically induced suppression of the cetacean immune system.[111] Moreover, butyltin contamination has also been linked to a cetacean mass mortality event in Florida, which has again been associated with chemically-induced immune system damage.[112]

Butyltins have been reported in harbour porpoises from UK waters, and although levels were relatively high in some individuals,[113] levels were generally lower than those reported for small cetaceans in other areas, such as Japan, the Adriatic Sea, and the United States.[114] Nonetheless, there could be a potential for toxic effects as the result of this exposure,[115] and researchers noted that butyltin contamination was very widespread, contaminating animals that were offshore as well as coastal.[116] The UK studies also noted that the examined cetaceans had higher butyltin levels than the seals that were analysed in the same study.[117] This discrepancy might be due to species-specificity in butyltin sensitivity;[118] in other words, cetaceans may be more prone to butyltin contamination as a result of their biology.

One final aspect of butyltins that should also be considered is their potential for synergistic effects when combined with other contaminants, notably, types of organochlorine PCBs.[119] Although levels might be low, the effects of the contaminants could combine with other pollutants—such as organochlorines—resulting in much greater damage to the immune system. As noted before (Sections 1.3.1.1 & 1.3.1.2), cetacean mortality resulting from infectious disease has been found to be greater in animals contaminated with

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[110] H. Iwata *et al.*, *Detection of Butyltin Compound Residues in the Blubber of Marine Mammals*, 28 MARINE POLLUTION BULL. 607–612 (1994); H. Iwata *et al.*, *High Accumulation of Toxic Butyltins in Marine Mammals From Japanese Coastal Waters*, 29 ENVT'L. SCI. & TECH. 2959–2962 (1995); S.M. Tanabe *et al.*, *Capacity and Mode of PCB Metabolism in Small Cetaceans*, 32 ENVT'L. SCI. & TECH. 193–198 (1998).

[111] K. Kannen & S. Tanabe., *supra* note 109, at 3035–3036; H. Nakata *et al.*, *Evaluation of Mitogen-induced Responses in Marine Mammal and Human Lymphocytes by In Vitro Exposure of Butyltins and Non-ortho Coplanar PCBs*, 120 ENVT'L. POLLUTION 245–253 (2002).

[112] P. Jones, *TBT Implicated in Mass Dolphin Deaths*, 34 MARINE POLLUTION BULL. 146 (1997).

[113] *E.g.*, 640 $ng.g^{-1}$ wet weight. R. J. Law *et al.*, *Organotin Compounds in Liver Tissue of Harbor Porpoises* (Phocoena phocoena) *and Grey Seals* (Halichoerus grypus) *From the Coastal Waters of England and Wales*, 36 MARINE POLLUTION BULL. 241–247 (1998).

[114] *Id.*; R. J. Law *et al.*, *Butyltin Compounds in Liver Tissues of Pelagic Cetaceans Stranded on the Coast of England and Wales* 38 MARINE POLLUTION BULL. 1258–1261 (1999).

[115] *Id.*

[116] *Id.*

[117] *Id.*

[118] G.B. Kim *et al.*, *In Vitro Inhibition of Hepatic Cytochrome P450 and Enzyme Activity by Butyltin Compounds in Marine Mammals*, 99 ENVT'L. POLLUTION 255–261 (1998).

[119] H. Nakata *et al.*, *Evaluation of Mitogen-Induced Responses in Marine Mammal and Human Lymphocytes by In Vitro Exposure of Butyltins and Non-Ortho Coplanar PCBs*, 120 ENVT'L. POLLUTION 245, 252 (2002).

higher contaminant levels, presumably as the result of immuno-suppression, and butyltin contamination could further increase this contaminant-induced mortality.

1.3.1.4 Oil

In terms of environmental pollutants, oil spills are one of the forms of pollutants that grab public attention.[120] Although catastrophic oil spills are what generally come to mind when oil pollution is mentioned, the greatest source of oil pollution is actually oil discharge through public sewage and waste water systems.[121] In fact, natural seepage of oil through the sea bed accounts for nearly double the oil input into the oceans compared to catastrophic spills.[122] Small, operational spillages during oil production, transfer, and transportation also account for larger volumes entering the marine environment annually than catastrophic spills.[123] The breakdown of oil pollution in the marine environment is largely dependent upon environmental factors such as turbulence, sunlight, and temperature, as well as the composition of the oil itself.[124]

With regard to cetaceans, oil can have the following possible effects:[125]

1. Animals can inhale the more volatile hydrocarbons, which evaporate rapidly from a fresh spill and may be present in significant concentrations just above the surface of an oil slick. These hydrocarbons may be more reactive and, therefore, toxic, with likely effects including, at the least, irritation of the respiratory membrane.
2. Through eating oil-coated or otherwise contaminated prey items, cetaceans might ingest hydrocarbon contaminants. However, in an experiment in which a bottlenose dolphin was force fed oil, the enzyme Cytochrome P-450 was detected, suggesting the metabolization of the hydrocarbons it had ingested. No adverse effects were noted in this, albeit limited, study.[126]

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[120] N. J. Scott & E.C.M. Parsons, *A Survey of Public Opinions in Southwest Scotland on Cetacean Conservation Issues*, 15 ACQUATIC CONSERVATION 299–312 (2005).

[121] For example, 363 million gallons of oil are discharged into the oceans via sewage systems as opposed to only 37 million gallons in catastrophic spills. G.C. Feldman & J. Gradwohl, *Oil Pollution*, *in* SMITHSONIAN INSTITUTION (1995), http://seawifs.gsfc.nasa.gov/OCEAN_PLANET/HTML/peril_oil_pollution.html.(*last updated in* 1995).

[122] *Id.*

[123] *Id.*

[124] Int'l Tanker Owners Pollution Fed. (ITOPF) *Fate of marine oil spills*, TTOPF, 2002, 1–8, http://www.itopf.com/uploads/tip2.pdf

[125] J. R. GERACI, PHYSIOLOGIC AND TOXIC EFFECTS ON CETACEANS IN SEA MAMMALS AND OIL: CONFRONTING THE RISKS (J. R. Geraci & D. J. St. Aubin eds., 1990); S. GUBBAY & R. EARLL, REVIEW OF LITERATURE ON THE EFFECTS OF OIL SPILLS ON CETACEANS (1999) (report submitted to Talisman Energy and Scottish Natural Heritage).

[126] GERACI (1990), *supra* note 126.

3. Cetaceans may become physically coated with oil. Cetacean skin is presumed to be impermeable to hydrocarbons, and no significant irritation of the skin has been reported after cetaceans have been immersed in these chemicals.[127] Even when the skin of cetaceans was cut, oil seemed to have little impact on subsequent healing.[128] There have even been reports of dolphins swimming through oil with no apparent ill effect, although some behavioural changes were observed.[129] Concerns have been raised that oil might clog the baleen plates of filter feeding whales. However, baleen whales that have reportedly become coated with oil appeared to have lost nine per cent of their oil covering within 24 hours and were taken to have not been unduly effected.[130]

It has been suggested that cetaceans seem to be able to detect and avoid, or swim underneath oil slicks[131] and, therefore, the direct effects of oil pollution may be relatively minor for cetaceans. Surveys on public opinion have, however, found that oil spills are considered by the general public to be one of the greatest threats to cetaceans in parts of the UK.[132]

The level of concern that the public gives oil spills as a threat to cetaceans may be due to the high levels of media attention that have been given to spills occurring in the UK in recent years, and the risk that they pose to non-cetacean marine wildlife; for example, the *Braer* (5 January 1993, Shetland Islands, Scotland) and the *Sea Empress* (15 February 1996, Mill Bay, Wales) oils spills. For both of these spills there was no evidence, however, of any direct cetacean mortality as the result of the spills[133] or any subsequent change in cetacean distribution.[134]

However, these oil spills have led to concern over contamination and intoxication of fish and shellfish in the areas effected by the spills, resulting in a fishery closure enacted under the Food and Environment Protection Act

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[127] *Id.*

[128] *Id.*

[129] These behavioural changes included spending less time at the surface, and faster and more infrequent blows. *Id.*

[130] *Id.*

[131] J.R. Geraci *et al.*, *Bottlenose Dolphins* (Tursiops truncatus) *can Detect Oil*, 40 CAN. J. OF FISHERIES & ACQUATIC SCI. 1516–1522 (1983); T.G. Smith *et al.*, *Reaction to Bottlenose Dolphin* (Tursiops truncates) *to a Controlled Oil Spill*, 40 CAN. J. OF FISHERIES & ACQUATIC SCI. 1522–1525 (1983); D.J. St. Aubin *et al.*, *How Do Bottlenose Dolphins* (Tursiops truncates) *React to Oil Films Under Different Light Conditions?*, 42 CAN. J. OF FISHERIES & ACQUATIC SCI. 430–436 (1985).

[132] Scott & Parsons, *supra* note 120, at 299; C. Howard & E.C.M. Parsons, *Attitudes of Scottish City Inhabitants to Cetacean Conservation*, BIODIVERSITY & CONSERVATION (accepted for publication).

[133] Sea Empress Envtl. Evaluation Comm., *The Environmental Impact of the Sea Empress Oil Spill* (Final Report, Her Majesty's Stationery Office, London 1998).

[134] M. Baines *et al.*, *A Cetacean Sightings Database for Wales and an Evaluation of Impacts on Cetaceans From the Sea Empress Oil Spill*, CCW SEA EMPRESS CONTRACT REP. NO. 227 (1997).

of 1985 (FEPA).[135] It should be noted, however, that although there were fears over possible human poisoning from oil products, there has been no subsequent research regarding the acute or more chronic toxic effects of these spills on cetaceans, in particular the possible contamination of cetaceans in these spill sites by Polynuclear Aromatic Hydrocarbons (PAHs; see Section 1.3.1.5).

1.3.1.5 Polynuclear Aromatic Hydrocarbons (PAHs)

Relatively little research has been carried out into the potential toxicity of polynuclear aromatic hydrocarbons (PAHs). PAHs are primarily produced during combustion, both natural (e.g., bush fires) and anthropogenic (e.g., vehicle exhausts and coal-fired power stations). PAH contamination has also been associated with oil spills.[136] Thus, spills and other forms of oil pollution could be contributing to PAH contamination, which could cause, for example, chronic health effects in species, such as cetaceans, that feed on contaminated prey items. Despite the toxic risk that PAHs pose, the UK has yet to set health regulation guidelines for PAH contamination in seafood,[137] let alone guidelines for levels that pose a risk to marine wildlife.

PAHs, notably benzoapyrene and its derivatives, can combine with DNA to produce an extremely carcinogenic compound.[138] Because of this, the high rate of cancer seen in beluga whales (*Delphinapterus leucas*) in the St. Lawrence Estuary has been attributed to PAH contamination.[139] Therefore, PAH contamination could be a potential threat to the health of other cetacean populations.[140]

Research conducted in the UK has detected PAHs in coastal and estuarine waters[141] and marine sediments[142] in England and Wales. At one sediment sampling site, PAH contamination was high enough to potentially cause the

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[135] Law *et al.*, *The Impact of the Sea Empress Oil Spill on Fish and Shellfish*, *in* THE SEA EMPRESS OIL SPILL: PROCEEDINGS OF THE INTERNATIONAL CONFERENCE HELD IN CARDIFF, 11–13 FEBRUARY 1998 109–136 (R. Edwards & H. Sime eds., 1998).

[136] C.A. Kelly & R.J. Law, *Monitoring of PAH in Fish and Shellfish Following the Sea Empress Oil Spill*, in THE SEA EMPRESS OIL SPILL: PROCEEDINGS OF THE INTERNATIONAL CONFERENCE HELD IN CARDIFF 467–473 (R. Edwards & H. Sime eds., 1998); R.J. Law & J. Hellou, *Contamination of Fish and Shellfish Oil Spill Incidents*, 6 ENVTL. GEOSCIENCES 90–98, (2000).

[137] *Law & Hellou* (2000), *supra* note 137, at 90.

[138] L.G. Hansen & B.S. Shane, *Xenobiotic Metabolism*, *in* BASIC ENVIRONMENTAL TOXICOLOGY 49–105 (L.G. Cockerham & B.S. Shane eds., 1994); M.J. Carvan & D.L. Busbee, *Mechanisms of Aromatic Hydrocarbon Toxicity: Implications for Cetacean Morbidity and Mortality*, in TOXICOLOGY OF MARINE ANIMALS 429–457 (J.G. Vos *et al.* eds., 2003).

[139] D. Marineau *et al.*, *Pathology and Toxicology of Beluga Whales From the St. Lawrence Estuary, Quebec, Canada: Past, Present, and Future*, 154 SCI. OF TOTAL ENV'T 201–215 (1994).

[140] Carvan, *supra* note 139, at 429–457.

[141] R.J. Law *et al.*, *Polycyclic Aromatic Hydrocarbons (PAH) in Seawater Around England and Wales*, 34 MARINE POLLUTION BULL. 306–321 (1997).

[142] R.J. Woodhead *et al.*, *Polycyclic Aromatic Hydrocarbons (PAH) in Surface Sediments Around England and Wales, and Their Possible Biological Significance*, 38 MARINE POLLUTION BULL. 773–790 (1999).

mortality of marine organisms. About 15 per cent of the samples analysed could lead to contaminant levels in marine organisms, which may lead to chronic health effects.[143]

Harbour porpoises have also been analysed in the UK for PAH contamination.[144] Although levels were relatively low,[145] the sample size was fairly small and the studies so far have been limited to only one specie. Calves and juveniles were, nonetheless, found to have detectable levels of PAHs, and if these contaminants bio-accumulate, it would be expected that there may be adults with relatively high levels. Moreover, samples from cetaceans in areas where oil spills have occurred or PAH contamination is prevalent should be specifically collected and analysed.[146] It would be expected, for example, that elevated levels of PAHs might be present in cetaceans from around the Shetland Isles and Wales, from areas in close proximity to the *Braer* and *Sea Empress* oil spills.[147]

Finally, the possible synergistic effects of PAHs with other forms of organic and inorganic pollutants, particularly those of a carcinogenic nature, should be investigated. Considering the potential for PAH contamination, the levels of this contaminant in cetacean tissues and their possible effects on cetacean health warrants further research.

1.3.1.6 Sewage Pathogens

Sewage entering UK coastal waters consists of domestic, industrial, agricultural, and fish farm wastes. Waste from these sources contributes a mix of organic and inorganic compounds (including trace elements; Section 1.3.1.2), quantities of marine litter (Section 1.2.2), and a mix of both harmless and infectious microorganisms.[148,149] As a result of the EU Water Framework Directive and other related legislation,[150] the UK government has made a

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[143] *Id.*

[144] R.J. Law & J.A. Whinnet, *Polycyclic Aromatic Hydrocarbons in Muscle Tissue of Harbor Porpoises* (Phocoena phocelena) *From UK Waters*, 24 MARINE POLLUTION BULL. 550–553 (1992).

[145] PAH concentrations ranged from 0.11–0.56 μg chrysene equivalents.g^{-1} wet weight, and 0.47–2.4 μg Ekofisk crude oil equivalents.g^{-1} wet weight. The highest values detected were extracted from a juvenile harbour porpoise stranded on the Isle of Man. *Id.*

[146] All recommendation relating to tissue sampling in this report relate to samples from animals that are found dead.

[147] Law & Hellou, *supra* note 137, at 93–94.

[148,] HMSO (Her Majesty's Stationary Office), *Fourth Report: Pollution of Beaches, in* 1 HOUSE OF COMMONS ENVIRONMENT (1990); G. Rees, *Health Implications of Sewage in Coastal Waters the Britain Case*, 26 MARINE POLLUTION BULL. 14–19 (1993).

[149] Pathogens found in sewage include *Salmonella* spp., *Escherichia coli, Streptococcus* sp., *Staphylococcus aureus, Pseudomonas aeruginosa,* the fungi *Candida,* and viruses such as enterovirus, hepatitis, poliomyelitis, influenza and herpes.

[150] EU Water Framework Directive (2000/60/EC), OJ L 327, http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:32000L0060:EN:NOT (Oct. 23, 2000). Other directives concerning coastal waters quality include the EU Urban Waste-Water Treatment Directive (91/271/EEC), OJ

commitment to upgrade sewage treatment for major urban populations where secondary sewage treatment plants will be installed. Such secondary treatment reduces the biological oxygen demand and removes the suspended solids that are not removed by less rigorous forms of treatment. Bacteria[151] and viruses[152] are present in large concentrations in raw sewage, and current sewage treatments do not remove all of the micro-organisms as it is uneconomical to do so.[153] Thus, substantial quantities of pathogens, as well as other pollutants, still enter marine waters despite the treatment of sewage effluent. Moreover, many small, rural coastal towns and villages discharge their sewage directly into the marine environment, via septic tanks or private outfalls, without any treatment at all, potentially causing hotspots of localised sewage pollution.

Several studies have suggested that marine mammals may be susceptible to infection from human or livestock pathogens transferred through sewage or agricultural effluents. For example, a hepatitis outbreak in the United States was believed to be the result of a virus transferred to marine mammals by human sewage.[154] Also, human-borne diseases such as influenza A and B, hepatitis B, herpes, and measles are amongst those believed to be capable of infecting cetaceans.[155] Also, bacteria associated with human pathogen contaminated sewage water[156] have been documented in marine mammals, such as *Escherichia coli*, *Mycobacterium tuberculosis*, *Vibrio cholera,* and *Salmonella sp.*[157,158] In addition, sewage-borne fungi could also, theoretically, infect

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L 135, http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX :31991L0271:EN:NOT (May 21, 1991), and the EU Bathing Water Quality Directive (76/160/EEC), OJ L 031, http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:31976L0160:EN:HTML (Dec. 8, 1975).

[151] Up to 4,000,000,000 per litre of raw sewage. HMSO, *supra* note 149.

[152] From 10,000 to 10, 000,000 per litre of raw sewage. *Id.*

[153] W.J. Reilly, *Human and Animal Salmonellosis in Scotland Associated with Environmental Contamination, 1973–79*, 108 VETERINARY REC. 553–555 (1981).

[154] J.O. Britt *et al.*, *Acute Viral Hepatitis in California Sea Lions*, 175 J. OF AM. VETERINARY MED. ASSOC. 921–923 (1979).

[155] G.D. Thurman, *Disease Problems Encountered in Free and Captive Dolphins*, 31 THE NATURALIST 23 (1987); G.D. Bossart *et al.*, *Hepatitis B-Like Infection in a Pacific White-Sided Dolphin* (Lagenorhynchus obliquidens), 196 J. OF AM. VETERINARY MED. ASSOC. 127–130 (1990).

[156] E.E. GELDREICH, INDICATORS OF VIRUS IN WATER AND FOOD (1977); V.P. Olivieri, *Bacterial indicators of pollution*, *in* BACTERIAL INDICATORS OF POLLUTION 21–41 (W.O. Pipes ed., 1982).

[157] Bacterial species found in cetaceans include *Alcaligens* spp., *Citrobacter freundii, Clostridium* spp., *Enterobacter* spp., *Escherichia coli, Klebsiella* spp., *Leptospira* spp., *Mycobacterium tuberculosis*, *Proteus mirabilis, Pseudomonas aeringinosa, Salmonella* spp., *Staphylococcus aureus,* and *Vibrio cholera.*

[158] W.L. Jellison & K.C. Milner, *Salmonellosis* (bacillary dysentry) *of fur seals*, 22 J. OF WILDLIFE MGMT. 199–200 (1958); A.W. Smith *et al.*, Leptospira pomona *and Reproductive Failure in California Sea Lions*, 165 J. OF AM. VETERINARY MED. ASS'N 996–998 (1974); J.C. Sweeny & W.G. Gilmartin, *Survey of Disease in Free Living Californian Sealions*, 10 J. OF WILDLIFE DISEASES 370–376 (1974); M.M. Streitfield & C.G. Chapman, *Staphylococcus aureus Infections of Captive Dolphins* (Tersiops trucatus) *and Oceanarium Personnel*, 37 AM. J. OF VETERINARY RES. 304–305 (1976); A.W. Smith *et al.*, *Hazards of Disease Transfer from Marine Mammals to Land Mammals: A Review and Recent Findings*, 173 J. OF AM. VETERINARY MED. ASS'N 1131–1132 (1978); S.S. Diamond *et al.*, *Fatal Bronchopneumonia*

marine mammals living in contaminated waters. For example, *Candida sp.* is a common component of sewage waste and has been isolated from cetaceans.[159]

In order for a pathogen to infect a cetacean, a site of entry is required. These include:[160]

1. Mucous membranes;
2. The respiratory tract;
3. Lesions and lacerations—cetaceans frequently receive cuts and scars from objects, such as wounds caused by marine litter or nets or from other cetaceans; these wounds are often the site of entry for bacterial diseases;[161] and
4. The gastrointestinal tract from ingesting polluted water and consuming prey that is contaminated by pathogens.[162]

Although research has been conducted on inorganic and organic pollutant contamination (see Sections 1.3.1.1–1.3.1.5), there has yet to be any

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and Dermatitis Caused by Pseudomorias aerinosa in an Atlantic Bottle-Nosed Dolphin, 175 J. OF AM. VETERINARY MED. ASS'N 984–987 (1979); J.R. Geraci *et al.*, *Mass Mortality of Harbor Seals: Pneumonia Associated with Influenza A Virus*, 215 SCI. 1129–1131 (1982); E.B. Howard *et al.*, *Bacterial Diseases*, in 1 PATHOLOGY OF MARINE MAMMALS DISEASES 69–118 (E.B. Howard ed., 1983); J.R. Baker & R. Baker, *Effects of Environment on Grey Seal* (Halichoerus grypus) *Pup Mortality, Studies on the Isle of May*, 216 J. OF ZOOLOGY 529–537 (1988); J.D. Buck & S. Spotte, *Microbiology of Captive White-Beaked Dolphins* (Lagenorhynchus albirostris) *with Comments On Epizootics*, 5 ZOO BIOLOGY 321–329 (1986); H.P. Minette, *Salmonellosis in the Marine Environment: A Review and Commentary*, 13 INT'L J. OF ZOONOSIS 55–65 (1986); G.H. Steiger *et al.*, *Mortality of Harbour Seal Pups at Different Sites in the Inland Waters of Washington*, 25 J. OF WILDLIFE DISEASES 319–328 (1989); J.D. Buck *et al.*, *Bacteria Associated with Stranded Cetaceans From Northeast USA and Southwest Florida Gulf Coasts*, 10 DISEASES OF AQUATIC ORGANISMS 147, 151 (1991); D. Forshaw & G.R. Phelps, *Tuberculosis in Captive Colony Of Pinnipeds* 27 J. OF WILDLIFE DISEASES 288, 288–295 (1991); G.V. Palmer *et al.*, Staphylococcus aureus *Infection in Newly Captured Pacific Bottlenose Dolphins* (Tursiops truncates), 22 J. OF ZOO & WILDLIFE MED. 330–338 (1991); M.B. Fothergill *et al.*, *Serum Alkaline Phosphates—Changes in Relation to State of Health and Age of Dolphins*, 17 AQUATIC MAMMALS 71–75 (1991); P.J. Thompson *et al.*, *Seals, Seal Trainers, and Mycobacterial Infection*, 147 AM. REV. OF RESPIRATORY DISEASE 164–167 (1993); J.D. Buck & S.A. McCarthy, *Occurrences of Non- 01 Vibrio cholerae in Texas Gulf Coast Dolphins* (Tursiops trucatus), 18 LETTERS IN APPLIED MICROBIOLOGY 45–46 (1994); J.R. Baker *et al.*, *Isolation of Salmonellae from Seals from UK Waters*, 136 VETERINARY REC. 471–472 (1995); E.C.M. Parsons & T.A. Jefferson, *Post-mortem Investigations on Stranded Dolphins and Porpoises from Hong Kong Water*, 36 J. OF WILDLIFE DISEASES 342–356 (2000).

[159] J.C. Sweeny *et al.*, *Systemic Mycoses in Marine Mammals*, 169 J. OF AM. VETERINARY MED. ASSOC. 946–948 (1976); J.L. Dunn *et al.*, *Candidiasis in captive cetaceans*, 185 J. OF AM. VETERINARY MED. ASS'N 1328–1330 (1982).

[160] V. Grillo *et al.*, *A Review of Sewage Pollution in Scotland and Its Potential Impacts on Harbour Porpoise Populations* (July 2001) (presented to the Int'l Whaling Comm'n Sci. Comm., 53d Meeting of the Int'l Whaling Comm'n, Paper SC/53/E13).

[161] R.S. Fujioka *et al.*, *Vibrio Damsela from Wounds in Bottlenose Dolphins* Tursiops truncatus. 4 DISEASES OF AQUATIC ORGANISMS 1 (1988).

[162] A.W. Smith & P.M. Boyt, *Calciviruses of Ocean Origin: A Review*, 21 J. OF ZOO & WILDLIFE MED. 3 (1990).

research in the UK on cetacean contamination by sewage-borne pathogens.[163] Nor has there been any research on pathogen exposure as the result of living in contaminated waters or consuming contaminated prey items. However, there have been suggestions that high rates of skin disease exhibited by bottlenose dolphins in the Moray Firth might be linked to pathogens in these waters.[164]

An estimation of sewage pathogen exposure for Scottish cetaceans, even when the researchers assumed that cetaceans were inhabiting waters that were clean enough to potentially be classified as bathing waters, predicted that porpoises and dolphins in Scotland could be exposed to substantial quantities of bacteria through ingesting seawater alone.[165] The everyday exposure of these cetaceans would be several orders of magnitude higher than levels considered unsafe for humans in just a "one-off" exposure.[166] Coastal waters close to urban centres are likely to be far more contaminated than the bathing beach waters used in the above exposure estimation. Therefore, it is likely that cetaceans living in coastal areas are likely to be exposed to even greater levels of pathogens.[167]

An important consideration with this exposure to sewage borne pathogens is the issue of immune suppression caused by anthropogenic chemicals such as organohalogens (Section 1.3.1.1), trace elements (Section 1.3.1.2), or butyltins (Section 1.3.1.3). Many pathogens contained in sewage are opportunistic, and if an animal is stressed, injured, or particularly if its immune system is compromised, infection could occur. Even in normal circumstances, animals might have been able to resist the infection. As mentioned previously, cetaceans in the UK, where disease is the cause of death, have been found to possess significantly higher concentrations of organohalogens[168] or trace element[169] contaminants. Therefore, exposure to anthropogenic pathogens (for example, through sewage pollution) should also be considered when assessing risks

1.3.1.7 Nutrient Pollution

Throughout the world, increased outputs of nitrogen and phosphorous wastes have led to the rapid growth of algae (known as "algal blooms"), which in turn decay and lead to the deoxygenation of bays, estuaries, and shallow

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[163] Grillo *et al.*, *supra* note 161.

[164] P.M. Thompson *et al.*, *Combining Power Analysis and Population Viability Analysis to Compare Traditional and Precautionary Approaches to the Conservation of Coastal Cetaceans*, 14 CONSERVATION BIOLOGY 1253 (2000).

[165] I.e., daily ingestion rate of up to 2,000–10,000 faecal coliforms day^{-1} for harbour porpoises or 6,000–30,000 faecal coliforms day^{-1} for bottlenose dolphins. Grillo *et al.*, *supra* note 161, at PPP.

[166] *Id.*

[167] *Id.*

[168] Jepson *et al.*(1999), *supra* note 76; Jepson *et al.* (2005a), *supra* note 76.

[169] Bennett *et al.*, *supra* note 97.

seas (i.e., eutrophication).[170] These excess nutrients are typically the result of sewage effluent or agricultural or industrial discharges; although in the UK, fish farm sites are also a significant source of increased levels of nutrient wastes.[171] Frequently, the algal blooms caused by these excess nutrients are also often accompanied by the algae's production of toxins.[172] Cetaceans could potentially be affected by these toxins, either absorbing them from the water column, or via consuming toxin-contaminated fish.[173]

It has been suggested that algal toxins were a major factor in several marine mammal mass mortalities,[174] including a mortality event in the UK.[175] However, the results of post mortems of animals in this particular UK event determined that although a small number of algal cells were found in the stomachs of the dolphins examined, no algal toxins were actually detected.[176] Further investigation into the possible effects of algal toxins, and their role in

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[170] A.J. Van Bennekom *et al.*, *Eutrophication of Dutch Coastal Waters,* 189 PROCEEDINGS OF THE ROYAL SOC'Y OF LONDON (SERIES B*)* 359 (1975); A.H. Taylor, *Modelling Contaminants in the North Sea,* 63 SCI. OF TOTAL ENV'T 45 (1987); P. Tett & D. Mills, *The Plankton of the North Sea: Pelagic Ecosystems under Stress?,* 16 OCEAN & SHORELINE MGMT. 233 (1991); D. Sarokin & J. Schulkin, *The Role of Pollution in Large-Scale Population Disturbances. Part 1: Aquatic Populations,* 26 ENVT'L. SCI. & TECH. 1477 (1992); S.R. Kerr & R.A. Ryder, *Effects of Cultural Eutrophication on Coastal Marine Fisheries: A Comparative Approach*, *in* MARINE COASTAL EUTROPHICATION: THE RESPONSE OF MARINE TRANSITIONAL SYSTEMS TO HUMAN IMPACT; PROBLEMS & PERSPECTIVES FOR RESTORATION 599 (R.A. Vollenweider *et al.* eds., 1993); R.A. Vollenweider, *Coastal Marine Eutrophication: Principles and Control, in* MARINE COASTAL EUTROPHICATION: THE RESPONSE OF MARINE TRANSITIONAL SYSTEMS TO HUMAN IMPACT; PROBLEMS & PERSPECTIVES FOR RESTORATION 1 (R.A. Vollenweider *et al.* eds., 1993); D. Justic *et al.*, *Stoichiometric Nutrient Balance and Origin of Coastal Eutrophication,* 30 MARINE POLLUTION BULL. 41 (1995).

[171] R.J. Gowen *et al.*, *Investigations Into Benthic Enrichment, Hypernutrification, and Eutrophication Associated With Mariculture in Scottish Coastal Waters (1984–1988)* (1988) (report to the Highlands and Islands Development Board, Crown Estate Commissioners, Nature Conservancy Council, Countryside Commission for Scotland and Salmon Growers Association); P.A. Gillibrand *et al.*, *Bottom Water Stagnation and Oxygen Depletion in a Scottish Sea Loch,* 43 ESTUARINE & COASTAL SHELF SCI. 217 (1996); G. Taylor *et al.*, *Collection and Treatment of Waste Chemotherapeutants and the Use of Enclosed-Cage Systems in Salmon Aquaculture*, SCOTTISH ENVT'L. PROTECTION AGENCY (1988).

[172] D.M. Anderson, *Toxic Algal Blooms and Red Tides: A Global Perspective, in* RED TIDES: BIOLOGY, ENVIRONMENTAL SCIENCE & TOXICOLOGY 11 (T. Okaichi *et al.* eds., 1989); G.M. Hallegraeff, *A Review of Harmful Algal Blooms and Their Apparent Global Increase*, 32 PHYCOLOGIA 79 (1993); K.A. Steidinger, *Some Taxonomic and Biologic Aspects of Toxic Dinoflagellates, in* ALGAL TOXINS IN SEAFOOD & DRINKING WATER 1(I.A. Falconer ed., 1993); F.M. Van Dolah, *Marine Algal Toxins: Origins, Health Effects, and Their Increased Occurrence*, 108 ENVTL. HEALTH PERSPECTIVES 133 (2000).

[173] A.M. Legrand, *Ciguatera Toxins: Origin, Transfer Through Food Chain and Toxicity to Humans*, *in* HARMFUL ALGAE 39 (B. Reguera *et al.* eds., 1998); Van Dolah, *supra* note 173.

[174] J.R. Geraci *et al.*, *Humpback Whales (*Megaptera Novaeangliae*) Fatally Poisoned by Dinoflagellate Toxin,* 46 CAN. J. OF FISHERIES & AQUATIC SCI. 1895 (1989); E. Costas & V. Lopez-Rodas, *Paralytic Phycotoxins in Monk Seal Mass Mortality*, 142 VETERINARY REC. 643 (1998); M. Hernandez *et al.*, *Did Algal Toxins Cause Monk Seal Mortality*, 393 NATURE 28 (1998); F.M. Van Dolah *et al.*, *Impacts of Algal Toxins on Marine Mammals*, *in* TOXICOLOGY OF MARINE MAMMALS 247 (J.G. Vos *et al.* eds., 2003); L.J. Flewelling *et al.*, *Red Tides and Marine Mammal Mortalities*, 435 NATURE 755 (2005).

[175] T. Kuiken *et al.*, *Mass Mortality of Common Dolphins* (Delphinus Delphis) *in South-West England Due to Incidental Capture in Fishing Gear*, 134 VETERINARY REC. 81(1994).

[176] *Id.*

cetacean health and mortality, should be undertaken in the UK, particularly in areas with high levels of nitrogenous waste (e.g., near discharges and fish farm sites).

1.3.1.8 Radionuclides

Although some radioactive materials in the marine environment come from natural sources, anthropogenic sources of radionuclides[177] include atmospheric fallout of nuclear weapons, accidental release from nuclear installations, and discharges from nuclear plants. Radionuclides have been detected in a number of cetacean species around the world,[178] including cetaceans from UK waters.[179] Indeed, in comparison with other population studies, radioactive contaminant levels in UK cetaceans[180] and other marine mammals[181] are the highest in the world.[182] As of yet, there has been little research to evaluate the effects of radionuclide contamination on UK cetaceans, despite these animals being thought to be particularly vulnerable to radioactive contamination.[183]

One of the most significant sources of anthropogenic radioactive discharge is the Sellafield nuclear fuel reprocessing plant, which has been discharging radioactive waste into the Irish Sea since 1952.[184] In 1994, discharges were supposed to decrease after the new EAR Plant[185] began operating, although in some marine areas, higher levels of radioactive contamination have actually been recorded since the operation of this new plant.[186] In fact, the discharges from Sellafield and a similar French facility in Le Havre have been blamed for a doubling of radioactive[187] contamination in Norwegian and Arctic Ocean waters since 1996, and researchers predict another doubling of contamination between 2001 and 2006.[188] Thus, radioactive discharges from

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[177] Radionuclides are the radioactive forms (isotopes) of elements.

[178] E.R. Samuels *et al.*, *Strontium-90 and Caesium-137 in Tissues of Fin Whales* (Balaenoptera Physalus) *and Harp Seals* (Pagophilius groenlandicus)*,* 48 CAN. J. OF ZOOLOGY 267 (1970); D. Calmet *et al.*, *210Pb, ^{137}Cs and ^{10}K in Three Species of Porpoises Caught in the Eastern Tropical Pacific Ocean*, 15 J. OF ENVTL. RADIOACTIVITY 153 (1992); R. Yoshitome *et al.*, 2003. *Global Distribution of Radionuclides (^{137}Cs and ^{40}K) in Marine Mammals,* 37 ENVTL. SCI. & TECHNOLOGY 4597 (2003).

[179] S.D. Berrow *et al.*, *Radionuclides (^{137}Cs and ^{40}K) in Harbour Porpoises* Phocoena Phocoena *from British and Irish Coastal Waters*, 36 MARINE POLLUTION BULL. 569 (1998).

[180] Up to 66.6 Bq.kg-^{1} (wet weight) for radioactive caesium (^{137}C) in a UK harbour porpoise. Berrow *et al.*, *supra* note 180.

[181] Up to 178.8 Bq.kg^{-1} (wet weight) for radioactive potassium (^{40}K) in a UK grey seals. *Id*.

[182] Yoshitome *et al.*, *supra* note 179.

[183] P.W. Johnston *et al.*, *Cetaceans and Environmental Pollution: The Global Concerns, in* THE CONSERVATION OF WHALES AND DOLPHINS: SCIENCE AND PRACTICE 245 (M. Simmonds & J.D Hutchinson eds., 1996).

[184] Leonard *et al.*, *Distribution of Technetium-99 in UK Coastal Waters*, 34 MARINE POLLUTION BULL. 628, 628–629 (1997).

[185] Enhanced Actinide Removal Plant.

[186] Leonard *et al.*, *supra* note 185, at 628.

[187] Specifically iodine.

[188] Alfimov *et al., Anthropogenic Iodine-129 in Seawater Along a Transect From the Norwegian Coastal Current to the North Pole*, 49 MARINE POLLUTION BULL. 1097 (2004).

UK facilities can not only cause impacts to UK cetaceans, but radioactive contamination might be an issue for cetaceans farther afield.

1.3.2 Noise Pollution

Levels of noise in the marine environment have increased greatly over the past few decades.[189] Cetaceans are largely reliant on sound for the detecting prey, determining their surroundings (via echolocation and passive listening), navigating, maintaining social contact, and communicating—including communication during courtship behaviour, the production of alarm calls, and group coordination.[190] Thus, anthropogenic noise poses a problem for cetaceans, including noise of a frequency that could clash with, and cover up (i.e., "mask"), biologically important sounds, making them undetectable by cetaceans.[191] One of the most ubiquitous producers of noise in the marine environment is shipping traffic. In addition to shipping-based noise, other sources of noise that may impact cetaceans include:[192]

1. Air guns used during oil and gas exploration;
2. Fish finders and depth sounders;
3. Sound sources used in oceanographic research;
4. Predator deterrent devices (seal-scrammers) used in fish farms;
5. Dredging;
6. Oceanic windfarms; and
7. Military activities.

1.3.2.1 Sources of Marine Noise

1.3.2.1.1 Shipping. In general, older vessels produce more noise than newer ones and larger vessels produce more than smaller ones.[193] Lower frequency noises produced by shipping traffic also travel further in the ocean than higher frequency noises. So, for example, the noise from a supertanker (at 6.8

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[189] Andrew *et al.*, *Ocean Ambient Sound: Comparing the 1960s With the 1990s for a Receiver Off the California Coast*, 3 ACOUSTIC RES. LETTERS ONLINE 65 (2002) reported a 10 decibel increase in ocean noise levels (in the frequencies 20–80 hertz) over a 33-year period, measures from a listening station off Point Sur in central California. This increase in marine noise was primarily attributed to shipping-produced sound.

[190] Parsons *et al.*, *The Use of Sound by Cetaceans*, *in* OCEANS OF NOISE (M. Simmonds et al. eds., 2003).

[191] Parsons *et al.*, *Noise as a Problem for Cetaceans*, *in* OCEANS OF NOISE (M. Simmonds et al. eds. 2003).

[192] Parsons *et al.*, *Sources of Noise*, *in* OCEANS OF NOISE 24, 24–43 (M. Simmonds, S. Dolman & L. Weilgart eds., 2003).

[193] Gordon *et al.*, *Underwater Noise Pollution and Its Significance for Whales and Dolphins*, *in* THE CONSERVATION OF WHALES AND DOLPHINS: SCIENCE AND PRACTICE 290 (M.P. Simmonds & J.D. Hutchinson eds., 1996).

Table 1. Summary of sound frequencies produced by vessel traffic and their source level[195]

Type of vessel	Frequency (kHz)	Source level (dB re 1μPa)	Reference
650cc Jetski	0.8–50.0	75–125	Evans and Nice (1996)
Rigid inflatable	6.3	152	Malme *et al.* (1989)
7m outboard motor boat	0.63	156	Malme *et al.* (1989)
Fishing boat	0.25–1.0	151	Greene (1985)
Fishing trawler	0.1	158	Malme *et al.* (1989)
Tug pulling empty barge	0.037	166	Buck and Chalfant (1972)
	1.0	164	Miles *et al.* (1989)
	5.0	145	
Tug pulling loaded barge	1.0	170	Miles *et al.* (1989)
	5.0	161	
34m (twin diesel engine) workboat	0.63	159	Malme *et al.* (1989)
Tanker (135m)	0.43	169	Buck and Chalfant (1972);
Tanker (179m)	0.06	180	Ross (1976);
Supertanker (266m)	0.008	187	Thiele and Ødengaard (1983);
Supertanker (340m)	0.007	190	
Supertanker (337m)	0.007	185	
Containership (219m)	0.033	181	Buck and Chalfant (1972);
Containership (274m)	0.008	181	Ross (1976);
Freighter (135m)	0.041	172	Thiele and Ødengaard (1983)

hertz) could be detected 139–463 kilometres away.[194] Whereas on a smaller scale, even the noise from a small, 70 horsepower, outboard engine, which produces noise levels of approximately 142 decibels (400 hertz–4 kilohertz), could be detected at only 50 metres from the source.[196]

Typically, shipping produces frequencies below one kilohertz (Table 1) although higher frequencies can also be produced. Hearing sensitivity tests conducted on captive animals indicate that most toothed whales and dolphins have poor auditory sensitivities at these low frequencies.[197] However, baleen

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[194] D. Ross, Mechanics of Underwater Noise (1976).

[195] C.R. Greene & S.E. Moore, *Man-Made Noise, in* Marine Mammals and Noise 101–158 (C.R. Greene *et al.* eds., 1995); E.C. M. Parsons *et al.*, *Sources of Noise*, *in* Oceans of Noise 26–27 (M. Simmonds et al. eds., 2003).

[196] Stewart *et al.*, Effects of Man-Made Waterborne Noise on the Behaviour of Belukha Whales *(Delphinapterus leucas)* in Bristol Bay, Alaska (1982) (unpublished report to the U.S National Oceanic and Atmospheric Administration, Juneau, Alaska).

[197] S. Andersen, *Auditory Sensitivity of the Harbour Porpoise* Phocoena phocoena, *in* 2 Investigations on cetacea (1970); Au *et al.*, *Acoustic Effects of the ATOC Signal (75Hz; 195 dB) on Dolphins and Whales*, 101 J. of Acoustical Soc. of Am. 2973, 2973–2976 (1997); Awbrey *et al.*, *Low Frequency Underwater Hearing Sensitivity in Belugas;* Delphinapterus Leucas, 84 J. of Acoustical Soc. of Am.

whales are believed, based on the frequencies of calls they produce,[198] to be more sensitive to lower frequency sound, although, recent studies on a rehabilitated gray whale (*Eschrichtius robustus*) calf suggest that baleen whales could also be able to hear higher frequency sounds.[199]

2273, 2273–2275 (1988); Jacobs *et al.*, *Auditory Thresholds of a Fresh Water Dolphin,* Inia geoffrensis blainville, 51 J. of Acoustical Soc. of Am. 530 (1972); C.S. Johnson, *Sound Detection Thresholds in Marine Mammals*, *in* Marine Bio-Acoustics (W.N. Tavolga ed., 1967); C.S. Johnson *et al.*, *Masked Tonal Hearing Thresholds in the Beluga Whale*, 85 J. of Acoustical Soc. of Am. 2651 (1989); Kastelein *et al.*, *Low-Frequency Aerial Hearing of a Harbour Porpoise* (Phocoena phocoena), *in* The Biology of the Harbour Porpoise (A.J. Read *et al.* eds., 1997); Ljungblad *et al.*, *Auditory Thresholds of a Captive Eastern Pacific Bottle-Nosed Dolphin,* Tursiops spp., 72 J. of Acoustical Soc. of Am. 1726, 1728 (1982); Ridgway *et al.*, *First Audiogram for Marine Mammals in the Open Ocean and at Depth: Hearing and Whistling by Two White Whales Down to 30 Atmospheres*, 101 J. of Acoustical Soc. of Am. 3136 (1997); Thomas *et al.*, *Underwater Audiogram of a False Killer Whale* (Pseudorca crassidens), 84 J. of Acoustical Soc. of Am. 936 (1998); Wang *et al.*, *Auditory Sensitivity of a Chinese River Dolphin,* Lipotes vexillifer, *in* Marine Mammal Sensory Systems (J.A. Thomas *et al.* eds., 1992); White *et al.*., Auditory Thresholds of two Beluga Whales (Delphinapterus leucas) (1978) (unpublished report to the U.S. Naval Ocean Systems Center, San Diego, California).

[198] C.W. Clark, *The Acoustic Repertoire of the Southern Right Whale: A Quantitative Analysis,* 30 Animal Behav. 1060 (1982); C.W. Clark, *Acoustic Communication and Behavior of the Southern Right Whale* (Eubalaena australis), *in* Behavior and Communication of Whales (R. Payne ed., 1983); C.W. Clark, *Acoustic Behavior of Mysticete Whales*, *in* Sensory Abilities of Cetaceans: Laboratory and Field Evidence (J.A. Thomas & R.A. Kastelein eds., 1990); C.W. Clark *et al.*, *The Sounds of the Bowhead Whale,* Balaena mysticetus*, During the Spring Migrations of 1979 and 1980*, 62 Can. J. of Zoology 1436 (1984); C. W. Clark *et al.*, An Acoustic Study of Bowhead Whales, Balaena mysticetus, off Point Barrow, Alaska During the 1984 Spring Migration 145 (1986); W. C. Cummings *et al.*, *Sounds and Source Levels from Bowhead Whales off Pt. Barrow, Alaska,* 82 J. of Acoustical Soc. of Am. 814 (1987); W.C. Cummings *et al.*, *Underwater Sounds From the Blue Whale,* Balaenoptera musculus, 50 J. of Acoustical Soc. of Am. 1193 (1971); W. C. Cummings & P.O. Thompson, *Characteristics and Seasons of Blue and Finback Whale Sounds Along the U.S. West Coast as Recorded at SOSUS Stations*, 95 J. of Acoustical Soc. of Am. 2853 (1994); W.C. Cummings *et al.*, *Underwater Sounds of Migrating Gray Whales,* Eschrichtius glaucus *(Cope),* 44 J. of Acoustical Soc. of Am. 1278 (1968); W.C. Cummings *et al.*, *Sound Production and Other Behavior of Southern Right Whales,* Eubalaena australis*,* 17 Transactions of the San Diego Soc. of Nat. Hist. 1 (1972); W.C. Cummings *et al.*, *Sounds from Bryde's,* Balaenoptera edeni*, and Finback,* Balaenoptera physalus*, Whales in the Gulf of California,* 84 Fishery Bull. 359 (1986); Dalheim *et al.*, *Preliminary Hearing Study on Gray Whales Eschrictius robustus in the Field*, *in* Sensory Abilities of Cetaceans, Laboratory and Field Evidence (J.A. Thomas & R.A. Kastelein eds., 1990); Dalheim *et al.*, *Sound Production by the Gray Whale and Ambient Noise Levels in Laguna San Ignacio, Baja California Sur, Mexico*, *in* The Gray Whale, *Eschrichtius robustus* (S.L. Swartz & S. Leatherwood eds., 1984); D.K. Ljungblad *et al.*, *Sounds Recorded in the Presence of an Adult and Calf Bowhead Whale*, 42 Marine Fisheries Rev. 86 (1980); D.K. Ljungblad *et al.*, *Underwater Sounds Recorded From Migrating Bowhead Whales*, Balaena mysticetus, 71 J. of Acoustical Soc. of Am. 447 (1982); Roger Payne & Douglas Webb, Orientation by Means of Long Range Acoustic Signaling in Baleen Whales 188 (1971); Würsig *et al.*, *Behavior*, *in* The Bowhead Whale (J. Burns et al. eds., 1993).

[199] *I.e.,* the gray whale calf would have good hearing in the three kilohertz, six kilohertz, and nine kilohertz range S.H. Ridgway & D.A. Carder, *Assessing Hearing and Sound Production in Cetaceans Not Available for Behavioral Audiograms: Experiences with Sperm, Pygmy Sperm, and Gray Whales*, 27 Aquatic Mammals 267 (2001), as opposed to previous studies suggesting gray whales are most sensitive to frequencies of between 0.8 and 1.5 kilohertz. Dalheim *et al.*, *Preliminary Hearing Study on Gray Whales* Eschrictius robustus *in the Field*, *in* Sensory Abilities of Cetaceans: Laboratory and Field Evidence (J.A. Thomas & R.A. Kastelein eds., 1990).

Extreme caution should be used when interpreting captive cetaceans' sensitivity to sound. For example, despite beluga whales being deemed to have low sensitivity to low frequency sound[200] they were able to detect, and react to, shipping noises at distances of up to 85 kilometres.[201] Wild beluga whales reacted to these noises at a distance much greater than predicted by mathematical models, which used data from hearing sensitivity tests of captive animals. Based on the data collected from captive animals,[202] the beluga whales should not have been able to hear the approach of shipping vessels until they were 20 kilometres away.[203]

A more recent study also documented significant behavioural reactions of harbour porpoises to low frequency noise,[204] which, according to hearing sensitivity tests on captive porpoises, they should not have been capable of detecting.[205] This emphasises the fact that wild cetaceans may be more sensitive, and thus show greater reactions to noise, than captive cetaceans. Accordingly, noise disturbance/impact predictions for shipping, or other forms of sound production, should interpret hearing sensitivity data with extreme caution.

1.3.2.1.2 Oil and gas exploration. In order to determine the location and nature of oil and gas deposits under the sea bed, the petrochemical industry conducts seismic surveys. These surveys produce high intensity sounds, which penetrate the seabed. Upon analysis, the echoes of these sounds tell the oil companies the structure of the sea bed and positions of probable fossil fuel deposits. Depending on the method being conducted, seismic surveys can produce sound of frequencies ranging from 5 hertz to 200 kilohertz, at levels of 225 decibels to 270 decibels (Table 2).

The sounds produced by seismic surveys can be detected more than 3,000 miles from their source.[206] In fact, researchers trying to record cetaceans in the mid-Atlantic found that whale calls were frequently being smothered and 'masked' by the high levels of continuous sound produced by seismic surveys.[207]

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[200] Awbrey *et al.*, *Low Frequency Underwater Hearing Sensitivity in Belugas; Delphinapterus leucas,* 84 J. OF ACOUSTICAL SOC. OF AM. 2273 (1988).

[201] K.J. Findley *et al.*, *Reactions of Belugas,* Delphinapterus leucas*, and Narwhals,* Monodon monoceros*, to Ice-Breaking Ships in the Canadian High Arctic*, 224 CAN. J. OF FISHERIES AQUATIC SCI. 97, 97–117 (1990).

[202] Johnson *et al.*, *supra* note 197.

[203] Findley *et al.*, *supra* note 201, at 97–117.

[204] The sounds in question were recordings of noises produced by an operating wind farm.

[205] S. Koschinski *et al.*, *Behavioural Reactions of Free-Ranging Porpoises and Seals to the Noise of a Simulated Two-Megawatt Wind Power Generator,* 265 MARINE ECOLOGY PROGRESS SERIES 263, 269 (2003).

[206] S.L. Nieukirk *et al.*, *Low-Frequency While and Seismic Airgun Sounds Recorded in the Mid-Atlantic Ocean,* 115 J. OF ACOUSTICAL SOC'Y OF AM. 1832, 1840 (2004).

[207] *Id.*

TABLE 2. Summary of sound frequencies produced by seismic surveys and their source level[208]

Activity	Frequency range (kHz)	Source Level (dB re 1 μPa)
Seismic surveys		
i) High Resolution pingers, side-scanner	10–200	<230
ii) Low resolution Airguns	0.008–0.5	230–250
Sleeve exploder	0.005–0.5	225–270
Vibroseis	0.02–0.07	260

Many direct observations of cetacean responses to seismic surveys have also been recorded in response to seismic surveys.[209] For example, sperm whales have been observed exhibiting a "startle" reaction two kilometres away from a seismic survey source.[210] Common dolphins have also been observed avoiding a seismic survey source, when received sound levels would only have been approximately 133 decibels.[211] Again, the reactions of wild cetaceans to these noises occurred at levels that the animals should not have reacted to—at least according to predicted hearing sensitivities based on studies on the hearing abilities of captive cetaceans.[212]

Seismic surveys have also been linked to stranding events. In 2002, two Cuvier's beaked whales (*Ziphius cavirostris*) stranded on the Isla San Jose, in the Gulf of California, while the U.S. National Science Foundation was conducting seismic surveys from the research vessel *Maurice Ewing*.[213] It is possible that seismic surveys are also the causative factor for cetacean strandings in other areas, such as the Galápagos Islands.[214]

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[208] From Greene & Moore, *supra* note 206, at 137–145; C. Perry, *A Review of the Impact of Anthropogenic Noise on Cetaceans* (1998) (paper presented to the Sci. Comm. at the 50th Meeting of the Int'l Whaling Comm'n).

[209] P.G.H. EVANS & H. NICE, REVIEW OF THE EFFECTS OF UNDERWATER SOUND GENERATED BY SEISMIC SURVEYS IN CETACEANS (1996); C.J. Stone, *The Effects of Seismic Activities on Marine Mammals in UK Waters 1998–2000,* 323 JNCC REPORT, JOINT NATURE CONSERVATION COMMITTEE 33 (2003); J.C. Gould & P.J. Fish, *Broadband Spectra of Seismic Survey Air-Gun Emissions With Reference to Dolphin Auditory Thresholds,* 103 J. OF ACOUSTICAL SOC'Y OF AM. 2177, 2177–2184 (1998); R. Swift, *The Effects of Array Noise on Cetacean Distribution and Behaviour, in* MSC. THESIS, UNIVERSITY OF SOUTHAMPTON (1997); J. Gordon & A. Moscrop, *Underwater Noise Pollution and Its Significance for Whales and Dolphins, in* THE CONSERVATION OF WHALES AND DOLPHINS: SCIENCE AND PRACTICE 281–319 (M.P. Simmonds & J.D. Hutchinson eds., 1996).

[210] Stone, *supra* note 209, at 33.

[211] Gould & Fish, *supra* note 209.

[212] J.C. Gould & P.J. Fish, *Response to "Comment on 'Broadband Spectra of Seismic Survey Air-Gun Emissions With Reference to Dolphin Auditory Threshold,'"* 105 J. OF ACOUSTICAL SOC'Y OF AM. 2049–2050 (1999); *See also* Gould & Fish, *supra* note 209.

[213] D. Malakoff, *Suit Ties Whale Death to Research Cruise,* 298 SCI. 722, 722–723 (2002).

[214] D.M. Palacios *et al.*, *Cetacean Remains and Strandings in the Galapagos Islands 1923–2003,* 3 LATIN AM. J. OF AQUATIC MAMMALS 127, 146 (2004).

1.3.2.1.3 Fish finders and depth sounders. Marine vessels have a variety of pieces of equipment that produce high levels of sound, the most common being echo-sounders and fish finders, which analyse received sound echoes from either fish or the seabed. Although sound levels for these pieces of equipment can be substantial[215] and their use widespread, there has been little consideration as to the impacts of this sound source on cetaceans in comparison to other high intensity sources.

However, the International Whaling Commission recently discussed the issue of depth sounders and other sound producing equipment on board survey vessels and whether their use may affect the behaviour and sightings rates of cetaceans.[216] It is possible that these types of equipment may have a more substantial effect on cetaceans than previously thought.

1.3.2.1.4 Oceanographic research. Oceanographers frequently use high intensity sound sources during their research, including the use of seismic surveys, which in the case of at least one research vessel, has been linked to a beaked whale stranding event (see Section 1.3.1.3).[217] However, one of the most infamous research projects was the Acoustic Thermometry of the Ocean Climate (ATOC) project which, apart from everything else, drew attention to the potential risks of intense low frequency sound to cetaceans. The ATOC project was designed to detect changes in oceanic temperatures using a high intensity, low frequency sound source.[218] The project was initially to have two transmitters operating from Kauai, in the Hawaiian Islands and the Monterey Bay National Marine Sanctuary, in California. After public protest, the California sound source was relocated to the Pioneer Seamount, outside of, but close to, the Monterey Bay Sanctuary area.[219]

In 1991, a field test was conducted on Heard Island (in the Antarctic) to investigate the potential impacts of the ATOC sound source on cetaceans. While the low frequency sound source was operating,[220] researchers monitored a 70 kilometre by 70 kilometre area of ocean via a network of underwater

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[215] For example, 220–230 decibels for side scan sonar (50–500 kilohertz); 180 decibels+ for depth sounders (12 kilohertz+); 200–230 decibels for bottom profilers (100–160 kilohertz) and 180–200 decibels for navigational transponders (7–60 kilohertz). Green & Moore, *supra* note 206, at 147.

[216] *See* K. Annex, *Report of the Standing Working Group in Environmental Concerns, in* INT'L WHALING COMM'N Section 8.5 (2005).

[217] Malakoff, *supra* note 213.

[218] W.H. Munk & A.M.G. Forbes, *Global Ocean Warming: An Acoustic Measure?*, 10 J. OF PHYSICAL OCEANOGRAPHY, 1765, 1765–1778 (1989); ADVANCED RES. PROJECTS ADMIN., FINAL ENVIRONMENTAL IMPACT STATEMENT FOR THE CALIFORNIA ACOUSTIC THERMOMETRY OF THE OCEAN CLIMATE PROJECT AND ITS ASSOCIATED MARINE MAMMAL RESEARCH PROGRAM (1995); ADVANCED RES. PROJECTS ADMIN., FINAL ENVIRONMENTAL IMPACT STATEMENT FOR THE KAUAI ACOUSTIC THERMOMETRY OF THE OCEAN CLIMATE PROJECT AND ITS ASSOCIATED MARINE MAMMAL RESEARCH PROGRAM (1995).

[219] ADVANCED RES. PROJECTS ADMIN. (CALIFORNIA), *supra* note 219; Parsons, *supra* note 206.

[220] 209–219 decibels re 1 μPa v-centreed on 57 hertz.

sound receivers.[221] Although long-finned pilot whales (*Macrorhynchus melas*) and sperm whales (*Physeter macrocephalus*) were acoustically detected nearly a quarter of the time[222] when the sound source was not operating, there were no acoustic detections of these species at all when the sound system was on.[223]

Despite the results of the Heard Island test, the ATOC project continued, albeit with a quieter (195 decibels) source level than used in the Heard Bay test.[224] Nonetheless, effects of the sound source on cetaceans were still recorded. In Kauai, distances and durations between surfacings increased in humpback whales (*Megaptera novaeangliae*) exposed to ATOC in two separate studies;[225] with the whales receiving ATOC signals at levels of 98–109 decibels.[226] The humpback whales did not appear to be displaced from the affected area, although when the sound source was on the whales were statistically significantly further away from the sound source than when the sound source was off.[227]

These results were also echoed by researchers conducting aerial surveys in the Californian site; humpback whales and sperm whales were sighted significantly further away from the ATOC sound source when it was turned on.[228]

Despite these results, the ATOC project was taken to have no biologically significant effects on marine mammals, either in the short term or the long term, an attitude that was criticised in a U.S. National Research Council report,[229] which took the stance that the marine mammal research program associated with the ATOC project was insufficient and had not adequately conducted research into whether there had, indeed, been short- or long-term effects on marine mammals or their biological significance.

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[221] A.E. Bowles *et al.*, *The Relative Abundance and Behaviour of Marine Mammals Exposed to Transmissions From the Heard Island Feasibility Test,* 96 J. OF ACOUSTICAL SOC'Y OF AM. 2469, 2469–2484 (1994).

[222] Over a period of 1,181 minutes (nearly 20 hours).

[223] Over a period of 1,939 minutes (over 30 hours).

[224] U.S. DEP'T OF COMMERCE, ENVIRONMENTAL ASSESSMENT ON THE HEARD ISLAND ACOUSTICAL EXPERIMENT (1990).

[225] A.S. Frankel & C.W. Clark, *Results of Low-Frequency Playback of M-Sequence Noise to Humpback Whales*, Megaptera novaeangliae, *in Hawaii*. 76 CAN. J. OF ZOOLOGY 521, 521–535 (1998); A.S. Frankel & C.W. Clark, *Behavioral Responses of Humpback Whales* (Megaptera novaeangliae) *to Full-Scale ATOC Signals*, 108 J. OF ACOUSTICAL SOC'Y OF AM. 1, 1–8 (2000).

[226] Frankel & Clark (2000), *supra* note 226.

[227] A.S. Frankel & C.W. Clark, *ATOC and Other Factors Affecting the Distribution and Abundance of Humpback Whales* (Megaptera novaeangliae) *Off the North Shore of Kauai*, 18 MARINE MAMMAL SCI. 644, 644–662 (2002).

[228] J. Calambokidis, *Effects of the ATOC Sound Source on the Distribution of Marine Mammals Observed from Aerial Surveys Off Central California*, *in* WORLD MARINE MAMMAL CONFERENCE, MONACO 20–24th JANUARY 1998: ABSTRACTS 22 (1998).

[229] NAT'L RES. COUNCIL, MARINE MAMMALS AND LOW FREQUENCY SOUND: PROGRESS SINCE 1994, 33 (2000).

Also linked to the ATOC tests were a number of whale strandings, which occurred coincident with the start of several ATOC tests.[230] However, none of the whales were recovered or appropriately necropsied to determine whether there were signs that the whales may have died due to acoustic exposure.

ATOC ceased operating in October 1999, but the sound source was reused for another related project in 2002—the North Pacific Acoustic Laboratory program (NPAL). NPAL is ongoing. In this second program, monitoring surveys of whale distribution were also conducted, and although humpback whales were also seen farther away from the source when the system was operating, this was not statistically significant.[231] The researcher noted, however, that this lack of a statistically significant effect might be due to the small number of whale sightings compared to other projects.[232]

Nonetheless, the studies investigating the effects of noise produced by acoustic research have shown statistically significant effects on cetaceans, and lack of information to date on the short or long-term impacts of these effects is the fault of the experimental and monitoring program design, rather than a lack of an actual effect.[233]

1.3.2.1.5 Acoustic Harassment Devices (AHDs). Fish farms are frequently predated by seals, sea lions, and other marine predators. In an effort to prevent marine mammals, in particular, from approaching fish farm sites, many companies have resorted to using acoustic harassment devices (AHDs) or "seal-scrammers," to scare away, or even cause pain from acoustic trauma, in these predators.

A recent study evaluated the source levels of three common varieties of AHDs within an open water setting. The AHDs produced mid to high frequency sounds (1.8 kilohertz–103 kilohertz) with a peak source level of

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[230] Three dead humpback whales were discovered on the 3rd and the 9th of November 1995 near the ATOC source in California. It was subsequently discovered that the ATOC source had been tested twelve times between 28th October and 2nd November, and the probably time of death for these three whales was during the period of ATOC operation. A few days after the Kauai source was activated, on 10 November 1997, a dead humpback whale was discovered on the north shore of the island. A juvenile sperm whale was also discovered a month later on 2 December on the shore of Oahu. B. Hall, *Two more dead whales associated with ATOC*, WHALES ALIVE!, April 1998, http://csiwhalesalive.org/csi98205.html. However, whether these strandings were coincidental "natural" mortalities or the result of ATOC exposure is again unknown.

[231] J.R. Mobley, *Assessing Responses of Humpback Whales to North Pacific Acoustics Laboratory (NPAL) Transmissions: Results of 2001–2003 Aerial Surveys North of Kauai*, 117 J. OF ACOUSTICAL SOC'Y OF AM. 1666, 1671 (2005).

[232] That is, only 70 whales were sighted over three years in the NPAL monitoring program as opposed to 207 humpback whales and 210 sperm whales in the California ATOC monitoring program. Calambokidis, *supra* note 229, at ABSTRACTS 22. The animals in the NPAL project might also be exposed to lower received levels of noise than the California ATOC study, meaning that responses may be more subtle and again difficult to show statistically with such a small sample size. Mobley, *supra* note 231, at 1666–1673.

[233] NAT'L RES. COUNCIL, *supra* note 230, at 33.

up to 193 decibels.[234] The frequencies used in these devices coincide with the hearing ranges and frequencies utilised by many cetacean species. Indeed, there are several studies that have documented displacement of cetaceans from their habitat by such AHDs.[235] One study concluded that harbour porpoises would be excluded from a 400 metre radius area around an AHD, and porpoise abundance would be significantly reduced within 3.5 kilometres of a device.[236] Another study[237] reported sustained avoidance of an area with AHDs over a period of months, indicating longer term impacts on cetaceans.

The conflict between cetacean habitat and fishfarm sites is increasingly becoming a cause for concern.[238] The issue is particularly pertinent in the waters of western Scotland, which have a high density of fish farms. Indeed, every major sea loch in the area is occupied by at least one fish farm facility, and more than half of these fish farm operations use AHDs as anti-predator mechanisms.[239] It has been calculated, based on potential exclusion areas around sites with AHDs,[240] that harbour porpoises would be excluded from 16 square kilometres of coastal waters, and porpoise abundance would be significantly reduced over an area of 1,187 square kilometres in western Scotland alone.[241] However, field studies have actually shown that AHDs are ineffective as an anti-predator device with respect to marine mammals.[242] Therefore, disturbance to cetaceans would seem to be occurring with no actual benefit to the fish farms. Simple removal of AHDs from fish farm sites would

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[234] P.A. Lepper *et al.*, *Source Levels and Spectra Emitted by Three Commercial Aquaculture Anti-Predation Devices*, *in* PROCEEDINGS OF THE SEVENTH EUROPEAN CONFERENCE ON UNDERWATER ACOUSTICS, ECUA 2004, DELFT UNIVERSITY OF TECHNOLOGY, THE NETHERLANDS, 5–8 JULY, 2004 (2004).

[235] P.F. OLESIUK *ET AL.*, EFFECTS OF SOUNDS GENERATED BY AN ACOUSTIC DETERRENT DEVICE ON THE ABUNDANCE AND DISTRIBUTION OF HARBOR PORPOISE (*PHOCOENA PHOCOENA*) IN RETREAT PASSAGE, BRITISH COLUMBIA (1996); G. TAYLOR *ET AL.*, COLLECTION AND TREATMENT OF WASTE CHEMOTHERAPEUTANTS AND THE USE OF ENCLOSED-CAGE SYSTEMS IN SALMON AQUACULTURE (1998); D.W. Johnston & T.H. Woodley, *A Survey of Acoustic Harassment Devices (AHD) use in the Bay of Fundy, NB, Canada*, 24 AQUATIC MAMMALS 51, 51–61 (1998); A.B. Morton & H.K. Symonds, *Displacement of* Orcinus orca (L.) *by High Amplitude Sound in British Columbia, Canada*, 59 ICES J. OF MARINE SCI. 71, 71–80 (2002); D.W. Johnston, *The Effect of Acoustic Harassment Devices on Harbour Porpoises* (Phocoena phocoena) *in the Bay of Fundy, Canada*, 108 BIOLOGICAL CONSERVATION 113, 113–118 (2002).

[236] P.F. OLESIUK *ET AL.*, *supra* note 236.

[237] Morton & Symonds, *supra* note 236, at 73.

[238] B. Würsig & G.A. Gailey, *Marine Mammals and Aquaculture: Conflicts and Potential Resolution*s, *in* RESPONSIBLE MARINE AQUACULTURE 45–59 (Robert R. Stickney & James P. McVey eds., 2002); Tim M. Markowitz *et al.*, *Dusky Dolphin Foraging Habitat: Overlap with Aquaculture in New Zealand*, 14 AQUATIC CONSERVATION 133, 133–149 (2004).

[239] N.J. Quick, *A Survey of Anti-Predator Controls at Marine Salmon Farms in Scotland*, 230 AQUACULTURE 169, 169–180 (2004).

[240] P.F. OLESIUK *ET AL.*, *supra* note 236.

[241] JULIETTE H. SHRIMPTON, THE IMPACTS OF FISH-FARMING ON THE HARBOUR PORPOISE (*PHOCOENA PHOCOENA*) (2001).

[242] Maritza Sepúlveda & Doris Oliva, *Interactions Between South American Sea Lions* Otaria flavescens *(Shaw) and Salmon Farms in Southern Chile*, 36 AQUACULTURE RES. 1062, 1062–1068 (2005).

be an easy way to reduce one source of acoustic disturbance to cetaceans in the UK.

1.3.2.1.6 Dredging. Dredging operations remove silt or sediment from the seabed to maintain shipping routes, quarry marine gravel, sand, and other materials typically for use in construction of roads, or as a means of fishing—notably for clams and other shellfish. Several studies have demonstrated that the noise produced by dredging operations can impact cetaceans. For example, gray whales (*Eschrichtius robustus*) were displaced for several years from the Laguna Guerro Neggro in Baja, California, after dredging operations occurred in the area.[243] In addition, bowhead whales were displaced from an area, moving over two kilometers away from the sound source, when sounds of dredging were played back to them,[244] even though the received sound levels were relatively low.[245] In this second case study,[246] the bowheads also stopped feeding, their vocalising decreased, and they also exhibited changes in surfacing, respiration, and diving patterns.[247]

In the UK, there are several areas where dredging is a major activity, including navigable waterways or estuaries inhabited by cetaceans and areas with benthic mineral or material deposits, which are currently, or may in the future be, exploited. For example, there are several sites in the western isles of Scotland where commercial mineral extraction via dredging pose a potential problem for cetacean populations.[248]

1.3.2.1.7 Windfarms. There has been considerable investment in the development of alternative technologies, particularly windfarms, in order to

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[243] P.J. Bryant *et al.*, *Reoccupation of Laguna Guerrero Negro, Baja California, Mexico, by Gray Whales*, *in* The Gray Whale, Eschrichtius robustus 375–387 (Mary Lou Jones *et al.* eds.,1984).

[244] W. J. Richardson *et al.*, *Behavior of Bowhead Whales,* Balaena mysticetus*, Summering in the Beaufort Sea: Reactions to Industrial Activities*, 32 Biological Conservation, 195, 195–230 (1985) [hereinafter Richardson, Behavior]; W. J. Richardson *et al.*, *Disturbance Responses of Bowheads and Industrial Activity,1980–84*, in Behavior, Disturbance Responses and Distribution of Bowhead Whales, *Balaena mysticetus*, in The Eastern Beaufort Sea, 1980–84, 255, 255–301 (W.J. Richardson ed., 1985) [hereinafter Richardson, Disturbance]; W. J. Richardson *et al.*, *Reactions of Bowhead Whales,* Balaena mysticetus*, to Drill and Dredge Noise in the Canadian Beaufort Sea*, 29 Me. Envtl. Res. 135, 135–160 (1990) [hereinafter Richardson, Reactions); D. Wartzok *et al.*, Movements and Behaviors of Bowhead Whales in Response to Repeated Exposures to Noises Associated With Industrial Activities in the Beaufort Sea (1989).

[245] i.e., broadband levels of 122–131 decibels re 1 μPa.

[246] Richardson, Behavior, *supra* note 245; Richardson, Reactions, *supra* note 245; Wartzok *et al., supra* note 245.

[247] However, bowhead whales have also been sighted within 800 metres of suction dredgers. *See* C. Perry, *A Review of the Impact of Anthropogenic Noise on Cetaceans*, in The 50th Meeting of the Int'l Whaling Comm'n, 27 April–9 May 1998, Oman SC50/E9 _, _ (1998) (noting that such dredgers can produce noise levels of 180 decibels at 380 hertz); Richardson, Disturbance, *supra* note 245, at 255–301; Richardson, Reactions, *supra* note 245, at 135–160. Therefore, although dredging certainly can be a substantial source of underwater noise, the reactions of the whales to noise sources, and the circumstances in which they show these reactions, needs further investigation.

[248] J.H. Shrimpton & E.C.M. Parsons, Cetacean Conservation in West Scotland 131 (2000).

provide a source of renewable energy for the UK. Due to competition over land use, land-based windfarms are becoming harder to site. Therefore, attention has become focused on marine windfarms. On the one hand, being a renewable source of energy, windfarms have a positive environmental impact. On the other hand, however, they could possibly have a negative impact on cetaceans due to the noise they produce and impacts they might have on habitats and the marine ecosystem in general.[249] Their potential to displace animals is one concern that it is particularly difficult to gauge since so little is known of current cetacean distributions around the UK.

When in operation, windfarms produce a considerable amount of low frequency noise,[250] which research has calculated increases background levels of marine noise by 80–110 decibels.[251] However, the construction of windfarms also produces considerable amounts of marine noise (260 decibels), as does the laying of submarine cables to service the windfarm site (176 decibels).[252] In fact, a study funded by a UK statutory authority investigated the possible effects on cetaceans (and marine fish) from noise and vibrations of offshore windfarms and determined that there would be significant effects during construction, with disturbance reactions likely up to a distance of several kilometers.[253] Close to windfarm construction (within 100 metres), it was estimated that noise levels might be so severe that cetaceans may suffer acoustic trauma.[254]

Disturbance reactions by cetaceans to noises produced by windfarms have also been documented. Researchers played back recordings of noises produced by a two mega-watt wind turbine (frequency <800 hertz)[255] and reported that the distance between harbour porpoise surfacings and the sound source significantly increased. There was also a significant increase in porpoise echolocation rates, thus indicating disturbance of the harbour porpoises by windfarm noise.[256] This disturbance occurred even though, according to

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[249] A. B. Gill, *Offshore Renewable Energy: Ecological Implications of Generating Electricity in the Coastal Zone*, 42 J. OF APPLIED ECOLOGY 606, 605–615 (2005).

[250] 1–400 hertz.

[251] E. HOFFMAN *ET AL.*, EFFECTS OF MARINE WINDFARMS ON THE DISTRIBUTION OF FISH, SHELLFISH AND MARINE MAMMALS IN THE HORNS REV AREA 6 (2000); T. FRISTEDT *ET AL.*, ACOUSTIC AND ELECTROMAGNETIC NOISE INDUCED BY WIND MILLS: IMPLICATIONS FOR UNDERWATER SURVEILLANCE SYSTEMS PILOT STUDY (2001).

[252] J. NEDWELL *ET AL.*, ASSESSMENT OF SUB-SEA ACOUSTIC NOISE AND VIBRATION FROM OFFSHORE WIND TURBINES AND ITS IMPACT ON MARINE WILDLIFE; INITIAL MEASUREMENTS OF UNDERWATER NOISE DURING CONSTRUCTION OF OFFSHORE WINDFARMS AND COMPARISON WITH BACKGROUND NOISE (Report 544 R 0424) 44 (2003); J. NEDWELL & D. HOWELL, A REVIEW OF OFFSHORE WINDFARM RELATED UNDERWATER NOISES (Report 544 R 0308) (2004).

[253] *Id.*

[254] *Id.*

[255] S. Koschinski *et al.*, *Behavioural Reactions of Free-Ranging Porpoises and Seals to the Noise of a Simulated 2 MW Windpower Generator*, 265 ME. ECOLOGY PROGRESS SERIES 263 (2003).

[256] *Id.*

hearing sensitivity tests conducted on captive porpoises, the animals should not have been able to detect these low frequency sounds.[257]

Another study monitored harbour porpoise acoustics both before and during the construction of a 166 mega-watt wind farm in the western Baltic Sea. The research revealed that porpoises were less frequently encountered by acoustic methods during the construction of the wind farm. In addition, during the pile driving phase of construction, porpoises were excluded from the study area for 27 hours before returning. This study demonstrated a significant effect of windfarm construction on porpoises, in particular, an extremely negative reaction to the noise produced by pile driving activity.[258]

1.3.2.1.8 Military activities. Of all the sources of marine noise, the potential of military-related noise, military active sonar in particular, is probably the most contentious and controversial. Numerous studies have linked military sonar to cetacean strandings in several areas of the world including the Canary Islands, Greece, Spain, the U.S. Virgin Islands, and the Bahamas.[259] Typically these strandings have been linked to mid-frequency (c. 3–7 kilohertz) sonar. Upon post-mortem examination, many animals had haemorrhaging in the inner ears and cranial air spaces—lesions consistent with impulsive trauma from intense, loud sound.[260] Lesions suggestive of decompression sickness ('the bends') have also been reported (see Section 1.3.2.2.3).[261] In addition to these stranding events, behavioural changes, like

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[257] *Id.*

[258] O. D. Henriksen *et al.*, *Impact on Harbour Porpoises from the Construction of the Nysted Wind Farm in Denmark,* in THE 18TH ANNUAL CONFERENCE OF THE EUROPEAN CETACEAN SOCIETY (2004).

[259] R. Vonk & V. Martin, *Goosebeaked Whales* Ziphus cavirostris *Mass Strandings in the Canary Isles*, 3 EUR. RES. ON CETACEANS 73, 73–77 (1989); M. Simmonds & L.F. Lopez-Jurado, *Whales and the Military*, 337 NATURE 448 (1991); A. Frantzis, *Does Acoustic Testing Strand Whales?*, 392 NATURE 29 (1998); A. Frantzis & D. Cebrian, *A Rare Mass Stranding of Cuvier's Beaked Whales: Cause and Implications for the Species Biology*, 12 EUR. RES. ON CETACEANS 332 (1999); K. C. Balcomb & D. E. Claridge, *A Mass Stranding of Cetaceans Caused by Naval Sonar in the Bahamas*, 8 BAH. J. OF SCI.1 (2001); D. L. EVANS & G.R. ENGLAND, JOINT INTERIM REPORT BAHAMAS MARINE MAMMAL STRANDING EVENT OF 14–16 MARCH 2000 (2001); A. Frantzis, *The First Mass Stranding That Was Associated with the Use of Active Sonar (Kyparissiakos Gulf, Greece, 1996)*, in PROCEEDINGS OF THE WORKSHOP ON ACTIVE SONAR AND CETACEANS ECS NEWSLETTER NO. 42, SPECIAL ISSUE 14 (P.G.H. Evans & L.A. Miller eds., 2004); B. Taylor *et al.*, *A Call For Research to Assess Risk of Acoustic Impact on Beaked Whale Populations*, Paper SC46/E36, (2004) (presented at the 56th Meeting of the Int'l Whaling Comm'n June 29–July 10, 2004).

[260] Balcomb & Claridge, *supra* note 260; EVANS & ENGLAND, *supra* note 260.

[261] P.D. Jepson *et al.*, *Gas-Bubble Lesions in Stranded Cetaceans: Was Sonar Responsible for a Spate of Whale Deaths after an Atlantic Military Exercise?*, 425 NATURE 575 (2003); A. Fernández *et al.*, *Whales, Sonar and Decompression Sickness*, 428 NATURE 1 (2004); A. Fernández *et al.*, *Gas and Fat Embolic Syndrome Involving a Mass Stranding of Beaked Whales* (Family Ziphiidae) *Exposed to Anthropogenic Sonar Signals*, 42 VETERINARY PATHOLOGY 446 (2005); P. D. Jepson *et al.*, *Acute and Chronic Gas Bubble Lesions in Cetaceans Stranded in the United Kingdom*, 42 VETERINARY PATHOLOGY 291 (2005).

TABLE 3. Military sources of high intensity noise[262]

Activity	Frequency range (kHz)	Source level (dB re 1μPa)
Search and surveillance	2–57	230+
Mine & obstacle avoidance	25–200	220+
Weapon mounted sonar	15–200	200+
Low Frequency Active Sonar (LFAS) used by NATO.	0.25–3.0?	230+
Surveillance Towed Array Sensor System (SURTASS) Low Frequency Sonar (LFA)	*c*.0.1–0.5	215–240
SONAR 2087 (Royal Navy Low Frequency Sonar System)	*c*.0.1–0.5	200+

changes in vocalisations, have been reported in sperm whales and long-finned pilot whales exposed to military sonar.[263]

The emerging issues of military sonar and its impact on cetaceans are discussed in Part 2 of this article. In particular, the potential issues related to mid-frequency active sonar and to new types of low frequency active sonar[264] recently introduced on UK naval vessels are discussed. It should be noted, however, that sonar is not the only source of underwater noise produced by military activities (Table 3). Submarine-to-submarine communication systems could also be a substantial source of submarine sound,[265] as could explosives used in military tests and live firing exercises (Table 3).[266] Military exercises also involve large numbers of vessels of different types, all of which produce noise.

Indeed, in the UK, statistically significant decreases in minke whale sightings have been reported during naval exercises in Scotland.[267] This decrease in sightings is presumably a disturbance effect resulting from a

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[262] Greene & Moore, *supra* note 206; E. C. M. Parsons & A. Woods-Ballard, *Acceptance of Voluntary Whalewatching Codes of Conduct in West Scotland: The Effectiveness of Governmental versus Industry-Led Guidelines*, 6 CURRENT ISSUES IN TOURISM 172 (2003).

[263] W. A. Watkins *et al.*, *Sperm Whales Acoustic Behaviour in the Southeast Caribbean*, 49 CETOLOGY 1 (1985); L. E. Rendell & J. C. D. Gordon, *Vocal Responses of Long-Finned Pilot Whales* (Globicephala melas) *to Military Sonar in the Ligurian Sea*, 15 ME. MAMMAL SCI.198 (1999).

[264] As these new systems use low frequencies, the sounds produced by these systems have the potential to travel much greater distances, and affect more individual cetaceans, than higher frequency sonar systems. There are also concerns about the impacts of these systems on baleen whales, which are believed to be more sensitive to low-frequency sounds.

[265] C. R. Greene & S.E. Moore, *Man-Made Noise*, in MARINE MAMMALS AND NOISE 101 (W.J. Richardson *et al.*. eds., 1995) (noting that such systems produce sounds of 5–11 kilohertz at a source levels of 180–200 decibels).

[266] i.e., 267 decibels with frequencies ranging from 45 hertz–7.07 kilohertz. *See* Greene & Moore, *supra* note 206, at 101–158; Evans & Nice, *supra* note 209.

[267] E. C. M. Parsons *et al.*, *The Possible Impacts of Military Activity on Cetaceans in West Scotland*, 14 EUROPEAN RES. ON CETACEANS 185, 186 (2000).

combination of noise sources including shipping-related noise and active sonar use.

There are a number of submarine and naval vessel exercise areas in UK waters, particularly in the coastal waters of Scotland,[268] including a submarine testing site in Garelochhead, near Glasgow. A number of northern bottlenose whale (*Hyperoodon ampullatus*) strandings[269] have clustered around this particular site over the past few decades. A torpedo testing range in the Sound of Raasay,[270] Scotland, is adjacent to the site of an unusual 1998 sighting of two normally deep-water (deeper than 250 metres) northern bottlenose whales in shallow waters (less than ten metres).[271] Missiles are fired from a missile range on South Uist, in the Outer Hebrides, into the western waters of Scotland, an area associated with a high number of sperm whale and Cuvier's beaked whale strandings.[272] Likewise, Scotland is also the location of several live firing ranges, such as Cape Wrath, where live ordinance is used in areas that are also frequented by a variety of cetacean species.

In a bid to reduce the impacts of naval activities on cetaceans in the UK, the Royal Navy has produced a code of conduct for military vessels.[273] However, due to the classified nature of military activities and reluctance by UK authorities to provide scientists with information on ship movements, gathering information on naval sound source use in order to compare it with data on the distribution and behaviour of cetaceans has been problematic.[274] This, together with a lack of knowledge of marine mammal abundance and distribution, limited range of on-board monitoring systems for cetacean presence during naval and other military activities, and a lack of independent oversight and monitoring by cetacean experts during military exercises, makes assessing the extent of impacts of military-produced noise sources on UK cetaceans extremely difficult at the present time.

1.3.2.1.9 Acoustic Deterrent Devices (ADDs). Acoustic Deterrent Devices (often referred to as "pingers") are noise-producing devices designed

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[268] *Id.* at 185.

[269] Shrimpton & Parsons, *supra* note 22 (summarizing stranding locations).

[270] The British Underwater Test and Evaluation Centre.

[271] M.P. Simmonds, *Northern Bottlenose Whales,* Hyperoodon ampullatus*, in Skye, Scotland: Behaviour and Disturbance* (paper presented to the Sci. Comm. at the 51st Meeting of the Int'l Whaling Comm'n, 1999).

[272] *See* Shrimpton & Parsons, *supra* note 22 (summarizing stranding locations). However, it should be noted that this high rate of strandings on South Uist may be more likely associated with the ease with which stranded cetaceans may be sighted on the beaches of these islands, and the position of the islands directly adjacent to the deeper waters of the Atlantic Ocean. The strandings nonetheless indicate a large number of deep diving, potentially sound vulnerable, cetacean species occur in this region. These species may be more vulnerable to the high intensity noise produced during missile firing exercises.

[273] Shrimpton & Parsons, *supra* note 22; Parsons *et al.*, *supra* note 268.

[274] S. Barry, *An Activity World-wide on Cetaceans Overview of the Effects of Naval Sonar With Relation to Cetaceans on the West Coast of Scotland* (2004) (unpublished Masters thesis, Heriot-Watt University Heriot-Watt University) (on file with E.C.M. Parsons; ecm-parsons@earthlink.net).

to be attached to fishing nets to make cetaceans aware of the net's presence or make them avoid areas where nets are set (see Sections 1.2.1). There is a major difference between AHDs (see Section 1.3.2.1.5) and ADDs. ADDs typically have a source level several orders of magnitude lower than AHDs.[275] It can be argued that any disturbance they cause to cetaceans is worthwhile given the reduced levels of bycatch-related mortality that results from their use.[276] However, there is concern that wide-scale use may lead to large areas of the ocean becoming esonified. Another issue is that the effectiveness of ADDs depends on marine mammals hearing the devices, and other sources of marine noise may mask the sounds produced by ADDs, rendering them ineffective. Therefore, conservation efforts to reduce bycatch should consider the indirect effects of underwater noise on the effectiveness of bycatch mitigation.

1.3.2.2 Impacts on Cetaceans

The ways in which sound can be detrimental to cetaceans can be broadly categorised into three main areas:[277]

1. Behavioural changes;
2. Acoustic trauma; and
3. Stress.

These three categories of impacts are discussed below, as is the arising issue of possible noise-induced decompression sickness in cetaceans.

1.3.2.2.1 Behavioural changes. "Disturbance," with respect to cetaceans, could be defined as changes in patterns of normal behaviour and habitat use that are the result of an outside agency, e.g., human activities. Various sources of noise have been documented to cause disturbance to cetaceans, including: seismic surveys (Section 1.3.2.1.2);[278] oceanographic research (Section 1.3.2.1.4);[279] fish farm predator deterrent devices (Section 1.3.2.1.5);[280]

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[275] Typically less than 150 decibels for ADDs, verses 180 decibels and higher for AHDs.

[276] *See* J. Barlow & G. A. Cameron, *Field Experiments to Show That Acoustic Pingers Reduce Marine Mammal Bycatch in the Californian Drift Gill Net Fishery*, 19 MARINE MAMMAL SCI. 265 (2003) (reporting a significant reduction in both seal and cetacean bycatch in the Californian drift gill net fishery, as the result of ADD use).

[277] M. P. Simmonds & S. Dolman, *A Note on the Vulnerability of Cetaceans to Acoustic Disturbance* (1999) (paper presented to the Sci. Comm. at the 51st Meeting of the Int'l Whaling Comm'n).

[278] Gould & Fish, *supra* note 209; Stone, *supra* note 209, at 10.

[279] Bowles *et al.*, *supra* note 222; Calambokidis, *supra* note 229; Frankel & Clark (1998), *supra* note 226; Frankel & Clark (2000), *supra* note 226; Frankel & Clark, *supra* note 228.

[280] Olesiuk *et al.*, *supra* note 236; Taylor *et al.*, *supra* note 172; Johnston & Woodley, *supra* note 236; Morton & Symonds, *supra* note 236; D. W. Johnston, *The Effect of Acoustic Harassment Devices on Harbour Porpoises* (Phocoena phocoena) *in the Bay of Fundy, Canada*, 108 BIOLOGICAL CONSERVATION 113 (2002).

dredging (Section 1.3.2.1.6);[281] windfarms (Section 1.3.2.1.7);[282] and military sonar[283] and naval exercises[284] (Section 1.3.2.1.8).

Most of the research on disturbance of cetaceans by human activities has focused on disturbance by shipping traffic. A wide variety of cetacean species have displayed changes in patterns of habitat use—even ceasing to utilise critical habitat completely—as the result of the presence of boat traffic. Those species include the Amazon river dolphin (*Inia geoffrensis*);[285] Ganges river dolphin (*Platanista gangetica*);[286] tucuxi (*Sotalia fluviatilis*); harbour porpoise (*Phocoena phocoena*);[287] and bottlenose dolphin (*Tursiops truncatus*).[288] Displacement from habitat due to boat-related disturbance has also occurred with baleen whales such as the humpback whale (*Megaptera novaeangliae*)[289] and the gray whale (*Eschrichtius robustus*).[290]

Disturbance by boat traffic has also resulted in observable behavioural changes, such as increases or decreases in diving times. The changes occur in many cetacean species: the Vaquita (*Phocoena sinus*);[291] bottlenose dolphin;[292] finless porpoise (*Neophocaena phocaenoides*);[293] Indo-Pacific humpback

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[281] Bryant *et al.*, *supra* note 244; Richardson, Behavior, *supra* note 245; Richardson, Disturbance, *supra* note 245; Richardson, Reactions, *supra* note 245; Wartzok *et al.*, *supra* note 245.

[282] Koschinski *et al.*, *supra* note 205; Henriksen *et al.*, *supra* note 259.

[283] Watkins *et al.*, *supra* note 263; Rendell & Gordon, *supra* note 263.

[284] Parsons *et al.*, *supra* note 267.

[285] S. Leatherwood *et al.*, *Observations of River Dolphins in the Amazon and Maranon Rivers and Tributaries, Peru*, *in* ABSTRACTS OF THE 9TH BIENNIAL CONFERENCE ON THE BIOLOGY OF MARINE MAMMALS, 42 (1991).

[286] Brian D. Smith, *1990 Status and Conservation of the Ganges River Dolphin* Platanista gangetica *in the Karnali River, Nepal,* 66 BIOLOGICAL CONSERVATION 159 (1993).

[287] P.G.H. Evans *et al.*, *A Study of the Reactions of Harbour Porpoises to Various Boats in the Coastal Waters of S.E. Shetland,* EUR. CETACEAN SOC'Y NEWSL., Spring/Summer 1994.

[288] Mark C. Allen & Andrew J. Read, *Habitat Selection for Foraging Bottlenose Dolphins in Relation to Boat Density near Clearwater, Florida*, 16 MARINE MAMMAL SCI. 815 (2000).

[289] C.S. BAKER *ET AL.*, *THE IMPACT OF VESSEL TRAFFIC ON THE BEHAVIOR OF HUMPBACK WHALES IN SOUTHEAST ALASKA* (1983); Debra A. Glockner-Ferrari & Mark J. Ferrari, INDIVIDUAL IDENTIFICATION, BEHAVIOR, REPRODUCTION AND DISTRIBUTION OF HUMPBACK WHALES, *MEGAPTERA NOVAEANGLIAE*, IN HAWAII (Marine Mammal Commission No. MMC-86/06 1985); M.L. Green, *The Impact of Parasail Boats on the Hawaiian Humpback Whale, Megaptera novaeangliae* (Mar. 1990) (delivered to the Marine Mammal Commission); G. Kaufman & K. Wood, *Effects of Boat Traffic, Air Traffic and Military Activity on Hawaiian Humpback Whales, in* ABSTRACTS OF THE 4TH BIENNIAL CONFERENCE ON THE BIOLOGY OF MARINE MAMMALS, DECEMBER 1981, SAN FRANCISCO (1981).

[290] RANDALL R. REEVES & U.S. MARINE MAMMAL COMMISSION, MMC-76/06, NTIS PB-272506, THE PROBLEM OF GRAY WHALE (*ESCHRICHTIUS ROBUSTUS*), HARASSMENT: AT THE BREEDING LAGOONS AND DURING MIGRATION (1977); Bryant, *supra* note 244.

[291] Gregory K. Silber *et al.*, *Observations on the Behavior and Ventilation Cycles of the Vaquita,* Phocoena sinus, 4 MARINE MAMMAL SCI. 62 (1988).

[292] Stephanie M. Nowacek *et al.*, *Short-Term Effects of Boat Traffic on Bottlenose Dolphins,* Tursiops truncatus*, in Sarasota Bay, Florida*, 17 MARINE MAMMAL SCI. 673 (2001).

[293] I. Beasley & T.A. Jefferson, *Behavior and Social Organization of Finless Porpoises in Hong Kong's Coastal Waters, in* CONSERVATION BIOLOGY OF THE FINLESS PORPOISE (*NEOPHOCAENA PHOCAENOIDES*) IN HONG KONG WATERS (T.A. Jefferson ed., 2000).

dolphin (*Sousa chinensis*);[294] Irawaddy dolphin (*Orcaella brevirostris*);[295] humpback whale;[296] bowhead whale (*Balaena mysticetus*);[297] fin whale (*Balaenoptera physalus*);[298] and blue whale (*Balaenoptera musculus*).[299]

Other behavioural changes observed include: increased swimming speeds;[300] increased incidences of aggressive behaviour;[301] attempts to physically shield young;[302] nursing females grouping together with other females;[303] increases in surfacing synchrony;[304] and alterations in acoustic behaviour and vocalisations.[305]

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[294] L. Karczmarski *et al.*, *Description of Selected Behaviours of Humpback Dolphins,* Sousa chinensis, 23 AQUATIC MAMMALS 127 (1997); L. Karczmarski *et al.*, *Recommendations for the Conservation and Management of Humpback Dolphins* Sousa chinensis *in the Algoa Bay Region, South Africa*, 41 KOEDOE 121 (1998); Sai Leung Ng & Sze Leung, *Behavioral Responses of Indo-Pacific Humpback Dolphin* (Sousa chinensis) *to Vessel Traffic*, 56 MARINE ENVTL. RES. 555 (2003); Georg Pilleri & M. Gihr, *Contributions to the Knowledge of the Cetacea of Southwest and Monsoon Asia (Persia Gulf, Indus Delta, Malabar, Andaman Sea and the Gulf of Siam), in* INVESTIGATIONS ON CETACEA 95 (G. Pilleri ed., 1974).

[295] Daniëlle Kreb & Karen D. Rahadi, *Living under an Aquatic Freeway: Effects of Boats on Irawaddy Dolphins* (Orcaella brevirostris) *in a Coastal and Riverine Environment in Indonesia*, 30 AQUATIC MAMMALS 363 (2004).

[296] Baker, *supra* note 290; Gordon B. Bauer, *The Behavior of Humpback Whales in Hawaii and Modifications of Behavior Induced by Human Interventions* (1986) (Ph.D. thesis, University of Hawaii, Honolulu); GORDON B. BAUER & LOUIS M. HERMAN, EFFECTS OF VESSEL TRAFFIC ON THE BEHAVIOR OF HUMPBACK WHALES IN HAWAII (1986); Gordon B. Bauer *et al.*, *Responses of Wintering Humpback Whales to Vessel Traffic*, 94 J. OF ACOUSTICAL SOC'Y OF AM. 184 (1993); FREDERICK C. DEAN *ET AL.*., ANALYSIS OF HUMPBACK WHALE, *MEGAPTERA NOVAEANGLIAE*, BLOW INTERVAL DATA/GLACIER BAY, ALASKA, 1976–1979 (1985); Marsha L. Green & Ronald G. Green, *Short-Term Impact of Vessel Traffic on the Hawaiian Humpback Whale,* Megaptera novaeangliae (June 10, 1994) (delivered to the Annual Meeting of the Annual Behavior Society), *available at* http://www.oceanmammalinst.org/w90.html

[297] Richardson, Disturbance, *supra* note 245; Richardson, Reactions, *supra* note 245; Wartzok, *supra* note 245.

[298] Peggy L. Edds & J. Andrew F. MacFarlane, *Occurrence and General Behavior of Balaenopterid Cetaceans Summering in the St. Lawrence Estuary, Canada*, 65 CAN. J. OF ZOOLOGY 1363 (1987).

[299] *Id.*

[300] Which has been reported in the bottlenose dolphin, Nowacek, *supra* note 293; beluga whale (*Delphinapterus leucas)*, Edds & MacFarlane, *supra* note 299; killer whale (*Orcinus orca)*, S. Kruse, *The Interactions Between Killer Whales and Boats in Johnstone Strait, B.C.*, *in* DOLPHIN SOCIETIES, DISCOVERIES AND PUZZLES (Karen Pryor & Kenneth S. Norris eds., 1991); minke whale (*Balaenoptera acutorostrata)*, Edds & MacFarlane, *supra* note 299; bowhead whale, Richardson, Reactions, *supra* note 245; Richardson, Disturbance, *supra* note 245; and fin whale, Edds & MacFarlane, *supra* note 299.

[301] R. Payne, MMC-77/031978, *Behavior and Vocalizations of Humpback Whales* (Megaptera sp.), *in* REPORT ON A WORKSHOP ON PROBLEMS RELATED TO HUMPBACK WHALES, *MEGAPTERA NOVAEANGLIAE*, IN HAWAII (Kenneth S. Norris & Randall R. Reeves eds., 1978); Dean, *supra* note 297; Bauer, *supra* note 297; Bauer *et al.*, *supra* note 297; BAUER & HERMAN, *supra* note 297.

[302] Karczmarski, *supra* note 295 (1997).

[303] *Id.*

[304] Gordon D. Hastie *et al., Bottlenose Dolphins Increase Breathing Synchrony in Response to Boat Traffic,* 19 MARINE MAMMAL SCI. 74 (2003).

[305] Alterations in vocalisations in response to boat traffic has been reported in species such as the bottlenose dolphin, Kara C. Buckstaff, *Effects of Watercraft Noise on the Acoustic Behaviour of Bottlenose Dolphins,* Tursiops truncatus*, in Sarasota Bay, Florida*, 20 MARINE MAMMAL SCI. 709 (2004); Indo-Pacific humpback dolphin, Sophie Van Parijs & Peter J. Corkeron, *Boat Traffic Affects the Acoustic*

Whale-watching boats have been associated with changes in cetacean behaviour,[306] and as these vessels target areas of high cetacean abundance, the relative effects of this disturbance are increased.

Moreover, fast motorised speed-boats seem to promote stronger reactions from cetaceans than slower moving vessels, even if the slower boats emit higher intensity noise.[307] For example, bottlenose dolphins in UK waters demonstrated stronger aversive reactions to high-speed motor boats than other classes of vessels.[308] The same was true for beluga whales in the St. Lawrence estuary,[309] even though the Canadian beluga whales noted in this study actually

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Behaviour of Pacific Humpback Dolphins, Sousa chinensis*,* 81 J. of Marine Biological Assoc. of the UK 533 (2001); killer whale, Andrew D. Foote *et al.*, *Whale-Call Response to Masking Boat Noise*, 428 Nature 910 (2004); humpback whale, Thomas F. Norris, *Effects of Boat Noise on the Acoustic Behavior of Humpback Whales*, 96 J. of Acoustical Soc'y of Am. 3251 (1994); and grey whale, Marilyn Elayne Dalheim, *Bio-acoustics of the Gray Whale,* Eschrichtius robustus (1987) (Ph.D. thesis, University of British Columbia, Vancouver).

[306] Such whale-watching associated behavioural changes include alterations in cetacean surfacing behaviour (N.M. Young, *Dive and Ventilation Patterns Correlated to Behavior of Fin Whales,* Balaenoptera physalus*, in Cape Cod and Massachusetts Bays*, *in* Abstracts of the 8th Biennial Conference on the Biology of Marine Mammals, December 1989, Pacific Grove, California 74 (1989); Jonathan Gordon *et al.*, *Effects of Whale-Watching Vessels on the Surface and Underwater Acoustic Behaviour of Sperm Whales Off Kaikoura, New Zealand, in* Science and Research Services Series No. 52 (1992), *available at* http://www.doc.govt.nz/upload/documents/science-and-technical/srs52.pdf; J.R. Heimlich-Boran *et al.*, An Overview of Whale-Watching in the Canary Islands, Eur. Cetacean Soc'y Newsl., Spring/Summer 1994; Vincent M. Janik & Paul M. Thompson, *Changes in Surfacing Patterns of Bottlenose Dolphins in Response to Boat Traffic*, 12 Marine Mammal Sci. 597 (1996); G.S. Stone *et al.*, *Respiration and Surfacing Rates of Fin Whales,* Balaenoptera physalus*, Observed From a Lighthouse Tower,* 42 Reps. of Int'l Whaling Commission 739 (1992); D. Lusseau, *Male and Female Bottlenose Dolphins* Tursiops spp. *Have Different Strategies to Avoid Interactions With Tour Boats in Doubtful Sound, New Zealand*, 257 Marine Ecology Progress Series 267 (2003)), acoustic behaviour (C. Scarpaci *et al., Bottlenose Dolphins,* Tursiops truncatus*, Increase Whistling in the Presence of* '*Swim-With-Dolphin*' *Tour Operations*, 2 J. of Cetacean Res. & Mgmt 183 (2000)), and group size (R. Crosti & A. Arcangeli, *Dolphin-Watching Activity as a Sustainable Industry in Marine Protected Areas: Influence on Bottlenose Dolphin* (Tursiops truncatus*) Behaviour* (May 6–9, 2001) (delivered to the 14th Annual Conference of the European Cetacean Society) or group cohesion, swimming speed (N. Aguilar *et al.*, *Evidence of Disturbance of Protected Cetacean Populations in the Canary Islands* (July 3–16, 2001) (delivered to the Sci. Comm. at the 53d Meeting of the Int'l Whaling Comm'n)) or direction (M.W. Cawthorn, *New Zealand progress report on cetacean research: April 1990 to April 1991*, *in* 42 Report of the International Whaling Commission 357 (1992); M. Scheidat *et al.*, *Behavioural Responses of Humpback Whales* (Megaptera novaeangliae) *to Whalewatching Boats Near Isla de la Plata, Machalilla National Park, Ecuador*, 6 J. of Cetacean Res. & Mgmt. 63 (2004)), feeding/resting patterns (R. Crosti & A. Arcangeli, *Dolphin-Watching Activity as a Sustainable Industry in Marine Protected Areas: Influence on Bottlenose Dolphin (*Tursiops truncatus*) Behaviour* (May 6–9, 2001) (delivered to the 14th Annual Conference of the European Cetacean Society); Rochelle Constantine *et al.*, *Dolphin-Watching Tour Boats Change Bottlenose Dolphin (*Tursiops truncatus*) Behaviour*, 117 Biological Conservation 299 (2004)) or an increased prevalence of aggressive behaviours (J.R. Heimlich-Boran *et al.*, *An Overview of Whale-Watching in the Canary Islands*, Eur. Cetacean Soc'y Newsl., Spring/Summer 1994).

[307] P.G.H. Evans *et al.*, *An Experimental Study of the Effects of Pleasure Craft Noise Upon Bottlenose Dolphins in Cardigan Bay, West Wales*, 6 Eur. Res. on Cetaceans 43 (1992).

[308] *Id.*; L. Goodwin & P. Cotton, *Effects of Boat Traffic on the Behaviour of Bottlenose Dolphins (*Tursiops truncatus), 30 Aquatic Mammals 279 (2004).

[309] Stewart, *supra* note 196.

showed behavioural changes in response to the vessels despite received sound levels being so low that researchers considered that they would be barely perceptible to beluga whales.[310] Baleen whales have also been reported to show increased negative responses to faster-moving vessels.[311]

Many of these disturbance reactions are short-term and sometimes subtle. This raises a number of questions: How do such reactions actually impact the cetaceans in the longer term? Are these impacts biologically significant and will they cause a decrease in the health of the disturbed cetaceans? It could be that the behavioural "responses to human activities may be adaptive, but not necessarily detrimental."[312]

Scholarship on anthropogenic disturbance to free-ranging cetaceans has been severely limited by a lack of long-term studies that evaluate cumulative impacts, as well as a lack of understanding about how an undisturbed population behaves. There are so few areas where cetaceans are not exposed to anthropogenic noise or other types of activity that there is hardly a normal "baseline" cetacean population against which researchers can compare the behaviour of disturbed animals.[313]

Another limitation is that one area of research on disturbance to cetaceans has been particularly neglected: How these disturbances translate into physiological changes,[314] and possibly due to the effects of chronic stress (see Section 1.3.2.2.4), into more population level effects such as impacts on reproductive rates, immune system function, and possibly increased mortality rates.[315] One problem is that research on cetacean reactions to disturbance is relatively short-term, and in order to discover impacts to health, reproduction, and survival, research projects that are long-term—even lasting decades—may be required.[316]

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[310] *Id.*

[311] For example, humpback whales moved out of critical habitat on days when fast boats were operating nearby (M.L. GREEN, THE IMPACT OF PARASAIL BOATS ON THE HAWAIIAN HUMPBACK WHALE, *MEGAPTERA NOVAEANGLIAE* (1990) (paper presented at the Marine Mammal Commission Hearings, Honolulu, Hawaii)), northern right whales (*Eubalaena glacialis*) avoided faster moving vessels in the Bay of Fundy (J. Goodyear, *Feeding Ecology, Night Behaviour, and Vessel Collision Risk of Bay of Fundy Right Whales*, *in* ABSTRACTS OF THE 8TH BIENNIAL CONFERENCE ON THE BIOLOGY OF MARINE MAMMALS 23 (1989)) and gray whales in Mexico exhibited stronger reactions to faster moving vessels (S.L. SWARTZ & W.C. CUMMINGS, GRAY WHALES, *ESCHRICHTIUS ROBUSTUS*, IN LAGUNA SAN IGNACIO, BAJA CALIFORNIA, MEXICO (1978); S.L. SWARTZ & M.L. JONES, EVALUATION OF HUMAN ACTIVITIES ON GRAY WHALES, *ESCHRICHTIUS ROBUSTUS*, IN LAGUNA SAN IGNACIO, BAJA CALIFORNIA (1978); S.L. SWARTZ & M.L. JONES, DEMOGRAPHIC STUDIES AND HABITAT ASSESSMENT OF GRAY WHALES, *ESCHRICHTIUS ROBUSTUS*, IN LAGUNA SAN IGNACIO, BAJA CALIFORNIA SUR, MEXICO CALIFORNIA (1981)).

[312] M. Orams, *Why Dolphins May Get Ulcers: Considering the Impacts of Cetacean-Based Tourism in New Zealand*, 1 TOURISM IN MARINE ENV'TS 17, 19 (2004).

[313] L. Bejder & A. Samuels, *Evaluating the Effects of Nature-Based Tourism on Cetaceans*, *in* MARINE MAMMALS: FISHERIES, TOURISM AND MANAGEMENT ISSUES 229 (N. Gales et al. eds., 2004).

[314] *Id.*

[315] Orams, *supra* note 313.

[316] P.J. Corkeron, *Whale Watching, Iconography, and Marine Conservation*, 18 CONSERVATION BIOLOGY 847, 847–849 (2004); Bejder & Samuels, *supra* note 314; Orams, *supra* note 313.

Despite this gap in scholarship, recent research has demonstrated that there could indeed be a link between disturbance and population level effects. For example, an Australian research project investigating bottlenose dolphin calf survival rates and reproductive data for known females discovered that female reproductive success decreased with cumulative exposure to boat traffic.[317] Indeed, other studies on whale-watching activities show: (i) how long-term meaningful studies may be conducted (see helpful review by Bejder and Samuels, 2004); and (ii) how seemingly subtle behavioural responses may hide population level impacts.

Finally, although there are many documented cetacean reactions to human disturbance, especially disturbance related to boats, it should not be thought that just because cetaceans do not produce an observable reaction, that there is not a significant impact. Research has suggested that when disturbed, animals that have fed adequately and are in good health may be the only animals that show a reaction, whereas animals that are ill fed or otherwise not at full fitness may not show a reaction at all.[318] This implies that animals that are better fed or in better condition can stop feeding sooner and move farther from habitats than animals that are in marginal condition.[319] Thus, there is a need to consider the animals that are at greatest risk, rather than the animals that show the clearest reaction, when evaluating human disturbance. In other words, less response to anthropogenic activities does not necessarily mean less impact on animals.[320]

Other cetacean researchers have theorized that marine mammals may remain in highly disturbed areas when there are no suitable alternative locations.[321] If they remain in such disturbed areas, chronic anthropogenic esonification could result in high levels of stress (see Section 1.3.2.2.4), which could lead to debilitation of and have health impacts on the cetaceans.

In the past, scientists have assumed that lack of a reaction to a disturbance indicates habituation to, or no effect from, the activity. However, using the terms "habituation," "sensitisation," and "tolerance" with respect to cetaceans and anthropogenic activities "can lead to misinterpretation of research findings with unintended and potentially dire consequences for wildlife communities."[322]

1.3.2.2.2 Acoustic trauma. High energy, intense sound can produce pressure waves, which have the potential to cause direct tissue damage, especially to tissues in the ear. Such damage can cause permanent or temporary deafness, or more correctly, can cause shifts in the sound threshold level at

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[317] L. Bejder, Linking Short- and Long-Term Effects of Nature-Based Tourism on Cetaceans (2005).

[318] C.M. Beale & P. Monaghan, *Behavioural Responses to Human Disturbance: A Matter of Choice?*, 68 Animal Behav. 1065, 1065–1069 (2004).

[319] *Id.*

[320] *Id.*

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[322] Bejder, *supra* note 318.

which an animal is able to hear a particular frequency: faint sounds are less easily detected. Such shifts are termed Temporary Threshold Shifts (TTSs) or Permanent Threshold Shifts (PTSs). To calculate the likely impact of sound in terms of acoustic trauma, sensitivity thresholds calculated from audiograms of captive cetaceans are extrapolated from traditional data on TTSs and PTSs in other species (e.g., in humans, noise levels of 155 decibels can cause permanent damage). For example, using these methods for beluga whale sound levels of 140 decibels could cause TTSs, i.e., decreased sensitivity to sound, with permanent damage to auditory systems (PTS) at between 195 to 210 decibels.[323] These threshold levels are dependent, however, on the frequency of the sound and the duration of exposure.

This means of calculating impacts is flawed. To date, there is information on the hearing abilities of only eleven species of cetaceans, and for most of those species, data was gathered from only one, two, or a small number of animals.[324] Since there could be considerable individual variety in hearing abilities of cetaceans, particularly if there are differences according to sex and age,[325] such a small sample size may lead to incorrect assumptions about hearing abilities. Using hearing sensitivity data based on a study of one or two older male animals to extrapolate potential hearing damage caused by a sound source would seriously underestimate the sensitivity of free-living cetaceans to the sound source.

Additionally, the studies on hearing sensitivity often use animals that have been in captivity for long periods of time, and the captive environment is a particularly noisy one. Many of the subject animals have also been exposed repeatedly to high levels of noise during sound-related experiments. Some medical treatments that animals receive in the captive environment also may lead to hearing loss.[326] Unsurprisingly, several captive animals have been found with impaired hearing.[327] Thus, the use of captive animals who may have already suffered some PTSs would give flawed data.(RUN IN) Bearing this in mind, it is perhaps not surprising that there is growing evidence of wild

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[323] W.J. RICHARDSON *ET AL.*, EFFECTS OF NOISE ON MARINE MAMMALS (unpublished report to the U.S. Minerals Management Service, 1991); Gordon & Moscrop, *supra* note 194; *See also* DOLMAN & M.P. SIMMONDS, NOISE POLLUTION—SOME THOUGHTS ON MITIGATION AND WIDER PROTECTION (30 May–10 June 2005) (paper presented to the Sci. Comm. at the 57th Meeting of the Int'l Whaling Comm'n).

[324] P.E. Nachtigall *et al.*, *Psychoacoustic Studies of Whale and Dolphin Hearing*, *in* HEARING BY WHALES 44, 48 (W.W.L. Au *et al.* eds., 2000).

[325] Typically, males and older animals are more likely to loose hearing ability. Ridgway *et al.*, *supra* note 197.

[326] J.J. Finneran *et al.*, *Pure Tone Audiograms and Possible Aminoglycoside-Induced Hearing Loss in Belugas* (Delphinapterus leucas), 117 J. ACOUSTICAL SOC'Y AM. 3936 (2005).

[327] *Id.*; S.H. Ridgeway & D.A. Carder, *Hearing Deficits Measured in Some* Tursiops truncatus*, and Discovery of a Deaf/Mute Dolphin*, 101 J. ACOUSTICAL SOC'Y AM. 590, 590–594 (1997); R.B. Brill *et al.*, *Assessment of Dolphin* (Tursiops truncatus) *Auditory Sensitivity and Hearing Loss Using Jawphones*, 109 J. ACOUSTICAL SOC'Y AM. 1717, 1717–1722 (2001).

cetaceans showing adverse reactions to sounds at received levels that captive-animal studies have deemed would not be disturbing or the cause of any impact for the species concerned.[328]

Another issue with hearing sensitivity tests is that they frequently use pure tones, which are sounds of just one frequency, and a type of sound animals would not encounter in the wild. It is possible that cetaceans have greater sensitivity to sounds that are biologically relevant (i.e., sounds that they are adapted to hear).[329] This may have implications for some sound types. For example, low-frequency active sonar used by the United States[330] actually sounds very similar to the sounds produced by cetaceans. Animals may also become more sensitive to sounds that they associate with threats (e.g., fast boats capable of causing injury). Thus, animals may be more sensitive to such sound types than predicted.

For cetacean species in which hearing sensitivity is unknown, extrapolations are made using other species, adjusted according to the known frequencies of vocalisations produced by particular species of concern. Again, such extrapolations are problematic because animals may have excellent hearing capabilities outside the ranges in which they produce vocalisations. For example, based on vocalisation data, a rehabilitated grey whale calf was discovered to have hearing capabilities in frequencies much higher than had previously been assumed.[331]

In short, there are many flaws in the current methods that estimate the potential source levels that could cause TTSs and PTSs in cetaceans. Particularly, it is known that chronic exposure to noise can cause TTSs and PTSs at lower received levels of sound, but there has been no research into this chronic effect. Any TTSs or PTSs will impact cetacean health by severely compromising abilities to communicate, forage, and navigate in their environment. In fact, PTSs could effectively be lethal if it leaves animals ‘blind’ in their acoustic environment.

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[328] K.J. Findley *et al.*, *Reactions of Belugas,* Delphinapterus leucas*, and narwhals,* Monodon monoceros*, to Ice-Breaking Ships in the Canadian High Arctic,* 224 CAN. J. OF FISHERIES & AQUATIC SCIS. 97, 97–117 (1990); J.C. Gould & P.J Fish, *Broadband Spectra of Seismic Survey Air-Gun Emissions, with Reference to Dolphin Auditory Thresholds*, 103 J. OF ACOUSTICAL SOC'Y OF AM. 2177, 2177–2184 (1998); J.C. Gould & P.J. Fish, *Response to "Comments on 'Broadband Spectra of Seismic Survey Air-Gun Emissions with Reference to Dolphin Auditory Threshold*,'" 105 J. OF ACOUSTICAL SOC'Y OF AM. 2049, 2049–2050 (1999); C.J. Stone, *Cetacean Observations during Seismic Surveys in 1997,* 278 JOINT NATURE CONSERVATION COMM. PPP (1998); S. Koschinski *et al.*, *Behavioural Reactions of Free-Ranging Porpoises and Seals to the Noise of a Simulated 2 MW Windpower Generator,* 265 MARINE ECOLOGY PROGRESS SERIES 263, 263–273 (2003).

[329] INT'L WHALING COMM'N, REPORT OF THE STANDING WORKING GROUP ON ENVIRONMENTAL CONCERNS Annex K (2004).

[330] LFA SURTASS.

[331] S.H. Ridgway & D.A. Carder, *Assessing Hearing and Sound Production in Cetaceans not Available for Behavioral Audiograms: Experiences with Sperm, Pygmy Sperm, and Gray Whales*, 27 AQUATIC MAMMALS 267, 267–276 (2001).

There may also be cumulative and synergistic effects caused by anthropogenic activities. For example, a recent discovery indicates that certain pollutants can cause auditory tissue damage.[332] Such issues need to be further investigated.

Then again, it is dangerous to use the probability of a cetacean suffering TTSs or PTSs as the only measure by which noise can cause biologically significant or health threatening effects. Strandings that result from sonar exposure have occurred at sound levels that are orders of magnitude lower than levels that would be likely to cause TTSs.[333] Certainly, with respect to sonar related impacts, behavioural or physiological changes may lead to stranding and ultimately mortality, which can occur at levels much lower than those which might cause acoustic trauma. It is also worth noting that floating bodies were recently recovered around the Canary Islands, and it is hypothesized that these deaths were the result of military activities. Therefore, the animals that actually come ashore and strand may just be the tip of the iceberg.[334]

1.3.2.2.3 Decompression sickness. Several mass stranding events over the past few years have been linked to or associated with naval sonar activities.[335] Initially, it was suggested that the stranding of beaked whales in the Bahamas was the result of sonar frequencies causing reverberation of the air spaces within the skulls of the stranded whales.[336] However, the discovery of bubble-like lesions and fat emboli in the tissues of cetaceans that had stranded in the Canary Islands coincident with naval exercises suggested something different.[337] European veterinarians and whale biologists conducted autopsies on 14 beaked whales that stranded four hours after a 2002 NATO

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[332] L. Song *et al.*, *On Membrane Motor Activity and Chloride Flux in the Outer Hair Cell: Lessons Learned from the Environmental Toxin,* 88 TRIBUTYLTIN BIOPHYSICS J. 2350, 2350–2362 (2005).

[333] INT'L WHALING COMM'N, *supra* note 330, at Annex K (providing an example of how it is very unlikely that the stranded beaked whales in the 2000 Bahamas incident were exposed to receive sound levels greater than 160 decibels—levels which were 100 times quieter than levels previously thought "safe" for cetaceans by the U.S. government).

[334] A. Fernández *et al.*, *supra* note 262, at 446–457.

[335] For example, the Bahamas (D.L. Evans & G.R. England, *Joint Interim Report Bahamas Marine Mammal Stranding Event of 14–16 March 2000.* National Oceanic and Atmospheric Administration, Washington, DC, (2001), *available at* http://www.nmfs.noaa.gov/prot_res/PR2/Health_and_Stranding_Response_Program/Interim_Bahamas_Report.pdf); Taiwan (J.R. Brownell *et al.*, *Mass Strandings of Cuvier's Beaked Whales in Japan: U.S. Naval Acoustic Link?*, Paper SC56/E37 (2004) (presented at the 56th Meeting of the Int'l Whaling Comm'n June 29–July 10, 2004)); Canary Islands (A. Espinosa *et al.*, *New Beaked Whale Mass Stranding in Canary Islands Associated with Naval Military Exercises* (2004) (presented at 19th Annual Conference of the European Cetacean Society and Associated Workshop April 2–7, 2005).

[336] K.C. Balcomb & D.E. Claridge, *A Mass Stranding of Cetaceans Caused by Naval Sonar in the Bahamas*, 8 BAHAMAS J. OF SCI. 1, 1–12 (2001).

[337] P. Jepson *et al.*, *Gas-Bubble Lesions in Stranded Cetaceans: Was Sonar Responsible for a Spate of Whale Deaths after an Atlantic Military Exercise?,* 425 NATURE 575, 575–576 (2003).

exercise[338] and three more that had stranded after a 2004 exercise,[339] as well as various dolphins that stranded in the UK.[340] The lesions observed during the autopsies were similar to those caused by decompression sickness, or 'the bends,' particularly in the beaked whales.[341]

It was formerly thought that cetaceans possessed physiological adaptations allowing them to avoid decompression sickness.[342] More recently, scientists have proposed that beaked whales (and perhaps other deep diving species) have extremely high levels of dissolved nitrogen in their blood. Beaked whales normally spend so little time at the surface, and thus so little time exposed to low pressure, that nitrogen stays dissolved in the blood, avoiding formation of tiny nitrogen bubbles that block blood vessels and cause "the bends." However, studies suggest that sonar pulses either cause nitrogen to come out of solution due to pressure changes[343] or an aversive behavioural reaction in whales causing them to rapidly come to the surface or enter shallow waters where they start to rapidly depressurise and experience bends-like lesions.[344]

These theories has been criticised, primarily on the grounds that the bends causes different types of lesions in humans and not bubbles in the liver as observed in stranded beaked whales.[345] In particular, critics of the beaked whale strandings studies have noted that for decompression sickness "chronic lesions are found only in the long bones and central nervous system."[346] However, the veterinarians, pathologists, and whale biologists who investigated the Canary Islands beaked whales stated that they did not investigate bone tissue and only investigated the central nervous system in two animals; so they could not say that there were no such lesions in these tissues of the whales. However, they noted that "acute, systemic and widely disseminated lesions consistent with, but not diagnostic of [decompression sickness]"[347] and stated that large

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[338] *Id.*; Fernández *et al., supra* note 262, at 446–457.

[339] A. Fernández *et al.*, *New Gas and Fat Embolic Pathology in Beaked Whales Stranded in the Canary Islands* (presented in 19th Annual Conference of the European Cetacean Society and Associated Workshops April 2–7, 2005).

[340] Jepson *et al.*, *supra* note 338, at 575–576; P. Jepson *et al.*, *Acute and Chronic Gas Bubble Lesions in Cetaceans Stranded in the United Kingdo*m, 42 Veterinary Pathology 291, 291–305 (2005).

[341] P. Jepson et al., *supra* note 338, at 575–576; Fernández *et al.*, *supra* note 262, at 446–457; Jepson *et al.*, *supra* note 341, at 291–305.

[342] Peter Evans, The natural history of whales and dolphins 6–7 (Christopher Helm ed., 1993).

[343] D.S. Houser *et al.*, *Can Diving-Induced Tissue Nitrogen Supersaturation Increase the Chance of Acoustically Driven Bubble Growth in Marine Mammals?*, 213 J. of Theoretical Biology 183, 183–195 (2001); L.A. Crum *et al.*, *Monitoring Bubble Growth in Supersaturated Blood and Tissue Ex Vivo and the Relevance to Marine Mammal Bioeffects*, 6 Acoustics Res. Ltrs. Online 214, 214–220 (2005).

[344] A. Fernández *et al.*, *Whales, Sonar and Decompression Sickness*, 428 Nature 1, 1–2 (2004); A. Fernández *et al.*, *supra* note 262, at 446–447.

[345] C.A. Piantadosi & E.D. Thalmann, *Pathology: Whales, Sonar, and Decompression Sickness*, 428 Nature 1, 1 (2004).

[346] *Id.*

[347] Fernández *et al.*, *supra* note 345, at 1.

numbers of gas bubbles liver vessels, and other lesions observed have been reported as a symptom of the bends in humans.[348]

A subsequent paper on sperm whale bones reported lesions associated with decompression sickness, adding more evidence to support the noise-induced/provoked bends scenario.[349] Although the lesions were reportedly found on bones of an animal that died 111 years ago (i.e., long before the invention of military sonar), the authors of the study noted that bone damage caused in recent years could be due to cetaceans being rapidly driven to the surface by underwater noise.[350] A commentator on this study also noted that although sonar was not around a century ago, commercial whaling certainly was,[351] and forced surfacing of whales was a technique that was used by these operations.[352] Theoretically, such methods might cause rapid depressurization and the onset of the bends as effectively as being forced to the surface by sonar-related noise.

Another published scientific paper raises issues that may compound the effects of sonar on whales.[353] The paper suggests that the effects of pressure on the central nervous systems of diving cetaceans may result in "hyperexcitability"[354] of the nervous system and that "the repetitive high intensity noise produced by sonar pinging may [cause more nerve cell stimulation] under high-pressure conditions than on the surface."[355] Also, the increased nervous stimulation may result in "secondary responses that may impair orientation, or maintenance of the regular diving response of the cetaceans."[356] Thus, exposure to sonar or other high intensity noise sources while a cetacean is submerged, particularly if at a great depth, "may give rise to an enhanced startle response leading to disturbance in normal behaviour. A severe startle response, possibly involving fear or panic, may cause stranding as a flight response."[357]

Thus, after being exposed to sonar, a cetacean's panicked flight to the surface and subsequent stranding could then lead to conditions which lead to decompression sickness in the cetaceans. Compounding the problem, the

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[348] T.J.R. FRANCIS & S.J. MITCHELL, *Pathology of Decompression Sickness*, *in* BENNETT AND ELLIOT'S PHYSIOLOGY AND MEDICINE OF DIVING 530, 530–556 (A.O. Brubank & T.S. Neuman eds., 2003).

[349] Michael J. Moore & Greg A. Early, *Cumulative Sperm Whale Bone Damage and the Bends*, 36 SCI. 2215 (2004).

[350] *Id.*

[351] E. D. Mitchell, *What Causes Lesions in Sperm Whale Bones?,* 38 SCI. 631 (2005).

[352] S. Ohsumi, *Criticism on Japanese Fishing Effort for Sperm Whales in the North Pacific,* in REPORTS OF THE INTERNATIONAL WHALING COMMISSION 19*,* 19–30 (1980); J.N. TONNESSEN & A.O. JOHNSEN, THE HISTORY OF MODERN WHALING 6–7 (1982).

[353] Aldolfo E. Talpalar & Yoram Grossman, *Sonar versus Whales: Noise May Disrupt Neural Activity in Deep-Diving Cetaceans*, 32 UNDERSEA & HYPERBARIC MED. 135, 135–139 (2002).

[354] *Id.* at 136.

[355] *Id.* at 137.

[356] *Id.*

[357] *Id.*

sonar exposure plus the effects of depth-induced pressure on the nervous system may actually enhance and exaggerate the behavioural reactions of cetaceans to noise.

That cetacean strandings coincident with naval sonar use seem to be occurring after levels of sound exposure much lower than would cause physical damage to cetacean auditory systems suggests that sonar exposure causes behavioural changes rather than physiological; for example, rapid surfacing may bring about decompression sickness, which in turn leads to pathological changes that injure, disable, or kill cetaceans.[358]

1.3.2.2.4 Stress. Prolonged exposure to high levels of noise can result in stress and debilitation. Researchers have reported increases in activity of adrenal and defence-related endocrine glands in relation to noise exposure.[359] Several marine species (including both fish and shrimp) have displayed reduced growth and reproductive success when exposed to chronic noise levels 20 to 30 decibels above background levels.[360] Thus, noise stress effects could impact cetacean prey species. With respect to cetaceans themselves, prolonged exposure to high levels of noise, and the resultant chronic activation of hormonal complexes from the stress entailed, could lead to reduced cetacean health.[361,362] Acute or chronic stress in cetaceans can ultimately lead to premature mortality.[363]

There is growing concern that cetacean scientists should be conducting more research into how noise and disturbance-related stress affects cetaceans and how such stress can lead to decreases in successful reproduction, immune

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[358] INT'L WHALING COMM'N, REPORT OF THE IWC HABITAT DEGRADATION WORKSHOP 324 (2005).

[359] B.L. WELCH & A.S. WELCH, PHYSIOLOGICAL EFFECTS OF NOISE (1970).

[360] P.J. Banner & M. Hyatt, *Effects of Noise on Eggs and Larvae of Two Estuarine Fishes*, 108 TRANSACTIONS OF AM. FISHERIES SOC'Y 134, 134–136 (1973); J.P. Lagadere, *Effects of Noise on Growth and Production of Shrimp* (Crangon crangon) *in Rearing Tanks*, 71 MARINE BIOLOGY 177, 177–185 (1982).

[361,] H. Seyle, *The Evolution of The Stress Concept*, 61 AMERICAN SCIENTIST 692, 692–699 (1973); C.A. Thomson & J.R. Geraci, *Cortisol, Aldosterone, and Leucocytes in the Stress Response of Bottlenose Dolphins,* Tursiops truncates, 43 CAN. J. FISHERIES & AQUATIC SCI. 1010, 1010–1016 (1986); D.J. St Aubin & J.R. Geraci, *Capture And Handling Stress Suppresses Circulating Levels of Thyroxine (T4) and Triiodothyronine (T3) in Beluga Whales,* Delphinapterus leucas, 61 PHYSIOLOGICAL ZOOLOGY 170, 170–175 (1988).

[362] Specific stress related ailments in mammals can include nutritional problems, stomach ulceration, arteriosclerosis, reproductive failure and suppression of the immune system. D.A. Brodie & H.M. Hanson, *A Study of the Factors Involved in the Production of Gastric Ulcers by the Restraint Technique*, 38 GASTROENTEROLOGY 353, 353–360 (1960); H.L. Radcliffe *et al., Coronary Arteriosclerosis in Swine: Evidence of a Relation in Behaviour*, 68 J. COMP. PHYSIOLOGICAL PSYCHOL. 385, 385–398 (1969); G.P. Moberg, *Influence of Stress on Reproduction: A Measure of Well-Being*, *in* ANIMAL STRESS 245, 245–268 (1985); L.A. Cohn, *The Influence of Corticosteroids on Host Defence Mechanisms,* 5 J. OF VETERINARY INTERNAL MED. 95, 95–104 (1991); J.A. SMITH & K.M. BOYD, LIVES IN THE BALANCE: THE ETHICS OF USING ANIMALS IN BIOMEDICAL RESEARCH (1991).

[363] R.J. Small & D.P. DeMaster, *Survival of Five Species of Captive Marine Mammals,* 11 MARINE MAMMAL SCI. 209, 209–226 (1995).

system suppression, and ultimately increased rates of mortality.[364] As noted previously (Section 1.3.2.2.1), such research into chronic stress effects would require long-term projects.

Most research on the impacts of human activities tends to be either short-term[365] and relatively superficial or involve desk-bound projects using modelling techniques with surrogate data from other species or different populations (rather than gathering empirical data from the species and situation in question). Therefore, answering some of the questions about stress effects on cetaceans may require a major re-think in the way that funding bodies provide cetacean conservation research funding.[366]

In the interim, one approach may be to develop a set of indicators or indices of stress levels in cetaceans, both behavioural indications (such as changes in respiration rates, inter-animal distances, and activity budget) and population level indicators (such as reproductive rates, stranding rates, and mortality rates).[367] These indicators could then be used to monitor "stress levels" in key cetacean populations.

1.4 Climate Change

Global warming has become an international environmental issue because of increasing concentrations of 'greenhouse' gases (particularly carbon dioxide) in the atmosphere trapping heat on the surface of the planet. The fact that land surface and oceanic temperatures are increasing, and the role anthropogenic emissions have played in causing this increase has clearly been confirmed by researchers using a variety of techniques, including satellite imagery.[368] During the 20th century, there was an observed 0.6 degrees Celsius increase in global temperatures.[369] Researchers, based on current rates of production, are estimating a doubling of atmospheric carbon dioxide from preindustrial levels by 2050 to 2100.[370] This increase in carbon dioxide will be accompanied by at least a 1.9 degrees Celsius rise in the current temperature, and estimates of temperature increases have ranged up to 11.5 degrees Celsius.[371] Even if greenhouse gas production is capped at present levels immediately, an increase

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[364] M. Orams, *Why Dolphins May Get Ulcers: Considering the Impacts of Cetacean-Based Tourism in New Zealand,* 1 TOURISM IN MARINE ENV'TS 17, 17–28 (2004).

[365] *Id.;* P.J. Corkeron, *Whale Watching, Iconography, and Marine Conservation,* 18 CONSERVATION BIOLOGY 847, 847–849 (2004).

[366] *Id.*

[367] Orams, *supra* note 365, at 17–28.

[368] R.A. Kerr, *Ocean Warming Model again Points to Human Touch,* 307 SCI. 1190 (2005); J. Hansen *et al..*, *Earth's Energy Imbalance: Confirmation and Implications,* 308 SCI. 1431, 1431–1435 (2005).

[369] G.A. Meehl *et al., How Much More Global Warming and Sea Level Rise*?, 307 SCI. 1769, 1769–1772 (2005).

[370] J. Peeley, *Estimates of Greenhouse Warming Double*, 39 ENVT'L. SCI. & TECH. 190A, PPP (2005).

[371] *Id.*

of at least 0.6 degrees Celsius will probably occur, and by the year 2400, the increase would be 2 to 6 degrees Celsius.[372]

In conjunction with the temperature rise, there will also be an increase in sea level due to the increased melting of ice and expansion of warming water. In the 20th century, there was a 15–20-centimetre sea level rise linked to global warming.[373] Even if carbon dioxide emissions are immediately stabilized, there will be at least a further 14–16 centimetre minimum increase in sea level with a possible subsequent 25 centimetre increase per century.[374] Without this stabilization, greater sea level rises will occur with estimates of up to 88 centimetres in the next century.[375] Most models and predictions of sea level rise do not take into account increased melting and disintegration of ice shelves in the Polar Regions, although these factors could well cause even greater increases in sea level.[376]

In addition to and perhaps exacerbating the effects of rising sea levels, climatologists have predicted an increase in wintertime storminess and precipitation in some regions of the northeast Atlantic, including the UK.[377] Rising sea levels together with increased winter rainfall and storm surges may also inundate polluted coastal areas. Such areas may include landfill sites or agricultural land, and hence, there is a real possibility that chemical pollutants and debris may be conveyed into the marine environment by these means.

Another potential effect of climate change is an increase in the acidity of the ocean due to higher levels of dissolved carbon dioxide (which forms carbonic acid).[378] Indeed, in August 2004, a meeting was held in the UK to develop a research plan to investigate this issue. Simultaneously, the Royal Society announced that they will be launching an inquiry into the possible ecosystem effects of this increase in acidity.[379] There is concern that the increases in acidity could seriously deplete coral and calcareous plankton populations as the carbonic acid effectively dissolves their structures. This could disrupt oceanic ecosystems.[380]

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[372] Hansen *et al.*, *Earth's Energy Imbalance: Confirmation and Implications,* 308 SCI. 1431, 1431–1435 (2005); Meehl *et al., supra* note 370, at 1769–1772; Wigley, *The Climate Change Commitment,* 307 SCI. 1766, 1766–1769 (2005).

[373] Meehl, *supra* note 370, at 1769.

[374] *Id.*; Wigley, *supra* note 373 at 1766–1769.

[375] J. Hansen, *A Slippery Slope: How Much Global Warming Constitutes "Dangerous Anthropogenic Interference?"* 68 CLIMATE CHANGE 269, 269–279 (2005).

[376] *Id.* at 273.

[377] INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE, 3RD ASSESSMENT REPORT, CLIMATE CHANGE 2001: SYNTHESIS REPORT—SUMMARY FOR POLICYMAKERS 21 (2001), *available at* http://www.ipcc.ch/pub/un/syreng/spm.pdf

[378] Q. Schiermeier, *Researchers Seek to Turn the Tide on Problem of Acid Seas,* 430 NATURE 820 (2005).

[379] *Id.*

[380] *Id.*

As oceans become more acidic, there is also a corresponding decrease in available oxygen for marine species. Some species that have a high biological oxygen demand—such as cephalopods and deep sea fish—are likely to be particularly affected as the external CO_2 change lowers the pH of their blood, thereby compromising their ability to transport oxygen internally.[381] Thus, important prey species of cetaceans, including squid, may be adversely affected if ocean pH reaches a critical level.

The worst case scenario for the effects of global warming was highlighted in the Hollywood movie *The Day After Tomorrow,* i.e., that global warming leads to the cessation of thermohaline circulation (the movement of water bodies) in the North Atlantic, leading to decreased heat exchange from the ocean to the north Atlantic region, ultimately causing rapid decreases in temperature in the northern hemisphere.[382] Although the Hollywood movie is somewhat far-fetched, scientists studying the flow of water and salinities in the North Atlantic have nonetheless reported changes in water flows and salinities over the Greenland–Scotland ridge that are possibly indicative of a weakening of thermohaline circulation. Conclusively, this issue should not be dismissed and requires further research.[383]

The effects of temperature increase have certainly been felt in Europe, with the summer of 2003 being reported as the hottest in Europe since AD 1500.[384] Researchers comparing European temperature trends with greenhouse gas accumulation have again confirmed the role that humans have played in this increase.[385]

With respect to the UK marine environment, seawater temperatures increased in the last quarter of the 20th century, with seawater temperatures in some areas of the UK increasing by as much as one degree Celsius.[386] It has been estimated that temperatures could increase in UK waters by a further two degrees Celsius by 2050,[387] or even more in southern UK waters.[388] This change in temperature has already had effects on the distribution of benthic marine species in UK waters.[389] In the wider Northeast Atlantic, there have also been

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[381] THE ROYAL SOC'Y, OCEAN ACIDIFICATION DUE TO INCREASING ATMOSPHERIC CARBON DIOXIDE 19 (2005).

[382] P.U. Clark *et al.*, *The Role of the Thermohaline Circulation in Abrupt Climate Change,* 415 NATURE 863, 863–869.

[383] B. Hansen *et al.*, *Already the Day After Tomorrow?*, 305 SCI. 953, 953–959 (2004); H.L. Bryden *et al.*, *Slowing of the Atlantic Meridional Overturning Circulation at 25° N.*, 438 NATURE 655, 655–657 (2005).

[384] P.A. Stott *et al.*, *Human Contribution to the European Heat Wave of 2003*, 432 NATURE 610, 610–614 (2004).

[385] *Id.*

[386] C. Sheppard, *Sea Surface Temperature 1871–2099 in 14 Cells Around the United Kingdom,* 49 MARINE POLLUTION BULL. 12, 12–16 (2004).

[387] M. HULME *ET AL.*, CLIMATE CHANGE SCENARIOS FOR THE UNITED KINGDOM: THE UKCIP02 SCIENTIFIC REPORT 7 (2002).

[388] Sheppard, *supra* note 387, at 12–16.

[389] K. Hiscock *et al., Effects of Changing Temperature on Benthic Marine Life in Britain and Ireland*, 14 AQUATIC CONSERVATION 333, 333–362 (2004).

major changes in plankton abundance, timing of blooms, and distribution in the latter half of the 20th century. The changes—linked to global warming—have in turn been linked to changes in food webs and declines in larger fish species such as North Sea cod.[390]

With respect to cetaceans, the potential effects of climate change are largely unknown, but the most likely impacts would result from a change in plankton levels and hence distribution of prey species, which are likely to change the distribution of cetacean species.[391] Certainly, researchers have shown that changing temperatures, which influences prey species, can have effects on cetacean behaviour. For example, bottlenose dolphin group size in the Moray Firth is affected by the presence of prey, which in turn is affected by water temperatures.[392]

A study of a North Sea demersal fish assemblage has also shown that nearly two-thirds of the species studied, including species such as cod,[393] are responding to changes in climate by adjusting their preferred latitude or depth in the water column.[394] Other principal prey species of cetaceans, such as cephalopods, may also be reacting to climate change. For example, the migration patterns of veined squid[395] in the English Channel seem to be responding to climatic changes.[396]

Analysis of stranding records has the potential to inform us how cetaceans around the UK coastline may be being affected by climate change.[397] In one analysis,[398] researchers discovered that strandings of cold water cetacean species have decreased and records of warm water species have increased in the UK, a trend that was also supported by survey data.[399] This pattern was believed to be consistent with a northward shift of warm water cetacean species. The researchers expressed concerns that as a result of a temperature-induced shift of these warm water species, cold water species, such as white-beaked

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[390] M. Edwards & A.J. Richardson, *Impact of Climate Change on Marine Pelagic Phenology and Trophic Mismatch*, 430 SCI. 881, 881–884 (2004); A.J. Richardson & D.S. Schoeman, *Climate Impact on Plankton Ecosystems in the Northeast Atlantic*, 305 SCI. 1609, 1609–1612 (2004).

[391] M. MacFarvin & M.P. Simmons, *Whales and Climate Change*, *in* THE CONSERVATION OF WHALES AND DOLPHINS: SCIENCE AND PRACTICE 321–332 (M. Simmonds & J.D. Hutchinson eds., 1996); K. Mulvaney & B. McKay, *Small Cetaceans: Small Whales, Dolphins, and Porpoises*, *in* 3 SEAS AT THE MILLENNIUM: AN ENVIRONMENTAL ASSESSMENT, 49–63 (C. Sheppard ed., 2000).

[392] D. Lusseau *et al.*, *Parallel Influence of Climate on the Behavior of Pacific Killer Whales and Atlantic Bottlenose Dolphins*, 7 ECOLOGY LTRS. 1068, 1068 (2004).

[393] *Gadus morhua.*

[394] A.L. Perry *et al.*, *Climate Change and Distribution Shifts in Marine Fisheries*, 308 SCI. 1912, 1912 (2005).

[395] *Loligo forbesi.*

[396] D.W. Sims *et al.*, *Timing of Squid Migration Reflects North Atlantic Climate Variability*, 268 PROC. ROYAL SOC'Y OF LOND. 2607, 2607–2611 (2001).

[397] [98] C.D. MacLeod *et al.*, *Climate Change and the Cetacean Community of Northwest Scotland*, 124 BIOLOGICAL CONSERVATION 477, 477–483 (2005).

[398] *Id.* at 479–482.

[399] *Id.* at 479–480, 483.

dolphins (*Lagenorhynchus albirostris*), might become displaced from their habitat or even become locally extinct in some areas.[400]

1.5 Prey Depletion

Currently, the UN Food and Agriculture Organisation (FAO) considers 28 per cent of global fish stocks to be significantly depleted or overexploited and 47 per cent to be fully exploited. Only 24 per cent of fish stocks are either under or moderately exploited.[401] It also estimates that illegal, unreported, and unregulated (IUU) fisheries exceed fishing quotas by 300 per cent.[402] Moreover, global fisheries catch estimates have declined by 0.66 million tons/year since 1988; 230 populations of marine fishes have suffered a 83 per cent reduction in historical breeding population; large predatory fish (sharks, skates, rays, and marlin) biomass is currently estimated to be only ten per cent of pre-exploitation levels; 55 species of marine fish have lost at least part of their geographical range; and three species of marine fish have gone extinct over the past two centuries.

In general, the world's fish stocks are declining as a result of human over-exploitation.[403] The effect that human exploitation can have on fish stocks is staggering. For example, fisheries typically can reduce fish community biomass by 80 per cent within just 15 years of exploitation.[404]

After such exploitation has occurred, there is frequently little recovery of fish stocks. An analysis of over 200 stocks of fish determined that, after exploitation, only 12 per cent of the studied fish stocks showed full recovery. Despite conservation measures or fisheries closures, it was not unusual for populations that had declined more than 60 per cent to exhibit little or no recovery as many as 15 years later.[405] This lack of recovery is generally due to poor fisheries management, which is often compromised by political pressures to maintain fishing even beyond the point where takes should cease.

Over-exploitation is also causing alterations in ecosystems. As caught fish species have shifted—due to sequential overexploitation—from long-lived, high trophic level, fish-eating bottom fish toward short-lived, low trophic

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[400] *Id.* at 482–483.

[401] FOOD AGRIC. ORG. OF THE UN FISHERIES DEP'T (FAO), THE STATE OF WORLD FISHERIES AND AQUACULTURE 23 (2002).

[402] *Id.*

[403] J.A. Hutchings, *Collapse and Recovery of Marine Fisheries*, 406 NATURE 882–885 (2000); Jeremy B.C. Jackson *et al.*, *Historical Overfishing and the Recent Collapse of Coastal Ecosystems* 293 SCI. 629, 629–638 (2001); FAO, *supra* note 402; R.A. Myers & B. Worm, *Rapid Worldwide Depletion of Predatory Fish Communities*, 423 NATURE 280 (2003); S.J. Omerod, *Current Issues With Fish and Fisheries: Editor's Overview and Introduction*, 40 J. OF APPLIED ECOLOGY 204, 204–213 (2003); V. Gewin, *Troubled Waters: The Future of Global Fisheries*, 2 PUB. LIBR. OF SCI. 422, 422–427 (2004); J.A. Hutchings & J.D. Reynolds, *Marine Fish Populations: Consequences for Recovery and Extinction Risk*, 54 BIOSCIENCE 297, 297–309 (2004).

[404] Gewin, *supra* note 404, at 422–427.

[405] *Id.*

level invertebrates and feeding pelagic fish, the mean trophic level of commercial species has declined.[406] Thus, the composition of marine ecosystems changes, an effect that has been most pronounced in the Northern Hemisphere where most industrialized fishing takes place.[407] The nature of the fish in the fish stock can also change. With fishing pressure on larger animals, there is a genetic change of the fish population so that fish become sexually mature at a younger age and generally smaller in size.[408]

Depletion of fish stocks is certainly an issue in UK waters, in particular the North Sea—an area that has experienced long-term fisheries overexploitation.[409] At present, there has been no research conducted on whether reduced fish stocks have resulted in effects on cetacean populations; effects, however, are probably likely.[410] For example, species may move to other areas or turn to alternative prey species.[411]

One possible effect of decreased prey abundance particular to cetaceans might be the metabolisation of stored blubber reserves. As mentioned previously (Section 1.3.1.1), cetaceans frequently have high concentrations of lipid-soluble pollutants in their blubber layer. It is possible that a sudden decline in prey species could result in the rapid release of pollutants into the cetacean's body, which then might lead to suppression of the immune system and susceptibility to disease. Indeed, it is possible that decreases in food supply may have triggered releases in pollutants, which subsequently led to marine mammal mass mortalities in the Mediterranean and other regions.[412]

1.6 Recommendations

Given that one major problem in conserving and adequately caring for cetaceans remains a lack of detailed knowledge about how they use our waters, more research is urgently needed to underpin policies relating to the use and protection of the marine environment and specifically before potentially harmful developments are allowed to proceed in UK and adjacent waters. However, the need for more research should not be used as an excuse to postpone conservation measures and this review recommends a series of important actions that should be taken by the UK authorities in order to safeguard the future of these animals. These are not exhaustive and are summarised below:

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[406] D. Pauly *et al.*, *Fishing Down Marine Food Webs*, 279 SCI. 860 (1998).

[407] *Id.* at 860–861.

[408] J.A. Hutchings, *The Cod That Got Away*, 428 NATURE 889, 889–890 (2004); E.M. Olsen *et al.*, *Maturation Trends Indicative of Rapid Evolution Preceded the Collapse of Northern Cod*, 428 NATURE 932, 932–935 (2004).

[409] W.J. Wolff, *The South-Eastern North Sea: Losses of Vertebrate Fauna During the Last 2000 years*, 95 BIOLOGICAL CONSERVATION 209, 209–217 (2000).

[410] Mulvaney & McKay, *supra* note 392, at 49–63.

[411] S. CURRAN *ET AL.*, RECOMMENDATIONS FOR THE SUSTAINABLE MANAGEMENT OF THE BOTTLENOSE DOLPHIN POPULATION IN THE MORAY FIRTH (1996).

[412] Simmonds, *supra* note 75.

1.6.1 Entanglement in Fishing Gear

The incidental capture (or bycatch) of cetaceans in fishing nets is widespread and for certain species in some areas is likely to be highly significant in conservation terms. Furthermore, once ensnared in nets, cetaceans can take some time to die, many suffering severe injuries in the process, making this an important welfare issue too. In order to address this urgent problem the UK Government should:

i) prioritise efforts to resolve the technical and administrative barriers to the effective implementation of the requirement for pingers to be deployed in specified gillnet and tangle net fisheries (under EC Regulation 812/2004);
ii) in the absence of effective deployment of pingers, introduce alternative means of reducing cetacean mortality in those fisheries with unacceptable bycatch levels—including fisheries closures if necessary;
iii) monitor gillnet and tangle net use, including gear type and size and temporal and geographic distribution, and their associated bycatch levels, in order to determine the most appropriate and effective bycatch mitigation measures;
iv) increase and speed up research and development of alternative by-catch mitigation measures, including more selective fishing gear;
v) press for further measures within the EU to address the bycatch in pelagic trawl and other fishery types not provided for in EC Regulation 812/2004, again, including the restriction or closure of fisheries where technical solutions are not yet available.

In the absence of any other effective measures for the mitigation of bycatch in pelagic trawls, the European Community must be prepared to introduce management measures including the suspension or closure of fisheries where necessary. In particular, where there is evidence of a serious threat to the conservation of cetacean populations, the European Commission should introduce emergency measures, as provided for by Article 7 of the new Framework Regulation of the CFP ((EC) No 2371/2002).

1.6.2 Chemical and Biological Pollution

It is important that the relevant authorities continue to carefully monitor pollution levels in UK waters and that they are particularly vigilant with respect to ‘novel’ pollutants. The detection of novel pollutants in marine top predators should be taken as a flag of concern and authorities should react with full independent investigations and where appropriate legislation.

1.6.3 Noise Pollution

1.6.3.1 Regulation of the Offshore Oil and Gas and Renewables Industries

- The activities of the fossil fuel industry offshore produce both chemical and noise pollution and need to be carefully regulated and monitored. The use of marine mammal observers on seismic vessels is welcomed but we believe that this system needs now to be reviewed and improved. For example, passive acoustic surveys (i.e. listening for cetacean vocalisations via electronic surveillance) should be conducted in conjunction with visual surveys, as this method increases the likelihood of cetaceans being detected in an area, i.e. acoustic detection while animals are submerged.
- The marine mammal observer (MMO) teams collect considerable data on cetacean distributions and responses. Efforts should be made to ensure that these data are of adequate quality (and, indeed, that the MMOs are suitably trained) to be included in national databases and reviews of cetacean distribution and behaviour.
- Where impacts are not clear—for example the extent of the impacts of decommissioning of oil rigs where explosives and equipment making loud noises may be deployed—the benefit of the doubt should be given to marine wildlife and the most precautionary approach taken.
- With regard to offshore windfarms, underwater turbines, wave energy generators and other forms of 'renewable energy' generation, consideration needs to be given to the potential impacts of construction, operation and decommissioning. The pile driving, for example, that is used to build wind farms is a substantive source of noise. Enthusiasm for green energy should not be allowed to override genuine marine conservation concerns.
- Thorough surveys of cetaceans should be conducted before any industrial offshore industry is allowed to develop—these should determine habitat use through the seasons across the area likely to be affected, which will potentially extend beyond the development site itself. Decision about whether or not the development should go ahead and related mitigation and management measures should be based on such information.

1.6.3.2 Assessment and Regulation of Military Activities

- The issue of military sonar is of such concern that there should be a moratorium on the peacetime deployment and development of new military sonar systems until more is known.

- The Royal Navy should work with independent scientists and conservationists to conduct a thorough, and open, assessment of the potential impacts of these sonar systems.

1.7 Summary

Cetaceans (whales, dolphins, and porpoises) in UK and adjacent waters are being adversely affected by various human generated activities. The precise significance of virtually all of these is poorly known and this situation is made even worse because we also know little of the distributions and habitat needs of these animals.

In short, we may well be in danger in the seas of repeating the mistakes made earlier on land for many terrestrial species: driving them from their natural habitats, reducing ranges and depleting or even extinguishing populations. For marine animals the old adage of "out of sight and out of mind" still applies all too often and it is likely that the cumulative impact of human pressures is compromising the very survival of cetaceans around the UK.

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