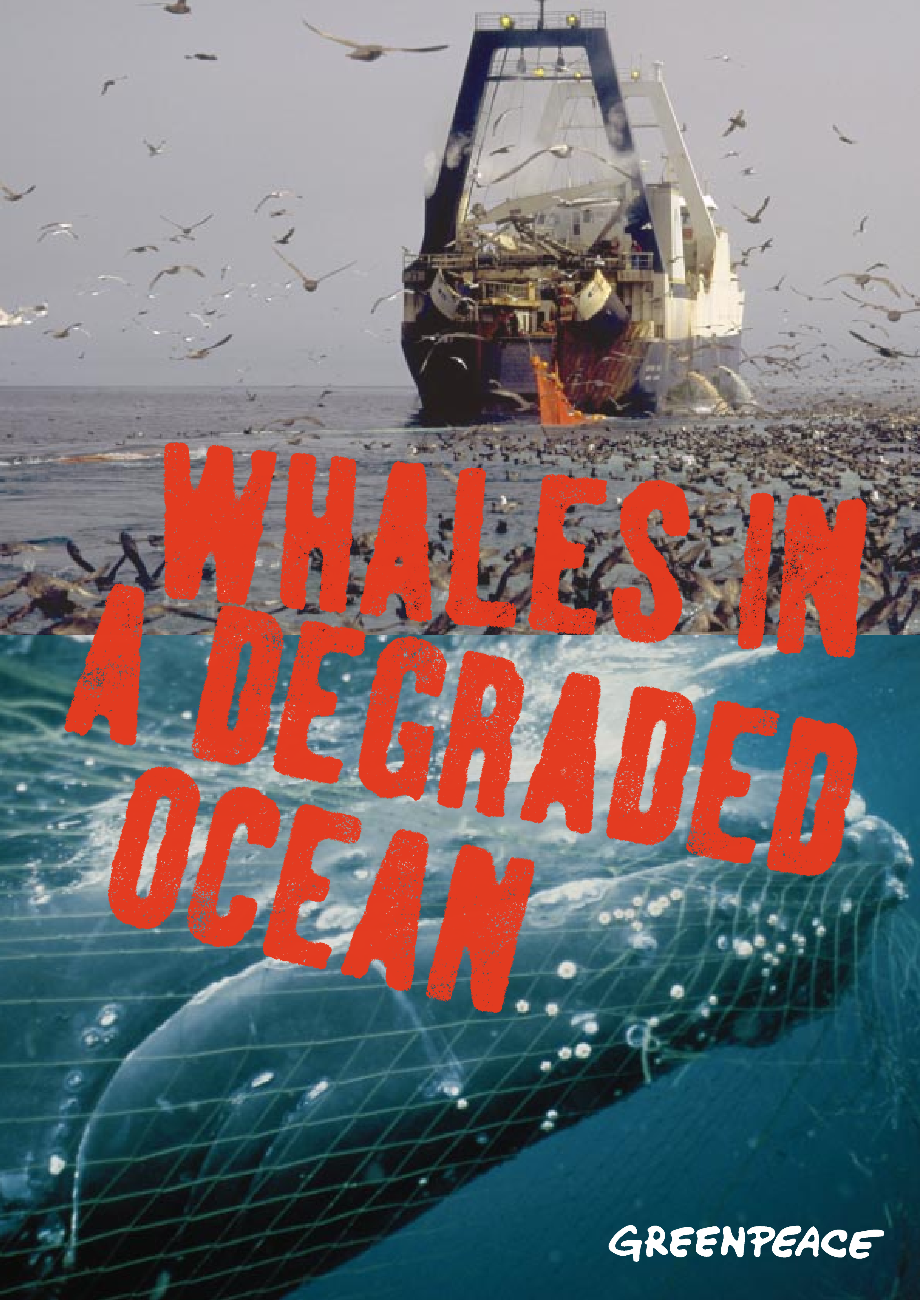
WHALES IN A DEGRADED OCEAN



GREENPEACE

MASA USHIODA/SEA PICS.COM

INTRODUCTION

There are few better indicators of the health of our oceans than whales. They are wide ranging, long-lived, exist in complex social groups and are positioned mainly toward the top of the food chain. Evidence of the impact of human activity upon them and their habitat has given serious cause for concern for some years. An assessment by Greenpeace seven years ago, *Whales in a Changing Ocean*, concluded that unless countries adopt a precautionary approach to the exploitation of the oceans any hope of ensuring the long-term protection of the world's remaining whale populations would be extinguished. The failure to do so has not changed our conclusion, but what has changed is the urgency of the need to take action now. Climate change, ozone depletion, toxic and noise pollution and prey depletion through over-fishing are all man-made threats to whale populations, some of which show little hope of recovery from their current alarmingly depressed status. Considered individually these human-made threats are desperately serious, in combination they may be viewed as threatening the future security of whales in our oceans.

Whales have inhabited the oceans for millions of years, evolving through a series of natural climatic changes. Today man-made climate change, brought about by the build up of greenhouse gases, is affecting our whole environment. Predictions concerning the severity of change have altered over the years, but it is now the commonly held view of independent scientists, that impacts are already, and will continue to be, far more serious than was first projected. Oceans, together with other global environments, are not immune to those impacts. For whales the rapidity of change is far beyond that previously experienced, possibly affecting their capacity to adapt and survive.

Going hand in hand with the effects of climate change are those resulting from the depletion of the ozone layer. The well-documented increase in ultraviolet (UV) radiation as a result of the thinning of the ozone layer is impacting not only individual whale species, but the marine eco-system as a whole. The scale of the problem is made clear by research published last year which shows the ozone hole over the Antarctic, an important feeding ground for many species of whales, is larger than ever (28.4 million km^2) – larger in fact than the surface of the Antarctic itself.

It is not only the chemicals that deplete the ozone that threaten marine life. Toxic pollution from the hundreds of millions of tonnes of chemicals pumped into the environment has both direct and indirect impacts on whales. Fatty tissue, which provides vital insulation for cetaceans, attracts and retains persistent pollutants, such as organochlorines. Organochlorine contamination results in immunological and reproductive disorders in many marine mammals and 'wherever the presence of endocrine disrupting chemicals have been sought in cetaceans, they have been found'.

Pollution of a different sort can also affect another of the whales' other vital systems – their hearing. Man-made noise pollution is not only severely physically debilitating for marine life with acute hearing, such as whales, but can prompt enforced changes in cetacean behaviour that drives them away from established feeding and breeding grounds, as well as disrupting communications. The growth of noise levels from shipping traffic, the military use of Low Frequency Active Sonar as well as oil and gas exploration threatens to radically alter the ability of whales to perceive their surroundings which is essential to their continued well-being.

While all the above impacts result from indirect human activity, the threat from direct competition by humans is also very real, through over-fishing. It is clear that our fisheries world-wide are in crisis, and the severe exploitation of certain traditional fish stocks has led to an ever-increasing demand for alternatives, and to attempts to blame whales for the over-exploitation of fish by humans.

Coupled with these identified threats are concerns about inexplicable strandings and 'die-offs', such as those of the many gray whales found dead along the US and Mexican coasts during 1999. One disturbing example of extreme consequences of human activity on whale populations is the North Atlantic right whale. Commercial whaling has already drastically reduced its numbers, yet now it is feared the species may soon become extinct because it is simply unable to cope with the additional pressures on its eco-system. Ship strikes and entanglement in fishing gear account for the majority of right whale deaths. Given the already low level of the population a single loss is not just an unfortunate loss of an individual, it also threatens the capacity for future population growth by removing potentially fertile males and females. Furthermore, for those right whales that do survive reproductive success is not guaranteed, as there has been a notable decline in calving rates.

With these combined dangers threatening the future of whales, it is surprising that some nations are still refusing to accept the reality of the situation. A large amount of evidence detailing the threats to cetaceans has already been presented to the International Whaling Commission's (IWC) Scientific Committee, yet the whaling nations, Japan and Norway, are still pushing to overturn the moratorium and for a return to the kind of large-scale whaling that in the past took many whale populations to the brink of extinction.

Disturbingly, at its last meeting in Adelaide, Australia, the IWC agreed to speed up work on developing the Revised Management Scheme (RMS). The RMS is the set of rules (including those that cover inspection and observation) that would be used if the IWC agreed to allow commercial whaling again. The completion and adoption of the scheme is needed before the moratorium can be removed, and if adopted it would be a clear signal by the IWC that they are willing to reconsider the moratorium. Greenpeace, which opposes all commercial whaling on the grounds that it can never be fully controlled and serves no real need, believes any moves to pursue or implement a management scheme for whales are grossly irresponsible. It is impossible to predict the long-term changes in whale populations because it is impossible to predict the long-term impacts of the multitude of human activities upon these species. The oceans have already changed dramatically in ways that were not foreseen when the IWC was established in 1946, the modern day threats to whales outlined in this report are no easier to quantify, but they are real and serious.

Some work has already begun to address these issues, most notably through the work of the IWC Scientific Committee, (particularly the SOWER 2000 and POLLUTION 2000+ research programmes), and in a series of resolutions passed by the Commission. At its most recent meeting in Adelaide, a resolution on environmental threats was passed by consensus that both recognised the value of a number of IWC initiatives but noted funding available to the Scientific Committee is insufficient for them to be developed or fully implemented.

There is now substantial evidence to suggest that all populations of whales are facing unprecedented pressures from human activities other than hunting and Greenpeace believes that the IWC should make addressing environmental threats a primary concern. To achieve this, the IWC must:

- Continue the moratorium on commercial whaling. Commercial hunting is the one threat to whales that can be removed both simply and cheaply
- Continue and expand the work conducted by the Scientific Committee on environmental threats and ensure that this is adequately funded
- Monitor and assist the recovery of whale populations depleted by commercial whaling (some of it conducted under the auspices of the IWC)

Failure of the IWC to take a fully precautionary approach and implement these recommendations is to gamble with the fate of the great whales.

DOUG PERRINE / INNER SPACE VISIONS

Humpback whales, once hunted, now face a multitude of environmental threats

EXECUTIVE SUMMARY

Climate change

Human-induced climate change is now beyond scientific dispute, with confirmation that our production of greenhouse gasses has been the major cause of global temperature increase during the last 50 years. Despite international efforts to stabilise and reduce the amount of anthropogenic CO_2 discharged to the atmosphere, 7 giga tonnes is still released annually and this amount is increasing. Climate models indicate that, as a result of continuing greenhouse-gas production, by end of the 21st century we can expect an increase in average global surface temperatures of between 1.5°C and 6.0°C. This increase is on top of the 0.5°C average surface temperature increase the earth has already experienced since the middle of the nineteenth century.

Such changes will produce significant alterations in the structure and functioning of natural systems throughout the globe. They will also produce notable and potentially drastic impacts upon marine eco-systems, with the result that the distribution, ecology and even the viability (i.e. the very survival) of a number of species, including cetaceans, will be affected.

One element of climate change that has particular impact on oceans is the change in the pattern of ocean circulation as a result of changing wind patterns and the alteration of thermohaline (temperature and/or salinity) processes. Differences in thermohaline characteristics are the main driving forces in producing many ocean currents, and evidence suggests that global warming is already having a direct impact upon them.

Climate change will impact upon:

- Ocean currents and wind patterns
- Sea surface temperature and long-term natural climatic cycles
- Primary production, changes in sea ice and ocean stratificatio

This will bring about changes in the ecology and food webs in areas important to cetaceans, including:

- The Antarctic, where stocks of krill – a highly important prey for most baleen whales – could be significantly reduced
- The Arctic – where ice sheets vital to the ecology and feeding of a number of whale species are in danger of totally disappearing
- The North Atlantic – where climate-related shifts are already being detected

Ozone depletion

While climate change is impacting upon our entire environment, the consequences of ozone depletion have particularly severe effects in specific areas that are key to some whale species. The earth's ozone layer serves a vital function in protecting life on the planet from the harmful impacts of solar ultraviolet (UV) radiation. However, through the production of a range of chemicals, human activity has resulted in its severe depletion, and thus its UV filtering ability. Human-produced halogonated compounds, such as CFCs, are carried into the upper atmosphere where they destroy the ozone layer. In polar regions, atmospheric conditions during certain times of the year are such that severe ozone depletion occurs, resulting in the formation of ozone 'holes' in late winter and early spring.

Despite efforts to phase out ozone–depleting chemicals, levels of destruction have not diminished. Research shows the 2000 Antarctic ozone hole was the largest ever recorded, covering an area of some 28.4 million km^2, with levels of ozone dropping to 60% below normal during the period of peak depletion in October. This situation seems unlikely to improve in the immediate future as levels of certain ozone-depleting chemicals in the atmosphere are still increasing.

The increase in UV radiation resulting from ozone depletion has a number of impacts on marine organisms and eco-systems – especially in polar regions where depletion is at its greatest – including:

- The impairment of photosynthesis in phytoplankton
- Significant reductions in biomass productivity as a consequence of the above
- Significant changes in zooplankton levels and communities as result of the above
- A decline in the survival of eggs and larvae of a number of aquatic species as a result of increased UV exposure

Given the damage that increased exposure to UV has on species that form the basis of marine food webs, it is logical to assume that this will have a knock-on effect on the overall ecology and eco-system structure, especially where UV exposure is greatest – i.e. polar regions. These regions are highly important for many cetacean species and increased UV levels may alter the distribution, supply, density or condition of prey species, such as krill *(Euphausia-superba)*, effectively reducing the cetacean food supply.

In addition, cetaceans that spend the greatest time at the sea surface, or upper layers are likely to be at risk from direct exposure to UV-B, which is known to result in genetic damage and cancer in a range of organisms.

Chemical pollution

Genetic damage, cancer and a range of other noxious impacts also come from other man-made chemicals. Today the range and volume of chemicals is immense. In 1995 alone,

Worldwide, fisheries are in a critical state as a result of over-fishing

annual worldwide chemical production stood at 400m tonnes. In Europe – the largest chemical producing region in the world – more than 100,000 chemicals have been registered in the European Inventory of Existing Commercial Chemical Substances (EINECS), though the exact number on the market is unknown. While even those producing the mass of chemicals cannot identify all of the effects that exposure to them has on the environment, research has established that:

- Many of these chemicals are persistent, and accumulate or magnify in food chains and fatty tissues
- Such persistent substances travel far beyond the point of origin affecting regions with little or no chemical industry or usage, such as the Arctic and deep ocean environments
- The range of chemical contaminants presents a significant threat to whales

Of prime concern is the group of chemicals known as persistent organic pollutants (POPs) – which include substances such as the pesticide DDT, poly-chlorinated bi-phenols (PCBs) and polycyclic aromatic hydrocarbons (PAHs). Because POPs have a tendency to be lipophilic or fat loving, they readily accumulate in fatty tissue such as blubber. They are also frequently magnified through the food chain. Consequently high levels of POPs have been recorded in cetaceans that are higher up the chain such as dolphins and other toothed whales. However, a significant loading of POPs has also been recorded in certain baleen whale species, which tend to feed at lower levels. For example, concerns have been raised about the level of pollutants in minke whales harvested by Norway and due to be exported to Japan, as they contain levels of POPs and other chemicals above the legal limits permitted in food by the Japanese authorities.

Scientists are increasingly concerned that a number of the pollutants accumulated by cetaceans may be interfering with their hormone function, reproductive success and development.

Noise pollution

Pollution is not restricted to contaminating chemicals. Since the industrialisation of society, marine noise has increased markedly with the rise of mechanical technology in transport and industrial processes. Sound is a vital sense for cetaceans, as important as sight for many other mammals. Cetaceans are highly reliant on their hearing for communication, navigation and prey detection making them particularly vulnerable to noise pollution and its adverse effects.

The effects of noise pollution on whales ranges from:

- Altering their natural behaviour by masking or interfering with the sounds produced and used by them
- Behavioural and physiological changes such as avoidance behaviour and alterations in breathing patterns as a result of being frightened or distracted by noise
- Causing temporary or permanent hearing damage, reducing an individual's chances of survival

Of particular concern is the use of high intensity Low Frequency Active Sonar by the military, which has been linked with the disturbance or even death of a range of cetacean species.

Over-fishing

Over-fishing has left the oceans in crisis. Worldwide, almost half of the fish stocks are considered fully exploited, 22% are over-exploited. Such extreme activity has altered and degraded marine ecosystems, and will continue to do so unless adequate management measures are introduced. This exploitation has direct impacts upon cetaceans including:

- Incidental capture – a considerable amount of research has indicated that both toothed and baleen whale species are caught and killed in fishing gear
- Competition for food – for example, it is claimed that the virtual removal of the North American Grand Banks stock of herring, due to over-fishing in the 1960s, removed a major prey source for baleen whales in the area. It has also been suggested that such exploitation substantially changed the eco-system dynamics, and therefore the feeding habits of baleen whales in the region

Advocates of the resumption of commercial whaling claim that the consumption of fish by whales poses a threat to the fishing industry; therefore whaling will help protect fish stocks. There is no scientific basis to these claims – global fisheries are in a critical state as a result of over-fishing, not over-predation. Put simply, whales do not eat too many fish, humans do.

WHALES AND CLIMATE CHANGE

GREENPEACE/EULER

The fact that human activity is causing an increase in global temperatures – the so called 'greenhouse effect' – is now beyond scientific dispute. The latest United Nations Intergovernmental Panel on Climate Change (IPCC) concluded earlier this year that past findings did not adequately reflect the extent of the problem and 'there is new and stronger evidence that most of the warming observed over the last fifty years is attributable to human activity'[1]

The panel also noted that 'human influences will continue to change atmospheric composition throughout the 21st century' and that unless emissions are curtailed, temperature increases of between 1.5 and 6.0°C would be seen by the end of the century, substantially higher than previous IPCC reports predicted. This view is further borne out by recent research, such as that undertaken by the Hadley Centre for Climate Research and Prediction, which confirms human activity (primarily through the generation of 'greenhouse gases' such as CO_2) has been the major cause of global temperature increase during the last 50 years[2].

The significance of change in the earth's temperature as a result of the production of greenhouse gasses is evident in records of global annual temperature anomalies. These show that temperatures were relatively stable from the beginning of the record through to about 1910, followed by relatively rapid and steady warming through to the early 1940s, and a further rapid temperature rise from the mid 1970s onwards[3]. The year 1998 holds the record for being the warmest to date (in terms of global mean temperature); and the seven warmest years since records began have all been in the 1990s[4].

The burning of fossil fuels has increased considerably since the advent of the industrial revolution. As a consequence, concentrations of CO_2 (one of the principle greenhouse gases found in the atmosphere) have risen by nearly 25% since the middle of the 19th century, with most of that increase during the last 50 years[5]. Despite international efforts to stabilise and reduce the amount of anthropogenic CO2 discharged to the atmosphere, approximately 7 giga tonnes are released annually[6] and this is increasing.

Scientists have developed a number of models that incorporate factors such as economic activity, population growth, technological advance and mitigating activity, in order to try to predict scenarios of future greenhouse gas levels within the atmosphere, and hence future levels of global warming. These indicate that, as a result of continuing greenhouse-gas production, by end of the 21st century we can expect an increase in average global surface temperatures of between 1.5 and 6.0°C[7]. This is in addition to the 0.5°C average surface temperature increase the Earth has already experienced since the middle of the nineteenth century[8].

Scientists agree that changes in global temperature will continue to significantly alter climatic conditions and the structure and functioning of natural systems throughout the globe. It is predicted that such changes will produce significant and potentially drastic impacts upon marine eco-systems, with the result that the distribution, ecology and even the viability (i.e. the very survival) of a number of marine species, including cetaceans, may be affected.

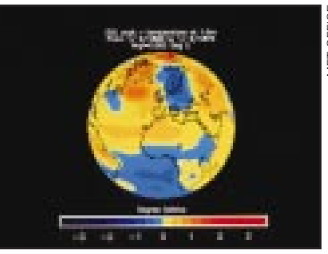
Climate change and the marine environment

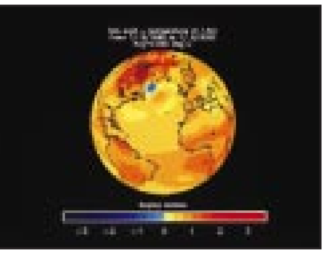
Climate change scientists use sophisticated computer models – incorporating simulations of key climatic and oceanographic conditions – to predict how increased and increasing levels of greenhouse gases will affect the earth's climate. Whilst such models are invaluable in providing indications of broad trends and large-scale associated impacts, even the most sophisticated models – general circulation models – are limited in their ability to make local or possibly even regional projections in timescales relevant to many biological processes[9]. The complex nature of climate change, uncertainties about precisely how it will alter local or regional oceanographic conditions, and the multitude of changes that can occur within oceanographic variables, make precise prediction of impacts on marine life impossible[10]. None the less, general predictions can be made. Outlined below is an overview of these predicted changes in marine physical and ecological processes, and the potential impacts they are likely to have on cetacean populations.

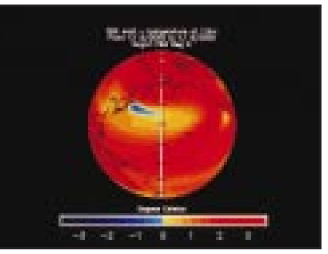
Ocean currents and wind patterns

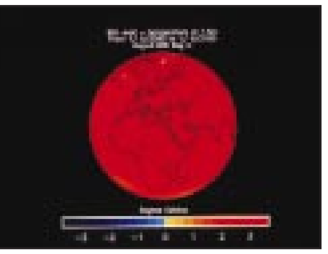
It is predicted that climate change will affect both the intensity and pattern of winds across the globe[11]. As a result of accelerated warming of the Earth, stronger winds may occur in certain areas, with a corresponding increase in storm events[12]. This is significant, as winds are partly responsible for determining the movement of seawater, resulting in such processes as coastal upwelling – which provides substantial amounts of nutrients required by phytoplankton for growth and reproduction[13].

In addition to wind-induced oceanic movement, the other major form of ocean circulation is thermohaline circulation, resulting from differences in the densities of different bodies of seawater. Such density differences are derived from temperature (thermo) or salinity (haline) characteristics of water masses. Thermohaline circulation results from dense water sinking in Polar Regions and then moving towards equatorial regions across the ocean floor. The action drives most of the major currents throughout the world's oceans. Water that sinks in Polar Regions is replaced by









MET OFFICE

Research published in 2000 shows the ozone hole over the Antarctic is larger than ever – 28.4 million km² – larger in fact than the surface of the Antarctic itself

surface flowing water originating from lower latitudes. Thermohaline circulation is important for two key reasons – it carries oxygenated water to deep ocean areas, preventing anoxic conditions developing, thereby allowing deep-sea ecosystems to exist, and it acts to redistribute heat from equatorial to higher latitudes[14]. Certain models have indicated that climate change could reduce or even potentially halt thermohaline circulation in certain oceanic areas[15]. Evidence exists to indicate that this may already be happening within the North Atlantic.

Changes in oceanic circulatory patterns may result in significant impacts upon the ecology of many marine species. Alteration in the direction or intensity of currents, for example, may carry larvae away from areas optimum for their survival[16].

Sea surface temperature and long-term natural climatic cycles

The predicted increase in average global temperatures of 1.5-6.0°C will not be uniform across the planet's surface, but will be greater in high latitudes[17]. Increases in sea temperatures through human-induced climate change are likely to disrupt marine eco-systems, forcing some species to relocate poleward where possible. Those unable to make the change could face extinction[18]. Increasing surface temperatures may also result in similar destruction or relocation of habitats essential for a range of marine species (see case studies below).

As well as the immediate effect climate change is having on sea temperatures, research indicates it may also be impacting on long-term climatic cycles, such as the El Niño/Southern Oscillation (ENSO) and the North Atlantic Oscillation. For example, two of the most severe ENSO events have occurred during the last two decades, with the worst happening in 1997/98[19]. As well as recent ENSO events being particularly intense, research suggests that their frequency and duration may have changed recently. Examination of sediment cores reveals that between 15,000 and 7,000 years ago, El Niño events occurred approximately every 15 years. More recently this has been between every 2 and 8.5 years[20]. Since the 1970's, El Niño events have become even more frequent, happening in five out of seven years between 1990-1997[21]. Researchers claim that climate change may be instrumental in altering the cycles that control the intensity and occurrence of ENSO events[22], as well as those within the North Atlantic – the North Atlantic Oscillation.

Ocean stratification and primary production

The vast majority of primary production – the synthesis of organic matter from inorganic material – is undertaken by phytoplankton in marine environments. Production by these microscopic plants provides the basis for the majority of marine food chains, with phytoplankton being consumed by zooplankton, which is in turn consumed by larger organisms, and so on up to the top predators. Cetaceans, depending up their ecology, survive at various levels of the chain, but all are ultimately dependent on the primary production that forms its base.

Primary productivity within a marine eco-system is greatly influenced by stratification of seawater which is itself primarily affected by climate[23]. During the summer – in non-tropical regions – seasonal warming of the ocean's surface layers by solar radiation occurs, making it less dense than the colder water beneath it and therefore resistant to mixing. This process is stratification. During autumn and winter, as the surface layers receive less solar radiation and storms increase in frequency and intensity, stratification breaks down and mixing again takes place. During periods of stratification, nutrients in the upper, warm layers of the ocean can become depleted, thereby limiting levels of phytoplankton production, but the breakdown of stratification allows nutrients in upper levels of the ocean to once again become replenished. Warming of the seas as a result of climate change may result in warm surface layers of the ocean becoming thicker and more greatly stratified, thereby reducing or preventing the upwelling of nutrient rich, colder waters from below. Such a reduction in the amount of nutrients in surface layers would be expected to result in a related reduction in primary production, which will have consequences throughout the whole of the marine food web[24].

Changes in temperature and oceanic conditions may also affect the species composition of phytoplankton, and this in turn will potentially impact the ecology of species elsewhere in the food web (see case studies 1 and 2).

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Case study 1 Climate change in the Antarctic and the consequences for cetaceans

The Antarctic marine region, encompassing the Southern Ocean which is designated a whale sanctuary, represents an extremely important habitat for a range of cetaceans, including baleen whales (such as the blue, sei, fin, southern right, minke and humpback whales) and toothed whales including sperm whales, killer whales, long-finned pilot whales and several species of beaked whale and dolphin[25]. Whilst a number of cetacean species may live all the year round in the Southern Ocean, many others – including most baleen species – migrate considerable distances to feed in the area.

It is anticipated that as a result of climate change, the temperature increase in Antarctica will be greater than any other region, with the possible exception of the Arctic[26]. It is predicted that such warming will influence natural processes within the Antarctic and the Southern Oceans, resulting in significant impacts upon marine ecosystems there. Some of the first impacts resulting from climate change are already apparent.

Records from paleoclimatic research, coupled with modern observation techniques, show that the Western Antarctic Peninsula has experienced warming of 4-5°C over the last half century, with 20 of the last 27 years registering warmer than average temperatures[27]. Recently, substantial melting and collapses in the Larsen A and B and Wilkins ice shelves have been observed. During the past 20 years, the total number of days when the temperature was above melting point within the region has increased by up to 6%[28].

Reductions in the extent and duration of sea ice within the Antarctic/Southern Ocean region would result in considerable impacts in marine production and food availability throughout the food web – including the availability of food for baleen whales. Analysis of historical records of the southern limit of whaling (which is constrained by sea ice) suggests a decline of 25% in sea ice cover between the 1950s and the mid 1970s[29].

Biologically, this sea ice forms a highly productive environment, with phytoplankton growing in high densities between the ice and seawater beneath. This plankton is grazed upon by substantial communities of small crustaceans, including krill[30]. The subsequent abundance of krill in the Southern Ocean during summer months is both directly and indirectly related to the extent and duration of sea ice the preceding winter[31 32]. For those baleen whales feeding in the Southern Ocean, krill forms a key constituent of their diet[33], and a number of species, such as the blue whale, are almost entirely dependent upon it as a food source[34]. A reduction in krill – resulting from loss of sea ice as consequence of climate change – will therefore affect feeding for these whales. Indeed, scientific records made during the 20th century indicate that when levels of krill were suppressed as a result of sea ice reduction due to natural climate cycles, foraging behaviour of blue whales was altered, and the condition of fin-whales was poor, with some individuals being exceptionally thin[35]. The 1996 IWC Workshop on Climate Change and Cetaceans noted, however, that there have been no studies examining the foraging ecology of baleen whales in the Southern Ocean, or the characteristics of patches of krill that they exploit, and little is known about the feeding competition, if any, between different species of baleen whale there[36]. In line with the recommendations made at this workshop, collaborative research has been initiated[37], but the results are unlikely to be available for some time. This means an accurate assessment of the exact nature and severity of impacts of prey depletion, resulting from climate change, on baleen whales in the Southern Ocean cannot be made at present.

In addition to the melting of ice in the Antarctic, climatologists have forecast that anthropogenic climate change will ultimately result in the reduction in, or cessation of, the formation of Antarctic bottom water – a deep flowing current resulting from thermohaline processes in the Southern Ocean[38]. This is likely to cause a general disruption to the circulation in the Southern Ocean, and may also have global consequences[39]. Although changes in the flow of Antarctic bottom water are not expected to occur for some years[40], it should be noted that changes in the earth's climate may be sudden as opposed to gradual, and the thresholds of climate change necessary to trigger sudden alterations in thermohaline circulation are unknown[41].

Alterations in ocean circulation are predicted to result in considerable impact upon the prey of toothed whales (odontocete) within the Antarctic region. Cephalopod species, such as squid, form a major part of the diet of a number of these whale species[42]. Scientists have concluded that given the relationship between the life cycles of squid and oceanographic processes within the region, any effects of climate change – such as changes in thermohaline circulation – may have dramatic effects on squid populations[43]. An IWC workshop on climate change has noted that – as is the case with baleen whales – little is known about the feeding ecology of toothed whales within the Antarctic region, or the ecology of their prey[44]. This effectively makes accurate prediction of the severity of the consequences for populations of the prey of toothed whales impossible at present.

Case study 2 Climate change in the Arctic and the consequences for cetaceans

As is the case with the Antarctic, the Arctic represents a highly important environment for a number of cetacean species. Four species of cetacean spend a considerable part of their lives in the Arctic region[45]: the bowhead whale, the narwhal, the white whale or beluga and the gray whale.

For all of these species, the sea ice of the Arctic provides an important habitat[46]. As is the case with sea ice in Antarctica, the boundary between ice and the underlying seawater forms an ideal site for the growth of phytoplankton. These phytoplankton communities form the basis of a food web, supporting crustacean 'grazers' which themselves are eaten by predators such as the arctic cod[47].

Belugas and narwhals undertake long distance migrations to feed on aggregations of Arctic cod which form in the areas under and adjacent to sea ice during the summer[48] Ice-associated algae that isn't grazed will eventually fall to the seabed, providing a the primary food source for benthic (seabed–dwelling) organisms, which in turn provide the main food source for gray whales[49]. Bowhead whales feed directly on the crustacean zooplankton – such as copepods – that graze on the ice-associated phytoplankton.

The importance of sea ice to the ecology of the cetacean species identified above is obvious. However there is now extremely strong scientific evidence that climate change is resulting in a significant decline in sea ice in the Arctic. Research has shown that the area of the Arctic covered by sea ice during summer months has fallen by 3% per decade during recent decades, and the rate of decline during the late 1970s-1998 is believed to have increased to 7% per decade[50]. Furthermore, not only is the area covered by ice in decline, but the thickness of ice is reducing also. Investigative work carried out by the US military, using sonar observations by submarines travelling under Arctic ice, has revealed that since the late 1950s it has been thinning by an average of 15% per decade[51]. Overall the Arctic has lost 40% of its ice volume in three decades. If thinning continues at such a rate it will only be a matter of a few more decades before the ice is gone[52]. The cause of this ice loss has been firmly established as being anthropogenic climate change, with scientists assessing the chances of it being due to natural climate processes as 'less than 0.1%[53].

Such losses in Arctic ice will obviously impact severely upon the ecosystems that are dependent upon it, including the cetaceans identified above. But the loss of feeding grounds will not be the only threat:

- Melting of sea ice would ultimately allow the opening of the Northwest Passage and the Russian Northern Sea Route for long periods during the summer. This would result in considerable increases in shipping and fishing activity in the region, all of which may result in disturbances of cetacean species[54]
- Seasonal changes in ice extent and human activity in the Arctic may lead to a redistribution of arctic whales and other marine mammals, and this may have implications for stock and genetic characteristics. For example the permanent pack ice of the central Canadian Arctic helps to separate the western and eastern populations of belugas. Such separate population structure amongst belugas helps to maintain maximum genetic diversity across the Arctic, and this may break down with the melting of the sea ice[55].

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Decline in the prey of the gray whales could have significant effects on the species

Mortality and low recruitment in gray whales in 1999

A significant increase in levels of mortality in gray whales migrating along the eastern Pacific seaboard, from their breeding grounds in Mexico to feeding areas off Alaska, was observed during 1999[56]. Mortality was twice as high as in any previous year dating back over the last 14 years[57], and involved a high number of adults and immature whales, as opposed to the more usual calves and yearlings[58]. Many of the dead whales were emaciated. Scientists believe that the 1999 strandings, and even higher stranding rates observed in Mexican breeding lagoons during 2000, are consistent with the whales being undernourished. It is believed that the most likely cause of this is a reduction in availability in the whales' principal prey – benthic (bottom living) amphipod crustaceans – in the Bering and Chukchi Seas, and this is likely to result in part from increased sea temperatures[59], a phenomenon concurrent with anthropogenic climate change. It is believed that declines in the whales' prey could have significant long term effects on the stability and growth of gray whale populations[60].

Conclusion

Research indicates that human-induced climate change is producing pronounced alterations in oceanic processes and impacting marine ecosystems. Such changes and impacts are expected to continue in the future, possibly at amplified levels and rates. Changes in oceanic systems and processes present a considerable threat to a number of cetacean species, altering their physical distribution, components of the food webs to which they belong and disrupting the ecosystems of which they form a part. While climate change might have a significant effect on virtually any population of cetaceans[61], a number of populations are considered to be especially vulnerable because of existing severe problems or other factors that might increase their susceptibility[62].

In its 1996 workshop on the impacts of climate change upon cetaceans, the IWC identified those populations it considered to be particularly vulnerable to climate change using the following criteria:

- Size of population
- Life history characteristics – reliance on a single prey source, slow rate of breeding and maturation, longevity etc.
- Restricted range

Those populations identified by the workshop include:

- All Northern right whale populations
- Eastern Arctic bowheads
- Western gray whales
- Okhotsh Sea bowheads
- Many true blue whale *(Balaenoptera musculus)* populations
- White whales (belugas)
- Narwhals
- Vaquita

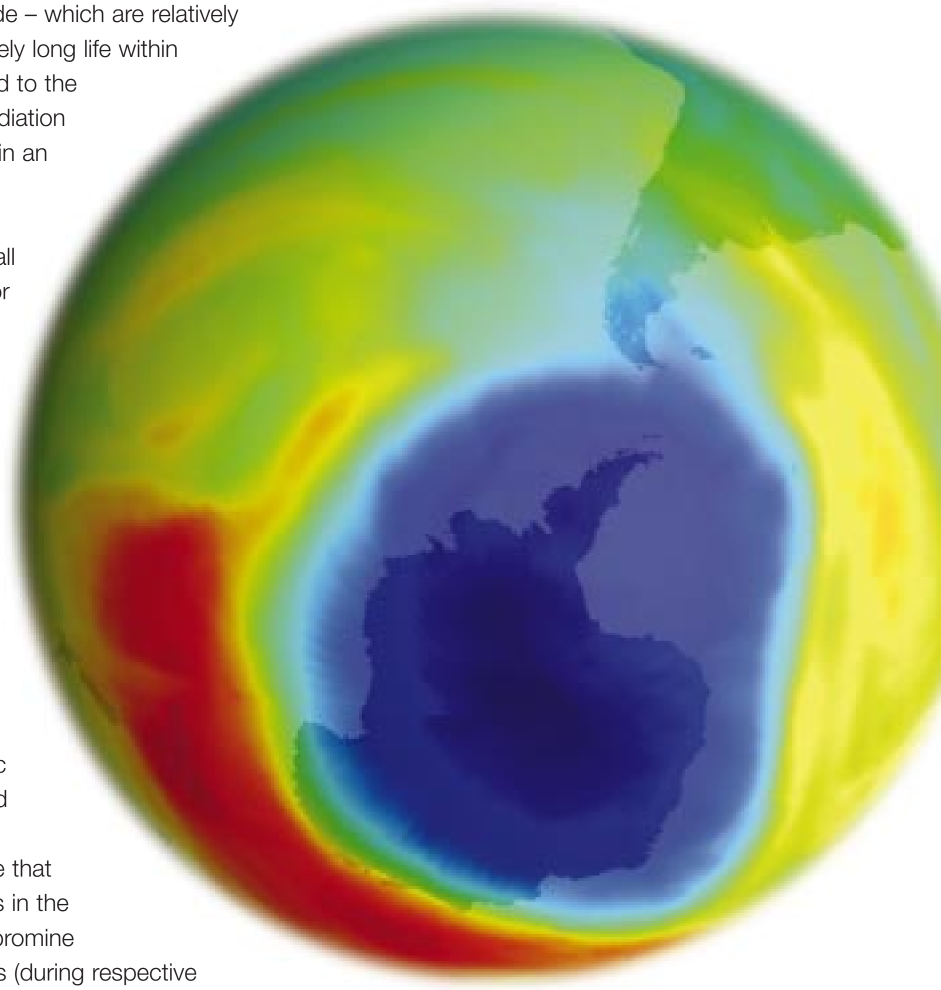
The workshop also noted that '…at present it is not possible to model in a predictive manner the effects of climate change on cetacean populations. Despite this the Workshop believed that the available evidence is sufficient to warrant some general concern for cetaceans…' and 'if prediction of the effects of climate change on cetaceans is a long-term goal, then a considerable amount of fundamental research is needed.' [63]

There can be little doubt that cetaceans, being relatively long-lived and slow-reproducing mammals, are highly susceptible to the rapid and extensive environmental changes resulting from climate change. For example, recent scientific work has indicated that bowhead whales living in the Arctic Ocean may live as long as 200 years, and potentially are the ultimate 'k-strategists' – a term used by ecologists to denote species that are slow growing and produce few offspring over a relatively long time period. If, as data suggests, ecological impacts of climate change may be very rapid, it is highly unlikely that cetaceans such as the bowhead will be able to adapt quickly enough to cope. Though our knowledge of the long-term impacts is far from complete, the information that is available suggests many cetaceans are at great risk.

WHALES AND OZONE DEPLETION

The earth's ozone layer serves a vital function in protecting life on the planet from the harmful impacts of solar ultraviolet radiation. However, through the production of a range of chemicals, human activity has resulted in a severe depletion in the thickness, and hence UV filtering ability, of this vital protective shield[64].

Located in the stratosphere, some 15-30km above the earth's surface, the ozone layer is a chemically dynamic atmospheric zone. Under normal conditions, at any given time ozone molecules are continually being formed and destroyed in the stratosphere, though the total amount of ozone present, measured in Dobson units (DU), remains relatively constant[65]. However for some 50 years humans have been producing a range of halogenated chemicals – including chloroflurocarbons (CFCs), methyl chloroform, methyl bromide and carbon tetrachloride – which are relatively chemically stable, and therefore have a comparatively long life within the atmosphere. This allows them to be transported to the stratosphere, where their exposure to strong UV radiation results in chemical breakdown, releasing halogens in an atomic form[66]. Such halogen atoms act to destroy stratospheric ozone much more quickly than it can naturally be regenerated. Even the presence of small amounts of halogens can have a serious impact, for example a single chlorine atom can destroy over 10,000 ozone molecules[67].



In polar regions, atmospheric conditions during certain times of the year are such that severe ozone depletion occurs, resulting in the formation of ozone 'holes' in late winter and early spring. The formation of these holes results from complex interactions, but a simplified summary of the process is given below:

- The polar winter leads to the formation of the polar vortex that isolates the air within it
- Cold temperatures form inside the vortex; cold enough for the formation of polar stratospheric clouds (PSCs). As the vortex air is isolated, the cold temperatures and the PSCs persist
- Once the PSCs form, reactions take place that convert the inactive chlorine and bromine reservoirs in the stratosphere to more active forms of chlorine and bromine
- No ozone loss occurs until sunlight returns (during respective hemispherical springs) to the air inside the polar vortex and allows the production of active chlorine and bromine, which initiates the catalytic ozone destruction cycles. Ozone loss is rapid[68]

Since the discovery of the Antarctic ozone hole in the early 1980s, and the subsequent detection of a hole over the Arctic, annual monitoring of their extent and severity has been undertaken. This research reveals that the 2000 Antarctic ozone hole was the largest ever recorded, covering an area of some 28.4 million km^2, with levels of ozone dropping to 60% below normal during the period of peak depletion in October[69]. A significant hole also appeared in the region of the Arctic. Measurements taken during winter and spring 2000 reveal that ozone levels there decreased by some 60% at the 18km level of the stratosphere[70].

By the end of the 21st century we can expect an average increase in temperature of between 1.5 and 6.0°C

Atmospheric ozone depletion – future trends

International efforts to prevent and reverse the depletion of the ozone layer have resulted in the formulation of the Montreal Protocol on Substances that Deplete the Ozone Layer. This protocol sets a mandatory timetable for the phase-out of ozone-depleting substances, and, since the protocol's inception in 1987, this timetable has been revised a number of times[71]. It was originally assumed that if all signatories to the protocol adhered to the timetable, upper-atmosphere ozone depletion would stabilise by 2000 and ozone levels would have returned to pre-depletion levels by the middle of the 21st century. However research has indicated that levels of certain ozone-depleting substances are continuing to increase in the atmosphere[72].

Of particular concern is the continued release of certain bromine-containing halon fire-extinguishing chemicals[73]. This is because bromine is 50 times more efficient at depleting ozone in the atmosphere than chlorine[74]. As a result of the continued release of these halons, the total amount of equivalent chlorine (chlorine + bromine) in the stratosphere will not stabilise but will increase[75], thereby hindering any recovery in stratospheric ozone to pre-depletion levels[76].

In addition to the continued release of ozone-depleting substances (ODS) hindering any recovery of stratospheric ozone, scientists now fear that increasing levels of greenhouse gases may also indirectly delay ozone recovery. While these gases warm the earth's surface, they conversely cool the stratosphere[77]. This cooling creates prime conditions for the formation of polar stratospheric clouds[78], and, as is indicated above, these clouds act as sites for the conversion of halogen molecules to the highly ozone-destructive atomic forms. Cooling in the stratosphere results in stratospheric clouds forming sooner and persisting longer, and this phenomenon may delay recovery of the ozone layer by decades[79].

The impact of ozone depletion upon marine ecosystems

In 1998 the United Nations Environment Programme produced an assessment of the environmental effects of ozone depletion. Included within it was a comprehensive review of available data and research relating to aquatic eco-systems. It acknowledged that the primary effects of ozone depletion relate to increased levels of UV radiation penetrating the water column, and consequently impacting on marine organisms and eco-systems[80]. The report highlighted that:

- The drastic stratospheric ozone depletion over the poles, as well as moderate decreases in total ozone over high- and mid-latitude waters has increased the amount of solar UV-B radiation penetrating the euphotic zone (the area of the water column where phytoplankton productivity takes place)
- There is evidence that ozone depletion alters the ratio of various types of UV radiation and photosynthetically active radiation (PAR) and this may impair photosynthesis and other light-dependent responses within marine organisms
- Significant changes in solar UV radiation in aquatic ecosystems may result in decreased biomass productivity
- Even small increases in UV-B solar radiation could result in significant changes in the size of consumer communities (i.e. grazing zooplankton)
- The eggs and larvae of many fish species are sensitive to UV-B, and increased exposure may contribute to declines in fish populations[81]. For example recent research has suggested that increased UV exposure in certain areas may be contributing to increased rates of mortality in cod larvae[82]

Given the impacts that increased exposure to UV has been demonstrated to have on species that form the basis of marine food webs, it has been suggested that this may affect ecology and ecosystem structure, especially in regions of substantial ozone depletion, where UV exposure is greatest – i.e. polar regions. Though it is often difficult to separate the effects of increased UV exposure from other natural and anthropogenic variables, research indicates that:

In Antarctic marine ecosystems

- Ozone depletion can inhibit primary production, and where UV exposure is particularly high, daily water column photosynthesis may be reduced by as much as 8.5%[83]
- Within phytoplankton, inter-species differences in tolerance to increased UV exposure, could result in changes in regional patterns of species and this may in turn affect the species composition of grazers (zooplankton), thereby altering the structure of the Antarctic marine ecosystem[84]

In Arctic marine ecosystems, a similar situation of increasing UV stress will be observed to that in the Antarctic[85]. However, the Arctic differs physically and ecologically from its antipode, and specific impacts that may occur include:

- In the Bering Sea, the sea-edge communities contribute approximately 50% of the productivity of the area. As a result of the shallow water and prominent stratification, phytoplankton may experience relatively high levels of UV-B exposure, which may impact levels of productivity[86]
- Many of the eggs and larvae of fish and crustacean species are found at or near the sea surface, and they will experience increased levels of UV-B exposure as consequence. This could affect survivability of these species[87], and thereby influence productivity and ecosystem structure[88]

The impact of ozone depletion upon whales

The impact of ozone depletion – leading to increased levels of UV radiation – is likely to have both an indirect and direct effect upon cetaceans. Such impacts could prove significant, as many areas important to cetaceans, such as the Southern Ocean, are coincidentally those areas experiencing greatest levels of seasonal ozone depletion.

For example, the Southern Ocean is known to be an important habitat for cetaceans including blue, fin, sei,

Many toxic pollutants are carried far from their original source and may accumulate in whales' body tissues

humpback and minke whales[89], as it is an area where these species are known to feed extensively. As detailed above, increased levels of UV radiation resulting from drastic ozone depletion in the atmosphere above the Southern Ocean could affect levels of production, and species composition within the food web there[90]. Any process that alters the distribution, supply, density or condition of krill – an important prey species for most stocks of large cetaceans – would be expected to alter foraging efficiency in these cetaceans[91]. Species that are stenophagous (i.e. reliant upon a single prey species) on krill – such as the blue whale – are likely to be most highly impacted[92], and in the case of the blue whale this will be compounded by the fact that populations have not recovered from the impacts of human exploitation. It should be noted however that assessment of the actual or expected impact of ozone depletion upon marine ecosystems is far from comprehensive, and the exact degree or nature of the damage ozone depletion is having upon such ecosystems, of which cetaceans form an integral part, is uncertain[93 94].

The direct effects upon cetaceans of significantly increased exposure to UV appear to be little studied[95]. This is despite the fact that, for example, many species of cetaceans arrive in the Southern Ocean during the austral spring, when penetration of UV-B to the ocean's surface is known to be greatest[96]. Exposure of cells to UV-B has been demonstrated to result in damage to DNA. Those cetaceans that spend the greatest time at the sea surface or upper layers are likely to be most at risk from direct exposure to UV-B[97]. It has been suggested that the surface-feeding behaviour of the southern right whale means that this species is particularly at risk, and there have been a number of reports of increased incidence of pox-like marks on the backs of these whales, though the cause of these has yet to be identified[98].

Conclusion

It is clear that ozone depletion currently presents a considerable threat to cetacean species, and recent research suggests that this will persist for a considerably greater period than originally believed. However, it would also appear that as a result of our limited understanding of the ecosystem effects of ozone depletion and scant knowledge of the direct impacts of increased UV radiation upon cetacean species, it is currently impossible to quantify the severity of this threat.

WHALES AND POLLUTION

Since the beginning of industrialisation, humans have been responsible for releasing billions of tonnes of chemicals into the environment. The introduction of chemicals that do not occur naturally and the unnatural elevation of those that do, results in contamination on a large scale.

Today the range and volume of chemicals that are produced is immense. In 1995 annual worldwide chemical production stood at 400 million tonnes[99]. In Europe alone – the largest chemicals-producing region in the world[100] – in excess of 100,000 chemicals have been registered in the European Inventory of Existing Commercial Chemical Substances (EINECS), though the exact number on the market remains unknown[101]. Disturbingly, despite being subjected to a limited degree of toxicity testing, as identified by the European Environment Agency, there remains '…a serious lack of monitoring and information on these chemicals; their concentration in air, water, sediments, soils, species and food; and related exposures and effects upon people and ecosystems'[102].

While the precise effects of this plethora of chemicals on the environment is still not fully researched and understood, it has been established that:

- Many of these chemicals are persistent, and accumulate or magnify in the food chain
- Such persistent substances are carried far beyond the point of origin, and are found in regions with little or no chemical production or usage, such as the Arctic and deep ocean environments[103 104]
- A range of chemical contaminants present a significant threat to whales[105 106]

In their recent review of stress in marine mammals, Fair & Becker[107] note that 'Chemical contaminants present a major threat [to marine mammals], and are the most insidious. Many of these contaminants are persistent and bio-accumulate, concentrating in marine mammals' brain, vital organs and body fat'.

Of prime concern amongst such contaminants are the following groups of chemicals: persistent organic pollutants (POPs) – which include substances such as the pesticide

DDT, poly-chlorinated bi-phenols (PCBs) and polycyclic aromatic hydrocarbons (PAHs); certain heavy metals, and endocrine- disrupting chemicals (EDCs).

Because POPs have a tendency to be lipophilic (fat loving), they are readily concentrated in fatty tissue such as blubber. They are also frequently magnified and transferred through the food chain. Consequently high body burdens of POPs have been recorded in cetaceans near the top of the food chain, such as dolphins and other toothed whales[108 109]. In addition a significant loading of POPs has also been recorded in certain baleen whale species, which feed at lower levels of the chain. Research has indicated that even young whales are susceptible to the effects of POPs, because they are passed from mothers to calves in milk during suckling. Consequently, burdens of POPs in young whales can be extremely high indeed[110].

The impacts of such accumulating and persistent chemical pollutants upon cetaceans are of obvious concern. This is not least because, as noted by Fair and Becker, many studies that have monitored the extent of contaminants in marine mammals have indicated that the levels are sufficiently high to warrant concern for the ecological health of such animals. While the sources of contaminants are known, definitive information about their full effects upon marine mammals is lacking[117]. Research is, however, now beginning to establish that elevated levels of contamination have demonstrable impacts upon cetaceans. Recent studies have indicated that increased levels of certain POPs may result in immunodeficiency, leading to increased vulnerability to disease[118] (see section below). In addition a number of chemicals also result in endocrine or hormone disruption.

Research in other species points to the possibility that a range of pollutants may assume the function of naturally occurring hormones within the body, thereby disrupting their natural functioning or significance[119 120]. The results of such endocrine disruption encompass[121]:

- Decreased embryonic viability
- Altered development of embryos
- Altered sexual maturation
- Altered endocrine function
- Altered immune function
- Altered growth and general health
- Altered reproductive behaviour
- Carcinogenesis (the initiation of cancer)

There is little published research identifying the impacts of endocrine-disrupting substances within cetaceans[122 123]. However, as noted by an IWC Scientific Committee workshop on chemical pollution and cetaceans, '…whenever endocrine disrupting chemicals have been sought within cetacean tissue they have been found'[124].

Certain scientific investigations may, however, have identified the initial signs of hormone disruption within cetaceans. For example, two out of 155 bowhead whales examined during a recent study, outwardly appeared to be female, but upon further investigation were shown to be males with underdeveloped sexual organs (a condition referred to as psuedohermaphroditism)[125]. For this to occur in two individuals out of such a small sample of 155 is an extremely high incidence of this condition, as for example, this condition in humans – resulting from a genetic defect – occurs on average in one in every 62,400 males[126]. Though it is possible that natural occurrence of this condition is much higher in bowhead whales, it could also result from the action of chemical contamination, though cause and effect have yet to be established. However, this phenomenon in such cetaceans is of considerable concern, given that this population of bowhead whales is endangered.

High pollutant loading has also been implicated in the population decline of the Southern Resident Population of orcas, of the Northeast Pacific coast of North America. These whales have been shown to be contaminated with levels of

Case study Whales and pollution

Blubber samples taken from 72 minke whales originating in the Northeast Atlantic were assessed for levels of organochlorine pollutants. Analysis revealed significant levels of POPs including PCBs, and the pesticides DDT and chlordane, amongst other organo-chlorine compounds[111]. The researchers noted that organochlorine contamination is exclusively related to dietary habits and, in the case of minkes in the Northeast Atlantic, such contamination may be related to the fact that the population is more of an opportunistic feeder than minke populations elsewhere[112], with a higher proportion of fish in the diet.

Concern about levels of chemical contamination has recently been voiced in Japan, where whale products continue to be consumed despite the current moratorium on commercial whaling. A recent study – conducted jointly between scientists based in Japan, the US and the UK – of whale products available for public consumption in Japan, revealed that they were contaminated with significant levels of PCBs, dioxins and mercury[113]. DNA analysis to identify the species and origin of the whale products revealed that half of the total sample taken from minke whales and small cetaceans shown to be imported from the northern hemisphere were discovered to contain levels of PCBs higher than the legal limit in Japan[114].

The problem of contamination in whale meat and blubber presenting a risk to human health is by no means confined to Japan. In the Faeroe Islands, a fishery for pilot whales captures between 500 and 3000 animals annually[115]. Consumption of meat from these whales results in the Faeroe Islanders having a total daily intake of PCBs more than double that recommended by the US Food and Drugs Administration[116].

POPs – including DDT, PCBs and dioxins – much higher than those found to harm other marine species. It is believed that toxins – which are bio-accumulated up the food chain – may be affecting the Southern Resident's immune, reproduction and endocrine systems as well as the development of foetuses and calves. Scientific research has indicated that the effects of such pollution, in conjunction with other factors such as loss of food and disturbance, are resulting in a population decline far more severe than previously observed fluctuations. So serious is the decline that scientists from the Centre for Biological Diversity have predicted that the Southern Resident population of orcas faces a 99% chance of extinction within the next 300 years[127].

While there has been some international effort to phase out the production and use of harmful chemicals – such as POPs – hazardous substances that are detrimental to cetaceans continue to pollute the marine environment. For example significant levels of brominated flame retardant chemicals, including polybrominated biphenyls (PBBs) and polybrominated diphenyl ethers (PBDEs), have been detected in a number of cetacean species, including sperm whales[128]. These chemicals are highly lipophilic, therefore bio-accumulate easily, and are very persistent – even more so than PCBs[129]. Researchers have concluded that these factors, together with the fact that – unlike PCBs – PBBs and PBDEs continue to be produced, imply that an environmental problem is imminent.[130]

Conclusion

As a result of the biology, ecology and feeding strategies of cetaceans, they are seen to be particularly susceptible to the accumulation of certain persistent pollutants. The fact that they are polluted (both through exposure and feeding) is beyond dispute, however the extent of the damage specifically caused to cetaceans is still to be fully assessed. It is disturbing to note that available information suggests pollutants commonly found at elevated levels in cetaceans may induce immune suppression and interfere with hormone function. Furthermore, as has been noted by the IWC Scientific Committee itself[131], there is precious little – if any – information on the synergistic impacts of pollutants upon cetaceans at a population or individual level. A considerable amount of further work is therefore needed to ascertain how current and future pollutants impact on individual cetaceans and their population levels.

WHALES AND NOISE POLLUTION

The increasing human exploitation of the earth's coastal, sea and ocean environments, has resulted in a corresponding rise in the levels of noise within them. Industrialisation has brought mechanisation on a huge scale, both for transport and exploration of the oceans, so much so that research suggests human-derived noise may have increased ambient noise levels in the world's oceans by 10 decibels between the 1950s and mid 1970s, alone[132].

Sound is vital for cetaceans to function effectively and can be compared to the importance of sight to many terrestrial mammals. Whales have acute hearing and use sound for prey location, navigation and communication – often over considerable distances in the case of baleen whale species[133]. The highly developed hearing of cetaceans, their heavy dependence upon it and their high levels of social interaction therefore make them particularly vulnerable to noise pollution and disturbance[134]. Increasing levels of noise stem from human activities including:

- Shipping
- Seismic survey (used in oil and gas exploration)
- Drilling and marine construction
- Active sonar devices

These can therefore be assumed to affect the ability of marine mammals to communicate and operate effectively in their environment[135].

Both the frequencies and thresholds at which cetaceans perceive noise vary between species. For example, the auditory sensitivities of dolphins and smaller toothed whales are greatest at high frequencies (i.e. between 10 and 150khz), whereas baleen whales are assumed to be sensitive to lower frequencies, possibly in the range of 10-100hz[136]. Though experimental difficulties result in a lack of data regarding thresholds of hearing in baleen whales, research has revealed that toothed whales' threshold of

hearing may be as low as 35dB for high frequency of sound – a level several orders of magnitude lower than that produced by a range of anthropogenic marine activities[137].

The degree and type of disturbance inflicted upon whales by human-generated noise depends on a number of factors: the level and frequency of noise; its duration; and the proximity of animals to it. Noise may mask or interfere with the sounds produced and used by cetacean species, thereby altering their natural behaviour[138]. Higher-level noise may frighten or distract whales, resulting in enforced avoidance behaviour or physiological disturbance (changing in breathing rate for example)[139]. In avoiding a sound source cetaceans may be forced out of important reproduction and feeding grounds. At still higher levels anthropogenic noise may cause temporary or permanent hearing impairment, posing a serious threat to the chances of survival[140,141]. A summary of the types of cetacean disturbance resulting from unnatural noise is given in the table[142].

1. Disruption of the normal range of behaviour, including:

- Feeding
- Breeding
- Rearing
- Migration
- Resting
- Communication between individuals

2. Physical displacement (either short or long term) from:

- Feeding grounds
- Breeding grounds
- Rearing grounds
- Migrating grounds
- Resting grounds
- Other individuals within a social group

3. Interruption of communication through human sounds masking those made by whales, affecting social activity and subsequently behaviour such as:

- Feeding
- Breeding
- Rearing
- Migrating
- Resting
- Social interaction

4. Physiological impacts including:

- Stress
- Shifts in hearing thresholds

Low-frequency active sonar

Of the many examples of human-generated noise pollution in the marine environment, a particularly worrying example is low-frequency active sonar (LFAS). Developed by the US navy since the 1980s to scan the world's oceans for submarines[143,144], LFAS is having a considerable impact upon a range of whale species. The sonar operates at an extremely high noise level – 240 decibels[145]. This is well above the threshold that researchers believe causes disturbances to whales[146].

Having used the LFAS system for several years – without completing an environmental impact statement – the US navy agreed to assess the effects of the system on four species of whales (blue, fin, humpback and gray) during 1997/98. Tests were carried out off the coast of California and Hawaii[147]. Though they only operated LFAS at 150 decibels – well below normal operating levels – behavioural changes in cetaceans were still observed, including:

- Decreases in the number of blue and fin whale calls
- Avoidance behaviour by gray whales, resulting in diversion from usual migration paths
- Temporary cessation of singing in humpback whales[148]

Though testing only focused on four whale species, other species of cetacean where also believed to be affected during the testing period. In Hawaii, immediately after the test period, a 2-3 month old spinner dolphin calf was seen without its mother or pod, and a single melon-headed whale calf was found alone and dehydrated – suggesting it had been without its mother for some time[149,150]. Furthermore, during testing a young humpback calf was seen without its mother, and displaying unusual behaviour for a period of several hours[151]. Abandonment of cetacean calves by their mothers is believed to be extremely rare[152], and the fact that three such events occurred during or immediately after the testing of the LFAS suggests there may be a link.

In addition to the impacts observed during the formal assessment of the LFAS, a number of other incidents have indicated that the system may seriously affect whales. In 1996, twelve Cuviers beaked whales were stranded and died along the coast of the Kyparissiakos Gulf, Greece[153]. When investigating scientists reported their findings in Nature, they concluded that a LFAS being operated by NATO in the area at the time caused the whales' deaths[154]. The most recently recorded incident involving LFAS occurred in March 2000, when around 16 whales, from four different species, beached in the Bahamas[155]. Autopsies on seven beaked whales that subsequently died revealed that they all had inner ear damage consistent with exposure to an extremely loud sound[156]. Following an investigation, the US navy and the National Oceanic and Atmospheric Administration (NOAA), admitted the deaths were almost certainly caused by the use of 'active' sonar by navy vessels travelling through the Bahamas at the time[157].

BRANDON D COLE/INNER SPACE VISIONS

The major predators of fish, and in marine eco-systems, are other fish – not whales

In addition, recently published research has indicated that male humpback whales may also modify their callings – believed to form part of the whales' sexual display – when exposed to LFAS[158]. Experiments involving the play back of LFAS transmissions at considerably less strength than usual operational levels resulted in male humpback whales' song lengthening by an average of 29%. The researchers concluded that the whales are singing longer to compensate for the acoustic interference.

Conclusion

A comprehensive body of research indicates that anthropogenic noise within the world's oceans and seas can have a considerable negative impact upon whale species. Disruption of communication, navigation, food finding, predator avoidance and care of the young are not only serious for the individuals concerned, but may also have consequences for the whole population[159]. As new technology allows human activities, such as oil and gas exploration and military actions, to expand ever further into previously relatively undisturbed marine areas – such as the Antarctic and the deep-sea/shelf edge areas of the Atlantic which are both important habitats for whales – it can be expected that noise-related impacts upon cetaceans will increase.

WHALES AND FISHERIES

Global fisheries are in a state of crisis. Many of the world's commercially exploited fish stocks are being plundered at or beyond maximum sustainable levels. Recent assessments by the United Nations Food and Agriculture Organisation (FAO) indicate a levelling off of landings during the 1990s at approximately 100m tonnes annually[160]. This trend is hardly surprising when it is considered that almost half of individual fish stocks are considered to be fully exploited with a further 22% being over-exploited[161]. Yet global demand for fish has not diminished. Alternatives to traditional catches are being sought, resulting in a shift away from those fish found toward the top of the food web (such as cod and tuna) to fish and even invertebrates occupying lower trophic levels[162].

Such extensive fisheries activity has altered and degraded marine ecosystems[163], and will continue to do so unless adequate management measures are introduced. Cetaceans of course form an integral part of these exploited marine ecosystems and have been impacted accordingly.

Incidental capture

There is considerable scientific evidence showing the substantial threat posed to cetaceans by their incidental capture by a range of fisheries. For example, the Eastern Tropical Pacific Ocean (ETP) purse seine fishery has been responsible for the deaths of many millions of spotted and spinner dolphins since the late 1950s[164]. Though levels of cetacean by-catch in this fishery have now been reduced dramatically to a few thousand animals a year[165] – a level that may still be viewed as unacceptable – numerous examples still exist of cetacean by-catch posing a considerable threat to populations. Of particular current concern is the harbour porpoise in the North Atlantic. A range of fisheries using gillnets off the coasts of the US, Canada and Ireland, and within the North Sea, have all been shown to incidentally capture a considerable number of harbour porpoise[166]. Recent research into the US coastal gillnet fishery identified that out of the total number of harbour porpoise carcasses studied, 60% of them showed signs of entanglement in fishing gear. Studies into the bottom-set gillnet fishery for hake in the Celtic Sea – off the coast of Ireland – indicate the by-catch of harbour porpoise there may be as high as 6% percent of the population per annum – a rate so high it threatens the population[167]. A similar danger is posed by the Danish North Sea gillnet fisheries, which account for annual harbour porpoise fatalities of between 4,600 and 7,000 individuals.

The problem of entanglement in fishing gear is not confined to small cetaceans. Large whale species are also known to become entangled and particularly at risk are the North Atlantic right whale and humpback whales in the Northwest Atlantic[168 169]. The extent to which the problem impacts other species of large cetaceans is not clear, but it is possible that small populations are being significantly depleted by entanglement in fishing gear[170].

Competition for food

By exploiting fish and invertebrate species, humans are effectively competing with whales for food. Though the extent of this competition is currently difficult to determine, it is likely that large whales in certain areas have been affected by over-harvesting of fish[171]. For example, it has been suggested that the virtual removal of the North American Grand Banks stock of herring, due to over-fishing in the 1960s, removed a major prey source for baleen whales in the area[172]. It has also been suggested that such exploitation substantially changed the eco-system dynamics, and therefore the feeding habits of baleen whales in the region[173].

Given that intense fisheries pressure now means that species occupying lower levels of the food web are being exploited[174], there is increasing concern that there will be renewed interest in the harvesting of Antarctic krill. This is presently regulated by the Convention on the Conservation of Antarctic Marine Living Resources (CCAMLR). CCAMLR uses modelling to estimate the biomass and variance of krill, and then sets precautionary catch limits within certain areas of the Southern Ocean[175]. However, as has been noted by Botsford et al.[176], the use of stock estimation to set catch limits for specific species has frequently been shown to be a far from reliable management tool, and certainly has been insufficient in preventing over-exploitation and stock collapse[177]. If levels of exploitation of Antarctic krill were to increase, in combination with such other factors as climate change and ozone depletion, it may not be possible to accurately predict krill stocks, leading to the risk of over-exploitation Given that krill forms a vital part of the diet of many cetaceans inhabiting Antarctic regions, including the blue whale which feeds almost exclusively on krill, any significant reduction in its abundance will have considerable consequences for the viability of individual species or even entire populations.

While available evidence suggests that cetaceans are significantly impacted by over-fishing, advocates of a resumption of commercial whaling have proposed a reverse hypothesis, suggesting that whales pose a threat to the fishing industry, through high levels of consumption of commercial fish species. A recent report, published by the Japanese Institute of Cetacean Research, has suggested that globally, cetaceans may consume 280m-500m tonnes annually, three to six times the amount taken by marine capture fisheries[178]. The hypothesis that whales are major competitors with commercial fisheries has been, and must continue to be, vigorously refuted, as scientific research indicates that:

- The major predators upon fish in marine ecosystems are other fish, not whales
- Both fish stocks and whale populations have been reduced, in some cases to the point of collapse and/or extinction as a result of poorly regulated and intensive commercial fishing and whaling operations
- There is currently no evidence to suggest that either baleen or sperm whales have a significant impact upon commercial fisheries. This is illustrated by the consumption by baleen and sperm whales of krill and of deep water cephalopods – prey species that do not make up a significant proportion of the total global catch[179]

Conclusion

There is well-documented evidence of significant levels of incidental fisheries by-catch amongst toothed cetaceans, at levels that may threaten populations. Populations of baleen whales may also be at risk but a lack of quantitative data currently means it is impossible to accurately assess this.

Over exploitation of fish stocks may reduce the availability of prey species to cetaceans, and this may be crucial, as many cetacean species have finely tuned energy budgets. Reduced food availability in combination with factors such as their highly migratory behaviour and seasonal feeding patterns may result in severe impacts. Modern fisheries and associated over-exploitation may also result in significant ecological changes – for example, increasing the abundance of species that compete with whales for particular prey items, thus reducing the level of prey available for whales alone. The fact that globally fisheries are persistently inadequately managed, and their consequences have not been adequately addressed, suggests that fishing presents a considerable threat to the status of cetaceans, a threat that is compounded by cetacean longevity, slow reproduction cycle and inability to adapt rapidly to change.

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WHALES AND DISEASE

Over recent years a number of mass fatalities of cetaceans have been attributed to disease[180]. For example, bottlenose dolphins in the Gulf of Mexico and mid-Atlantic region and striped dolphins in the Mediterranean where found to have died as a result of infection from the highly virulent morbilli-virus[181]. While such mass fatalities have affected smaller whale species, research suggests that the virus may also be present in larger whales. Pathological investigation of sperm whales stranded on the coast of the Netherlands and Belgium in the mid 1990's revealed that lesions in the animals' mouths and on the skin may have been viral in origin, possibly resulting from poxvirus and morbilli-viruses[182].

It is interesting to note that in the case of the striped dolphin mass fatality in the Mediterranean, pollution loading in the animals was identified as a potential contributory factor. Research has confirmed that those animals had considerably higher concentrations of organochlorine pollutants in comparison to healthy populations sampled prior and post the event[183]. It is suspected that high levels of such pollutants may have suppressed the animals' immune systems, making them more susceptible to infection from such pathogens as the morbilli-virus[184].

In addition to infectious pathogens, it has also been demonstrated that cetaceans are at risk from toxins produced by algal blooms[185]. For example, scientists believe that domoic acid, a neurotoxin produced by an algal bloom off the coast of California during the summer of 2000, has now entered the food chain and is potentially impacting humpback and blue whales[186]. It has been suggested that human-produced pollution may make the algal blooms that produce such toxins more frequent; however there is currently a lack of concrete data to confirm this[187].

Human activities conspire to threaten whales

As has been demonstrated time and time again within this report, whales are being consistently threatened by human activity, and in many cases the level of the threat is increasing. Taken in isolation the significant impacts on cetaceans resulting from climate change, ozone depletion, noise, fisheries and pollution are serious enough, but the reality is that whales are subjected to the composite effect of all of these threats. The scientific evidence presented here indicates that a large number of cetacean species may simultaneously:

- Be exposed to the impacts of climate change, which is resulting in major shifts in both the physical characteristics of the world's oceans and seas, impacting on the ecosystems of which cetaceans are a part, and the food webs on which they depend
- Encounter the degradation of polar environments – which are key to many whale species – as a result of increased levels of UV radiation, the consequence of continuing and possibly increasing depletion of the ozone layer
- Be bombarded by a range of human-derived sound sources, due to the continuing industrialisation and militarisation of seas and oceans, which may disorientate, deafen and potentially kill
- Suffer from the direct removal of prey and indirect ecological disturbance resulting from widespread unsustainable fishing
- Be consistently exposed to a plethora of chemicals that are either directly toxic, or suppress physiological processes, with consequences for their immune and/or hormonal functioning

While research has indicated how human activities may impact cetaceans, our knowledge is far from complete, and we appear to have no understanding of how such activities will affect cetaceans when synergistically exposed to them.

It should not be forgotten when considering the magnitude of these impacts, that many cetacean populations are already threatened as a result of human exploitation through whaling, some to the point of being critically endangered. For some whale species, even where exploitation has ceased, anthropogenic impacts have stifled any recovery. For example, the North Atlantic right whale is critically endangered throughout its range[188] as a result of commercial hunting that continued illegally despite a ban on taking the species since the 1930s[189]. The species seems to suffer from anthropogenic fatalities more than any other cetacean, with entanglement in fishing gear and ship strikes causing numerous deaths in recent years, and this has undoubtedly contributed to the lack of recovery of the species[190]. It is also feared that the species dependence on a specialised food source (copepods), would make it less adaptable to major environmental change[191], such as that already being witnessed as a result of climate change.

It is clear that human activity is and will continue to substantially impact cetacean populations, and we are not in a position to be able to quantify the immediate scale of such impacts, nor its future pattern. One thing that is certain however, as identified by Fair and Becker in their review of stress in marine mammals[192], the survival and recovery of many marine mammal species is still far from certain.

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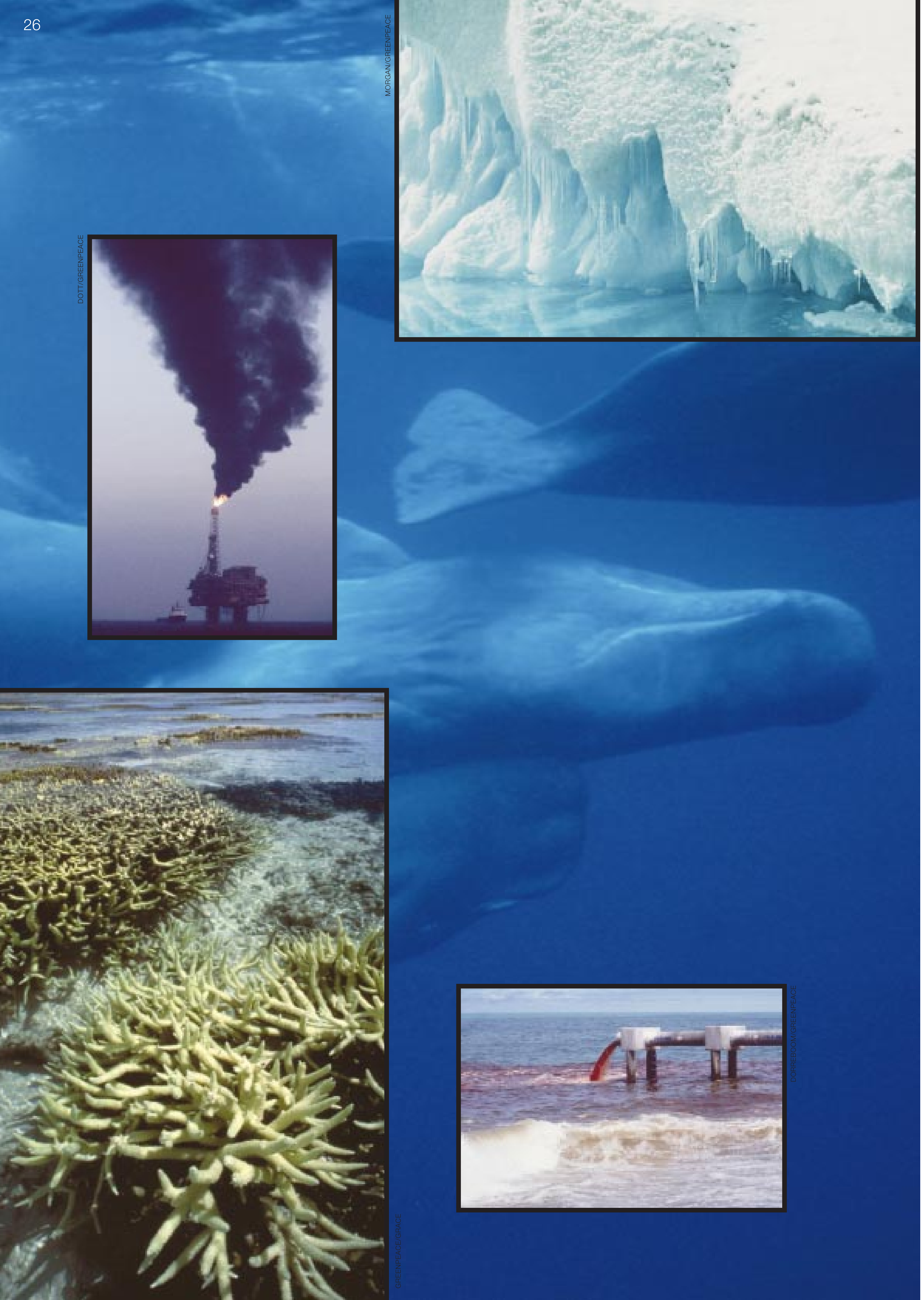

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This report, written for Greenpeace by Christopher Berry, of Berry Marine Consultants, highlights the threats to the world's whale populations whose ocean habitat is being constantly degraded through global warming, pollution and over-fishing.

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