Oceans of noise

A WDCS Science report

Editors: Mark Simmonds, Sarah Dolman
and Lindy Weilgart

WDCS
Whale and Dolphin Conservation Society

WDCS is the global voice for the protection of whales, dolphins and their environment.

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WDCS is the global voice for the protection of cetaceans (whales, dolphins and porpoises) and their environment.

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Contents

	Author biographies	4
	Preface	6
1.	**Introduction**	9
2.	**Physics of underwater sound**	11
2.1	What is sound?	11
2.1.1	Basic properties of acoustic waves	11
2.1.2	Measuring sound intensity	18
2.1.3	Comparison of sound intensities measured in air and water	19
2.2	Types of sound source	21
2.3	The propagation of underwater noise	21
3.	**Sources of marine noise**	24
3.1	Natural noise producers	24
3.2	Vessel traffic	25
3.3	Oil and gas exploration	26
3.3.1	Seismic surveys	26
3.3.2	Marine seismic surveys	27
3.3.3	The seismic source (airguns and airgun arrays)	28
3.4	Industrial noise associated with oil and gas exploration and production	28
3.4.1	Noise sources	28
3.4.1.1	Machinery noise	30
3.4.1.2	Propeller noise	30
3.4.1.3	Hydrodynamic noise	31
3.4.1.4	Impulsive noise	31
3.4.2	Rig and platform noise	31
3.5	Ocean experiments	37
3.5.1	Acoustic thermography	37
3.6	Marine science research	38
3.7	Military	38
3.8	Purposeful scaring of marine mammals	40
3.8.1	AHDs	40
3.8.2	ADDs	41
3.9	Dredging	42
3.10	Marine wind farms	42
3.11	Research	43
3.11.1	Controlled Exposure Experiments and ‘Playback’	43
4.	**The use of sound by cetaceans**	44
4.1	Echolocation	44
4.2	Navigation	44
4.3	Communication	45
4.3.1	Intrasexual selection	45
4.3.2	Intersexual selection	45
4.3.3	Mother/calf cohesion	46
4.3.4	Group cohesion	46
4.3.5	Individual recognition	46
4.3.6	Danger avoidance	47
4.4	Prey stunning	47
4.5	Acoustic sensitivities of cetaceans	47
4.6	Cetacean vocalisations	48
5.	**Noise as a problem for cetaceans**	53
5.1	Particular cetacean vulnerabilities	53
5.2	Short-term observations	53
5.2.1	Disturbance and displacement reaction	53
5.2.2	Masking of biologically important sounds	55
5.2.3	Social disruption	55
5.2.4	Depth of animal	55

5.3 Longer-term impacts 56
5.3.1 Sensitisation and habituation 56
5.3.2 Stress 56
5.3.3 Physiological damage to tissues and organs 56
5.3.4 Understanding of biological significance 57
5.4 Indirect impacts 58
5.5 Cumulative impacts 58
5.6 A New Concern: Is noise causing decompression sickness in cetaceans? 59
6. **Examples of regulation and national legal instruments protecting marine wildlife from noise pollution** 62
6.1 The Ligurian Sea Sanctuary 62
6.2 The Habitats and Species Directive (Council Directive 92/43/EEC of 21st May 1992) 62
6.3 ASCOBANS and ACCOBANS 64
6.4 The US Marine Mammal Protection Act (MMPA) 65
6.5 Discussion and conclusion 65
7. **Solutions – mitigation and management** 67
7.1 Consideration of voluntary vs. mandatory levels of protection 68
7.2 Solutions 68
7.2.1 Awareness / education 68
7.2.2 Research 68
7.2.2.1 Data gaps 68
7.2.3 Captive studies 69
7.2.4 Measurement of hearing abilities in wild cetaceans 69
7.2.5 Software models 70
7.3 Long-term impacts 70
7.4 Cumulative impacts 70
7.5 Communication 71
7.6 Methods of protection 72
7.6.1 Monitoring 74
7.6.1.1 Visual, acoustic and aerial observations 74
7.6.1.2 Use of equipment 74
7.6.2 Practical mitigation 76
7.6.2.1 Localised measures 76
7.6.2.2 Offshore operational measures 76
References 78

Annexes

1. **The Application of Marine Pollution Law to Ocean Noise** 94
1.1.1 Introduction 94
2. Global instruments on marine pollution 94
2.1 The United Nations Convention on the Law of the Sea 94
2.2 Other global instruments 98
2.3 Conclusion 101
3. Applying the Part X11 framework to sources of ocean noise 102
3.1 Pollution from seabed activities subject to national jurisdiction 102
3.2 Pollution from activities in the area 111
3.3 Pollution from vessels 115
4. Conclusion 123
Appendix A - Some international instruments of actual or potential relevance to protection of cetaceans from ocean noise (other than specifically in relation to pollution) 124
Appendix B - Treaties underlying regional seas initiatives 127
Appendix C - Selected provisions of regional seas treaties 129

2 **Guidelines for cetacean watching activities in the ACCOBAMS area** 133
3 **Documented examples of cetacean disturbance by boat traffic** 137

Author biographies

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Sarah first came to work at WDCS as a volunteer whilst still a student at the University of Bath. Later, armed with an Honours degree in Electrical and Communications Engineering, she joined the Society's staff full-time and started to work with the Science Department. This was seven years ago and she is now the WDCS Science Officer - specialising in marine noise pollution - and is based in Canberra, Australia. Her role includes contributing on many different issues, including the coordination of the WDCS Southern Ocean campaign. Sarah has co-authored a number of reports contributed to the International Whaling Commission on environmental threats to cetaceans. She has recently taken part in field work involving visual and passive acoustic studies including humpback whale research off the coast of Queensland, Australia, studies of orca populations in Johnstone Strait, British Columbia, Canada and of small cetaceans off Wales in the UK.

Daniel Owen

Daniel is a barrister at Fenners Chambers in Cambridge, UK. His practice covers all areas of environmental law, but with a particular specialisation in marine environmental law and marine fisheries law at the domestic, European Union, and international levels. His clients include environmental non-governmental organisations, public bodies, and businesses. Prior to joining the Bar, Daniel worked for three years as marine policy officer at the Royal Society for the Protection of Birds (RSPB) and for four years as a technical adviser on marine oil spill response at the International Tanker Owners Pollution Federation (ITOPF). In 1999, he worked for one month as a CCAMLR International Observer on board a toothfish longliner in the South Atlantic, and in 2000 he worked for five months in the legal unit of DG Fisheries at the European Commission in Brussels. Daniel's original degree is a BA in Zoology from the University of Oxford.

E.C.M. (Chris) Parsons

Chris Parsons has been the Director of the Research and Education Departments of the Hebridean Whale and Dolphin Trust (HWDT) since 1998. He is also a research associate at the University Marine Biological Station, Millport and an Honorary Research Fellow at Aberdeen University.

Chris has been involved in whale and dolphin research for over ten years and has conducted projects in South Africa, India and China, as well as the UK. Prior to working at HWDT he carried out research on Indo-Pacific humpback dolphins and finless porpoises in Hong Kong and China, studying the behaviour and ecology of Hong Kong's cetaceans, marine pollution, and its effects on marine life. In Scotland, Chris has been involved in research on the distribution and abundance of cetaceans in West Scotland, whale-watching and marine ecotourism, marine pollution and the conservation of marine mammals. He has been a member of the scientific committee of the International Whaling Commission since 1999. He was awarded a Fellowship by the Royal Geographical Society in 1997, won a Scottish Thistle Award in 2000 for his work in Environmental Tourism, and was acknowledged a young achiever in Scotland for his achievements in cetacean conservation by the Queen and the Duke of Edinburgh in 1999. In addition, Dr Parsons has published over 50 scientific papers, articles and reports.

Mark P. Simmonds

Mark is the Director of Science for the Whale and Dolphin Conservation Society. Before joining WDCS he was a university lecturer and he is currently a guest lecturer at the University College of Wales (Bangor) and a Visiting Research Fellow at the University of Greenwich. Mark specialises in investigating the threats posed to cetaceans by human-made changes in the habitats and has produced over 100 papers, articles and reports on related themes. He has been the chair of the UK Marine Animal Rescue Coalition since 1989 and also currently chairs the Whale Working Group of Wildlife and Countryside Link (the UK's forum for conservation and welfare organisations).

René Swift

René is a research assistant at the University of Aberdeen's Lighthouse Field Station, where he is studying the distribution, behaviour and acoustic environment of large whales in the Faroe Shetland Channel. Before joining the University of Aberdeen, René worked for the International Fund for Animal Welfare's Song of the Whale Research Team and the Hebridean Whale and Dolphin Trust. René has been involved in passive acoustic monitoring / mitigation of seismic surveys and his master's thesis looked at the impact of seismic surveys on sperm whale distribution and behaviour.

Lindy Weilgart

Lindy first became involved in undersea noise issues in 1993, when she raised concerns regarding the ATOC project. She has since written articles, attended workshops and conferences, reviewed several environmental impact statements and other documents, and given numerous lectures on this topic. She has been studying whale sounds since 1982. She received her M.Sc. (Memorial University of Newfoundland) studying pilot whale vocalisations and behaviour, and her Ph.D. (Dalhousie University) researching sperm whale acoustic communication. An NSERC post-doctoral fellowship (Cornell University) allowed her to study the dialects of sperm whales in the South Pacific. She is currently an assistant professor and honorary research associate at the Biology Department, Dalhousie University, Halifax, Nova Scotia.

Preface

Over the course of the last couple of decades, scientists and conservationists have become increasingly aware of threats to biodiversity that are diffuse and hard to assess but are, nonetheless, of great concern. Three examples are climate change, chemical pollution and marine noise pollution. Of the three, chemical pollution has received the greatest attention and response mechanisms are already enshrined in a host of national and international law. However, by contrast, noise pollution in the marine environment is still an emerging, but undoubtedly serious, concern. Its implications are less well understood than other global threats but like chemical pollution it is usually largely undetectable to everyone but the specialist. It is also difficult to comprehend, particularly for those that live above the sea surface and who do not readily appreciate the profound importance of sound to cetaceans in the oceans.

As this report shows, we are only now starting to focus on how to manage noise in the marine environment and how to mitigate its effects on wildlife. Arguably, we are around the same stage that we reached with chemical pollution some thirty years ago. There are many similarities, not the least of which is the lack of definitive evidence linking cause to effects, yet in the case of noise we are also dealing with a pollutant that can disperse over wide areas, with subtle and yet important consequences. There is another similarity in that it is possible to receive a lethal or chronically damaging dose of both chemical and noise pollution.

The history of aquatic chemical pollution control shows that it is possible to respond logically to threats where data are poor and inconclusive. Indeed, the precautionary principle – now widely used to address the full spectrum of environmental threats – was initially developed from concerns about chemical pollution. This same paradigm applies equally well to noise pollution.

Some years ago, WDCS became concerned that human activities in the seas were generating more and more loud noise but that this was not widely recognised as a threat. Our attention was primarily taken by the expansion of the oil and gas exploration out into the deep seas and, in particular, the accompanying expansion of seismic testing. This seismic testing uses high intensity sound to investigate the sub-sea rock strata and find fossil fuel deposits. It represented probably the loudest noises ever deliberately introduced into the marine environment by humankind, on par with the loudest natural noises, such as underwater earthquakes, but much more persistent in some areas. We later saw maps showing that seismic surveys had crossed and re-crossed survey regions of hundreds of miles in diameter until the tracks of the survey vessels merged into an indecipherable tangle, representing months of continual surveys and noise.

Our early interest in seismic testing led us swiftly to realise that there were other significant noise sources in the marine environment. For example, large vessels are loud vessels and the increase in vessel traffic has actually fundamentally changed the noise profile of the world's oceans. The seas are a far noisier place overall than they were a few decades ago and vessel traffic is still increasing. The significance of this from a biological perspective may be profound. For example, it has been suggested that the abilities of the great whales to communicate with each other across entire ocean basins has now been reduced by orders of magnitude.

In the same way that chemical pollution issues have involved powerful protagonists (principally the chemical industry), so seismic testing involves the powerful multi-national fossil-fuel producers. The latest development in the history of ocean noise has brought another mighty player into the ring. It seems that as submarines have become more stealthy, so those that need to detect them have been obliged, for reasons of national security, to use ever stronger sonars to track them. In many ways, this is an ironic development because cetaceans have used biological sonar for millenia. Now, however, military interests have followed suit. Indeed, this can probably be described as a current cutting edge of what is left of the cold war and is also likely affected by concerns relating to terrorism. Regrettably, marine nature conservation interests and those of national security are now coming head to head in a manner that has rarely happened before and arguably never on such a grand scale.

In the US, the deployment of Low Frequency Active Sonar (LFAS) by the military has become a prominent public issue. This is largely because US law requires that threats to marine mammals are recognised and publicly debated. Elsewhere (and we really only know about Europe at this point) there is no such transparency but similar powerful sonars are in development and their deployment in the near future is planned.

As reviewed in this report and despite the great problems involved in studying such matters, there is some early evidence that cetaceans can be directly harmed by powerful noises. At lower exposure levels, where physical damage is not caused, behavioural reactions may still have signifiant negative consequences for the animals.

WDCS, of course, is primarily concerned about cetaceans (whales, dolphins and porpoises) and we have more than adequate reason (as outlined in Chapter 5) to believe that these animals are especially vulnerable to noise pollution. In a nutshell, this is a group of animals that has evolved to use sound as a primary sense and which, if deprived of this sense, can be expected to perish.

We issued our first report on noise pollution in 1994. This report supersedes it and is a response to the urgency of the present situation in the marine environment. The science of marine noise pollution is a very complex one – and increasingly recognised as a specialist area of science. A further complication is that the numbers of specialists in this field remains small.

We are most grateful to the contributors to this report for their help, including the important and comprehensive review of existing legal regimes kindly contributed by Daniel Owen towards the end of this report (Annex 1).

Within this report you will find the following topics explained:

- the physics of underwater sound;
- sources of marine noise (including vessel traffic; oil and gas exploration, seismic surveys, ocean experiments; military sources, acoustic harassment devices, dredging, and marine wind farms);
- the use of sound by cetaceans;
- noise as a problem for cetaceans;
- a review of relevant international laws; and
- some thoughts on the mitigation and management and sound.

In the annexes you will also find a comprehensive list of recorded examples of disturbance of cetaceans by vessels (i.e. the best studied source of disturbance to these animals).

THE WDCS MARINE NOISE ACTION PLAN

Noting the scale of the potential threat to cetaceans and other marine wildlife posed by marine noise, WDCS believes that some urgent actions are required at this time. We make the following six recommendations that we hope others will now heed if we are going to both adequately understand and react appropriately to this threat:

1. That attention is given to the development of international law to regulate marine noise pollution – we call either for

- **an international treaty dedicated to this issue; or**
- **the development of comprehensive regulation through existing regimes;**

2. That an independent body should be established to initiate, promote, monitor and fund marine noise research;

3. That all major developments in the marine environment – to include those of an industrial or military nature - are

- **subject to full environmental assessment in terms of their input of noise pollution to the wider environment;**
- **that this process takes due regard of the precautionary principle; and**
- **that wherever it occurs, environmental assessment is subject to full public scrutiny;**

4. That these same major developments

- **make a public commitment to mitigate their effects relating to noise and**
- **employ effective mitigation measures and develop alternative technologies to address this issue;**

5. We urge the navies of the world seek to effectively mitigate their noise-producing activities, avoid the deployment of powerful sonars and ideally develop a treaty that means that powerful sonars are not required; and

6. That the boundaries and management regimes of Marine Protected Areas and Sanctuaries are developed to take noise pollution and its propagation beyond those declared boundaries into account, including the creation of buffer zones.

Mark Simmonds
Director of Science
Whale and Dolphin Conservation Society May 14 2003

Whilst every effort has been made to ensure the accuracy of this report, this is a complex topic where knowledge is rapidly developing. We welcome comment and correction to help improve the accuracy of future editions of this report. Comments can be sent to mark.simmonds@wdcs.org This report reflects the opinions of its authors and editors and, except where explicitly stated, as above in the Action Plan, not necessarily those of WDCS.

1. Introduction

Lindy Weilgart

The undersea noise issue has steadily increased in crescendo with a greater awareness of the potential effects on marine mammals of military sonars, seismic surveys, shipping and boat traffic, oceanographic experiments, as well as other noise sources. What has made the noise problem so intractable, though, is the inherent difficulty in studying marine mammals, particularly cetaceans, and the effects of sound on them. Free-ranging whales and dolphins, which are visible above water for only short periods of time, are notoriously challenging research subjects. The lack of precision in most cetacean research is best exemplified by population estimates, which can vary over orders of magnitude for the same cetacean population, i.e. we can't even accurately *count* most populations of cetaceans with any degree of confidence. To ascertain the effects of noise on marine mammals, however, we must be able to know which sounds they are capable of hearing (something still largely unknown for the great whales) and how they react to them, if at all. In our assessment of cetacean reactions, we are usually limited to detecting only the crudest, most obvious, short-term changes in behaviour. Practically impossible to discern are changes in population characteristics, such as birth and death rates, in response to changing noise levels. Such measures are the best indicators of the population's welfare and therefore would be vital to obtain before we can be more confident that, for example, a particular noise source is "harmless" to that population. Even then, however, we cannot be assured that noise levels are not indirectly affecting that population's prey or ecosystem in such a way as to have a lag effect on the population in question. Linking changes in population measures to changes in noise levels is also usually not straightforward, as many other factors (e.g. oceanographic, ecological, etc.) can affect a population's well-being. As many whale species are exceedingly slow reproducers, any changes in reproductive rates will be difficult to discern. Additionally, low reproductive rates make whale populations more vulnerable to disturbances as they will be slow to recover.

Past studies on the reactions of whales to noise have shown widely divergent responses depending on the individual, age, sex, and the activity in which the animals were engaged. Again, this presents problems in how to interpret reactions correctly. Are whales which enter a loud sound field in order to pursue a patch of prey putting themselves at risk of hearing damage or are they truly unaffected? (hearing damage can occur before the threshold of pain is reached). Do increasing numbers of animals at the surface mean that whales are attracted by a noise or are surfacing to seek out the lower sound levels at the surface? What about sounds that aren't particularly loud, but are nevertheless "grating" or "irritating" to our or whale's ears because of some indefinable quality?

All of these difficulties in ascertaining how whales react to noise mean that results are usually not clear-cut and are very much open to interpretation. This, in turn, becomes problematic when scientists funded directly by a noise polluter conclude that the reactions of whales to a noise source are "biologically insignificant". The scientists' credibility can suffer under accusations of actual or perceived bias. To avoid such conflicts-of-interest, efforts could be made to have funds directed to an independent, non-aligned body which would establish priorities for the research, commission it, and review the results to regulate the original, noise-producing project. In addition, because of the imprecision and uncertainty surrounding studies of the effects of noise on cetaceans, there is a great need to proceed in a precautionary manner regarding the deployment of noise sources. Particularly areas critical to marine mammal feeding or breeding should be kept as free from noise pollution as possible, even in the absence of conclusive scientific evidence of harm.

Although I have portrayed research results on the effects of noise on marine mammals as frequently ambiguous, there can be no doubt that certain noise sources are harmful, even fatal, to marine mammals. When I first became active in the undersea noise issue, I assumed that, given how dependent cetaceans are on sound, there would be deleterious effects from noise on cetaceans. After having spent years at sea with whales studying their sounds, I reasoned, "How could it be otherwise?" What I did not assume, though, was that these effects would be immediate and deadly. I often had to endure being called a "Chicken Little," even by my own colleagues, because they felt I was overplaying the potential harm of undersea noise. Sadly, even I was much too optimistic.

The best evidence for noise being fatal comes from the multiple species stranding in the Bahamas in 2000, where dissected animals showed hemorrhaging in their inner ears and brain as a result of an intense, acoustic event. The U.S. Navy later admitted that its own tactical, mid-range sonar was the most plausible cause of the injuries and stranding. No one had predicted such a severe, immediate reaction, especially as the sonar appears to have caused a population-level effect. The resident population of Cuvier's beaked whales was probably destroyed, or at least seriously displaced. While this stranding event is noteworthy as the first "smoking gun" of anatomical, physiological damage in whales caused simply by sound (as opposed to a nearby explosion), what is often forgotten are the much greater ramifications of noise affecting the health of *populations*. How noise could affect the health of ecosystems is given even shorter shrift. The above stranding also highlights the insidiousness of the noise threat. Had the whales not stranded but died at sea and sunk, unnoticed, or even had the whales stranded but had no fresh samples been obtained from them, this acoustic trauma would have gone largely undetected.

A publication such as this one is necessary to educate us on the issues, review the research to date, identify problem areas, and suggest future protocols and legal approaches for the prudent regulation of undersea noise. Only in this way, can we hope to curb the growing cacophony in our oceans and provide some respite for our beleaguered cetaceans.

2. The physics of underwater sound

René Swift

The evolution of acoustic communication and detection (echolocation) systems within marine mammals has been shaped by the properties of the medium (water) in which they live. In water, sound offers the best compromise between speed and resolution and transmission range, although light and electromagnetic waves propagate faster and have greater resolving power than sound, they have a limited range (10 of metres compared to kilometres). Sound propagates over a range of biologically significant distances depending on its frequency (from metres to thousands of kilometres), at higher speeds in water (~1500ms^{-1}) than in air (340ms^{-1}), and has frequency dependent resolving power (higher frequencies giving increased resolution but over a limited distance). So when *Archaeocetus* first returned to the sea, evolutionary forces were faced with little choice in order to maintain contact with conspecifics or to detect prey.

2.1. What is sound?

A propagating sound wave consists of alternating compressions and rarefactions of molecules within an elastic medium (liquid or gas or solid), which are detected by a receiver as changes in pressure. Structures in our ears, and also most man-made receptors, are sensitive to these changes in sound pressure.

Acoustic waves are classified as longitudinal waves because energy is propagated parallel to the source, see Box 1 Figure 2.1: Longitudinal and transverse waves.

2.1.1. Basic properties of acoustic waves:

Acoustic waves are characterised by their amplitude, frequency, wavelength, phase, speed and intensity, Box 1 Figure 2.1.

Amplitude (a)

The amplitude (**a**) of a sound wave is proportional to the maximum distance a vibrating particle is displaced from rest, i.e. the peak pressure reached in one cycle. Small variations in amplitude produce weak or quiet sounds, while large variations produce strong or loud sounds, Box 1 Figure 2.2.

Frequency (*f*)

The frequency (***f***) of a sound wave is the rate of oscillation or vibration of the wave particles, i.e. the rate that pressure cycles from high to low to high, Box 1 Figure 2.3. Frequency is measured in cycles/sec or Hertz (Hz). To the human ear, an increase in frequency is perceived as a higher pitched sound, while an increase in amplitude is perceived as a louder sound.

Wavelength (λ)

The wavelength (λ) of a wave is the distance between two successive compressions or the distance the wave travels in one cycle of vibration.

Phase

The phase of an acoustic wave can be best described as its alignment to other propagating waves with respect to time, see Box 1 Figure 2.4. Although **phase** is less directly related to perceived sound intensity it is important in describing how complex sounds can be constructed from simple sinusoidal waves, for example, waves with the same phase will **constructively interfere** to produce a wave

Box 1. Characteristics of sound / longitudinal waves

Figure 2.1. A schematic diagram of a sound wave depicting its amplitude (pressure) and wavelength.

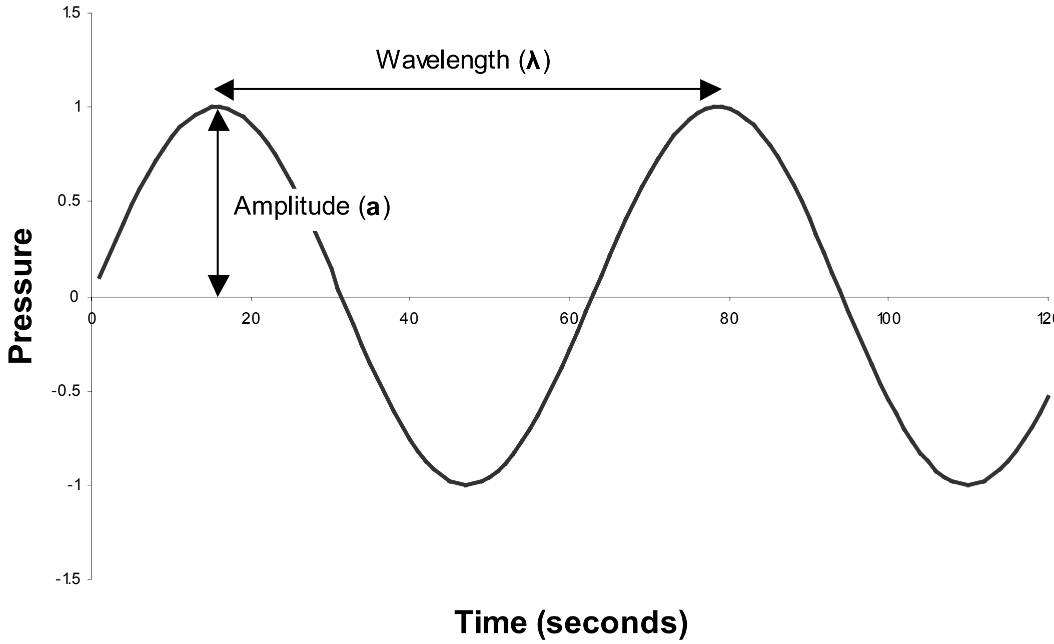
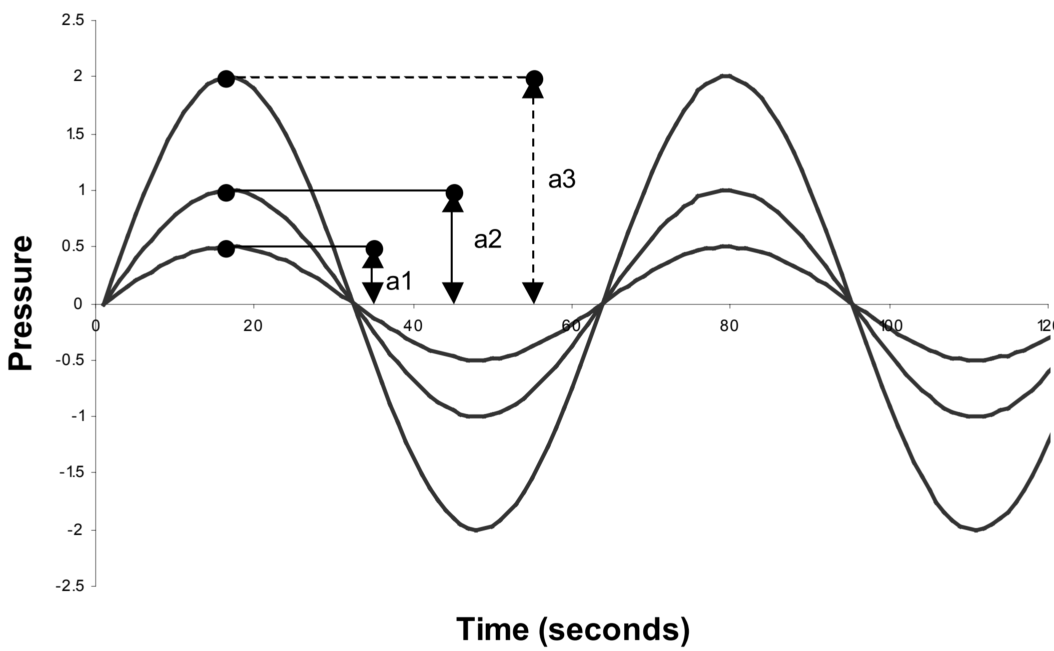


Figure 2.2. A schematic diagram of three sound waves with differing amplitudes (a1, a2, a3). Note that each wave has the same the same frequency and wavelength.



Box 1. Characteristics of sound / longitudinal waves

Figure 2.3. A schematic diagram of two sound waves with differing frequencies and wavelengths (λ1 and λ2). Note that each wave has the same the amplitude.

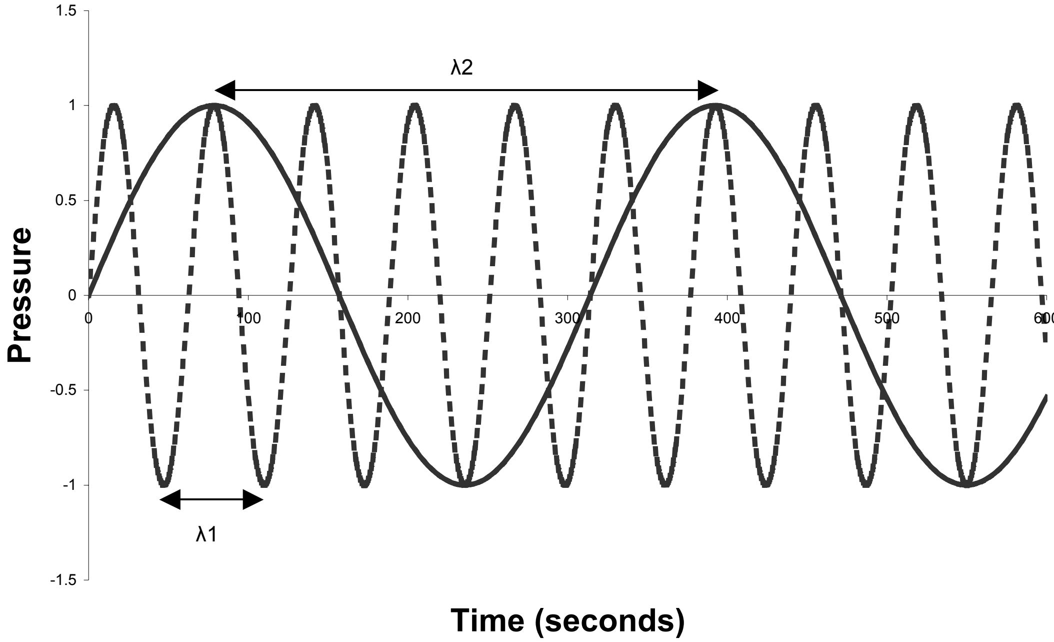
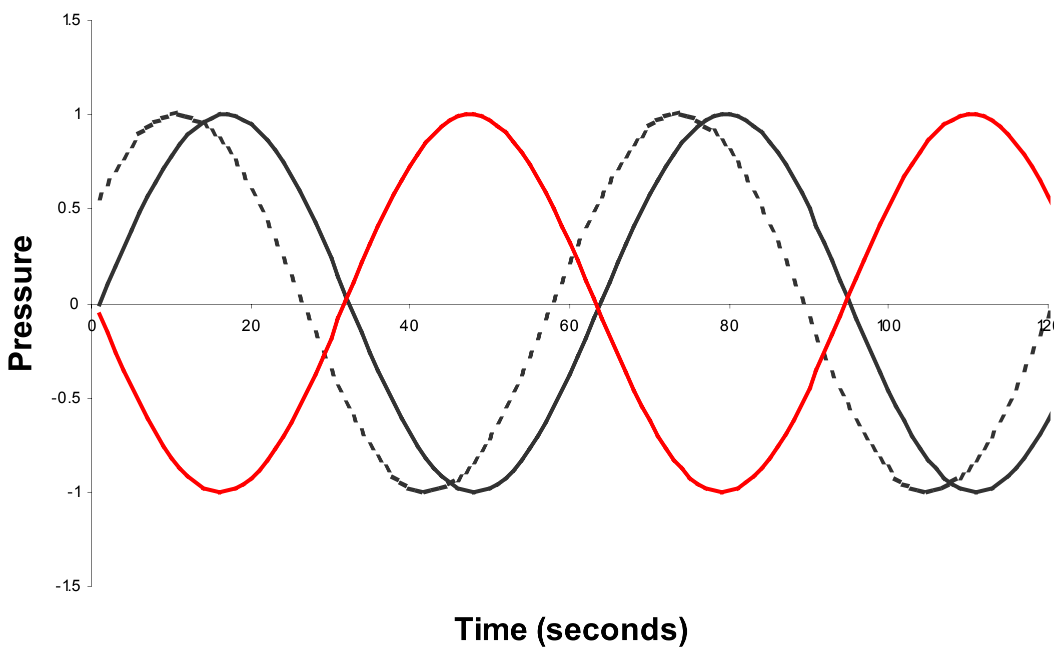


Figure 2.4. A schematic diagram of three waves with different phases. Note that all three waves have the same amplitude, frequency, and wavelength, and the waves represented by the red and black solid lines will cancel each other out, i.e. destructively interfere.



Sound speed (c)

The speed (***c***) of a wave is the rate at which vibrations propagate through an elastic medium, and is characteristic of that medium, for example, the speed of sound in water is approximately 1500 ms^{-1} (metres per second) while the speed of sound in air is approximately 340ms^{-1}. Speed (***c***) is related to the square root of a medium's elastic properties (bulk modulus) divided by its density. In a volume medium the wave speed takes the general form

$$c = \sqrt{\frac{B}{\rho}} \qquad ms^{-1} = \sqrt{\frac{Nm^{-2}}{kgm^{-3}}}$$

Where **B** is the bulk modulus or elastic property of the medium and **ρ** (rho) is the density of the medium. For water B=2.2-x10^9 Nm^{-2} and ρ =1x10^3 kgm^{-3}, giving a speed in water of approximately 1500m/s.

$$c_{water} = \sqrt{\frac{2.2\times10^9}{1\times10^3}} = 1483ms^{-1} \approx 1500ms^{-1}$$

The speed of sound can also be calculated if the frequency and wavelength of a wave are known.

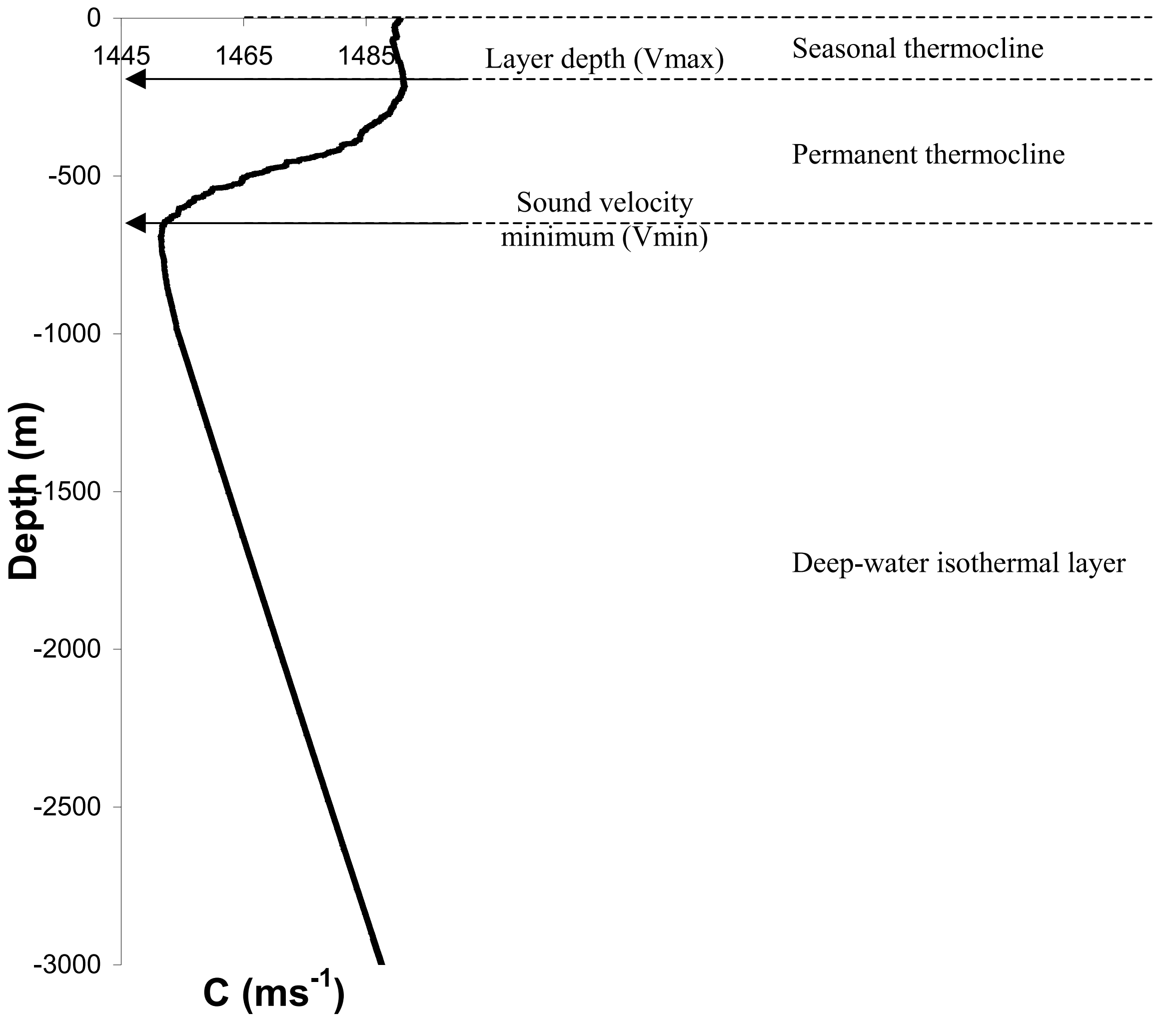
$$c = \lambda / f \qquad ms^{-1} = m / s$$

Where ***c*** is the speed of sound in the medium, **λ** (lambda) is the wavelength and f is the frequency of the sound.

In reality, the speed of sound in water will depend on the density structure of the water column, which is a complex function of temperature (**t**), depth (pressure) and salinity, Box 2. These environmental parameters have important consequences for propagation, and these are described in the sections below.

Box 2. The effects of temperature, salinity and pressure on sound speed

Figure 2.5. A typical sound velocity profile showing the "Layer" depth (depth of maximum sound velocity or Vmax), the sound velocity minimum (Vmin), the signatures of seasonal and permanent thermoclines, and the signature of the deep water isothermal layer.



Box 2. The effects of temperature, salinity and pressure on sound speed

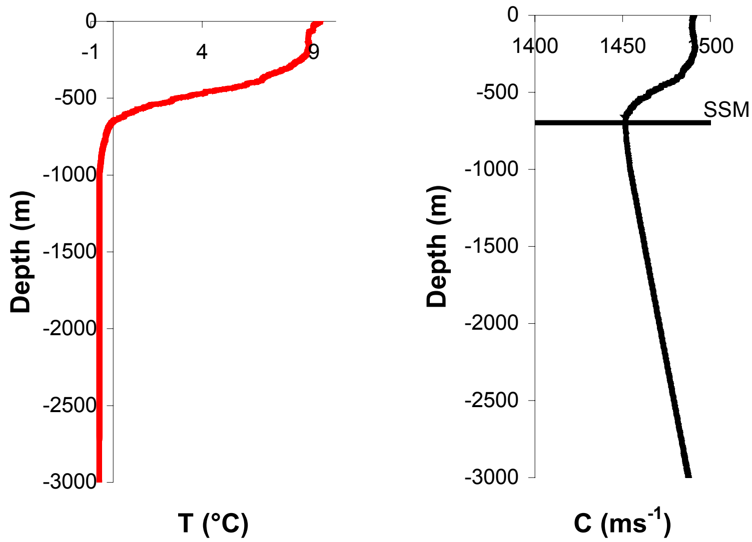


Figure 2.6. The effects of temperature on sound speed (c). As temperature decreases with depth, speed (**c**) decreases. Above the Sound Speed Minimum (Vmin) changes in temperature with depth have the greatest influence on c. Below the SSM temperature is fairly constant, i.e. the water is isothermal. A change in temperature of 1°C (ΔT), results in a $3ms^{-1}$ change in **c** (Δc).

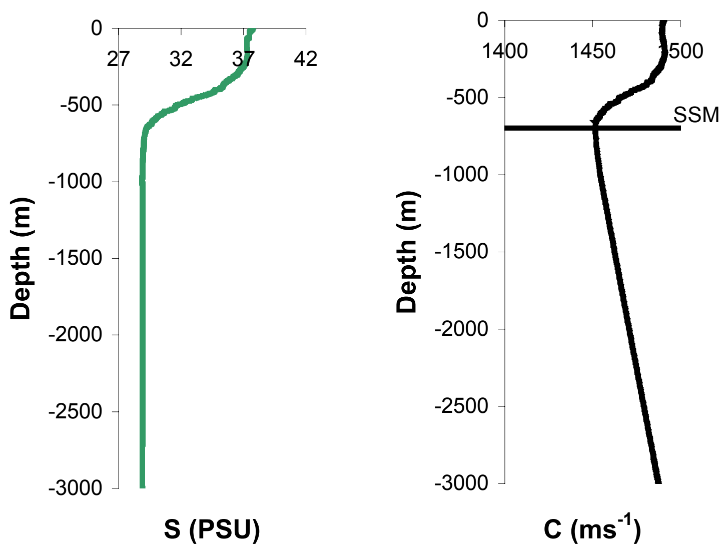


Figure 2.7. The effects of salinity on sound speed (c). A change in salinity (ΔS) of 1PSU results in a $1.3ms^{-1}$ change in **c** (Δc).

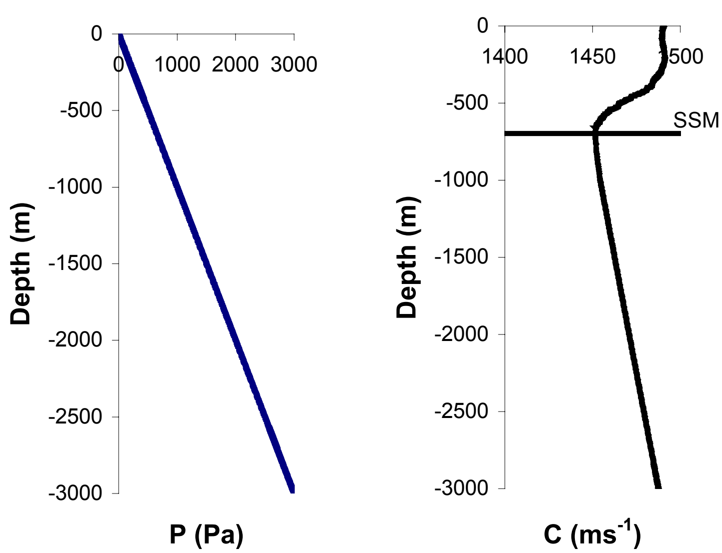


Figure 2.8. The effects of pressure on (c). As pressure increases with depth, (c) increases. Below the Sound Speed Minimum (Vmin) pressure has the greatest influence on c, as temperature and salinity remain fairly constant at depth. A change in pressure (ΔP) of 1Pa results in a $1.7ms^{-1}$ change in **c** (Δc).

Intensity

The intensity of a sound is defined as the acoustical power per unit area in the direction of propagation, i.e. Intensity is a measure of the mechanical (kinetic) energy and potential energy carried by a propagating wave per unit area. Note that the kinetic energy of a wave is the result of particle motion, and its potential energy results from the stresses set up in the elastic medium as the result of this motion.

Intensity is proportional to the square of the acoustic pressure.

$$I = \propto p^2$$

Where acoustic pressure (***p***) is defined as the sound force per unit area, and is usually measured in micropascals (µPa). Note that 1µPa is the pressure resulting from a force of one Newton exerted over an area of one square meter (Nm^{-2}). The instantaneous pressure ***p(t)*** that a vibrating object exerts on an area is directly proportional to the vibrating object's velocity (***v***) and acoustic impedance (***ρc***).

$$p(t) = \rho c v \qquad \mu Pa$$

Note that the product of density (***ρ***) and sound speed (**c**) is defined as the acoustic or characteristic impedance (***ρ*c**) of that medium. Acoustic impedance (***ρc***) is analogous to electrical resistance (impedance), and the differences (Δ ***ρc***) in this value at a boundary between two media are an important determinant of how much energy is reflected by that boundary, see Snell's Law. The acoustic impedance of water is 1.5×10^6 and of air is 4.15×10^2 $kgm^{-2}s^{-1}$.

Thus the intensity of sound can be defined as:

$$I = \left(\frac{p_e}{\rho c}\right) = \left(\frac{\left(\frac{p}{\sqrt{2}}\right)}{\rho c}\right) = \rho c v \qquad Watts \cdot m^{-2}$$

Where p_e is the effective or RMS pressure, i.e. the peak pressure (amplitude) divided by the square root of two.

2.1.2. Measuring sound intensity

Ideally, acousticians would be able to measure intensity directly but practically it is easier to measure and detect changes in pressure and then convert these to intensities. However, the use of pressure as a measurement unit presents the acoustician with two problems, the first is related to the range of pressure differences that the human auditory system can detect (10µPa – 100,000,000µPa) and the second is related to the way in which the human auditory system processes differences in pressure, i.e. how it judges relative loudness. The former is a practical problem where the magnitude of pressure differences detectable by the human ear can make calculations clumsy, and the latter is a subjective problem whereby the human auditory system processes pressure differences logarithmically and judges these relatively. It is for these reasons that **Decibel Scale** and dimensionless unit the **Decibel** (dB) were introduced, and the terms Sound Pressure Level (**SPL**) and Sound Intensity Level (**SIL**) were defined.

$$SPL(dB) = 20\log\left(\frac{p}{p_{ref}}\right) \qquad dB \cdot re.1\mu Pa$$

Where $\boldsymbol{p}$ is the measured pressure and $\boldsymbol{p_{ref}}$ is the reference pressure. In underwater acoustics $\boldsymbol{p_{ref\ water}}$ = 1µPa, in air $\boldsymbol{p_{ref\ air}}$ = 20µPa

$$SIL(dB) = 10\log\left(\frac{I}{I_{ref}}\right) \qquad dB \cdot re.1\mu Pa$$

Where $\boldsymbol{I}$ is the measured intensity and $\boldsymbol{I_{ref}}$ is the reference intensity. Historically, the reference intensity ($\boldsymbol{I_{ref}}$) in air was the sound intensity barely audible to humans at 1000Hz, i.e. $1x10^{-12}Wm^{-2}$ (1 pico Wm^{-2}). Note that if both SPL and SIL are quoted in dB they are equivalent, i.e.

$$SIL(dB) = 10\log\left(\frac{I}{I_{ref}}\right) = 20\log\left(\frac{p}{p_{ref}}\right) = SPL(dB)$$

From the definitions of SPL and SIL above it should be clear that **decibel scale** is a log ratio scale of intensity that has dimensionless units – the decibel. It should also be clear that decibel scale overcomes the problems discussed above, (1) ratios are a convenient way of dealing with the large range of intensities (pressures) that the human ear can detect, (2) logarithms simplify computations since multiplication and division are reduced to addition and subtraction, and (3) the logarithmic scale approximates the mechanism by which the human auditory system judges relative loudness.

It is important to note the dB scale is relative and that dB values are only meaningful if a reference level is included. The reference levels for SPL and SIL are equivalent but are reported in different units. In underwater acoustics a reference pressure of 1µPa is commonly used, while the reference pressure in air is 20µPa (this approximates the human hearing threshold at 1000Hz). The reference intensity in water can be calculated from reference pressure by:

$$I_{ref} = \left(\frac{p_{ref}^2}{(\rho_{medium}c_{medium})}\right)$$

For water, $\boldsymbol{pref}$ = 1μPa rms, $\boldsymbol{\rho}$ = $1\text{x}10^3$ kgm^{-3}, $\boldsymbol{c}$ =$1.5\text{x}10^3$ ms^{-1}.

$$I_{ref} = \left(\frac{1^2}{(1\times10^3)\times(1.5\times10^3)} \right) = 6.7\times10^{-19} Wm^{-2}$$

In the scientific literature you will often see the terms Source and Received Levels. In underwater acoustics, source level usually represents the sound level at a distance of one metre from the source, referenced to 1μPa. On quoting a source level, the distance from the source at which the reference level was measured must also be cited; typically the units of SIL /SPL are dB relative to the reference intensity at 1 metre (e.g. 20 dB re 1μPa @ 1m). In practice, one can rarely measure source level at the standard 1m reference, so that source levels are usually estimated by measuring SPL at some known range from the source (assumed to be a single point), and then predicting and subtracting the attenuation effects from the measured value to estimate the level at the reference range.

The received level is the sound level at the listener's actual position, which is usually considerably more distant that the reference source level.

2.1.3. Comparison of sound intensities measured in air and water

For measurements made in air the Sound Intensity Level is defined as:

$$SIL_{Air}(dB) = 20\log\left(\frac{p}{p_{ref.Air}} \right) = 20\log\left(\frac{p}{20\mu Pa} \right)$$

For measurements made in water the Sound Intensity Level is defined as

$$SIL_{Water}(dB) = 20\log\left(\frac{p}{p_{ref.Water}} \right) = 20\log\left(\frac{p}{1\mu Pa} \right)$$

It should be clear that direct comparisons of sound intensity levels measured in air and water cannot be made, unless levels are adjusted to take into account:

(1) the differences in acoustic impedance between air and water ($\boldsymbol{\rho c}_{water}$ =$1.5\text{x}10^6$ and $\boldsymbol{\rho c}_{air}$ =$4.15\text{x}10^2$) and
(2) the differences in reference pressures used for air and water ($\boldsymbol{p_{ref\ water}}$ = 1μPa and $\boldsymbol{p_{ref\ air}}$ = 20μPa). However, although the physics behind these adjustments is correct it may not reflect the complexities of marine mammal hearing. Bearing this in mind and that direct comparisons of hearing in terrestrial mammals and marine mammals is both controversial and flawed, adjusting the levels to make such comparisons is a two stage process.

Stage 1. Adjusting for differences in pressure reference levels

$$20\cdot\log\left(\frac{p_{Air}}{p_{water}} \right) = 20\cdot\log\left(\frac{20}{1\mu Pa} \right) = +26dB$$

i.e. Equal pressure measurements differ by 26dB in air and in water

Stage2. Adjusting for differences in acoustic impedance (**ρc**) between air and water.

$$10\log\left(\frac{I_{Air}}{I_{Water}}\right) \approx 10 \cdot \log\left(\frac{(\rho c)_{Air}}{(\rho c)_{Water}}\right) = 10\log(3600) = +36dB$$

i.e. The difference between a SIL measured in water and SIL measured in air is:

$$26dB + 36dB = 62dB$$

Therefore if a SIL is measured in air it has been proposed that its equivalent SIL underwater might be achieved by adding 62 dB, and, conversely if a SIL is measured in water, subtract 62dB from its value to get its equivalent value in air.

However, this may be a risky comparison because the mechanisms leading to damage in the ear underwater may be significantly different to those in the air.

2.2. Types of sound source

Sounds can be *transient* (short duration sounds with obvious start and finish points) such as those produced by explosive blasts or percussion piling, or *continuous* (such as drilling). Transient sounds are usually described by their *peak level* (the maximum amplitude measured in dB) with an accompanying indication of how this varies in time. If a transient sound is *impulsive* (with a duration of less than 0.5 seconds) it is best described by its energy level. Continuous sounds and long duration transient sounds are conventionally described by their *mean square pressure*.

2.3. The propagation of underwater noise

Source path receiver model of sound

When describing the propagation of underwater noise it is useful to apply a simplistic model to this process. These models are based on the sonar equation and perhaps the simplest of these is the Source Path Receiver Model. The basic parameters of this model are:

(1) Source: the noise source, e.g. ship, sonar etc. Parameter of interest = source level (SL)
(2) Path or medium: the water column. Parameters of interest include transmission loss (TL), and ambient noise level (NL)
(3) Receiver: e.g. whale, hydrophone etc. Parameters of interest include signal to noise ratio (SNR), received sound intensity level (RL) and detection threshold (DT).

A simple model of sound propagation is:

$$RL = SL - TL$$

Where RL is the received level, SL is the source level and TL is the transmission loss.

Transmission Loss (TL)

Transmission loss is the decrease in intensity of a sound as it propagates through a medium, and is the result of spreading, absorption, scattering, reflection and rarefaction. Transmission loss can also be estimated by adding the effects of geometrical spreading (TL_{sp}), absorption (TL_a) and the transmission loss anomaly (A). The transmission loss anomaly includes scattering loss and losses due to reflection and rarefaction at boundary interfaces.

$$TL = TL_{spreading} + TL_{absorption} + A$$

For simplicity we'll only deal with spreading (TL_{sp}) and absorption loss (TL_a):

$$TL = TL_g + TL_a$$

(1) TL_{sp} - Spreading loss

Spreading loss is a major component of transmission loss and is range (distance) dependent. Two forms of spreading loss are common underwater (1) Spherical or Geometrical spreading loss (TL_g), and (2) Cylindrical spreading loss (TL_{cy}).

Spherical or Geometrical spreading loss (TL_g)

Spherical spreading loss assumes a uniform or homogenous environment that is typical of deep waters (>2000m). Sound from a point source will spread outward as spherical waves, and intensity varies inversely with the square of the distance from the source:

$$TL_g = 20\log\left(\frac{R}{R_0}\right) \qquad\qquad R < R_1$$

Where R is the range in metres of the receiver from the source and R_0 is a reference range, usually 1m. With spherical spreading, sound levels decrease by 6dB if distance is doubled and by 20dB when distance increases by a factor of 10. R_1 is the range in metres at which spherical spreading stops and cylindrical spreading begins.

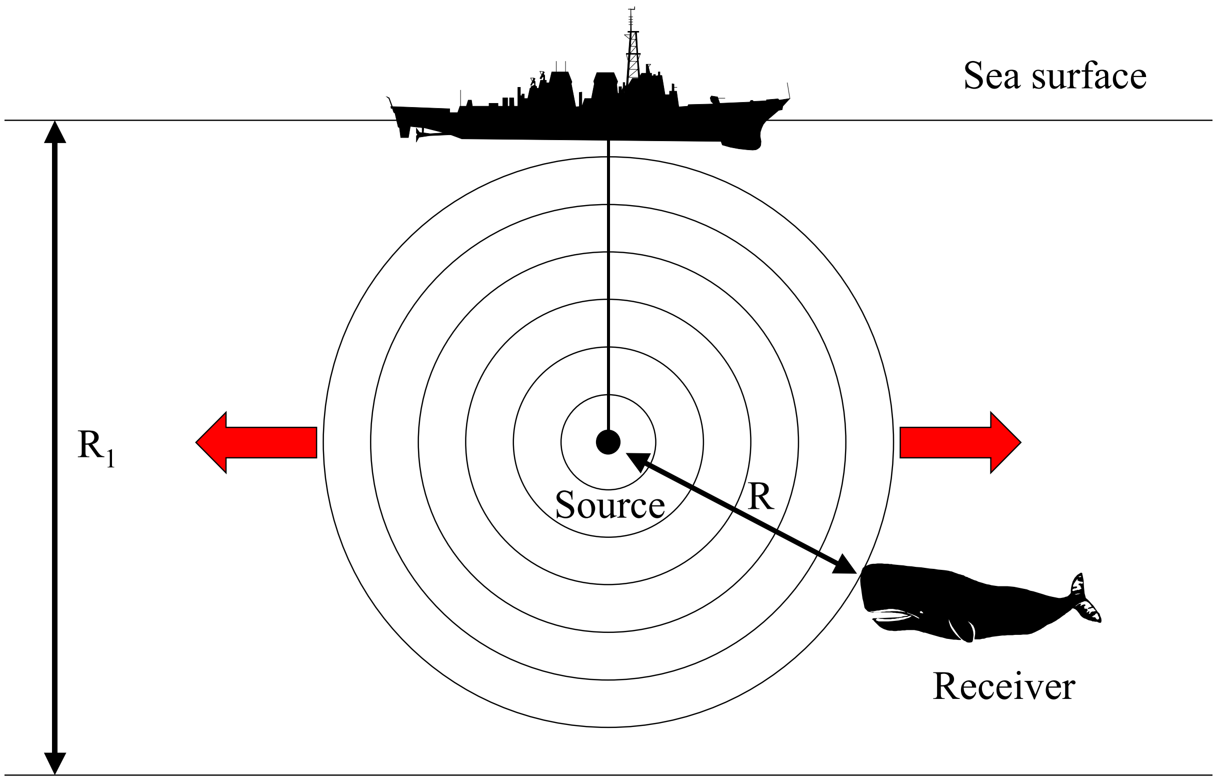


Figure 2.9. Spherical spreading. Note that for spherical spreading to occur $R_1 > R$. (adapted from http://www.fas.org/man/dod-101/navy/docs/fun/part08.htm)

Cylindrical spreading loss

Cylindrical spreading is appropriate when the medium is non-homogenous. Non-homogenous mediums are typical of stratified or shallow coastal waters (<200m), where sound is reflected or refracted off the sea surface and seabed or off different density layers according to Snell's Law. At a given distance from the source, which is long in comparison to the water depth, various reflected waves combine constructively to form a cylindrical wave front. Where cylindrical spreading occurs, sound intensity varies inversely with distance from the source:

$$TL_{cy} = 20\log R_1 + 10\log\left(\frac{R}{R_0}\right) \qquad R > R_1$$

Cylindrical spreading is applicable where the range of the receiver from the source is greater than the depth of the water column or density layer, i.e. for $R > R_1$. Where R_1 is the range in metres at which spherical spreading stops and cylindrical spreading begins. For ranges $R < R_1$, TL is spherical. Spreading loss for cylindrical spreading ($R>R_1$) is less than for spherical spreading ($R < R_1$), and sound intensity decreases by 3dB if distance doubles and by 10dB when distance increases by a factor of 10. Therefore, a sound source generated in shallow coastal waters or estuaries travels twice the distance of an equal sound source in the open ocean.

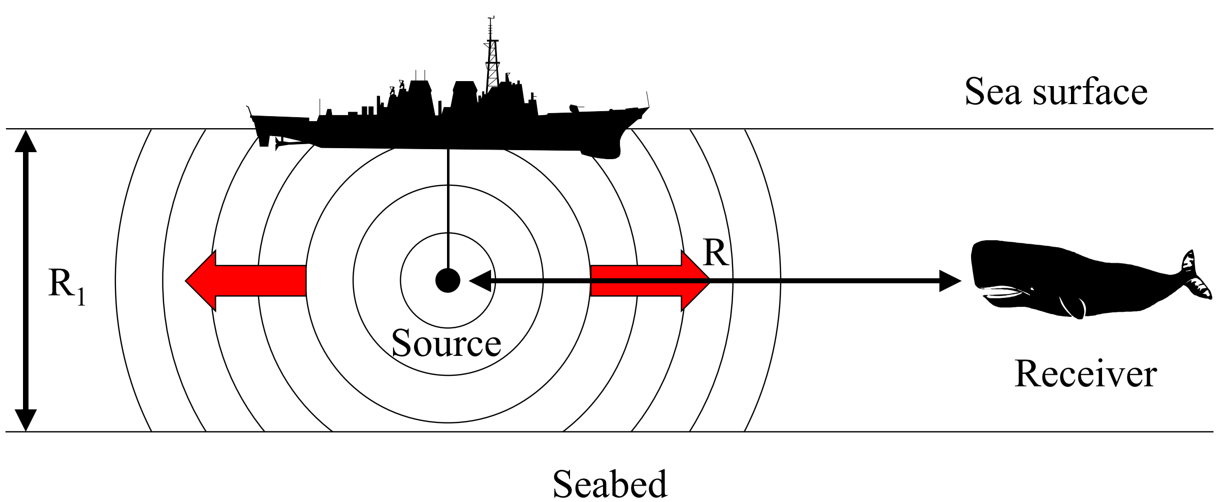


Figure 2.10. Cylindrical spreading. Note that for spherical spreading to occur, $R_1 < R$.

3. Sources of Marine Noise

Chris Parsons, Rene Swift and Sarah Dolman

3.1. Natural noise producers

Ambient or background noise levels are the product of many oceanic noise sources, including natural and distant man-made sources. Noise from natural sources is typically generated by physical or biological processes. Examples of physical processes generating noise are: tectonic (seismic) activity in the earth's crust (volcanoes and earthquakes), wind and waves, while examples of biological noise sources are the vocalisations of marine mammals and fish.

Wind and wave-generated noise

Ambient underwater noise related to wind is caused primarily by wave action and spray. The level of wind-generated noise is a product of duration, speed, fetch, water depth, bottom topography, and proximity to the coastline. Wind is the major contributor to noise between ~100Hz and 30kHz, while wave generated noise is a significant contributor in the infrasonic range (1-20Hz). Note that surf noise is specific to coastal locations.

Spectrum levels of wind dependent ambient noise can be approximated using Wenz's "rule of fives", simply stated, as in Richardson *et al*. (1995), these are:

(1) A **5**dB **decrease** in spectrum levels per octave with **increasing** frequency between 500Hz and 5kHz.
(2) A **5**dB **increase** in spectrum levels with each **doubling** of wind speed between 2.5 and 40 knots (5-75 km/h).
(3) When the wind speed is **5** knots (9km/h) the spectrum level at 1kHz in **deep** water is 51dB re 1_Pa^2/Hz.
(4) When the wind speed is **5** knots (9km/h) the spectrum level at 1kHz in **shallow** water is **5** dB higher than in deep water, i.e. 56dB re 1_Pa^2/Hz.

As rules of thumb, Wenz's "rule of fives" are reasonably accurate up to 20kHz, but variations in local conditions will generate site-to-site variability.

Table 3.1 - Characteristics of natural noise sources

Ambient noise sources	Source levels, dB re 1 μPa-m							Highest level					
	Broad-band	1/3rd octave band centre frequencies (kHz)						1/3rd octave band					
	(0.045-7.07 kHz)	0.05	0.1	0.2	0.5	1	2	Freq.	Level	Strong infrasonics?	Freq. Range (Hz)	Dom. Freq. (Hz)	Source level (dB re 1μPa-m
Wind and waves	-	-	-	-	-	-	-	-	-		1->30,000	-	
Volcanoes & earthquakes	-	-	-	-	-	-	-	-	-		2-500	-	

Rain	-	-	-	-	-	-	-	-	-		100-500	-	
Biological noise (shrimps, cetaceans, etc.)	-	-	-	-	-	-	-	-	-		1->100,000	-	
Sea Ice noise											0.5-8,000	-	

3.2. Vessel traffic

Noise from ships dominates marine waters and emanates from the ships' propellers, machinery, the hulls passage through the water (Gordon and Moscrop 1996), and the increasing use of sonar and depth sounders (Perry 1998). Most shipping has a low frequency range i.e. less than 1kHz (Table 3.1) that coincides with the frequencies used, in particular, by baleen whales for communication and other biologically important activities (see Section 4). In general, older vessels produce more noise than newer ones and larger vessels produce more than smaller ones (Gordon and Moscrop 1996). Ross (1976) noted that noise from a supertanker (at 6.8 Hz) could be detected 139-463 km away.

The distant shipping noise adds to the constant ambient noise level in the marine environment. There has been a large increase in ambient noise in recent years, particularly in the Northern Hemisphere and this has implications for cetaceans. For example, Wiggins (2001) observed that blue whales (*Baleanoptera musculus*) vary the intensity of their sound production level in response to varying ambient noise levels.

Although, typically, shipping produces frequencies below 1 kHz, small leisure craft generate sound from 1 kHz, up to 50 kHz range (Evans 1996) which has the potential to impact toothed whales also. Propellers on these vessels tend to cause some cavitation which generates higher frequencies of noise, and these higher frequencies could be disturbing smaller cetaceans that would appear to be more sensitive to high frequency sound (see section 4). Evans *et al.* (1992) studied the effects of pleasure craft on bottlenose dolphins and reported that the cetaceans exhibited negative responses to boat traffic, including changes in dive times and the avoidance of an approaching vessel at a distance of 150 - 300m. Quieter, faster boats caused more disturbance than slower larger boats, as noise emitted by high speed boats rises above ambient levels only a short time before closest contact, thereby provoking a 'startle' reaction. More information on responses of cetaceans to boat traffic can be found in Annex A3 of this report. A summary of frequencies produced by shipping and their source levels are listed in Table 3.2.

Table 3.2. Summary of sound frequencies produced by shipping traffic and their source levels.

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 1.0	166 164	Buck and Chalfant 1972; Miles *et al.* 1989

	5.0	145	
Tug pulling loaded barge	1.0 5.0	170 161	Miles *et al.* 1989
34m (twin diesel engine) workboat	0.63	159	Malme *et al.* 1989
Tanker (135m) Tanker (179m) Supertanker (266m) Supertanker (340m) Supertanker (337m)	0.43 0.06 0.008 0.007 0.007	169 180 187 190 185	Buck and Chalfant 1972; Ross 1976; Thilele and Ødengaard 1983
Containership (219m) Containership (274m) Freighter (135m)	0.033 0.008 0.041	181 181 172	Buck and Chalfant 1972; Ross 1976; Thilele and Ødengaard 1983

3.3. Oil and gas exploration

3.3.1. Seismic surveys

During seismic surveys, high intensity, low frequency sounds are directed through the earth's crust and are reflected at the geological boundaries defining different strata. The reflected sound is processed to provide information about the structure and composition of geological formations below the sea bed and to identify potential hydrocarbon reservoirs (Figure 3.3). During marine seismic surveys, the sound source, usually an array of airguns, is towed at 4-6 knots at a depth of 4-10 m (McCauley 1994, Gulland and Walker 1998), and reflected signals are recorded using arrays of hydrophones several kilometres long. Shots are fired at approximately 6 - 20 second intervals along pre-determined routes (commonly called “transect” lines or legs). Each transect line can be several hours long, and surveys can last several months and can consist of hundreds of transects.

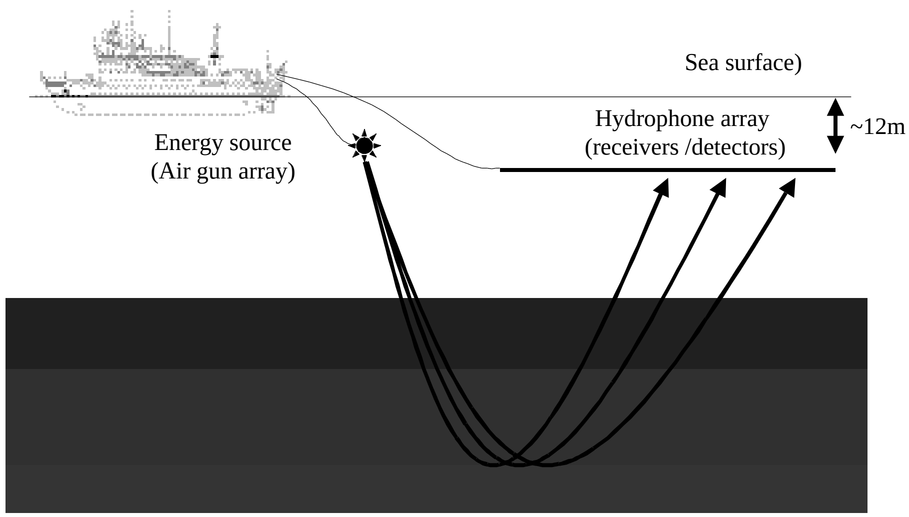


Figure 3.3. The basic components of a marine seismic reflection survey (the layers of the seabed are shaded).

3.3.2. Marine seismic surveys

Marine seismic surveys are commonly either two-dimensional (2-D) or three-dimensional (3-D), and the type of survey used not only affects the type of data collected but can also affect the extent and duration of exposure to high sound levels.

Two-dimensional surveys employ a single airgun array and hydrophone streamer, and are conducted along single lines, or pre-determined tracks within an open grid, to produce a vertical slice or 2-D image through the earth's crust (McCauley 1994; Gulland and Walker 1998). The source in this type of survey is often made as strong as possible for maximum penetration (Gulland and Walker 1998). Two-dimensional seismic surveys provide little or no information about the true position of reflecting points in the sub-surface (Gulland and Walker 1998) and are typically used for speculative surveys covering large geographical areas (McCauley 1994).

Three-dimensional seismic surveys are characterised by the need to record a grid of data, with each grid being close enough to allow processing along both grid axes (Gulland and Walker 1998), and where each grid point is the centre of a grid cell (usually 25 m by 25 m). The appropriate processing grids can be used to produce a 3-D reconstruction of the traversed surface, giving a much higher resolution than conventional 2-D surveys. By their nature, 3-D surveys require accurate positioning and use multiple parallel hydrophone streamers often in conjunction with multiple airgun arrays. Tracklines are often separated by 50 or 100 m (McCauley 1994). Three-dimensional seismic surveys are typically used to define potential and / or existing hydrocarbon deposits and fewer exploration wells are needed as a result. However, there are now moves to use 3-D surveys for speculative exploration, with the extra cost being balanced by the quality and quantity of data produced (McBarnet 1993 in McCauley 1994).

The source used during 3-D surveys is often less strong than those used in conventional 2-D surveys because subsequent processing is able to handle the resulting difference in data quality (Gulland and Walker 1998). However, the staggered firing of multiple arrays, to reduce signal interference, increases the period of noise exposure (McCauley 1994). Additionally, the need to grid concentrates seismic activity in a small area for a prolonged period, subjecting resident fauna to high levels of sound for protracted periods and may consequently have greater long-term effects (McCauley 1994).

3.3.3. The seismic source (airguns and airgun arrays)

Most seismic surveys now use airguns as their noise source; these are pneumatic devices that produce an acoustic signal by rapidly releasing a volume of compressed air into the water column.

In general, single air-guns produce broadband source levels between 215 and 230 dB re 1 μPa-m, with highest energies falling in the range 10 - 300 Hz (McCauley 1994, Greene *et al*. 1995). The waveform of this signal resembles a damped sinusoid, and depends on the energy contained in the compressed air prior to discharge (Turnpenny and Nedwell 1994). Although most energy is produced at lower frequencies, considerable energy above ambient noise levels may be produced at frequencies up to 22kHz (Gordon and Moscrop 1996).

Broadband peak to peak source levels of 230 – 255 dB re 1 μPa-m in a downward direction are reported for air-gun arrays, with peak frequencies covering the range 10-100 Hz (McCauley 1994, Greene *et al*. 1995). Recently, however Goold and Fish (1998) reported levels as high as 90 dB re 1 μPa^2/ Hz at a frequency of 20kHz and at a range of 1km from the seismic source.

Although the direction of greatest sound intensity is downwards, a considerable amount of energy is radiated in directions away from the beam axis (McCauley 1994). The far-field signature may be detected many kilometres from the source (for example, 50-75 km in water 25-50 m deep in Greene and Richardson (1988). Seismic activity off Nova Scotia is prominent in the acoustic background off the Bahamas and along the Mid-Atlantic Ridge, several thousands of kilometres away (Weilgart *pers. comm*.). These propagation characteristics imply that the sound levels received by an animal in close proximity to the source will depend on its depth and position relative to the array's axis. Those animals perpendicular to the array's axis will experience a given sound pressure level at greater range than those in the line axis of the array. Similarly, at medium depths (several hundred metres) and assuming free field propagation, animals deeper in the water column and directly below the array will receive a higher intensity sound than those animals closer to the surface but at the same range from the array.

There is now a world-wide trend towards increasing oil exploration in deeper waters, and this has brought with it an increased potential for conflict between those species of cetacean thought to be most vulnerable to seismic pulses; for example the low frequency specialists, such as mysticete whales, and deep divers, like the sperm and beaked whales.

3.4 Industrial noise associated with oil and gas exploration and production

3.4.1 Noise sources

Noise is generated during all phases of oil and gas production, noise sources may be continuous or impulsive and can be described as being transient or permanent (Table 3.4). Activities generating noise are many and varied, ranging from seismic surveys (exploration), through pile driving and pipe-laying (installation) to drilling and platform operations (production) and explosive wellhead decommissioning (decommissioning). Most noise sources associated with oil and gas production can broadly classified as noise originating from (1) machinery, (2) propellers (cavitation), (3) hydrodynamic excitation of structures (turbulent flow) or (4) impulsive sound sources (airguns / pile drivers) (Figure 3.1).

Table 3.4. Summary of noise sources and activities associated with oil and gas exploration and production.

	Activity	***Source***	***Source type***	***Duration (duty cycle)***
Exploration	*Seismic surveys* *Exploratory drilling* *Transport (equipment + personnel)*	*Air guns + seismic vessel* *Machinery noise* *Helicopters + support vessels*	*Impulsive + continuous* *Continuous* *Continuous*	*Transient (weeks)* *Transient (weeks)* *Transient (days, weeks)*
Installation	*Pile driving* *Pipe-laying* *Trenching* *Transport (equipment + personnel)*	*Pile driver +support vessel* *Pipe laying vessel + support* *Trenching vessel + support* *Helicopters + ships*	*Impulsive + continuous* *Continuous* *Continuous*	*Transient (weeks)* *Transient (weeks)* *Transient (weeks)* *Transient (weeks)*
Production	*Drilling* *Power generation* *Pumping* *Transport (equipment + personnel)*	*Machinery noise* *Gas turbines, generators* *Pumps, separators* *Helicopters + support vessels*	*Continuous* *Continuous* *Continuous* *Continuous*	*Permanent (years)* *Permanent (years)* *Permanent (years)* *Transient (days, weeks)*

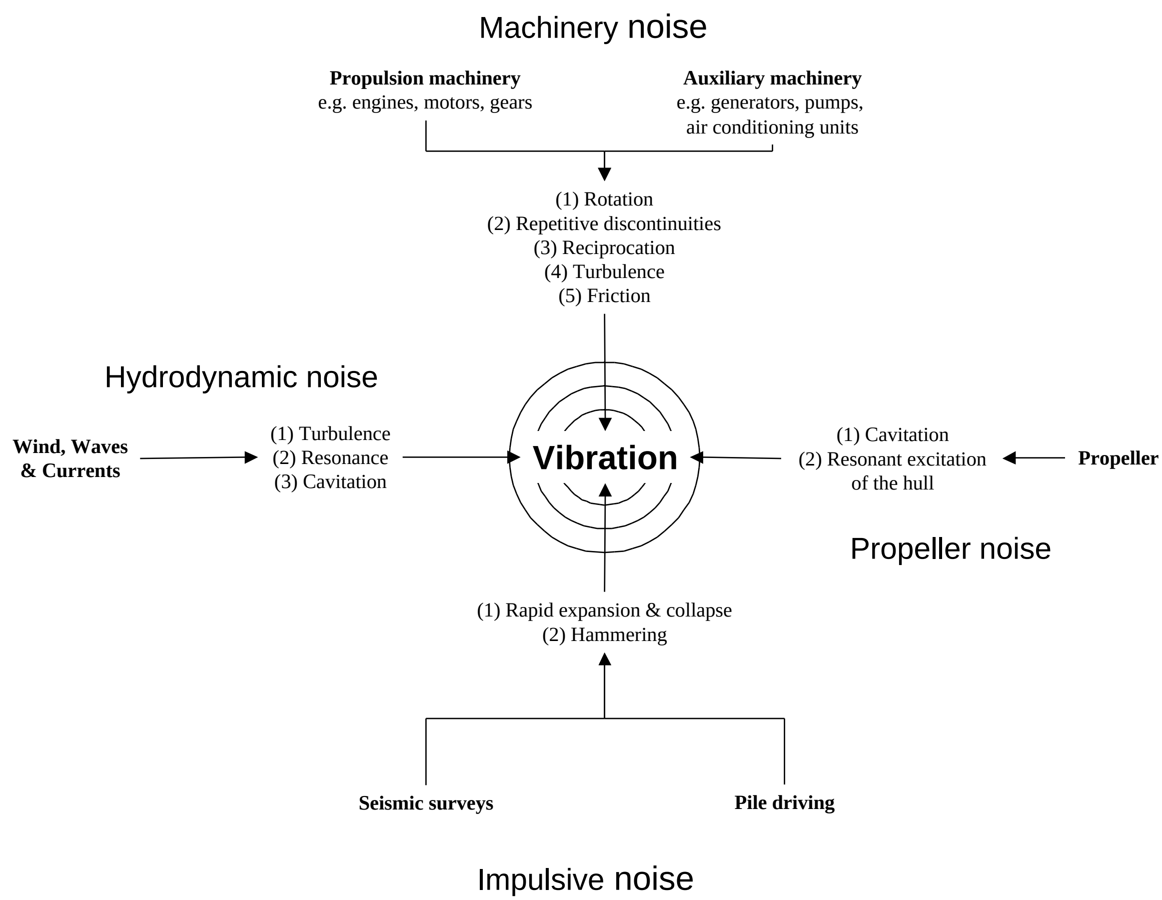


Figure 3.1. Sources and causes of underwater noise associated with the oil and gas industries

3.4.1.1 Machinery noise

Underwater machinery noise is the result of mechanical vibration that is coupled to the sea via, for example, a ship hull, oil platform legs or through the ground. Within the machinery noise class, a distinction between propulsion machinery (diesel engines, thrusters, main motors and reduction gears) and auxiliary machinery (generators, pumps and air-conditioning equipment) can be made. Causes of machine vibration are:

- Unbalanced rotating shafts
- Repetitive discontinuities, e.g. gear teeth, armature slots or turbine blades
- Reciprocating parts e.g. combustion in engine cylinders
- Cavitation and turbulence in fluids flowing through pipes, pumps, valves, condensers
- Mechanical friction

3.4.1.2 Propeller noise

Propeller noise is distinguished from machinery noise in that it is the result of propeller action and originates on the surface of the propeller. As the propeller rotates through the water, regions of low or negative pressure are created at its tips, if and when these negative pressures become sufficiently strong, bubbles (cavities) begin to form. These bubbles are short lived and collapse in either a turbulent stream or against the surface of the propeller. A sharp pulse of sound is produced as the bubble collapses and this process, "cavitation", is responsible for the loud "hiss" often associated with ships. Causes of propeller noise are:

- Cavitation
- Propeller-induced vibration

3.4.1.3 Hydrodynamic noise

This type of noise is distinguished from propeller noise in that it does not originate at the propeller but is caused by the flow of water past a physical structure such as the hull of a vessel or the legs or risers of platforms. Causes of hydrodynamic noise are:

- Vortex-induced vibration
- Resonant excitation of cavities, plates, and appendages
- Turbulent flow within pipes

3.4.1.4 Impulsive noise

Impulsive sounds are those created by the rapid expansion and collapse of an air bubble (seismic air gun) or from the instantaneous application of pressure to a solid structure (pile driver). Impulsive sounds are typically short-lived and characterised by rapid rise times. Causes of impulsive noise are:

- Explosions, for example during explosive wellhead decommissioning (decommissioning)
- Airguns used during seismic surveys (exploration)
- Pile drivers (installation)

3.4.2 Rig and platform noise

Rigs and platforms come in various forms, shapes and sizes and are found across a wide range of depths from coastal to oceanic waters. They fall into three general categories (1) man made islands / caissons, (2) fixed platforms and (3) drill ships / semi-submersibles (Figure 3.2). Their design, construction and local oceanographic conditions will affect both the path of the sound into the water column and how much sound is transmitted (Figures 3.3 and 3.4).

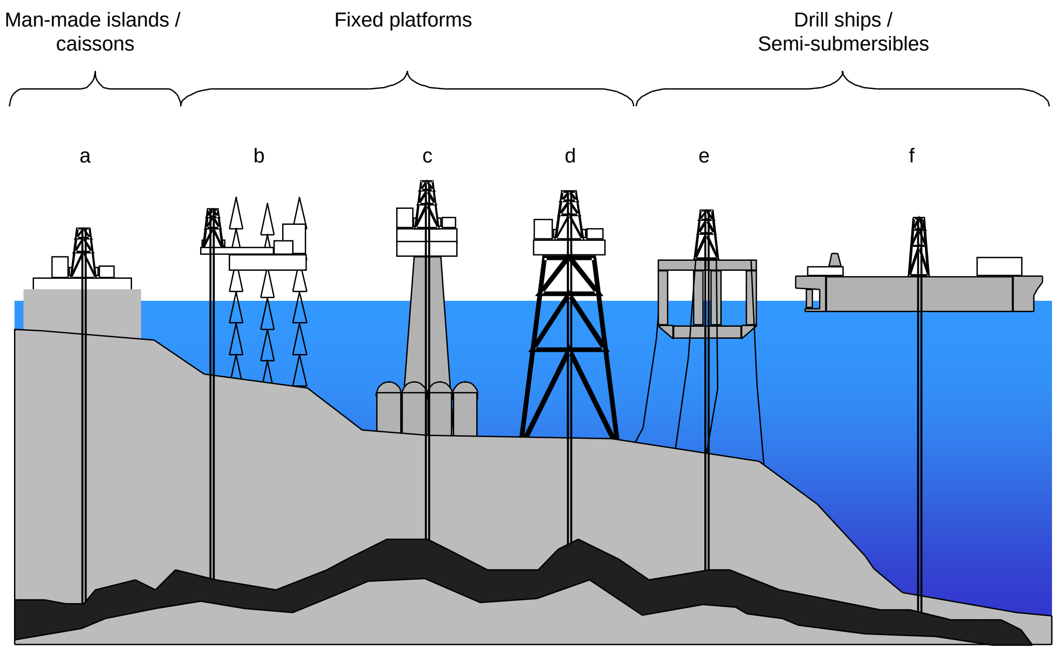


Figure 3.2. Common oil and gas rig and platform types, (a) Man-made island, (b) Jack-up rig, (c) gravity based structure, (d) metal jacket, (e) semi-submersible rig, (f) drill ship.

(1) **Design:**

a. Surface area: As a rule of thumb the larger the surface area in contact with the water, the more noise an object transmits, thus drill ships, FPSO's (floating production storage and offloading platforms) and semi-submersibles will transmit more noise into the water column, than fixed platforms or man-made islands, and jack-up rigs and rigs mounted on a metal jacket will typically produce less noise than gravity based structures, as these generally have larger surface areas.

b. Top drive or rotary? Rotary drill tables are noisier than top drive mechanisms.

c. Isolators or baffles? Rubber mounting pads for machinery can isolate vibration; baffles can direct noise from exhausts away from water and into the air.

(2) **Construction:** Noise is more efficiently coupled to the water through steel or concrete hulls or caissons than it is through gravel or sand islands, which are quieter in the water.

(3) **Local oceanographic conditions:** Temperature, salinity and pressure will affect how efficiently sound is transmitted, for example, if rigs are ice-bound, noise will not propagate as far as if the rig were in open water conditions.

Relatively few studies of underwater noise around drilling platforms have been undertaken, and where studies have been carried out they have tended to focus on noise from semi-submersible rigs or drill ships. In all studies low frequency noise was transmitted most efficiently (<200Hz), and broadband noise sources decayed more rapidly to ambient levels than tonal noise sources (Richardson *et al.* 1995). Noise from various rigs and platforms are summarised in Tables 3.4.2a and 3.4.2b.

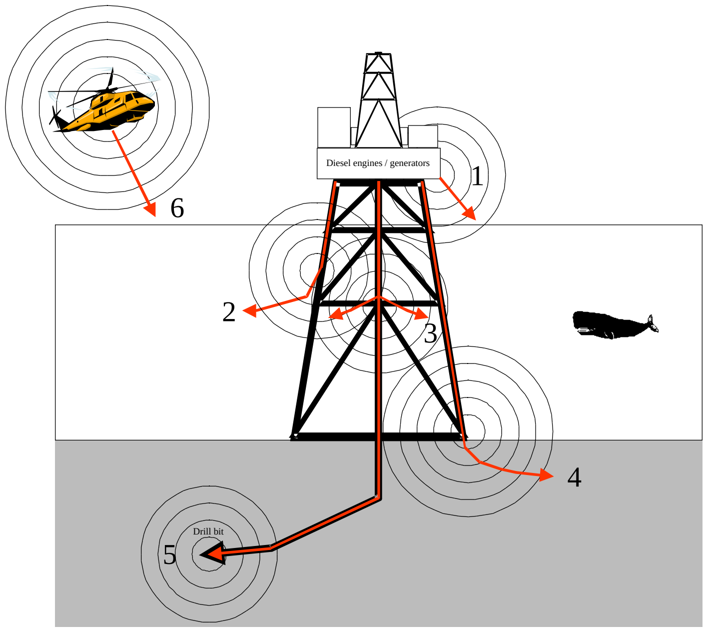


Figure 3.3. Sound transmission pathways associated with a fixed platform. (1) Diesel engine / generator exhaust port, (2) Vibration through legs into the water, (3) Vibration through drill string and casing, (4) Vibration into the seabed, (5) Vibration of drill bit, (6) Noise from helicopters and vessels.

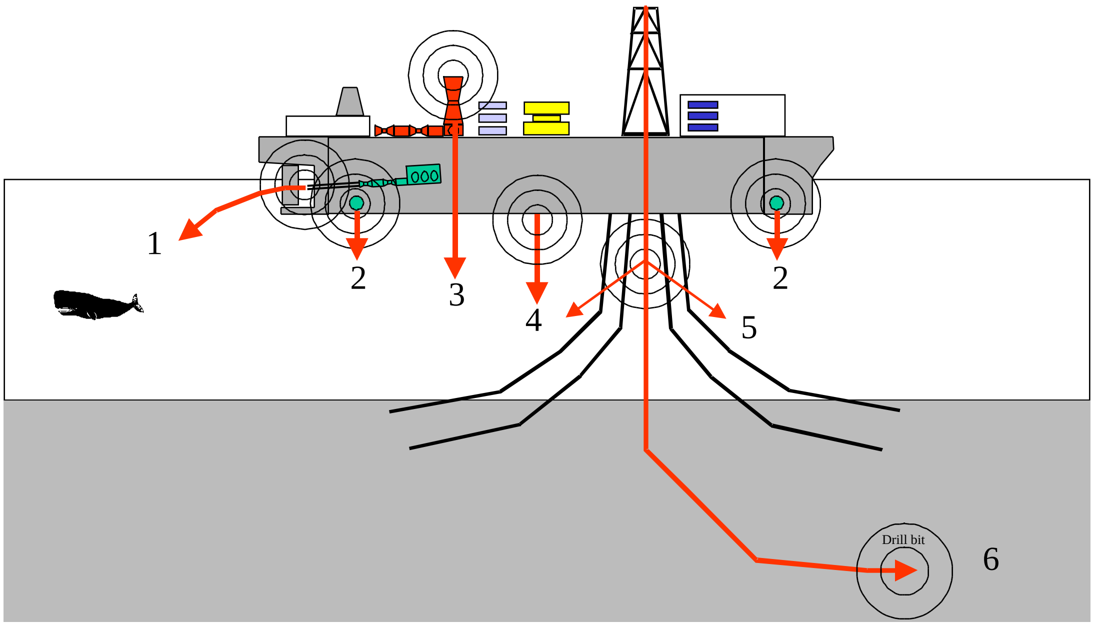


Figure 3.4. Sound transmission pathways and sources of noise associated with a drill ship or an FPSO (floating production storage and offloading facility). (1) Cavitation associated with the propeller, (2) Cavitation associated with bow and stern thrusters, (3) Exhaust ports, (4) Hull vibration associated with machinery noise, (5) Vibration through drill string casing or risers, (6) Vibration of the drill bit. Red - Gas turbines (Machinery noise), Light blue - Compressors (Machinery noise), Yellow - Separators (Machinery noise), Dark blue - Water injection pumps (Machinery noise), Green - Propulsion units – thrusters (Machinery noise + propeller noise).

It is difficult to predict which species will be most vulnerable to man-made noise because of the wide range of individual and population sensitivities as well as differences in wariness or motivation. Currently, it may only be possible to make generalisations about the vulnerability of species groups based on behavioural observations of responses to man made sounds, habits and what is known about a species' auditory sensitivity or vocal range.

When evaluating likely impacts, consideration should also be given to differences in local conditions that may affect sound propagation, e.g. depth, bottom type, size and type of source. As can be seen in the table below, a majority of man-made sounds have significant amounts of energy at low frequencies, thereby leading to potential disturbance, damage or interference to the mysticete whales. There is evidence of low frequency hearing in sperm whales (Ketten, 1992; Ketten, 1997) and this species appears to be extremely sensitive to disturbance from a variety of sound sources. Deep diving odontocetes may also be at risk as their behaviour puts them in the deep sound channel or SOund Fixing And Ranging (SOFAR) channel, along which sound is believed to travel efficiently for distances of hundreds to thousands of kilometres. Noise from seismic sources tends to be focussed downwards, exposing any submerged or deep diving cetaceans to high levels of acoustic energy. Deep diving mammals may dive for periods of up to 2 hours. For example, sperm whales have extremely finely balanced energy budgets and spend only limited periods at the surface to rest and recover. Any disturbance during these periods may result in loss of long term fitness or reproductive fitness. Small odontocetes may be the least vulnerable to low frequency industrial sounds, however there is recent evidence of low frequency hearing in bottlenose dolphins (Turl, 1993) and exclusion from around the vessel and distress in common dolphins when exposed to seismic activities (Goold and Fish 1998). Smaller odontocetes are likely to be more susceptible to the higher frequency components of seismic sources and also to active sonars.

Tables 3.4.2a and 3.4.2b. Summary of noises produced during oil and gas exploration activities. Adapted from Richardson *et al*. (1995); Gilders (1988); Evans and Nice (1996) and various other sources.

Continuous noise sources	Source levels, dB re 1 μPa-m							Highest level					
	Broad-band	1/3rd octave band centre frequencies (kHz)						1/3rd octave band					
	(0.045-7.07 kHz)	0.05	0.1	0.2	0.5	1	2	Freq.	Level	Strong infrasonics?	Freq. Range (kHz)	Dom. Freq. (kHz)	Source level (dB re 1μPa-m
VESSELS UNDERWAY													
Tug & Barge (18 km/h)	171	143	157	157	161	156	157	630	162	Yes			
5-m Zodiac	156	128	124	148	132	132	138	6300	152	No			
Supply ship (*Kigoriak*)	181	162	174	170	166	164	159	100	174	Yes			
Large tanker	186	174	177	176	172	169	166	100 & 125	177	Yes			
DRILLSHIPS, RIGS, PLATFORMS													
Kulluk (45-1780 Hz)	185	174	172	176	176	168	-	400	177	No?			
Canmar Explorer II	174	162	162	161	162	156	148	63	167	No			
Jack up rig during drilling (Sedco J)	59	55.9	54	55.6	46.9	-	-	16	62.5	-	0.005 -1.2		
Semi-submersible											0.016 -0.20		
Drilling production												0.25	
DREDGING													
Aquarius (45-890 Hz)	185	170	177	177	171	-	-	160	178	No?			
Beaver Mackenzie (45-890 hZ)	172	154	167	159	158	-	-	100	167	No?			

Transient noise sources	Source levels, dB re 1 μPa-m							Highest level					
	Broad-band	$1/3^{rd}$ octave band centre frequencies (kHz)						$1/3^{rd}$ octave band					
	(0.045-7.07 kHz)	0.05	0.1	0.2	0.5	1	2	Freq.	Level	Strong infrasonics?	Freq. Range (kHz)	Dom. Freq. (Hz)	Source level (dB re 1μPa-m
Aircraft													
Helicopter fly over @ 305m (Sikorsky-61)	108	97	94	97	97	91	88	25	98				
Helicopter fly over (Bell 212)	162	154	155	151	145	142	142	16	159	Yes			
Helicopter takeoff (Super Puma)	-	112	96	85	88	88	85	20	109				
Helicopter flyover @ 305m (Super Puma)	-	98	96	85	88	88	85	20	109				
Seismic surveys													
Airgun or airgun array	216	210	209	199	184	191	178	50	210	Yes	0.02-22	10-1,200	230-260
Vibroseis on ice	210	203	198	194	188	177	168	125	204	Yes			
Vibroseis										Yes	-	10-200	187-260
Sleeve exploders										Yes	-	5-500	217-270
Water gun										Yes			217-245
Sparker – 30 kj										Yes?			221
Boomer – 500 j										Yes			212
Explosives													
0.5 kg TNT	Peak 267							21		Yes		Broadband	267
2 kg TNT	Peak 271							13		Yes			
20 kg TNT	Peak 279							6		Yes			
Blackpowder 0.5 kg												Broadband	246
Pile driving													
Pile driving on Scotian Shelf	165	134	145	158	154	141	136	250	159	Yes			
Commercial sonar													
Depth sounder											12-200	> 12	180
Bottom profilers											0.4 – 30		200-230
Side scan											50-500		220-230

Navigation (transponders)											7-60		180-200

Until recently, impacts of seismic activities on cetaceans have been limited to visual behavioural observations within a small radius of the working vessel. However, in 2002 the US National Science Foundation (NSF) was conducting acoustic research aboard the R/V Maurice Ewing when the stranding, and subsequent death, of two Cuvier's beaked whales (*Ziphius cavirostris*) occurred in the Isla San Jose, Gulf of California, Mexico.

These beaked whales appeared to be in good physical condition, and showed no overt signs of trauma or disease, suggesting an external factor was in play. Furthermore, National Marine Fisheries Service (NMFS) scientists have testified that they believe that the stranding was related to the actions of the R/V Maurice Ewing. The intense acoustic activities being undertaken by the research vessel in the vicinity may have caused the animals to strand alive and consequently perish.

3. 5. Ocean experiments

3.5.1. Acoustic Thermography

Sound travels faster in warm water than in cold. Acoustic Thermography of Ocean Climate (ATOC) a programme led by the US Scripps Institute of Oceanography that utilised the deep sound channel reportedly to gain measurements of average ocean temperature (and, therefore, climate change). The source intended to be detected over a very large area, 3000-10,000 km (Heathershaw *et al.* 1997). Two underwater speakers were located in the Monterey Bay National Marine Sanctuary and off Kauai, Hawaii, respectively. After public outcry in 1994, the former speaker was relocated to Pioneer Seamount, out of but still near the sanctuary. ATOC has since been re-named NPAL (North Pacific Acoustic Laboratory), and received permission in January 2002 to continue broadcasting for 5 years. NPAL only uses the underwater speaker off Kauai.

A trial took place in 1991 and became known as the "Heard Island Feasibility Test" (HIFT), as it was conducted 50 km from the Island, just outside the Antarctic Circle. The source levels of this initial experiment were higher than the tests that followed (US Dept. of Commerce, 1990). The source level was 209-219 dB re 1 μPa, centred at 57 Hz and consisting of a continuous tone, a narrow-band pulse-encoded signal; pentaline, 15Hz bandwidth and broader band pulse-encoded signals; M-sequence, 30 Hz bandwidth. It was focused at a depth of 175 m and transmitted for 1 hour out of every 3 (Bowles *et al.* 1994). For five days, a variety of low frequency coded signals were transmitted from an underwater source to a number of hydrophone receivers around the world (Forbes, 1991).

Observers conducted surveys and monitored the behaviour of marine mammals visually and acoustically over an area of 70 x 70 km. Sperm and pilot whales were heard in 23% of 1181 minutes of baseline acoustic surveys; but in none of the 1939 minutes transmission period (Bowles *et al.* 1994).

The sound transmission efficiency of the deep sound channel is evident from various extremely long-range transmission experiments. Noise from 91kg and 136 kg explosive charges, detonated at 732 – 1800 m depth off Perth, Western Australia, was clearly detected near Bermuda at distances of 19,766 and 19,810 km (Shockley *et al*. 1982).

Results from the aerial surveys conducted as part of the ATOC Marine Mammal Research Program showed that both humpback and sperm whales were generally seen farther from the sound source during experimental compared with control surveys ($p<0.05$) (Calambokidis *et al*. 1998).

Further studies suggested that humpback whales showed a variable response to ATOC with whales being both closer to, and further away from, the source during transmissions.

There is some controversy over these results, and some scientists, having looked at the data, believe that sperm whales, at least, were avoiding (both vertically and horizontally) the ATOC source during conditions of poor food availability. When prey was present, however, the sperm whales apparently "put up" with the noise to get to food (Whitehead , *pers. comm.*).

National Research Council (2000) found the ATOC MMRP's results to be lacking. It stated that MMRP was not designed to investigate the effects of the source most effectively. It continues that as a consequence, the results of the MMRP do not conclusively demonstrate that the ATOC signal *either* has an effect *or* has no effect on marine mammals in the short or long term. In view of the lack of data for marine mammals exposed to the ATOC signal at received levels above 137 dB, and the incomplete analyses of much of the data collected off the Kauai source, the Committee could reach no conclusions about the effects of the ATOC source at the source level of 195 dB. Further, they concluded that the biological significance of short and long term exposure cannot be extrapolated from the limited data acquired during the short term MMRP studies. Redistribution of marine mammals from traditional feeding or breeding areas was not observed, but cannot be ruled out.

3.6 Marine science research

Noise making devices are used in a variety of types of marine science throughout the worlds' oceans. Uses include mapping the ocean bed, and the sediments beneath it, the study of distribution and movement of marine species, finding lost or wayward vessels or equipment and discovering the ocean's role in climate change. Whether Environmental Impact Assessments (EIAs) are conducted before these activities progress largely depends on the legislation of the country concerned. Even in the Antarctic, governed by the Antarctic Treaty, which contains procedures for EIAs, there are currently no guidelines or procedures that are adhered to by all countries to protect marine life from intense acoustic pollution.

3.7. Military

There is a growing body of information pointing to military activities as a major source of underwater noise. For example, naval vessels routinely use active sonar on exercises and during routine activities. These sonar systems usually emit short pulses of sound and are designed to focus as much energy as possible in narrow ranges of direction. Simple sonar systems target this sound in just one direction, although more complicated systems may emit beams of sound in multiple directions. Frequencies commonly used by sonar systems and their source levels are summarised in Table 3.6. However, the exact acoustic frequencies and sound characteristics of military sonar are usually classified, and some systems may use frequencies which are lower or louder that the summarised data.

Table 3.6. The acoustic properties of some active sonar systems (Richardson *et al*. 1995; Perry 1998; Møhl 2003)

SONAR TYPE	FREQUENCY RANGE (KHZ)	AV. SOURCE LEVEL (dB re 1 uPa/1 a)
53C sonar used during Bahamas stranding	2.6, 3.3	223
Search and surveillance	2-57	230+
56 sonar used during Bahamas stranding	6.8, 8.2	245
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 (UK Royal Navy Low Frequency Sonar System)	c. 0.1-0.5	200

Several studies have voiced concern over the potential impacts of military activities upon cetaceans. Vonk and Martin (1989), Simmonds and Lopez-Jurado (1991), Frantzis (1998) and Frantzis and Cebrian (1999) have all suggested that loud military noise may have caused mass strandings of beaked whales in the Canary Islands and the Ionian Sea. The Greek stranding was found to coincide with the testing of military sonar. Moreover, sperm whales and long-finned pilot whales have both demonstrated changes in vocal behaviour in response to the use of military sonar (Watkins *et al*. 1985; Rendell and Gordon 1999) and Parsons *et al.* (2000) reported a significant decrease in minke whale sightings during NATO exercises in West Scotland, during which active sonar was being used by military vessels.

Rowles *et al*. (2000) reported that of 49 reports of beaked whale mass strandings, 8 have been associated with military activities, and all of those have involved Cuvier's beaked whale, *Ziphius cavirostris,* as the principal species (see also Simmonds and Lopez-Jurado, 1991).

Professor Hal Whitehead (a renoun whale biologist) comment on the significance of these data, in a letter to Donna Wieting of NMFS (the US National Marine Fisheries Service) dated May 1, 2001, wrote:

"The International Whaling Commission's Standing Working Group on Environmental Concerns reported that 8/49 beaked whale strandings, and 6/6 multiple species beaked whale strandings occurred with "military activities". We do not know the rate of occurrence of "military activities", but, by assuming rates, it is possible to calculate the probability of these numbers of coincidences (or more) between strandings and military activities, under the null hypothesis that they are unrelated. In fact the probability that 8/49 (or more) beaked whale strandings occurred with military activities to be greater than p=0.05 (the usually accepted level for rejection of a null hypothesis), military activity would have had to occur more than 8.4% of the time, and for the probability that 6/6 multiple beaked whale strandings occurred with military activities to be greater than p=0.05, military activity would have had to occur more than 60.7% of the time. The actual rate of military activities in any area is probably nearer 0.1%. Thus, the number of strandings of beaked whales with military activities is very unlikely to be a coincidence. Military activities are strongly implicated in these events" (Whitehead *pers comm*.).

Another mass stranding of 17 cetaceans (including two species of beaked whales and minke whales) occurred in March 2000, in the Bahamas. A US governmental report has determined that mid-frequency sonar (3-7 kHz) being used in a US military exercise was responsible for this mass stranding (Weiss, 2001). Researchers reported that the whales demonstrated signs of haemorrhaging in the inner ears and cranial air spaces, consistent with impulsive trauma - i.e. intense, loud sound, that did not come from a nearby explosion (Balcomb and Claridge 2001). The levels of sound that would have been received by the whales were estimated to be between 140 dB and 160 dB. The researchers calculated that the frequencies produced by the mid-frequency sonar system employed, at that received level, could cause resonance in the cranial air spaces of the cetaceans (Balcomb and Claridge 2001). This resonance could cause haemorrhaging (as had been observed in the stranded animals), disorientation and an inability to navigate and echolocate. However, this is only one theory. Other possible mechanisms to explain the injuries observed include static or rectified diffusion in which intense acoustic exposure could cause a type of compression sickness in whales (similar to the "bends", as seen in human divers), and perhaps especially the deep divers, by stimulating bubble formation or growth in the whales' tissues (Houser *et al*. 2001). (This matter is considered in more detail later in this report.)

Two sonar systems are currently in the process of being introduced: in the US (SURTASS LFA) and the UK (SONAR 2087). Both rely on low frequency sound to determine military targets. Other countries already operate, or plan to operate, similar systems. There has, however, been considerable concern over these proposed systems, because of:

i. the loudness of the sources;
ii. the distance that the sounds may travel, because of their low frequency nature; and
iii. tests that have demonstrated short-term behavioural changes in cetaceans in response to the sonar. For example, blue and fin whales demonstrated possible vocal responses, gray whales displayed avoidance of the noise during their migration, and humpback whales temporarily stopped singing and lengthened the duration of their song. These responses occurred when the whales received the source at levels of 155dB, and even as low as 115-125dB. The operational source level of the sonar system will, however, be well over 200dB (US Navy 2001), thus potentially exposing any whales in close proximity to much louder levels than those which can induce these observed behavioural changes.

In addition to sonar, submarine-to-submarine communications systems are also a substantial source of submarine sound: the systems produce sounds of 5-11 kHz at source levels of 180-200 dB (Richardson *et al*. 1995). Moreover, explosives used in military tests and exercises can be a considerable source of underwater noise with source levels of 267 dB in a 0.45-7.07 kHz range (Evans and Nice 1996; Perry 1998).

A recent victory for cetaceans came in a 2002 court decision to limit the use of the US Navy LFAS. The area of operation has temporarily been reduced to a large part of the Pacific Ocean focused around the remote Mariana Islands - an estimated area of one million square miles. While this is a substantial area of ocean, it's only about 10-15% of the area for which the U.S. regulators originally proposed permits (NMFS, 2002).

As the military undertake activities in all the waters of the world, their potential encroachment of cetacean habitats is considerable. Because public information on the exact nature and extent of military activities is highly restricted, the total impact of the military's ensonification of the world's oceans will be difficult to quantify.

3.8. Purposeful scaring of marine mammals

3.8.1 Acoustic Harassment Devices (AHDs)

The finfish aquaculture industry suffers predation by seals and other marine mammals and, in response, acoustic harassment devices (AHDs) or 'seal-scrammers' have been developed to deter them from approaching fish farm cages. These devices produce high powered (190-205 dB) omni-directional sounds (10-25 kHz) to frighten and/or induce pain in seals and displace them from the fish farming sites. There is growing evidence illustrating the effects of AHDs on non-target species such as cetaceans (Morton 1995; Olesiuk *et al.* 1995; Taylor *et al.* 1997; Johnston and Woodley 1998; Morton and Symonds, 2002). AHDs are designed to cause pain in seals in an area up to 3000 m^2 around fish cages. Shrimpton (2001) reported on cetaceans that approached up to 15 m from fish farm cages and it is very likely that cetaceans at such close ranges would suffer hearing impairment, extreme pain and possibly physical damage (Taylor *et al.* 1997).

Moreover, AHDs are designed to exclude marine mammals from areas and although designed for pinnipeds, cetaceans would also be displaced, potentially from key habitats. Olesiuk *et al.* (1995) concluded that harbour porpoises are excluded within 400m of an AHD, and abundance is significantly reduced within 3.5 km of a device. Shrimpton (2001) calculated from surveys of AHD use in West Scotland that harbour porpoises would be completely excluded from 16km^2 of coastal waters, and porpoise abundance would be significantly reduced in a total area of 1187 km^2.

Taylor *et al*. (1997) modelled the potential impacts of three brands of AHD on harbour porpoises and determined that the zone of audibility ranged between 2.8 km to 12.2 km, which may represent a significant proportion of coastal habitat, particularly where there are large numbers of aquaculture facilities. This study calculated that physical damage may occur within 7 metres of the source of some devices. Dolman and Simmonds (1998) conducted a field investigation of AHD use in 1997 in Shetland and detected AHDs at three farms up to 600m away with a peak intensity of 60 –70 dB above ambient noise levels. The frequency varied within the sampling time from continuous noise to intermittent 'bleeps'.

One recent development in the field of AHDs is the 'silent scrammer'. This device incorporates a sensor that detects fish panic movements and assumedly the presence of a predator. This then triggers the AHD to sound, startling the predator. While this type of AHD was designed to prevent seals from becoming habituated to the noises produced by AHDs, the sudden burst of sound, at close proximity, could be particularly detrimental to the more sensitive acoustic sensory systems of cetaceans that trigger the AHD.

AHDs are a cause for concern, especially for coastal cetaceans, such as harbour porpoises, bottlenose dolphins, minke and killer whales, in areas with high levels of aquaculture.

3.8.2 Acoustic Deterrent Devices (ADDs)

The Acoustic Deterrent Device (ADD) is an underwater sound-generating device installed to deter marine mammals that may predate on fisheries. The impacts of ADDs may however extend beyond just keeping predators away from nets and fish pens. For example, Carlström *et al.* (2002) commented on the displacement of porpoises from critical habitat and effects on their movement patterns.

The longest term studies of use of ADDs to protect baleen species from entanglement in fishing gear have probably occurred in Canada. Lien *et al.* (1990) noted that such studies have been conducted for over a decade. Todd *et al.* (1992) acknowledged that for the system to be effective, the signal produced must first be detectable or noticed and then, the signal should be associated with the fishing net. They go on to state that at least the first requirement for the development of an alarm has been achieved as humpback and minke whales clearly react to operating alarms.

However they also noted that whales may simply habituate to the sound, or not learn to use it as a cue that indicates the presence of fishing gear.

The predator species concerned, as well as the source level and frequency of the device used, are likely to affect the level of success initially. Yet both AHDs and ADDs may ultimately provide the 'dinner bell' effect, where alarm may give way to eventual habituation to the devices, and even attraction that may be initiated by association of the sound with an easy meal. Therefore, caution is warranted where considering the use of such devices. Studies that have been conducted over a number of years have shown varying results in effectiveness to date.

Participants in a US Department of Commerce workshop (NOAA 1996) have repeatedly emphasised that artificial sound should be introduced into the underwater environment only when the costs and benefits of doing so are clearly understood, and only after the potential ecological consequences have been carefully considered. The does not seem to be the general practice with AHDs and ADDs as they continue to proliferate worldwide, largely as a quick-fix solution. Gordon and Northridge (2001) make some useful general recommendations as well as more specific recommendations on addressing knowledge gaps on the effects of ADDs, improved development of ADDs and on distribution, abundance and biology of vulnerable wildlife. These could equally be applied to AHDs.

3.9. Dredging

Dredging comes in many forms: it can be for removing silt and sediment from the seabed, or as a means of fishing for shellfish. Several studies have documented the effects of underwater noise produced by dredging operations on cetaceans. For example, grey whales avoided the Laguna Guerro Neggro, Baja, California, for several years after dredging operations started in the area (Bryant *et al.* 1984).

In addition, bowhead whales exposed to playbacks of dredger noise recordings at broadband received levels of 122-131 dB were displaced from the area (Richardson *et al.* 1985a, 1985b; 1990; Wartzok *et al.* 1989). Bowhead whales stopped feeding and moved until they were over 2km away from the sound source. Moreover, whale vocalisations decreased and changes in surfacing, respiration and diving patterns were recorded (Richardson *et al.* 1985a, 1985b; Wartzok *et al.* 1989). However, bowhead whales were also observed within 800m of suction dredgers where noise levels of 120dB were detected at 1.2km from the site (Richardson *et al*. 1985b, 1990). Therefore, although dredging has been shown to be a source of underwater noise pollution, further investigation into the effects on marine mammals is required.

3.10. Marine Wind Farms

Offshore wind farms have the potential to make a large contribution to renewable energy production. As a relatively new area of development, there is a lack of detailed information concerning potential impacts on marine life, including cetaceans (see, for example, Vella *et al*. 2001; Henriksen *et al*. 2001).

Possible direct negative impacts might include noise disturbance and habitat loss. There may also be indirect effects on cetaceans, as impacts from the turbines and connecting sub-sea cables may result in changes to the local sediment patterns, which may lead to habitat changes in the vicinity of the wind farm. This may have knock-on effects on local prey species, such as fish and invertebrate populations. Establishing offshore wind farms is a large-scale and long-term activity for which thorough environmental evaluation should be required.

3.11. Research

3.11.1. Controlled Exposure Experiments and 'playback'

To improve the knowledge and understanding of the impacts of anthropogenic noise on short term and observable cetacean behaviour, some efforts have been made to expose cetaceans to specific sounds with the aim of monitoring their responses. Such studies are aimed at filling data gaps that currently exist regarding responses to specific potentially damaging sounds, vulnerabilities of different species, and individual groups within those species (for example mother and calf pairs) and perhaps most urgently, the assessment of auditory thresholds.

A strong case should have to be made that such studies can produce valid results that cannot be achieved by less intrusive means. This approach only allows short-term and well known behaviours to be monitored (Gordon and Thompson 2001) and may have long term implications for those animals involved. The link between possible behavioural responses and the onset of physical damage cannot currently be determined. Further to this, no obvious or measurable response does not mean there is no impact.

Introducing further noise into the marine environment obviously has a potential to negatively affect those individuals that are being targeted, and may also have implications for others.

4. *The Use of Sound by Cetaceans*

Chris Parsons and Sarah Dolman

An understanding of cetacean hearing and aural mechanisms is essential in order to assess the potential effects of anthropogenic noise on them.

Cetaceans live in an environment in which vision is not the primary sense; this is because light does not penetrate far beneath the surface of the ocean. As you dive down from the sea's surface, longer wavelength light is the first to vanish, with red light no longer being visible at depths of 10m, followed by yellow, then green and finally blue light. Hardly any light penetrates depths greater than 200m. Therefore, cetaceans have become reliant upon sound, instead of light, as their primary sense for communication and being aware of their surrounding environment.

Moreover, many cetaceans inhabit underwater environments that restrict visibility further, such as turbid rivers and estuaries, or plankton rich oceanic waters. These species rely on sound even more heavily as their primary sense; with the extreme being the river dolphins, whose visual senses are greatly degenerated to the extent of being limited to the simple detection of dark and light areas.

4.1. Echolocation

Echolocation is the ability by which animals can produce mid- or high-frequency sounds and detect the echoes of these sounds that bounce off of distant objects, to determine the physical features of their surroundings. To date, toothed whales (odontocetes) are the only marine mammals known to produce echolocation sounds.

Echolocation provides accurate and detailed information about the cetacean's surroundings and allows odontocetes to detect objects only a few centimetres across at distances of tens of metres. They can even distinguish differences in the composition of objects that are externally identical (Kamminga and Van der Ree 1976). Echolocation sounds tend to be produced at high frequencies. Bottlenose dolphins produce echolocation clicks in frequencies of 50 kHz up to 130 kHz (Au 1993), whereas porpoises produce echolocation clicks of 110-150 kHz. (Kamminga and Wiersma, 1981). The higher the frequency used by the cetacean, the greater resolution the clicks have (and the smaller an object that can be detected), however, higher frequency sounds have a more limited range underwater.

Echolocation is vital to odontocetes. They not only rely on the process for detecting and catching prey species, but also use it for 'seeing' the environment around them. An odontocete unable to produce or hear echolocation clicks would effectively become 'blind' and presumably quickly die. Even a slightly reduced ability to echolocate would severely impact the health of cetaceans, particularly those inhabiting low visibility habitats such as rivers and estuaries.

4.2. Navigation

Mysticete cetaceans are known to produce low frequency calls of high source level. As low frequency sounds attenuate less quickly in a marine environment, these sounds could theoretically travel great distances. In addition, the hydrography of oceanic water causes the production of submarine sound channels, where water layers of differing temperatures and densities cause sound waves to be concentrated and channelled for great distances (particularly sounds of low frequencies). These sound channels would allow low frequency sounds produced by mysticetes to travel even further.

It has been estimated that a 20 Hz call from a fin whale could be detected at a distance of several hundred kilometres from the calling whale (Spiesberger and Fristrup 1990). It has been suggested that mysticete whales use low frequency calls to orientate and navigate in a way similar to echolocation (Norris 1969; Payne and Webb 1971). Low frequency calls would echo back from the seabed in a fashion similar to a depth sounder (Thompson *et al.* 1979), or distant oceanographic features, such as a continental shelf edge, submarine mountain range or island chain (e.g. Hawaii, the Azores or Bermuda) (Tyack 1997). Such a form of navigation would seem essential to assist whales navigating on their long migrations. Polar-dwelling cetaceans such as the bowhead whale could also use these calls to monitor the location of the ice edge (Ellison *et al*. 1987) which could be vital, not only in finding prey species which concentrate near the ice edge, but also in ensuring that the whale does not travel too far into pack and become trapped.

Unfortunately, many forms of anthropogenic sound are also produced at these low frequencies. A whale unable to migrate or manoeuvre around the ice edge safely due to high levels of anthropogenic noise would presumably have seriously reduced chances of survival.

4.3. Communication

Communication is the production of a stimulus or signal that is received by another organism eliciting a response. Cetaceans communicate within and between species in a variety of ways, although due to the environment in which they the live, as explained above, the majority of this communication is in the form of acoustic signals.

Cetacean communication has a variety of functions such as:

- intrasexual selection;
- intersexual selection;
- mother/calf cohesion;
- group cohesion;
- individual recognition; and
- danger avoidance.

4.3.1. Intrasexual selection

Intrasexual selection, incorporates a variety of behaviours that maintains social orders within the sexes, such as hierarchies of dominance, or maintenance of territories. This type of communication is clearly seen in the humpback whale. It is believed that only the male humpback whales sing and their song has been demonstrated to maintain distances between whales (Tyack 1981; Helweg *et al.* 1992). Aggressive interactions occur between singing humpack whales and other males (Tyack 1982) and similar results have also been recorded for singing minke whales (Gedamke *et al.* 2001).

4.3.2. Intersexual selection

Vertebrate species use vocal calls as an “honest” means of demonstrating their fitness (Davies and Haliday 1978; Clutton-Brock and Albon 1979), the call being a costly and, therefore, honest signal (Zahavi 1987; Grafen 1990a, 1990b). It allows a female to choose the best male possible to father her offspring (ensuring that the offspring would be as healthy and as viable as possible). It seems logical, therefore, that if this is the case in other vertebrates, it is also feasible in cetaceans. It has been suggested that female humpback whales assess the fitness of males as song length would be an honest indicator of male breath-holding ability (Chu and Harcourt 1986).

Norris (1994) studied the effect of boat traffic on the vocal behaviour of humpback whales in Hawaii and discovered that duration of some song elements changed in response to approaches by boats. Miller *et al*. (2000) reported that whale songs lengthened in response to LFA sonar. It is possible that male humpback whales consider an active sonar source to be competition from other male singers, but we can only guess about the full and long-term biological implications of such occurrences. If females are using male song as a way to choose their mate, any changes in the song duration or structure could disrupt cetacean courtship behaviour and the fitness of any offspring that are produced during a disrupted courtship.

4.3.3. Mother/calf cohesion

One of the most important social bonds in cetaceans is that between a mother and her calf. A cetacean calf may stay with its mother for up to a decade (or even throughout its life in some species) and the calf learns important life skills, such as foraging and social behaviour during this period. Communication is required between the mother and her calf to maintain this bond. Dolphins do this via unique whistles: if a mother and calf are separated in the wild they start whistling at high rates (Sayigh *et al.* 1990). Calves will also whistle in order to bring the mother closer (Smolker *et al.* 1993). If anthropogenic noise disrupts this communication it could lead to the severe debilitation and even death of a dependant calf. Van Parijs and Corkeron (2001) reported that groups of Indo Pacific humpback dolphins containing mother/calf pairs significantly increased the rate at which they produced whistling vocalisations when boats were present and these data suggest that mother-calf pairs are affected by transiting boat traffic.

4.3.4. Group cohesion

Cetaceans frequently form groups and co-operate, and co-ordinate, with group members to forage. Co-ordinated herding of prey allows cetaceans to catch larger and greater quantities of prey. In order to co-ordinate, these groups need to be able to communicate effectively. One of the best examples of this is exhibited in killer whales in the eastern North Pacific. In this area, killer whales specialising in feeding on fish form larger social groups. These groups possess distinct calls that are unique to their group members (Ford 1989, 1991). The group specific calls are believed to be important in maintaining group cohesion. Moreover the groups produce different types of calls according to the type of behaviour they are engaged in, whether foraging or resting, this supports the notion that killer whales possess specialised calls used during different activities. It is conceivable that without this form of communication, group foraging would break down and the animals would be less successful at catching prey.

4.3.5. Individual recognition

Caldwell and Caldwell (1965) reported that dolphins produced whistles that were unique to individual animals. These whistles are believed to play an important role in the recognition of individual animals. The whistles can, for example, allow individual dolphins to distinguish closely related animals from others (Sayigh *et al.* 1999). Individual recognition would play an important role in the behaviour of sociable animals such as cetaceans (Tyack 1986a, 1986b), allowing animals to identify relatives, form alliances, and aid in co-ordinated behaviours such as foraging and repelling competitors or predators.

4.3.6. Danger avoidance

Many vertebrate species produce alarm calls, many of which provide information as to the type of threat, so that group members can respond appropriately (e.g. Seyfarth *et al.* 1980; Cheney and Seyfarth 1985). Cetaceans are vulnerable to predation by several marine species such as sharks (Cockcroft 1991) and killer whales (Jefferson *et al.* 1991). Although there are few data recording specific alarms calls produced by cetaceans encountering predators, several studies have documented increases in certain odontocete calls believed to be 'alarm' calls, in response to boat traffic (Findley *et al.* 1990; Lesage *et al.* 1999). The potential biological impacts of a cetacean unable to hear or distinguish an alarm call are obvious.

4.4. Prey stunning

Another use of sound by cetaceans may be to debilitate and stun prey. Several researchers have remarked upon the fact that production of intense sound sources could be used by cetaceans when foraging (Berzin 1972; Norris and Møhl 1983; MacKay and Pegg 1988). Certainly, intense sound waves directed at fish bearing air-filled swim bladders could cause rapid pulsations of the swim bladders and cellular damage. Sound waves could also cause the reverberation of microscopic bubbles contained in seawater, and if this seawater was in a fishes' lateral line or around the gills, it would cause tissue damage (Miller and Williams 1983). It has, moreover, been demonstrated experimentally that acoustic pulses can be used to stun fish (Zagaeski 1987). Information on cetaceans using this method to catch prey is limited, but plausible, and would encompass another way in which cetaceans use sounds for vital biological processes.

4.5. Acoustic sensitivities of cetaceans

At present, the sensitivity of cetacean hearing to various sound frequencies has been conducted by series of behavioural experiments. Simply, these involve playing sounds of various frequencies and intensities to captive cetaceans, where the cetaceans indicate whether the sounds are detected. These experiments produce audiograms, u-shaped curves that give the threshold acoustic intensity (in dB) above which cetaceans can hear sounds of varying frequencies.

Toothed cetaceans are capable of hearing sound over a broad frequency range, with a specialisation for higher frequencies (Nachtigall *et al*. 1998). Their sensitivity to high frequency sounds is related to their use of relatively high frequency sounds for communication and high frequency pulses for echolocation.

Of the species for which auditory sensitivity has been studied, e.g. beluga whale, false killer whale, bottlenose dolphin, harbour porpoise and Risso's dolphin, sensitivity is greatest over 10kHz (Au *et al.* 1997; Kastelein *et al.* 1997; Ridgeway *et al.* 1997). The upper limits of auditory sensitivity are believed to range from 31kHz in the killer whale to over 150kHz (Richardson *et al.* 1991).

Most man-made noise is below 10kHz in frequency and behavioural experiments have shown that hearing thresholds increase and hence sensitivity to sounds of these frequencies decrease for beluga whales and bottlenose dolphins. Sensitivity to sounds is poor below 1kHz. Au *et al.* (1997) and Nachtigall *et al.* (1998) determined that at 75Hz, false killer whales and Risso's dolphins have auditory thresholds of 140dB, that is to say sounds with a frequency of 75Hz must be over 140dB before they can be heard.

However, despite the reported low auditory sensitivity of beluga whales to low frequencies (Awbrey *et al.* 1988; Johnson *et al*. 1989) they were able to detect, and reacted to, low frequency noises at distances of up to 85km. The beluga whale reactions occurred at a distance much greater than would have been predicted by mathematical sound propagation models, using data on auditory thresholds (the minimum sound level required before an animal can hear a sound of a certain frequency). Acoustic sensitivity data gathered from captive animals predicted that beluga whales would not have been able to hear the approach of shipping vessels any greater than 20km away (assuming a threshold of 104 dB re 1μPa at 1 kHz; Johnson *et al.* 1989). It can not be completely ruled out, however, that the belugas were reacting to higher harmonics of the generally low frequency shipping noise or that modelled propagation conditions did not represent actual conditions.

Most auditory sensitivity experiments are conducted on cetaceans in captivity. The tanks in which captive cetaceans are kept frequently have a high level of ambient noise from human activities nearby, machinery associated with the tanks (filters, pumps and chillers) and the nature of the tanks often causes cetacean vocalisations and echolocation clicks to reflect multiple times, further ensonifying the tanks. It is highly likely that animals kept in such environments may suffer some hearing impairment through living in a high noise environment. Doubt, therefore, should be placed on studies of cetacean hearing capabilities produced in captive environments, and free-ranging cetaceans are likely to be more sensitive to sounds, at lower levels, than portrayed in the cited studies above.

In addition, low frequency sounds may be detected by some mechanism other than conventional hearing. This has been suggested to be the case for bottlenose dolphins (Turl 1993) when research showed that bottlenose dolphins could detect frequencies of only 50-150Hz. The skin of toothed whales is extremely sensitive (Palmer & Weddell 1964; Yablokov *et al.* 1974) and sensitive to vibrations (Ridgeway 1986) or small pressure changes in the area surrounding the eyes, blowhole and head region (Kolchin and Bel'Kovich 1973; Bryden and Molyneux 1986). These authors suggest that dolphin skin receptors can detect changes in hydrodynamic and hydrostatic pressure, including low frequency sound.

Most studies investigating the acoustic sensitivities of cetaceans are, as mentioned above, conducted on captive animals. As mysticetes are too large to keep in captivity, experiments have largely not been conducted to determine to auditory sensitivity of baleen whales. Ridgeway and Carder (2001), however, attempted to determine the auditory sensitivity of a stranded and rehabilitated gray whale calf. This study suggested that the calf was most sensitive to frequencies of 3 kHz, 6 kHz and 9kHz although the authors had difficulties in obtaining definitive results from the experiment (Ridgeway and Carder 2001). However, behavioural reactions from gray whales in the wild to differing frequencies, suggest that they are most sensitive to frequencies of between 0.8 and 1.5 kHz (Dalheim and Ljungblad 1990).

4.6. Cetacean vocalisations

The vocalisations of cetaceans also give us an idea of their hearing sensitivities, i.e. we expect that they will have very sensitive hearing for sound frequencies that are the same as their social calls and echolocation clicks. Cetacean vocalisations extend over a wide range of frequencies from the ultrasonic pulses of porpoises (130-150 kHz) (see Table 4.1) to the low frequency moans of blue whales (10-15 Hz) (Table 4.2).

Table 4.1. Summary of sound frequencies used by selected toothed whales (odontocetes) for communication and echolocation.

Species		**Frequency range (kHz)**	**Reference**
Delphinapterus leucas	Whistles Pulsed tones Misc. vocalisations Echolocation clicks	0.26-20 0.4-12 0.5-16 40-60, 100-120	Schevill and Lawrence 1942; Au *et al*. 1985, 1987; Sjare and Smith 1986a, 1986b; Au 1993
Delphinus delphis	Whistles Chirps Barks Clicks	2-18 8-14 <0.5-3 0.2-150	Busnel and Dziedzic 1966 Caldwell and Caldwell 1968; Moore and Ridgeway 1995
Grampus griseus	Whistles Rasps Echolocation clicks	1.9-23.7 0.1-8+ 65	Caldwell *et al.* 1969; Watkins 1967; Au 1993
Globicephala melas	Whistles Clicks Echolocation clicks	1-8 1-18 6-11	Busnel and Dziedic 1966; Taruski 1979; Steiner 1981; MacLeod 1986
Hyperoodon ampullatus	Whistles Clicks Clicks (only)	3-16 5-26+ 2-26	Winn *et al.* 1970 Hooker and Whitehead 2002
Kogia breviceps	Clicks	60-200	Santoro *et al.* 1989; Caldwell and Caldwell 1987
Lagenorhynchus albirostris	Squeals Whistles Echolocation clicks	8-12 3.4-16.4 up to 325	Watkins and Schevill 1972; Mitson 1990
Lagenorhynchus acutus	Whistles	6-15	Steiner 1981
Monodon monoceros	Pulsed tones Whistles Click	0.5-5 0.3-18 40	Ford and Fisher 1978; Møhl *et al*. 1990
Orcinus orca	Whistles Click Scream Pulsed calls Echolocation clicks	1.5-18 0.1-35 2 0.5-25 12-25	Schevill and Watkins 1966; Diercks *et al.* 1971; Diercks 1972; Steiner *at al.* 1979; Awbrey *et al*. 1982; Ford and Fisher 1983; Morton *et al.* 1986; Moore *et al.* 1988
Phocoena phocoena	Clicks Echolocation clicks	2 110-150	Busnel *et al.* 1965; Busnel and Dziedzic 1966; Schevill *et al.* 1969; Møhl and Andersen 1973;

			Kamminga and Wiersma 1981; Akamatsu *et al.* 1994.
Physeter macrocephalus	Clicks	0.1-30	Backus and Schevill 1966; Levenson 1974; Watkins 1980a, 1980b
Pseudorca crassidens	Whistles Echolocation clicks Echolocation clicks	1.87-18.1 25-30 95-130	Busnel and Dziedic 1968; Kamminga and Van Velden 1987; Thomas and Turl 1990
Stenella coeruleoalba	Whistles	1.1-24+	Smyth 1994
Tursiops truncatus	Whistles Click Bark Low frequency calls Echolocation clicks	0.8-24 0.2-150 0.2-16 0.05-0.9 110-130	Lilly and Miller 1961; Evans and Prescott 1962; Caldwell and Caldwell 1967; Diercks *et al*. 1971; Evans 1973; Au *et al.* 1974; Tyack 1985; Caldwell *et al.* 1990; Turl 1993; Schultz and Corkeron 1994; Schultz *et al.* 1995 Wang *et al*. 1995

Table 4.2. Summary of sound frequencies used by selected baleen whales (mysticetes) for communication.

Species		Frequency range (kHz)	Reference
Balaena mysticetus	Calls Moans Pulsive sounds Song	0.1-0.58 0.025-0.9 0.025-3.5 0.02-0.5	Thompson *et al.* 1979; Ljungblad *et al.* 1980, 1982; Norris and Leatherwood 1981; Clark and Johnston 1984; Würsig *et al.* 1985; Clark *et al*. 1986; Cummings and Holliday 1987; Würsig and Clark 1993
Balaenoptera acutorostrata	Down sweeps Moans, grunts Ratchet Sweeps, moans Thump trains	0.06-0.13 0.06-0.14 0.85-6 0.06-0.14 0.1-2	Schevill and Watkins 1972; Winn and Perkins 1976
Balaenoptera borealis	Sweeps	1.5-3.5	Thompson *et al.* 1979; Knowlton *et al*. 1991
Balaenoptera musculus	Moans	0.012-0.4	Cummings and Thompson 1971, 1994; Edds 1982; Stafford *et al*. 1988
Balaenoptera physalus	Clicks Constant call Moans Moans, downsweeps Moans, upsweeps Pulses Ragged pulse Rumble Whistles & chirps	16-28 0.02-0.04 0.016-0.75 0.014-0.118 0.03-0.075 0.018-0.075 <0.03 0.01-0.03 1.5-5	Thompson *et al.* 1979; Watkins 1981b; Cummings *et al.* 1986 Watkins *et al.* 1987; Edds 1988; Clark 1990; Cummings and Thompson 1994
Eubalaena australis	Pulsive calls Tonal calls	0.03-2.2 0.03-1.25	Cummings *et al.* 1972; Clark 1982,1983
Eubalaena glacialis	Call Moan	<0.4 <0.4	Watkins and Schevill 1972; Thompson *et al.* 1979; Spero 1981; Clark 1990
Eschrichtius robustus	Call Clicks FM sweep Moans Modulated pulses Pulses	0.2-2.5 0.1-20 0.1-0.35 0.02-1.2 0.08-1.8 0.1-2	Cummings *et al*. 1968; Fish *et al.* 1974; Norris *et al.* 1977; Swartz and Cummings 1978; Dahlheim *et al.* 1984; Moore and Ljungblad 1984; Dahlheim and Ljungblad 1990;
Megaptera novaeangliae	Grunts Horn blasts Moans Pulse trains	0.025-1.9 0.41-0.42 0.02-1.8 0.025-1.25	Thompson *et al*. 1979; Watkins 1981b; Edds 1982, 1988; K. Payne *et al.* 1983;

	Song	0.03-8	Payne and Payne 1985;
	Social calls	0.05-10	Silber 1986;
	Shrieks	0.75-1.8	Thompson *et al.* 1986
	Slaps	0.03-1.2	

5. Noise as a problem for cetaceans

Chris Parsons and Sarah Dolman

5.1 Particular cetacean vulnerabilities

Lack of knowledge means that risk assessment for cetaceans is most often based on assumptions. For example, it is assumed that those cetacean species with a hearing range within the range of an introduced sound are likely to be most affected by the sound (with the possible exception of explosions and other such impulsive signals). Certain individuals within a group might be considered more vulnerable to noise; for example, mother and calf pairs. Similarly, those species with a poor conservation status, for example, endangered species, may be given special attention. The significance of introduced noise might also be given a higher priority where geographical and/or seasonal areas of critical habitat have been identified.

Deep-diving species such as the sperm and beaked whales may also be vulnerable as they travel into zones where noise may be concentrated. These animals leave the surface with enough oxygen in their organs and blood to sustain the dive, but may not have reserves to swim away from intense and unexpected noise (Simmonds and Dolman 1999). An individual may not have the capacity, particularly towards the end of its dive, to swim away from the introduction of an intense noise source.

5.2 Short-term observations

It cannot be assumed that no biological consequences result from exposure to loud noises where no behavioural response is measured. However, in terms of determining if a noise is significant, consideration of behavioural responses might provide useful information. Identification of significant behavioural responses requires that a cetacean's normal behaviour (within the particular circumstances under which they are exposed to the noise) is well categorised and that changes to it must be measurable and be able to be linked to the noise disturbance. It also requires researchers to be able detect changes in this behaviour, something which is particularly difficult with animals which spend so much of their time out of sight, submerged beneath the surface.

5.2.1 Disturbance and displacement reactions

Human-introduced noise has been documented to induce short-term behavioural reactions including cessation of feeding, socialising and vocalising, changes in diving behaviour as well as avoidance or attraction. In addition, noise has been documented as causing displacement of cetaceans from preferred habitats. If these impacts were of only short duration they would not necessarily be significant. However, if these disturbances are repeated or are of long duration, they may cause stress, debilitation and ultimately mortality.

Approach, as well as avoidance of a noise source, should be considered as disturbance, because an animal has altered its natural behaviour (Moscrop and Swift 1999). Individuals have been seen to directly approach and investigate loud sources of noise which may place them in greater danger.

Yet, displacement from a key habitat could have profound effects. Disturbance and displacement reactions caused by shipping traffic, for example, may have a significant negative impact and perhaps particularly in discrete coastal populations. These animals are besieged by a variety of anthropogenic factors that make their existence difficult (e.g. high contaminant loads, over-fishing, sewage-contaminated habitats etc.). The effective loss of important habitats (e.g. feeding grounds) could deteriorate these populations ever further, leading to increased morbidity and mortality.

There is a vast collection of evidence of cetacean reactions to boat traffic and shipping noise. Reviews of the scientific literature documenting these reactions are summarised in Annex A3.

Fright, avoidance and changes in behaviour and vocal behaviour, have been observed in both Mysticeti and Odontoceti over a range from tens to hundreds of kilometres (Gordon *et al*. 1998). These effects have also been documented in some fish and invertebrates (Swan *et al*. 1994). Other marine species have been shown to react to human-induced noise (seismic airguns) at similar levels to cetaceans, including green *Chelonia mydas* and loggerhead *Caretta caretta* sea turtles and squid *Sepioteuthis australis* (McCauley *et al*. 2000).

It should be noted that even where there is no measurable behavioural response, it can not be assumed that no biological consequences are resulting from exposure to loud noises. Gordon *et al.* (1998), for example, found no measurable response from sperm whales to ATOC-like sounds based on blow rate patterns. Responses such as shorter blow intervals would suggest that these animals are disturbed, as might more rapid swimming, leading to increased energy expenditure; and might lead to the development of a lactic acid deficit. Cetaceans have finely balanced energy budgets and this type of behaviour could lead to loss of general or reproductive fitness if prolonged. Humpback whales subjected to explosions showed no obvious response, but local entanglement rates, and thus mortality, increased (Todd *et al*. 1996).

Table 5.2.1. Possible impacts of noise on cetaceans (after Simmonds and Dolman, 1999)

Physical

Non Auditory

- Damage to body tissue
- Induction of the "bends"

Auditory

- Gross damage to ears
- Permanent hearing threshold shift
- Temporary hearing threshold shift

Perceptual

- Masking of communication with conspecifics
- Masking of other biologically important noises
- Interference with ability to acoustically interpret environment
- Adaptive shifting of vocalisations (with efficiency and energetic consequences)

Behavioural

- Gross interruption of normal behaviour (i.e. behaviour acutely changed for a period of time)
- Behaviour modified (i.e. behaviour continues but is less effective/efficient)
- Displacement from area (short or long term)

Chronic/Stress

- Decreased viability of individual

Increased vulnerability to disease
Increased potential for impacts from negative cumulative effects (e.g. chemical pollution combined with noise-induced stress)
Sensitisation to noise (or other stresses) – exacerbating other effects
Habituation to noise – causing animals to remain close to damaging noise sources

Indirect Effects

Reduced availability of prey.
Increased vulnerability to predation or other hazards, such as collisions with fishing gear, strandings, etc.

5.2.2 Masking of biologically important sounds

Anthropogenic noise can be of such a frequency and intensity as to clash with and cover up biologically important sounds, making them undetectable by cetaceans. Biologically important sounds include:

- Echolocation clicks for finding prey;
- sound cues from conspecifics, prey or predators;
- courtship or group cohesion vocalisations;
- those for navigational aid; and
- calls between mothers and calves.

Masking these sounds will make it more likely that cetaceans will be unable to feed; more likely that they will be attacked by predators; and unable to socialise, reproduce or rear their young properly. Thus, calf production and health in cetacean populations would likely be reduced and mortality rates increased.

In order for a cetacean to detect and respond appropriately to sounds, it must be able to locate them. It has been generally assumed that marine mammals will respond to loud noises by moving away. However, this response requires them to be able to both localise the source and recognise it as a threat. Unknown noises could invoke responses of curiosity or, if they were mistaken for a competitor (for example, another noisy male), even aggression.

5.2.3 Social disruption

Social disruption brought about by noise may be especially important if mother/calf pairs become separated. Animals resting or with small calves could be weak and vulnerable to predation and exhaustion (McCauley *et al*. 1998). The potential continual dislocation of these animals may have serious consequences at the population level.

5.2.4 Depth of animal

A cetacean may experience different sound levels depending on the depth at which they are encountered. Sound levels to which marine mammals are exposed while near the surface and visible, are often unrepresentative of those received when they are out of sight below the surface. For some underwater sources, especially those emitting low frequency sound, pressure release and Lloyd mirror effects may cause lower levels near the surface.

5.3 Longer-term impacts

Noise is clearly biologically significant if it induces long-term abandonment of an area important for feeding, breeding or rearing the young, as it may lead to reduced fecundity, carrying capacity, or both (Richardson 1997). Consequences will not become apparent until more research is conducted into the long-term effects of noise pollution.

5.3.1 Sensitisation and habituation

Sensitisation occurs, when, for example, an animal has been exposed to a painful level of noise from a particular source, causing it to avoid the source. Habituation occurs when the stimulus is no longer novel although adverse consequences may still be associated with it. Weilgart (1997) noted that damage from very intense sound might not be obvious at sea, especially in the short-term. Marine mammals are intractable animals to study in the wild and auditory damage is almost impossible to detect in free-ranging large whales. Gradual deafness might easily be misinterpreted as a growing tolerance or habituation to noise.

5.3.2 Stress

Stress is a condition often associated with the release of adrenocorticotrophic hormone (ACTH) or cortisol. It is recognised that noise and disturbance lead to an increase in activity of glands producing these hormones (Welch and Welch 1970). Increases in these hormone levels are usually associated with changes in behaviour, such as increased aggression, changes in respiration patterns or altered social behaviour. However, noise-induced stress may be present but does not necessarily cause overt changes in behaviour (Thomas *et al.* 1990).

Prolonged noise-induced stress can lead to debilitation, e.g., in fish and invertebrates, prolonged exposure can induce infertility, pathological changes in digestive and reproductive organs and reduced growth (Banner and Hyatt 1973; Lagadere 1982). Prolonged exposure to high levels of noise and the resultant chronic activation of stress-related hormonal complexes could lead to harmful effects in cetaceans (Seyle 1973; Thomson and Geraci 1986; St Aubin and Geraci 1988), for example:

- Arteriosclerosis (Radcliffe *et al.* 1969)
- Nutritional problems (Smith and Boyd 1991)
- Stomach ulceration (Brodie and Hanson 1960)
- Suppression of reproductive function (Moberg 1985)
- Reduction in resistance to infection (Cohn 1991).
- Decrease in life expectancy (Small and DeMaster 1995)

5.3.3 Physiological damage to tissues and organs

The sudden pressure changes cause by intense noise can result in actual physiological damage. Ketten (1995) divides the physiological effects of intense noise into two categories:

1) Lethal blast injuries;
2) Sub-lethal acoustic trauma.

Lethal effects are those that result in the immediate mortality or serious debilitation of animals in or near an intense noise source (e.g. submarine blasting). Sub-lethal effects occur when sound levels exceed the ear's tolerance, i.e. auditory damage results from metabolic exhaustion or over-extension of one of the ear's components. Sub-lethal, noise-induced trauma is possible as a result of high levels of shipping noise, for instance. Sub-lethal impacts can lead indirectly to death in cetaceans as they render animals unable to detect prey or predators and also make them unable to orientate and avoid shipping traffic or obstacles.

Ketten (1995) divides acoustic trauma resulting from intense noise levels into three categories:

1) Mild (recovery possible), e.g. pain, vertigo, tinnitus, hearing loss, tympanic tears.
2) Moderate (partial hearing loss), e.g. otis media, tympanic membrane haematoma, serum or blood in the inner ear, dissection of the mucosa.
3) Severe (permanent hearing loss and damage), e.g. ossicular fracture or dislocation, round/oval window rupture, CSF leakage into the inner ear, cochlear and saccular damage.

Sound at any level can cause hearing damage by decreasing auditory sensitivity. One of the most common mild traumatic effects is a threshold shift. The auditory threshold of a sound is the minimum level of intensity at which a sound can be heard. After this level of auditory trauma, the threshold becomes higher and hearing sounds becomes more difficult. Threshold shifts may be temporary (TTS), or can be permanent with greater intensities of noise. Multiple or longer periods of exposure to noise levels causing TTS can also cause permanent threshold shifts (PTS). These threshold shifts are caused by hair cell fatigue, hair cell damage or nerve degeneration.

Submerged humans exposed to underwater source sounds at intensities of 150-180 dB (re 1 μPa; 0.7-5.6 kHz) suffered TTS. This could be used as a rough guideline for sound intensities that could cause TTS in cetaceans, though the greater sensitivity of the cetacean ear and the more efficient coupling of sound with the cetacean body may require a more conservative view.

It has been suggested that some hearing impairment has led to the deaths of sperm and humpback whales in industrial areas as they are unable to detect potential threats e.g. boat traffic and fishing gear (Lien *et al.* 1993; Andre in Moscrop 1997).

Significant, physiological impacts repeatedly go undetected, as we don't have the ability to detect and assess them. Even carcasses are very rarely encountered at sea, as they sink relatively quickly. There is no way to quantify such impacts.

5.3.4. Understanding of biological significance

The impact of noise pollution on non-migrating animals or animals engaged in a more localised activity such as calving or feeding is probably most significant over the longer term. For example, continual displacement from these areas by sustained noise pollution could have a much more profound and serious effect on individual animals at a population level.

Consequences will not become apparent until more research is conducted into the long-term effects of noise pollution. This is difficult in areas where minimal information about cetacean distribution is available.

5.4 Indirect impacts

The above impacts of noise are all direct impacts, i.e. they can directly affect the behaviour or physiology of cetaceans. Noise could also have indirect impacts on cetaceans as the result of changing the distribution of prey species or other aspects of the ecosystem.

Reduced catch rates for several species of fish have been reported in highly ensonified areas (see sources in McCauley 1994). Skalski *et al.* (1992) demonstrated that catches in *Sebastes* spp. decreased by 50% when exposed to anthropogenic noise from oil exploration. Dalen and Knutsen (1986) found decreases of 54% for pelagic fish and 36% for demersal fish when exposed to similar noise sources, whilst Engas *et al.* (1993) documented a 70% reduction in cod and haddock catches within 3 miles of sound sources used in oil exploration and a 45% decrease in catches within 18 miles of the sound sources.

McCauley *et al.* (2003) exposed some species of Australian marine fish to received levels from an airgun at 180 dB re 1µPa over the range of 20 – 100 Hz. The results of the study suggested that airguns damage sensory hair cells in fish.

In summary, high levels of anthropogenic noise resulting from human activities will probably cause a decrease in fish stocks within the impacted area that could be detrimental to cetaceans.

5.5 Cumulative impacts

Long-term displacement from a habitat has not been studied extensively, but the short-term responses reported suggest that repeated noise exposure might have cumulative negative effects (Richardson *et al.*, 1991). Cumulative or synergistic effects of all such stresses can be expected to affect individual viability, reduction in calving rates and increases in mortality.

5.6 A New Concern: Is noise causing decompression sickness in cetaceans?

John Potter and Sarah Dolman

At the point that we were almost signing off on this whole report, new information came to our attention concerning another way in which cetaceans may be being harmed by exposure to powerful acoustic sources. Whilst investigations and understanding about this concern are still in their very early stages, the editors still felt that this issue was highly important and it was appropriate to include an introduction to the ideas here. It is quite likely that the short overview presented here will be swiftly overtaken by new research.

Until recently, concerns about the immediate acoustic impacts on cetaceans have been predominantly focused on the organs of hearing. This may have been due, at least in part, to the focus of research effort on auditory systems. This has seemed logical and especially because of our experience with other species, including our own. There is also evidence to show that cetacean auditory systems can be, and have been, damaged by military activities (Degollada *et al.* 2003) and by other noise sources, including explosions and shipping activity (for example, Todd *et al.* 1996 and André and Degollada, 2003).

However, for sometime now, other symptoms in cetaceans resulting from exposure to powerful sounds have also been suggested. For example, there is the possibility that acoustic fields might cause gas filled organs to resonate and be damaged (Crum 1984). The complex sinuses in the heads of cetaceans, and other organs, could be harmed in this way by a received acoustic field of a specific frequency and sufficient intensity.

Most recently, a third mechanism of harm has also been considered. This theory is now focusing people's attention as a result of pathological studies of animals that have died in unusual circumstances, including around the Bahamas (Evans and England, 2001), the Canary Islands (Fernández *et al.* 2003), and the UK (Jepson *et al.* 2003), where deaths appeared, at first, to be natural.

Cetaceans have a range of highly specialised adaptations to allow them to dive. They include the ability to hold large concentrations of dissolved gases in their blood and other organs. However, it appears that under certain circumstances, gas (principally nitrogen) comes out of solution, forming significant bubbles that, in turn, can grow and make damaging 'holes' in tissues. The principle means of injury may not be in causing 'holes' in tissues, but in blocking the passage of blood, and hence oxygen, to tissues as gas bubbles obstruct narrow blood circulation pathways. This process is known as Decompression Sickness (DCS). Initial attention on how DCS might occur in the presence of sound was focussed on the growth of bubbles by a process known as rectified diffusion, where an acoustic field pulses bubbles and can effectively pump gas into them, inflating the bubbles, in both saturated and super-saturated tissues (Crum and Mao, 1996 and Houser *et al.* 2001). This process appears to be significant only for very high levels of received sound, perhaps 210 dB re 1 μPa or more, even for super-saturated tissues. A more recent idea is that, in the highly super-saturated tissues (perhaps 300% or more) that can exist in deep-diving marine mammals on surfacing after a long dive, there could be a mechanism whereby an acoustic field could trigger the activation of previously stabilized microbubbles, following which the process of static diffusion would proceed to inflate the bubble even in the absence of further acoustic impact.

Sufficiently large bubbles can be observed as 'holes' in tissues, hemorrhages and fat emboli in vital organs (for example the liver) and in the acoustic organs and are consistent with decompression sickness (DCS) as seen in humans. We expect cetaceans to have evolved not to be susceptible to DCS during their normal activity, but by the very nature of evolutionary pressure on development, we do not expect that deep-diving marine mammals would have developed mechanisms with a safety margin any larger than was necessary, and certainly not to deal with anthropogenic triggers such as loud acoustic fields. So, in the case of species such as beaked whales it is possible that they have not evolved a large safety margin, given their necessity to exploit extreme ecological niches (i.e. long, deep dives in search of prey) (Goold, *pers. com*.).

Acoustically-triggered DCS in cetaceans is postulated to come about in one of two ways. Either as a behavioural modifier, where the presence of an acoustic field might induce unusual and undesirable behaviour in a deep-diving marine mammal perhaps in particular shortly after surfacing, or by direct physical activation of previously stable microbubbles.

For example, a loud acoustic signal might cause an animal to dive or surface unusually quickly, erratically or in some way that increases its DCS risk. Some deep-diving marine mammals are known to take a number of shallow dives after surfacing from a deep foraging dive (Balcomb, *pers. comm.)* reminiscent of the safety and decompression stops that human divers perform to mitigate DCS risk after deep diving. Depending on the propagation conditions and frequency, it is possible that an acoustic field might be significantly less intense directly below the surface compared to at a few metres depth, and certainly much less intense just above the water than just below. Seeking to avoid the noise, a marine mammal might thus be encouraged to spend time at the surface instead of in a shallow dive, thus failing to perform the DCS risk-reducing behaviour that it would normally display. Another behavioural modification that could increase DCS risk would be to induce the animal to exert greater muscular effort, leaping or swimming rapidly to avoid the sound, since physical activity is known to increase DCS risk in human divers.

Alternatively, 'Acoustically-Triggered Cetacean DCS' could be the direct result of exposure to a powerful acoustic field, where a decompression-like condition is brought on because sounds directly activate previously stable microbubbles, allowing them to grow by static diffusion from super-saturated tissues. The precise mechanisms of how sound might precipitate bubble formation are being considered and may form the focus of important debate for some time.

Whatever the causes, scientists are finding both chronic and acute forms of this condition in the handful of animals that they have looked at so far. Some cetaceans appear to be affected yet do not die immediately. They may continue to survive at least for a while with chronic tissue damage.

The animals that were involved in the Bahamas stranding showed various signs of trauma that was similar to DCS (Evans *et al.* 2002). In fact, Crum and Mao (1996) reported that computations made in their article suggest that a diver or a marine mammal located in the *near vicinity* of a sonar dome is under considerable risk from gas bubble growth and its associated consequences. But this would only be at very high levels, where direct trauma tissue damage would already be an issue in the hearing complexes.

However, it is relatively unlikely that a marine mammal will come into the extremely intense sound zone in the immediate proximity of a sonar dome. It is more likely that animals will be exposed to lower sound levels over a much wider area (sound intensity decays at increasing distance from the source). The worry is that even at these reduced sound levels it may be possible for bubble growth to be activated in a whale's body, by mechanisms that are not yet understood. In addition, if the whale is 'panicked' to the surface by a loud and discomforting noise, then 'the bends' may take effect as it does in human divers. The report from the Bahamas stranding incident suggests that the whales were not exposed to sound levels that would normally be thought to be physiologically damaging, yet the whales showed signs of internal bleeding that appeared to be acoustically induced (Goold, *pers. com*.).

Whatever the precise cause and mechanism of bubble growth, we currently have no idea at what exposure levels this effect is being induced, nor are we sure that it is being induced at all. This means that no safety limits for exposure can be set, although levels at which physiological damage is known to occur can be alluded to.

6. Examples of regional and national legal instruments protecting marine wildlife from noise pollution

Mark Simmonds

A brief review is provided here of some international and national law that relates to cetaceans, disturbance and noise, with particular reference to "whale watching" activities, where concerns about disturbance are best developed.

6.1 The Ligurian Sea Sanctuary

In November 1999, Italy, France and Monaco signed the Agreement that created the "Ligurian Sea Marine Mammal Sanctuary" (Tethys, 2002). The designated area comprises the Corso-Ligurian Basin and the Golfe du Lion, with Corsica roughly at its centre.

The Agreement concluded by the three states clearly took the UN Law of the Sea Convention (LOSC) into account and includes the following in its preamble:

> "Considering that according to the United Nations Convention on the Law of the Sea, the area in question is in part constituted by waters, with respect to which, each of the Contracting Parties exercises its sovereignty or jurisdiction."

Article 1c of the Agreement specifically recognises harassment by including it within the definition of "take".

In the operative section of the Agreement, Article 6.1 refers to "the fight against any form of pollution" but then Article 6.2 refers explicitly to "toxic substances". Article 7a forbids deliberate take or intentional disturbance and Article 8 deals with "whale watching", stating that it shall be regulated in the Sanctuary.

6.2 The Habitats and Species Directive (COUNCIL DIRECTIVE 92/43/EEC of 21 May 1992)

This is certainly the most important and far reaching environmental legislation in force within the European Community. Like all other EU Directives, the requirements of the Directive should be enacted via the laws of European Union member states and some of its provisions have yet to be fully interpreted. The Directive provides two forms of protection for cetaceans and other marine wildlife.

Article 2 explains that

> "The aim of the Directive shall be to contribute towards ensuring biodiversity through the conservation of natural habitats and of wild fauna and flora in the European territory of the member states, to which the treaty applies."

Article 3 then requires that

> "A coherent European network of special areas of conservation shall be set up… hosting the natural habitat types listed in Annex I and habitats of the species listed in Annex II."

The only cetaceans listed in Annex II are the harbour porpoise, *Phocoena phocoena*, and the bottlenose dolphin, *Tursiops truncatus.*

Article 12 refers to another list of species (i.e. Annex IV, which includes all cetaceans) and establishes a range of measures that should be applied to them. This includes prohibition in their natural range of:
(a) all forms of deliberate capture or killing, and
(b) deliberate disturbance of these species, particularly during the period of breeding, rearing and hibernation.

There are some derogations that apply to these measures but they are outside the scope of this paper.

Since the Directive was passed, national laws will have been modified. For example, in the UK, laws have been amended and, in addition, three bottlenose dolphin Special Areas of Conservation (SACs) have been proposed (these are presently classified as "candidate sites", whilst the European Commission is considering all proposals). No sites for porpoises have been proposed in the UK..

The issue of whether, or not, this Directive applied to the UK's full Economic Exclusion Zone (rather than only territorial waters) was the subject of a recent Judicial Review[4]. Several aspects of the resulting judgement are of interest. Firstly, the presiding judge concluded that the Directive did apply to the UK Continental Shelf and to the "superadjacent waters up to a limit of 200 nautical miles from the baseline from which the territorial sea is measured."

In addition, considerable evidence was submitted to the Judicial Review concerning the threat caused by offshore oil and gas development, including the disturbance it might create. The judge commented:

> "the evidence and materials provided...are to the effect that oil exploration, including seismic activity, is harmful to cetaceans <u>and</u> has serious implications for conservation. There is no real evidence to the contrary before me. I shall proceed on the basis that it is substantially correct."

Amongst the measures currently enacted in UK offshore waters and which might be said to meet the requirements of the Habitats and Species Directive are "Seismic Guidelines", issued to the fossil fuels industry. These guidelines are intended as mitigation in relation to the very loud noises used in marine prospecting.

The UK Countryside and Rights of Way Act, passed in 2000, made "reckless" (in addition to deliberate) disturbance of cetaceans (and basking sharks) an offence.

However, it may be that, in practice, what constitutes 'disturbance' is not presently adequately defined and, similarly, interpretation of the terms "deliberate" and "reckless" may present problems. The IWC Scientific Committee and other expert bodies could play an important role in helping to define these terms.

[4] R v Secretary of State for Trade and Industry, ex parte Greenpeace Ltd ([2000] 2 CMLR 94).

6.3 ASCOBANS and ACCOBAMS

Two regional agreements that are specific to cetaceans have been concluded under the auspices of the Convention for Migratory Species: the 1992 Agreement for Small Cetaceans of the Baltic and North Seas (ASCOBANS), and the 1996 Agreement on the Conservation of Cetaceans of the Black and Mediterranean Seas and Contiguous waters (ACCOBAMS).

The 'purpose' of ASCOBANS is to "maintain a favourable conservation status for small cetaceans" and each party is meant to "apply within the limits of its jurisdiction and in accordance with international obligations the conservation, research and management measures presented in the Annex."

In the Annex Point 1.d commits the Parties to work towards "…the prevention of other significant disturbance, especially of an acoustic nature", and Point 4 in states that

> "Without prejudice to the provisions of paragraph 2 above, the Parties shall endeavour to establish (a) the prohibition under national law of the intentional taking and killing of small cetaceans where such regulations are not already in force."

However, "take" is not defined in the Agreement text.

ACCOBAMS came into force in June 2001. It is the more ambitious of the two agreements and recognises "disturbance" in one preambular paragraph and LOSC in another. Here again, Parties are required to "take co-ordinated measures to achieve and maintain a favourable conservation status for cetaceans" and Article II 4 requires that in implementing the prescribed conservation measures the Parties shall apply the "precautionary principle".

The "Conservation research and management measures" for ACCOBAMS are again spelled out in an annex (Annex 2), where Point 1c requires that Parties shall

> "Require impact assessments to be carried out in order to provide a basis for either allowing or prohibiting the continuation and the future development of activities that may affect cetaceans or their habitat……including…..offshore exploration and exploitation, nautical sports, tourism and cetacean watching, as well as establishing the conditions under which such activities may be conducted."

In the original text of the Act "take" is defined (Article 13) as "to harass, hunt, capture or kill, or attempt to harass, hunt, capture or kill any marine mammals."

More latterly, the ASCOBANS parties have recognised again the threat of disturbance and noise by, for example, passing a resolution on this issue (Resolution No.4) at the last meeting of Parties in 2000 (ASCOBANS, 2002).

Similarly, at the first meeting of ACCOBAMS Parties, a resolution providing a detailed code of conduct for whale-watching was passed (This is provided here in Box 1, as an illustration of whale watching guidelines).

The consequences in practice of the "soft law" provided by such resolutions can only be gauged over time. The guidelines for whale watching agreed by the ACCOBAMS parties are unusual in that they are provided as an exemplary regime for states in the agreement area to follow. The guidelines, which are still under development, are reproduced in full here as Annex A2.

6.4 The US Marine Mammal Protection Act (MMPA)

The 1972 US Marine Mammal Protection Act (MMPA) is often proposed as the exemplary national legal regime for the conservation of cetaceans and is, therefore, important in a wider context than its geographical remit. Whilst a full consideration here of this complicated Act is not within the scope of this chapter, it clearly applies to a large sea area and many species and populations. Baur *et al*. (1999) provide a useful review of relevant US law and commented that

> "the centrepiece of the Act is its moratorium on taking in section 101(a). The moratorium established a general ban on the taking of marine mammals throughout areas subject to U.S. jurisdiction and by any person, vessel or conveyance subject to the jurisdiction of the United States on the high seas.
>
> Take is defined under section 3(13) of the act to mean 'to harass, hunt, capture or kill any marine mammal'".

This early recognition of the importance of harassment for marine mammals was further developed under the 1994 amendments (part of the reauthorisation of the US Act made in that year), when the US Congress provided the following statutory definition of the term "harassment":

"any act of pursuit, torment or annoyance which:

1. <u>Level A Harassment</u> – has the potential to injure a marine mammal or marine mammal stock in the wild; or
2. <u>Level B Harassment</u> – has the potential to disturb a marine mammal or a marine mammal stock in the wild by causing disruption of behaviour patterns, including but not limited to migration, breathing, nursing, breeding, feeding or sheltering" (NMFS, 2002)

6.5. Discussion and conclusions

With regard to noise in the context of disturbance, the Ligurian Sea sanctuary, ASCOBANS and ACCOBAMS all give consideration to disturbance and the first, at least, provides regulation that relates to this factor. Whilst disturbance of marine wildlife was recognised at early as 1972, at least in domestic law in the US, there is growing recognition of this issue in international law, especially that which relates to cetaceans.

Scientifically-supported definitions of what constitutes unacceptable or dangerous noise pollution, disturbance or harassment would help to inform the development and interpretation of existing and future law. The development of such definitions is therefore recommended.

When an earlier version of this chapter was presented to the 2002 meeting of the Scientific Committee of the International Whaling Commission (arguably the foremost international scientific body for cetaceans today) the author suggested that consideration should be "given to the meaning of the term 'harassment' and/or what constitutes unacceptable disturbance". This was considered primarily in the context of whale watching and the response (as noted in the report of the sub-committee on whale watching, IWC 2002a) was as follows

"Some members were of the opinion that this was an extremely difficult task as there are several confounding variable that might affect whale behaviour. In addition the term harassment has legal implications and the discussion should be science-based. The Full Committee (IWC 2002b) concluded that:

1. Persistent changes in cetacean behaviour associated with the presence of whale-watching platforms may indicate a negative effect.

2. Further research is encouraged.

This high level recognition of persistent behavioural changes as a key issue can help to provide direction to future attempts at noise-pollution mitigation and related legislation. The recommendation is clearly not limited in application exclusively to whale watch platforms (because if persistent behavioural change is of significance for this source of disturbance it will be of significance for any other). A common-sense reading of the recommendation would also infer that persistent behavioural change should also be viewed in addition to any direct evidence of physical harm.

The recognition for a need for further research should be coupled, in conservation and management terms, with recognition that responses to noise pollution should be highly precautionary in nature. As discussed elsewhere in this report, a full understanding of the implications of noise pollution for cetaceans is still far away. However, many authorities read the threat as severe and increasing.

The recognition made of disturbance in the legal instruments discussed here, show that a precautionary approach has been initiated in at least some regions.

7. Solutions – mitigation and management

Sarah Dolman

> "*To fully address the adverse effects of noise on the marine environment, it will also be necessary to look at the long-term impact on species, ecosystems and habitats. Appreciating this, acoustic pollution in the marine environment is clearly an issue whose solution remains to be found in the coming decades*" (Dotinga and Elferink, 2000).

The reality is that little is known about the full consequences of noise pollution for cetaceans, particularly in the longer term. The various mechanisms by which marine mammals can be adversely impacted indicate considerable subtlety in the range of interactions, and a great deal of additional effort is required before we can expect to predict and quantify the potential for damage to populations (Potter and Delory 2001). Physiological impacts, as a result of exposure to noise pollution, are almost impossible to study. We currently rely on stranded or bycaught animals and, subsequently, analysis of ears and internal organs, to assess such impacts.

With this limited knowledge, preventing impacts of noise pollution completely is unlikely, short of bringing to an end those activities responsible for producing intense noise. This situation has led to the pursuit of mitigation procedures suitable to minimise observable and short term behavioural impacts, with the aim of reaching commonly acceptable standards.

Mitigation measures are operational techniques designed to reduce the adverse impact on the species or stock and its habitat (Roberts and Hollingshead 2002). Specific measures imposed upon an activity to reduce these impacts will vary depending on the nature and scale of the noise produced, and on the nature of the activity itself.

There are little baseline data on the effectiveness of any mitigation measures (Moscrop and Swift 1999). This is emphasised by the non-uniform way in which sound travels through water (see Chapter 2) and the differing requirements and susceptibilities of different cetacean species, individual members within those groups and the activities being undertaken.

Further, cetacean biology and behaviours are difficult to study and interpret. Ljungblad *et al.* (1988) noted that determining when subtle behavioural changes occurred was the most difficult part of experimental observations. The significance of behavioural responses is also often open to interpretation and debate. Likewise there can be debate about what is actually observed and recorded. Details of observations may depend on many elements including observer skill, nature of observation platform, observation conditions (such as weather and sea state) and whether acoustic as well as visual methods are used. In addition, measurements themselves may not be sensitive enough to detect effects (Borggaard *et al*. 1999).

It remains that those using loud sources are typically the most likely to be those in a position to fund forums of discussion about such impacts and investigate mitigation techniques, as well as fund research studies. However, this may restrict academic freedom and lead to a perception of bias (Whitehead and Weilgart 1995), and ensuring that independent, non-aligned studies are conducted is likely to be a step towards finding solutions.

7.1. Consideration of Voluntary vs. Mandatory Levels of Protection

Mitigation measures intended to offer a level of protection to marine mammals are increasingly commonplace for a variety of human activities that introduce noise into the marine environment.

A number of countries are implementing environmental legislation to protect vulnerable marine mammals from noise pollution (see chapter 8: part 2). The Marine Mammal Protection Act (MMPA) in the US is currently under review and it is expected to include specific measures for marine mammal protection from noise pollution.

Other countries offer some measure of protection through voluntary, largely self-regulating, means. Although, guidelines introduced to protect marine mammals from seismic activities in the UK have recently become statutory (*Offshore Petroleum Activities (Conservation of Habitats) Regulations (2001)*. These same measures, or similar, may also be used by some companies operating in European waters, and perhaps beyond, through voluntary means.

Compliance and enforcement will be better controlled if acoustic pollution is addressed through a legislative process. Other benefits could include a requirement for data collection.

Impacts that are expected to be extensive and continuous in nature are generally likely to require a different approach to mitigation procedures than those that are temporary and highly localised. Similarly, there may be special cases where a cetacean population is concentrated in a small area or where the area to be exposed to noise forms part of that which is thought to be biologically significant habitat that is considered critical for survival.

7.2. Solutions

7.2.1. Awareness/ Education

Many operators in the marine environment are unaware of underwater noise and the disturbance it can cause to marine life and, because of this, they give little thought to alleviating it (Gordon and Moscrop 1996). A better understanding of the issue and of the susceptibilities of different species will serve to focus attention on the most acute problems (Gordon and Moscrop 1996).

A willingness by operators to implement effective mitigation measures for the protection of cetaceans is likely to be looked on favourably by the community if the community is aware of the problem. Awareness raising must therefore be a priority in the coming years.

7.2.2. Research

7.2.2.1. Data gaps

The deficit of data available about the distributions, biology and vulnerabilities of cetacean species in many regions continues to be a problem. Clear quantifiable evidence of impacts of noise pollution is not currently available. Research studies should therefore focus on two levels of investigation:

1. Identification of research methods to determine generic approaches to investigating the effects of noise pollution on all species

2. More targeted studies into each form of noise pollution at a local level on those populations or individuals exposed and potentially affected

Consideration should be given to all cetacean species when developing mitigation protocols, although it may not always be useful to apply data collected from one species, to another. Mitigation should be tailored to the needs of those suspected to be most vulnerable, both in terms of individuals (i.e. mothers and calves) and species (where status may be endangered, vulnerable or unknown).

Because of the exceptional variety in marine mammal ears and the implication of this variety for diversity of hearing ranges, there is no single frequency or combination of pulse sequences that will prevent any impact (Ketten 1998).

Roberts and Wieting (2001) state that National Marine Fisheries Service (NMFS) decision-making under high levels of uncertainty is an obstacle, and go on to state that scientific issues include:

1. A lack of standardised baseline data,
2. A need for cumulative impact assessment,
3. A need for a better understanding of the "biology of disturbance",
4. Population level effects and;
5. Improved knowledge of the effects of noise on marine mammal prey species.

Where observations recorded during mitigation procedures are adequately detailed, they may provide valuable baseline data that could better detail cetacean distribution, seasonality and abundance. Data may also be collected concurrent with attempts at mitigation to show whether measures are effective. Borggaard *et al.* (1999) state that the effects of anthropogenic noise may not always be apparent even with control designs because of natural variation in dependant measures.

A level of commitment to researching what is currently largely unstudied and presently unknown, but assumed to be true in the absence of statistically robust data, is needed. For example, detailed studies on the efficacy of 'ramp-up', where the source of the noise is gradually introduced into the marine environment in the hope that any animals in the vicinity will find the noise offensive and leave the area, would be useful.

Identification of a framework for long-term research and development programs with the potential for closing identified information gaps would be an important step forward, as would enforcement of effective and comprehensive protection measures.

7.2.3. Captive studies

Auditory studies have been conducted in captive environments on a limited number of manageable odontocete species. These are regularly applied to all species due to limited data. Ethical concerns aside, captive cetaceans are living in very different circumstances to that of wild cetaceans and there are likely to be gross inconsistencies in comparing the two. (See also section 4.5).

7.2.4. Measurement of hearing abilities in wild cetaceans

Studies using portable instrumentation are conducted in the US to assess the hearing abilities in large cetacean species that cannot be kept in captivity. Recordings of physiological and, to date, acoustic measurements have been made on a few stranded or rehabilitated cetaceans (Ridgeway and Carder 2001).

Caution should be encouraged in the use of captive or stranded (and therefore compromised) animals to obtain data.

7.2.5. Software models

Computational models of whale auditory sensitivities, such as the humpback whale hearing model (Helweg *et al*. 2000) may be of assistance in determining cetacean sensitivity to sound. Software models to estimate the potential effects of noise impacts have proved valuable for whale watching (Erbe and Farmer 2000).

A spatial model of collision risk has been developed (Tregenza *et al*. 2000). This model has identified that mitigation procedures are urgently required. For example, the model indicates that a population of short finned pilot whales off the Canary Islands is at risk of extinction from collisions, unless consistent and effective mitigation action is carried out.

Autopsied animals, and computational studies that do not require the use of trained or wild cetaceans, should be used wherever possible to obtain auditory data. Correlational studies, such as correlations of strandings with increases in noise levels or military manoeuvres, are generally preferred to experimental ones (Whitehead and Weilgart 2001).

7.3. Long-term impacts

HESS (1997) stated that behavioural effects of concern related to feeding, social behaviour, migration, avoidance and abandonment of critical habitat. Changes in these behaviours could have an effect that could impact a population over the longer term. It generally remains difficult to detect these changes and therefore designation of certain critical areas as sacrosanct is urgently required. Unlike land-based critical habitat, marine critical habitat is likely to be less fixed. Thus, it may be necessary to adjust the boundaries or zones over time as, for example, cetacean distributions change with oceanic conditions. With larger overall protection areas, it can be easier to adjust or move the boundaries of the core reserve or critical habitat zones. One precautionary tool is the marine protected area, where core components of highly protected areas should ideally be nested within a network of multi-zone areas.

There has been an increase in the number of forums held specifically for discussion of noise impacts to cetaceans and suitable mitigation procedures in recent years. The majority of these forums have been focused on activities that propagate over large ocean areas, for example, seismic activities (see HESS 1997; etc) and even outside the dominion of national EEZs, as is the case for some military activities (see Gisiner 1998). Other forums have looked more generally at the issue of noise pollution and cetaceans (see, for example, NZ 1996; JASA 2001; 2000).

7.4. Cumulative impacts

The cumulative impacts of noise pollution should be considered alongside individual mitigation measures for a particular activity, or part of that activity. For example, there are often rules for whale watch vessels, limiting the number of vessels at one time, and designating a larger distance of protection around the animals as the number of vessels increases (see Annex 2A for an example of detailed whale watching guidelines).

Noise pollution also needs to be considered in synergy with other factors, such as chemical pollution and habitat degradation, that can also be expected to impact cetaceans. Conservation management that considers cumulative and synergistic impacts over large habitat areas (including national jurisdictions, as well as the high seas, where appropriate) would seem to be the way forward.

The cumulative impacts of some forms of noise pollution have been considered through a process of Strategic Environmental Assessment (SEA). This approach requires consideration of all ecosystem threats, considering individual impacts in unison rather than discretely. Such a process can make recommendations that lead to further scientific understanding, monitoring of environmental effects and review and assessment of the cumulative effects. For example, the UK SEA policy document makes specific reference to study behavioural responses of marine mammals to seismic noise (DTI 2001).

The cumulative or synergistic effects of all such stresses can be expected to further affect individual viability, through a reduction in calving rates, avoidance of critical habitat and other such impacts that may lead to increases in mortality.

A range of literature has been produced that include potential mitigation procedures for various forms of noise pollution. Richardson (2000) has produced a document listing needed research concerning airgun effects on marine mammals (also see Moscrop and Swift 1999; Hess 1997). Aburto *et al*. (1997) make recommendations for further research, with particular reference to active sonar military operations, and Vella *et al*. (2001) for wind farms. Ketten (1998) suggests mitigation and research needs for fisheries acoustic devices and Kastelein *et al.* (2000) for pingers. Erbe (2001) presents future research suggestions for whale watching vessels.

A more generic list to develop an understanding of the effects of sound on marine mammals has been identified in National Research Council (2000) (relating to low frequency sound) and by Richardson *et al*. (1995), Richardson and Wursig (1997) and Richardson (1997).

7.5. Communication

The International Whaling Commission (IWC) recognised that anthropogenic noise is a complex subject and that scientific study on this issue involves the integration of a broad range of disciplines including acoustics, audiology, physiology, behaviour, behavioural ecology, ecology, oceanography, and population biology (IWC 1999).

Research will be most useful if it is independent and non-aligned, co-ordinated and committed to improving environmental legislation. Better access to data would help in monitoring long-term effects and in planning mitigation (Gisiner 1998). Standardisation of field procedures and data formats should be encouraged where feasible (Gisiner 1998).

It might be useful to convene an independent legislative panel consisting of relevant international scientists to continually review the mitigation procedures that are put in place for major forms of noise pollution. Such a panel was recommended by Moscrop and Swift (1999) in connection with licensing of the oil and gas industry. This may offer a practical solution to ongoing issues involved in mitigation, including future decision-making processes such as the nature of the necessary format for collected data and details of a standardised training protocol for observers. This panel could be responsible for prioritising research needs and guiding national and international regulation.

7.6. Methods of protection

Compliance monitoring is undertaken to meet conditions of legislation or voluntary guidelines (Gisiner 1998) and, in fact, monitoring is essential to assess whether required mitigation measures are effective (Gisiner 1998, HESS 1997).

Dotinga and Oude Elferink (2000) and Richardson (1995) noted that there are four types of mitigation measures. Each of these is considered in turn:

1. Construction, design and equipment standards: Where more 'environmental friendly' options are available, these should be considered, as should investigation into developing such technologies. A reasonable assumption would be that lower noise levels are always to be preferred. Seismic surveys are considered an extreme noise source of concern for cetaceans. A marine vibrator – another method for seabed survey – has been developed and has a lower peak amplitude, slower rise time and significantly less energy above 100Hz (Deffenbaugh 2001) and may be a realistic alternative to the airgun arrays that are currently used worldwide in seismic activities.

A nearby ship is likely to produce substantially higher sound levels locally than distant shipping noise (Cato 2000), yet the impact may be over a short time period. Should a population use an area in or near a shipping lane however, there are long term implications for these individuals.

Vessels used for whale watching can produce high levels of underwater sound in close proximity to the animals. The factors most affecting the noise levels are the distance from the whale and vessel speed, and to a lesser extent, vessel type (McCauley *et al*. 1996). Thus, whilst benign observation and study of whales is to be encouraged, the expanding cetacean watching industry clearly benefits from regulation to ensure that it does not become harmful to cetaceans (ANZECC 2000). Various whale watching guidelines are available and practised widely as a mitigation measure (see for example Annex 2). Harassment and noise from whale watching boats is an increasing concern in areas such as Puget Sound where whale watching has become popular in recent years (Erbe, 2000).

A variety of concerns have been raised about the potential of whale watching to harm *O. orca* (Kruse, 1991; Osborne, 1991; Duffus and Dearden 1993; Phillips and Baird 1993; Williams *et al*., 1998). The vessels used for whale watching can produce high levels of underwater sound in close proximity to the animals. The factors most affecting the noise levels are the distance from the cetacean and vessel speed and, to a lesser extent, vessel type (McCauley *et al*. 1996).

Bain (2002) states that a shift from primarily large, low RPM vessels to small, high RPM vessels that may have resulted in an increase in the average noise exposure experienced by whales in the southern resident population.

The noise level of boats circling *O. orca* is already considered to be very close to the critical level assumed to cause permanent hearing loss over prolonged exposure (Erbe, 2000). Masking of *O. orca* calls has been recorded over 14km (Erbe, 2001). This could reduce detectability of prey (Trites and Bain, 2000).

Bain and Dahlheim (1994) found that noise could mask echolocation and impair communication required for cooperative foraging. Bain (2002) calculated that above ambient noise levels, noise from whale watching vessels above this level will increase masking and reduce echolocation range. Therefore prey must be closer to the whale for it to be detected. Bain (2002) calculated that a reduction in prey of 80% or more was possible off San Juan Islands.

Williams *et al.* (2002) viewed boat traffic as one factor that can influence the 'cost of living' for whales. Low levels of disturbance may not be problematic in a thriving population, but when coupled with reduced prey availability and increased contaminant load, short term behavioural responses should not be dismissed lightly. Simmonds and Dolman (2000) list the physical, behavioural and perceptual impacts that may be associated with acoustic pollution (see table 5.2.1) and continuous noise pollution can lead to permanent avoidance of critical habitat (Erbe, 2000).

Another 'special case' is the use of acoustic devices attached to fishing gear and pens to try to keep marine mammals away. Death, habituation, displacement and attraction have all been postulated as negative consequences of their use (for example, Kemper and Gibbs 1997, Stone *et al*. 2000, Kastelein *et al*. 2000, Morton *pers. comm*.). Again, more research is needed, environmental assessments should be made before such devices are deployed and, preferably, answers should be found that do not depend on the introduction of loud noise.

2. Restrictions: Areas that are known to be important biologically might be expected to benefit from geographical and/or seasonal restrictions. The Sable Island Gully in Canadian waters and the Marine Mammal Protection Zone in the Great Australian Bight are examples of areas offering cetacean's geographical protection from oil and gas exploration and seasonal protection from fishing activities.

3. Routing and positioning: This involves management of a vessel's movements or other activities around an area where there is a high risk of impacting cetaceans, particularly where biologically important areas have been identified. Sufficient information on cetacean movements is required for such measures to be effective.

Similarly, aerial movements may be restricted due to the presence of cetaceans. For example, Australian National Guidelines for Cetacean Observation (ANZECC 2000) state that aircraft should not operate lower than 1000 ft within a 300 m radius of a cetacean, or approach a cetacean head on.

4. Operational measures: the success of different methodologies varies for different goals. Part of the methodology for mitigation is usually to observe the reactions of as many individuals as possible.

Indeed, emphasis should be placed on obtaining identification of:

(1) As many individuals and sections of the population (mother-calf pairs, mature male groups, etc.) as possible
(2) Pre-exposure behaviours, especially under many different conditions (prey availability, activities animals are engaged in, time of year, etc.).
(3) Changes in behaviours
(4) Examination and analysis of such changes; and
(5) Redefining mitigation methods and guiding legislation

7.6.1 Monitoring

7.6.1.1 Visual, acoustic and aerial observations

Distance of the animal from the vessel is a commonly used parameter in monitoring. This kind of record should include consideration of the type of observation platform involved, propagation of sound, likely received level of sound as well as the vulnerability of the species encountered.

Observers that have been appropriately trained and are well motivated have been shown to identify many more individuals than crew and others (for example, Barton 2001). The number of observers should reflect the length and type of the survey. Multiple observers may be required, especially during longer activities. (There may also be health and safety issues to consider.)

Observations may commence before the start of the survey and continue after the survey has been completed, to offer a fuller record of impacts and allow comparisons with before and after behaviours.

Acoustic studies are valuable because some vocal species are difficult to detect visually, perhaps because they are a small species or a deep-diver. Acoustic studies would greatly improve chances of detecting at least the more vocal species. Some species are vocal when foraging and others at certain times of the year. For this reason, combined visual and acoustic surveys are to be encouraged. Gillespie *et al.* (1998) reported at least an eight-fold improvement in detection rates of odontocetes when undertaking acoustic monitoring.

There are some now technical developments that will help investigate noise impacts. “Pop-ups”, for example, are passive acoustic recorders that are mounted on the seafloor, operated autonomously, and can provide continuous sound sampling from a fixed location for periods of up to a month at a time. These can be used to help determine whether a noise disturbance affects the acoustic output of the surrounding animals or whether animals have aggregated in or left the area. Additionally, “pop-ups” can monitor local noise levels, which could prove useful, among other things, for the enforcement of noise regulations. Similarly, the deployment of PODs (porpoise detectors) has also been useful, for example, in monitoring the impacts of noise from marine wind farms on harbour porpoises in Europe (Teilmann, *et al*. 2002).

Aerial surveys can provide valuable information over a wider area. Conducting aerial surveys for a period of time before, during and after the activity involving potential disturbance will give survey managers a good idea of species in the particular area at that time. The longest term study of cetacean and seismic interactions began in the Alaskan Beaufort Sea in the 1980s. Data since then has shown that behavioural changes of Bowhead whales have extended as far out to 30 km, where received levels 107-126 dB re 1 μPa (rms) (Richardson 1999). McCauley and Duncan (2001) stated that for blue whales, airguns could elicit behavioural changes in the tens of km, and probable avoidance at 3-20 km. These are clearly distances that cannot be detected from a vessel.

7.6.1.2 Use of equipment

Photo-identification

Photo-id is used as an individual recognition technique. It offers a permanent record of individuals based on their physical features that can be added to over time to establish records of movements and residency of individuals. Computer programs now aid in the cataloguing and identification of images collected. This method is useful where populations are expected to be found in, or return to, an area repeatedly and where individuals have distinctive marks.

Data loggers and telemetry

Tagging devices record information for either later retrieval, or for continuous remote monitoring of cetacean movements. It is possible to acquire detailed data on many aspects of wildlife biology using increasingly sophisticated tags, for example, dive depths, durations, water temperature, and time spent at the surface as well as levels of biological and anthropogenic noise. Data may be collected for periods of hours, weeks or months.

However, this may also be an expensive and time-consuming technique, and such devices have proved to be unsuitable for use in some species (for example due to the animal's size) although this is changing as technology advances and costs decrease. Physiological impacts (of the tag in addition to the noise itself, as well as impacts associated with close contact with the animal for attachment) have not been investigated to any great extent, and there are other limitations, such as battery life. Consideration should also be given to the invasiveness of this process. It is important to consider the value of the information gained against the disturbance and damage that may be inflicted upon the individual.

Image intensifiers and infra-red sensors

Such devices are used in some areas of the world to monitor for cetaceans at night. Whilst all attempts to monitor cetaceans exposed to loud noise are welcomed, we have concerns about the abilities of such devices to detect cetaceans, both at night and in poor weather conditions.

Active and passive acoustic methods

Vessel-mounted acoustic detection systems have been proposed as a solution to collisions for some depleted species. Such devices may warn the vessel that a cetacean is in the area, or warn the animal, and hopefully encourage it to move away from the source of the noise, and hence the vessel. Gerstein (2002) developed a highly directional low intensity acoustic alerting device to alert manatees to vessels to prevent collisions.

The US Navy has invested in the HF/M3 detection system for its Low Frequency Active Sonar (LFAS) program. An active acoustic deterrent is an alarm signal to warn the cetacean to move away. As part of the Sound Oceanography and Living Marine Resources (SOLMAR) project, the NATO SACLANT Undersea Research Centre is investigating the use of active sonar for the detection and localisation of marine mammals as an early warning, collision-avoidance sonar for shipping (Bondaryk 2001). The consequences of addition noise in the marine environment should be weighed up against the effectiveness of the system. There are also issues with habituation (see chapter 5). Passive acoustics are often used as a mitigation measure for noise sources, in an attempt to localise cetaceans by their own sounds and ensure that there are no cetaceans nearby. Unfortunately, the reactions of many cetaceans may be to fall quiet when they hear noise, which can be expected to reduce the effectiveness of this mitigation method.

Andre and Potter's (2001) preliminary findings indicate that the solution to the problem of accidental collisions may lie in a better understanding of the hearing sensitivities of the local populations of whales, coupled with measures to decrease acoustic exposures of these whales rather than by increasing the acoustic loading by deployment of active acoustic deterrents.

Delory *et al*. (2002) use Ambient Noise Imaging (ANI) Sonar (which does not emit sound) to detect a silent sperm whale near the sea surface from the backscatter of known natural acoustic sources.

Detection of large baleen whale sounds are recorded in several regions of the world with the use of seafloor hydrophones and recorders (primarily used for Navy purposes in many instances). Clark and Charif (1999) used such equipment to discover, for example, that blue whales are found out in the Atlantic Frontier, an area off the north west of the UK, year round.

7.6.2. Practical Mitigation

Mitigation generally requires a detailed case-by-case assessment and constant review of methods in order to be effective. In this way, as information is gathered, it can be analysed and input back into the assessment process to further ameliorate impacts.

Mitigation measures can be expected to vary depending on the intensity, duration and level of the source of the sound.

7.6.2.1. Localised measures

Speed restrictions

Speed limits may be imposed in certain areas to protect cetaceans. This is usually a localised measure to protect resident populations or individuals.

Slow approach and safety radius

Whale watch guidelines often operate a ‘no wake’ speed to a certain distance, and no approach closer than 100 to 500 metres (often depending on the number of vessels).

7.6.2.2. Offshore operational measures

Initial observations before work begins

Observations from the vessel are commonly initiated at least 30 minutes before ‘ramping-up’ airguns. Detection of cetaceans within the specified acoustic radius is reported in order that starting the activity involving noise be delayed until the cetacean has moved out of the area, and has been clear for 30 minutes. Observations continue until after the completion of the operations and all observations are reported, including any behavioural changes outside of the acoustic radius (where this is possible).

Safety radius

Current 'safety zones' are largely distance related with little reference to science or the physical characteristics of an area. They range widely from 500 m to 3 km. Work methods that utilise distance criteria are easy to implement and to monitor. All guidelines and/or regulations should recognise that observers cannot see a reasonable percentage of animals within a radius of even several hundred metres. Therefore animals will be inadvertently exposed to high levels of sound. It is likely impossible to know how many were exposed and what effect it had (Moscrop and Swift 1999).

Pierson *et al*. (1998) indicated a more flexible exclusion zone based on received sound pressure levels is needed.

Exposure levels

A panel has been convened in the US (see for example, HESS 1997) to set a maximum sound level to which a cetacean should be exposed. Such levels are commonly used for mitigation purposes in military and industry activities. This is not such an easy task for whale watching or AHDs/ADDs where source levels and sound characteristics may vary dramatically.

However, some consider that there are insufficient data to accurately determine acoustic exposure guidelines for any marine mammal (Ketten 1998).

Stop-work procedures

Once an animal has entered a designated area of protection, in some instances, operations are shut down. This is particularly so with seismic activities and military applications involving active sonar and explosives. Once the animal moves out of the protected area, after a designated time, operations are ramped up to normal operating levels.

Ramp-up

It has been previously assumed that ramp-up or 'soft start' would alert marine animals with sufficient time that they would move away from the noise source before physical damage occurred. However, some studies show that animals may become habituated to persistent noise and may remain in the vicinity when repeated exposure could cause physical damage (HESS 1997). It is possible that ramping up a high energy sound source could be harmful (Pierson *et al.* year unknown), as animals might be attracted to the source by initially weak sounds and thus exposed to potentially harmful levels as sound intensity increases.

While ramp-up must be considered as a minimum standard in the absence of other methods, it cannot be assumed that these measures are reducing harm to animals in the area, as it is not known that they do actually move away from the source (Pierson *et al*. 1998). Studies are being conducted to test the effectiveness of ramp-up (MMS 2001).

Bubble screening

This method of mitigation has been shown to reduce sound levels at the source (Wursig and Evans year unknown). A curtain of air bubbles consumes some of the sound energy produced and then propagated from the source. Further investigations are needed into this potential source of mitigation before its effectiveness can be assessed.

Use of explosives

Explosives may be used in some instances to deter marine mammals, and particularly seals, from an area. This may occur before the use of larger explosives, for example, to decommission an oil rig or for military purposes. As well as concerns about the introduction of an additional source of noise into the marine environment, consideration should be given to the impulsive nature of explosives, which may have a physical impact (see for example, Lewis 1996).

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ANNEX 1

The Application of Marine Pollution Law to Ocean Noise

Daniel Owen[5]

1. Introduction

This paper addresses the application of marine pollution law to the regulation of ocean noise. Of course, other categories of law may also be of assistance in the regulation of ocean noise, but for reasons of space it is not possible to address these here.[6] Likewise, it will not be possible to address relevant principles of international environmental law, despite the clear importance in this context of matters such as the precautionary principle.

2. Global instruments on marine pollution

2.1 The United Nations Convention on the Law of the Sea

The 1982 United Nations Convention on the Law of the Sea ("the LOSC")[7] establishes duties on its contracting parties in respect of pollution of the marine environment "from any source".[8] The nature of these duties will be discussed in more detail below. At this point, it is appropriate to

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[6] Nevertheless, Appendix A of this paper lists some international instruments of actual or potential relevance to protection of cetaceans from ocean noise, other than specifically in relation to pollution. For discussion of the use of some of these instruments in relation to ocean noise, see: H.M. Dotinga & A.G. Oude Elferink, *Acoustic Pollution in the Oceans: The Search for Legal Standards*, Ocean Development & International Law, 31: 151-182, 2000, pp 166-170.

[7] Available at: http://www.un.org/Depts/los/convention_agreements/texts/unclos/closindx.htm (last visited 25.02.03).

consider just the definition of pollution in the treaty. Art 1(1)(4) LOSC states that:

> "pollution of the marine environment" means the introduction by man, directly or indirectly, of substances or energy into the marine environment, including estuaries, which results or is likely to result in such deleterious effects as harm to living resources and marine life, hazards to human health, hindrance to marine activities, including fishing and other legitimate uses of the sea, impairment of quality for use of sea water and reduction of amenities; [Emphasis added]

It is necessary to decide whether the term "energy" in Art 1(1)(4) LOSC may be interpreted to include energy in the form of human-induced ocean noise. Art 31 ("General rule of interpretation") of the Vienna Convention[9] states in paragraph 1 that "[a] treaty shall be interpreted in good faith in accordance with the ordinary meaning to be given to the terms of the treaty in their context and in the light of its object and purpose". Context comprises, *inter alia*, the treaty's text including its preamble.[10] In the current case, context is provided, *inter alia*, by the setting of the term "energy" within a definition of pollution, and by the subsequent use of the term "pollution" in the LOSC (in particular in Part XII). Furthermore, the preamble to the LOSC refers to, *inter alia*, "the desire to settle ... all issues relating to the law of the sea" and to "the desirability of establishing through this Convention ... a legal order for the seas and oceans ...". On the basis of this evidence, it is strongly arguable that human-induced ocean noise should be included within the ordinary meaning of "energy" in Art 1(1)(4) LOSC.

Art 31(3)(b) of the Vienna Convention states that "[t]here shall be taken into account, together with the context ... any subsequent practice in the application of the treaty which establishes the agreement of the parties regarding its interpretation".[11] Sinclair states that Art 31(3)(b) "does not cover subsequent practice in general, but only a specific form of subsequent practice - that is to say, concordant subsequent practice common to all the parties".[12] Consistency of practice is also

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[8] Art 194(1) LOSC; see also Art 194(3) LOSC.
[9] 1969 Vienna Convention on the Law of Treaties; available at: http://fletcher.tufts.edu/multi/texts/BH538.txt (last visited 25.02.03).
[10] Art 31(2).
[11] Art 31(3)(b).
[12] I. Sinclair, *The Vienna Convention on the Law of Treaties*, 2nd edition, Melland Schill Monographs in International Law (Manchester: Manchester University Press, 1984), p 138.

an important factor.[13] The judgement of the International Court of Justice in the *Case concerning Kasikili/Sedudu Island (Botswana/Namibia)*[14] indicates that for a given practice to be considered as “subsequent practice” under Art 31(3)(b), that practice by a party must be linked to a belief by that party that the treaty is to be interpreted as such, and the other parties must be fully aware of, and accepting of, such practice as an interpretation of the treaty.[15] Aust notes that acceptance of a practice by the parties need be tacit only.[16]

There are treaties on marine pollution that expressly cover seismic surveys (i.e. the 1994 Barcelona Protocol and 1989 Kuwait Protocol, both referred to later in this paper). It could be argued that such coverage of seismic surveys demonstrates that “energy” in Art 1(1)(4) LOSC has been interpreted by the parties to include noise. However, although both treaties refer to the LOSC in their respective preambles,[17] they are clearly only regional in their scope and also apply to non-parties to the LOSC.[18] The latter two points can also be made for the Arctic Environmental Protection Strategy, which expressly recognises noise as a pollutant.[19] Furthermore, as noted below, several marine pollution treaties have to date focused on the substances aspect of pollution rather than on the energy aspect[20] and some States have taken measures in respect of ocean noise without necessarily regarding noise expressly as “pollution”.

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[13] Sinclair, *ibid*., p 137; see also: A. Aust, *Modern Treaty Law and Practice* (Cambridge: Cambridge University Press, 2000), p 194.

[14] Judgment of 13 December 1999; available at: http://www.icj-cij.org/icjwww/icases/ibona/ibonajudgments/ibona_ijudgment_19991213.htm (last visited 25.02.03).

[15] Paras 73-74.

[16] A. Aust, *Modern Treaty Law and Practice* (Cambridge: Cambridge University Press, 2000), p 195.

[17] The preamble to the Barcelona Protocol reads, *inter alia*: “Bearing in mind the relevant provisions of the United Nations Convention on the Law of the Sea ...”. The preamble to the Kuwait Protocol reads, *inter alia*: “Being aware of the Articles 76, 197 and 208 of the United Nations Convention on the Law of the Sea (1982) ...”.

[18] The preamble to the Barcelona Protocol reads, *inter alia*: “The Contracting Parties to the present Protocol, Being Parties to the Convention for the Protection of the Mediterranean Sea against Pollution, adopted at Barcelona on 16 February 1976 ...”. However, parties to the Barcelona Convention include the following non-parties to the LOSC: Albania, Israel, Libya, Morocco, Syria and Turkey. The preamble to the Kuwait Protocol reads, *inter alia*: “The Contracting States, Being Parties to the Kuwait Regional Convention for Cooperation on the Protection of the Marine Environment from Pollution ...”. However, parties to the Kuwait Convention include the following non-parties to the LOSC: Iran and the United Arab Emirates.

[19] 1991 Arctic Environmental Protection Strategy, pp 2 & 12; available at: http://www.arctic-council.org/files/pdf/artic_environment.PDF (last visited 25.02.03). States participating in the Strategy include the following non-parties to the LOSC: Canada, Denmark and the United States.

[20] Of note, the LOSC itself does likewise in some places, despite the environmental protection context of the provision in question and the potential relevance of energy as a source of pollution in that context (see in particular Arts 246(5)(b), 194(3)(a) & 207(5) LOSC).

This evidence therefore suggests that the "subsequent practice" to date does not establish agreement of the parties to the LOSC regarding the interpretation of the term "energy" in Art 1(1)(4) LOSC. However, Brownlie states that "[s]ubsequent practice by individual parties also has some probative value"[21] and Sinclair considers that subsequent practice which does not qualify under Art 31(3)(b) "may nonetheless constitute a supplementary means of interpretation within the meaning of Article 32 of the [Vienna] Convention".[22] It should also be borne in mind that awareness of the environmental impact of ocean noise and the regulatory response to such noise are still very much emerging issues. As the issue matures, State practice will become increasingly valuable as a guide to interpretation of the term "energy" within the definition of pollution in Art 1(1)(4) LOSC.

Art 32 ("Supplementary means of interpretation") of the Vienna Convention allows recourse to, *inter alia*, the preparatory work of the treaty as a supplementary means of interpretation (a) to confirm the meaning resulting from the application of Art 31 or (b) to determine the meaning when the interpretation according to Art 31 leaves the meaning ambiguous or obscure or leads to a result which is manifestly absurd or unreasonable. The definition of "pollution of the marine environment" in Art 1(1)(4) LOSC approximates to definitions adopted initially by the Group of Experts on the Scientific Aspects of the Marine Environment ("GESAMP") and latterly by the 1972 United Nations Conference on the Human Environment.[23] Dotinga and Oude Elferink state:[24]

> Initially, the definition of marine pollution discussed in GESAMP only referred to the introduction of substances. At a later stage the term "energy" was added, apparently to include thermal pollution, since there was evidence available to show that heat in seawater encouraged the development of certain undesirable organisms and interfered with the migration of fish in certain areas.

Thus it is possible that those drafting Art 1(1)(4) LOSC had thermal pollution (rather than noise) specifically in mind when they used the term "energy". However, any evidence along these lines

[21] I. Brownlie, *Principles of Public International Law*, 5th edition (Oxford: Clarendon Press, 1998), p 635.
[22] I. Sinclair, *The Vienna Convention on the Law of Treaties*, 2nd edition, Melland Schill Monographs in International Law (Manchester: Manchester University Press, 1984), p 138.
[23] S.N. Nandan, S. Rosenne & N.R. Grandy (eds.), *United Nations Convention on the Law of the Sea 1982: A Commentary* vol II (Dordrecht: Martinus Nijhoff), p 41.
[24] H.M. Dotinga & A.G. Oude Elferink, *Acoustic Pollution in the Oceans: The Search for Legal Standards*, Ocean Development & International Law, 31: 151-182, 2000, p 158.

in the preparatory work of the LOSC would merely be a supplementary means of interpretation. Most weight should be put on the ordinary meaning of the term "energy" regarding which, as noted above, there is a strong argument for including human-induced ocean noise. Furthermore, it is notable that though the negotiators may have had only thermal pollution specifically in mind at the time of their use of the word "energy", they chose not to use a more specific term like "heat" or "thermal energy". Thus it is arguable that "energy" was chosen to facilitate the treaty indeed being a legal order covering all issues, capable of responding to evolving issues.

For the purposes of this paper, in light of the above, the term "pollution" in the LOSC will be taken as including human-induced ocean noise.[25] The other elements of the LOSC's definition of "pollution of the marine environment" should also be noted: thus to be treated as pollution under the LOSC, ocean noise should result or be likely to result in the specified "deleterious effects", including "harm" to living resources and marine life. If these conditions are met, then the various rights and duties established by the LOSC in relation to pollution of the marine environment should apply to ocean noise.

2.2 Other global instruments

As well as the LOSC, there are two other treaties of global application addressing marine pollution: MARPOL[26] and the London Convention.[27] The London Convention will not be discussed here.[28] There are also some non-treaty instruments, including (a) Chapter 17 of Agenda 21,[29] (b) the Global Programme of Action for the Protection of the Marine Environment from Land-based Activities ("the GPA"),[30] and (c) the UNEP Conclusions of the study of legal aspects concerning the environment related to offshore mining and drilling within the limits of national

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[25] See also: H.M. Dotinga & A.G. Oude Elferink, *ibid.*, p 158.

[26] International Convention for the Prevention of Pollution from Ships, 1973, as modified by the Protocol of 1978 relating thereto. The text is available in: *MARPOL 73/78 - Consolidated Edition 2002* (London: International Maritime Organization, 2002).

[27] 1972 Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter; available at: http://www.austlii.edu.au/au/other/dfat/treaties/1985/16.html (last visited 25.02.03).

[28] The justification for this is that the London Convention addresses dumping; it is unlikely that dumping in itself constitutes a significant source of ocean noise.

[29] Agenda 21 is the action plan adopted at the 1992 United Nations Convention on Environment and Development; it is available at: http://www.un.org/esa/sustdev/agenda21text.htm (last visited 25.02.03).

[30] 1995 Global Programme of Action for the Protection of the Marine Environment from Land-based Activities; available at: http://www.gpa.unep.org (last visited 25.02.03).

jurisdiction ("the UNEP Conclusions").[31]

Chapter 17 of Agenda 21

Chapter 17 of Agenda 21 refers to "pollution" in the context of marine environmental protection. However, the focus is on substances and effluents,[32] and no express reference is made to energy or noise or similar terms. Nevertheless, the general references to "pollution" are helpful.

GPA

The GPA is a non-binding instrument that deals only with land-based sources of environmental degradation. The list of "contaminants" in the GPA does not include energy or noise or similar terms.[33] However, the GPA does identify, *inter alia*, "military installations", "coastal mining (e.g., sand and gravel)" and "aquaculture" as point sources of degradation.[34] The cited point sources are all potentially sources of ocean noise and the term "degradation" could arguably be interpreted to include the impacts of ocean noise.

UNEP Conclusions

The UNEP Conclusions address "pollution and other adverse effects" from "offshore exploration for and exploitation of hydrocarbons and other minerals, and related activities, within the limits of national jurisdiction".[35] The Conclusions are general in nature. They do not refer expressly to energy or noise or similar terms, and (with one or two exceptions[36]) may be regarded as applying equally to both substances and energy as pollutants. The UNEP Conclusions are non-binding. However, Churchill & Lowe[37] state that "[t]he Conclusions were endorsed as guidelines for State

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[31] Reproduced in: P.H. Sand, *Marine Environment Law in the United Nations Environment Programme* (London: Tycooly, 1988), chapter 9.
[32] E.g. see paras 17.18, 17.20, 17.28 and 17.30.
[33] See para 21(b).
[34] See para 21(d)(i).
[35] Para 1.
[36] Para 7 states, *inter alia*, that: "The authorization should provide for concrete requirements on environmental protection. Such authorization should, in particular, require the operator ... to take all necessary measure to ensure that spillage, leakage or wastes resulting from the operations do not endanger public health, fauna and flora and coastal regions" (emphasis added). This represents an emphasis on substances in a context where pollution from ocean noise is potentially equally relevant.
[37] R.R. Churchill & A.V. Lowe, *The Law of the Sea*, 3rd edition, Melland Schill Studies in International Law (Manchester: Manchester University Press, 1999), pp 371-372.

practice by the UNEP Governing Council and the UN General Assembly in 1982".

MARPOL

MARPOL addresses pollution from ships. However, the term "ship" is defined broadly to mean "a vessel of any type whatsoever operating in the marine environment and includes hydrofoil boats, air-cushion vehicles, submersibles, floating craft and fixed or floating platforms".[38] Thus MARPOL applies beyond, say, merchant vessels to installations used in exploration and exploitation of the natural resources of the seabed and subsoil.[39] Under Art 1(1) of MARPOL:

> The Parties to the Convention undertake to give effect to the provisions of the present Convention and those Annexes thereto by which they are bound, in order to prevent the pollution of the marine environment by the discharge of harmful substances or effluents containing such substances in contravention of the Convention.

Thus in contrast to the LOSC, the term "pollution of the marine environment" in MARPOL focuses solely on substances. This focus is reflected in the treaty's six annexes,[40] none of which may be construed even indirectly as dealing with ocean noise. The term "discharge" as used in Art 1(1) is defined in Art 2(3)(a).[41] Arguably, this definition does not exclusively limit the scope of the term to substances. Nevertheless, the scope of Art 1(1), by its wording, is clearly restricted to substances.

To extend the scope of Art 1(1) to include energy or noise, one option would be to retain "discharge" in Art 1(1) in respect of substances but to then add, say, "emission" in respect of energy or noise (with an appropriate definition of "emission"). Another option would be to define the term "substance" such that it includes energy or at least ocean noise. Such an approach does appear to have been taken by the IMO in its *Guidelines for the Identification and*

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[38] Art 2(4).

[39] This is reflected in Annex I - *Regulations for the Prevention of Pollution by Oil* (see Reg 2(1) and Reg 21).

[40] The six annexes are: Annex I: Pollution by Oil; Annex II: Pollution by Noxious Liquid Substances in Bulk; Annex III: Pollution by Harmful Substances Carried by Sea in Packaged Form; Annex IV: Pollution by Sewage from Ships; Annex V: Pollution by Garbage from Ships; Annex VI: Air Pollution from Ships. Annexes IV and VI have not yet entered into force.

[41] Art 2(3)(a): "*Discharge*, in relation to harmful substances or effluents containing such substances, means any release howsoever caused from a ship and includes any escape, disposal, spilling, leaking, pumping, emitting or emptying;".

Designation of Particularly Sensitive Sea Areas.[42] These impliedly refer to noise as a substance.[43] Based on this approach in the Guidelines, it is tempting to suggest that MARPOL need not be amended in order to cover ocean noise. However, the Guidelines are not primarily intended as an interpretation of MARPOL.

For current purposes, it will assumed that in order to use MARPOL to regulate ocean noise, it would be necessary to extend the scope of Art 1(1) to include energy or, more specifically, noise. Of course, the task of generating the necessary political will to effect this change should not be underestimated. But with the scope of Art 1(1) extended as suggested, in principle a new annex to MARPOL on ocean noise could then be drafted.

It is noteworthy that Art 2(3)(b)(ii) of MARPOL currently excludes from the meaning of discharge the "release of harmful substances directly arising from the exploration, exploitation and associated offshore processing of sea-bed mineral resources". The impact of this provision is clear: it avoids MARPOL being used as a general means of regulating operational discharges from the offshore minerals industry. Thus even if the scope of Art 1(1) could be extended as suggested, it is likely that there would be pressure from governments to draft a provision equivalent to Art 2(3)(b)(ii) in respect of emissions of noise from such operations. Clearly, if successful, any such pressure would remove any opportunity for using MARPOL to control noise from important sources such as seismic surveys, construction and drilling.

2.3 Conclusion

The LOSC is the most promising global treaty with potential for the regulation of ocean noise, on account of (a) its definition of pollution including "energy" and (b) its intention to address pollution from all sources. MARPOL too offers possibilities, assuming that the scope of Art 1(1) could be extended to include energy or noise; even then, pressure to introduce an equivalent of Art 2(3)(b)(ii) is likely to be strong.

It is necessary to analyse the provisions within the LOSC in order to assess how they may be used to promote the regulation of ocean noise. The most relevant part of the treaty is Part XII (on

[42] Annex 2 to Resolution A.927(22) adopted on 29 November 2001.
[43] See para 2.2.

protection and preservation of the marine environment). Much of Part XII focuses on six categories of pollution,[44] addressing for each one both standard setting and enforcement. This paper will focus on just three of these categories, referred to in Part XII as: (a) pollution from seabed activities subject to national jurisdiction; (b) pollution from activities in the Area; and (c) pollution from vessels.

3. Applying the Part XII framework to sources of ocean noise

3.1 Pollution from seabed activities subject to national jurisdiction

This is addressed by Arts 208 & 214 LOSC. Art 208 LOSC deals with standard setting. Art 208(1) LOSC states that:

> Coastal States shall adopt laws and regulations to prevent, reduce and control pollution of the marine environment arising from or in connection with seabed activities subject to their jurisdiction and from artificial islands, installations and structures under their jurisdiction, pursuant to articles 60 and 80.

This provision has two elements: (a) pollution "arising from or in connection with seabed activities subject to their [i.e. the coastal States'] jurisdiction" and (b) pollution "arising ... from artificial islands, installations and structures under their [i.e. the coastal States'] jurisdiction, pursuant to articles 60 and 80". Regarding the former, the term "seabed activities" is not defined in the LOSC. For the purposes of this paper, it will be assumed to mean, *inter alia*, exploration and exploitation of the natural resources of the seabed and subsoil (e.g. oil and gas).[45] The term "subject to their jurisdiction" is also open to interpretation. For the purposes of this paper, it will be assumed to mean activities occurring within zones that are under coastal State jurisdiction (i.e.,

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[44] Pollution: (a) from land-based sources; (b) from seabed activities subject to national jurisdiction; (c) from activities in the Area; (d) by dumping; (e) from vessels; and (f) from or through the atmosphere.

[45] This view is corroborated by Art 194(3)(c) LOSC which refers to "pollution from installations and devices used in exploration or exploitation of the natural resources of the seabed and subsoil". (Note that Art 77(4) LOSC provides that the term "natural resources" in the context of the legal continental shelf includes not only non-living resources but also sedentary species. As such, the term "seabed activities" in relation to the legal continental shelf could potentially also include exploration and exploitation of sedentary species.)

inter alia, internal waters, the territorial sea, the exclusive economic zone ("EEZ") and the continental shelf).[46] Art 208(1) LOSC requires that laws and regulations should be adopted not just in relation to pollution "arising from" the seabed activities, but also in relation to pollution "in connection with" such activities.

The second element of Art 208(1) LOSC refers to "artificial islands, installations and structures under their [i.e. the coastal States'] jurisdiction, pursuant to articles 60 and 80". Though Art 80 LOSC refers to such objects "on the continental shelf", Art 60 LOSC is much broader in scope. Art 60 LOSC relates to the EEZ (an area beyond and adjacent to the territorial sea but not extending beyond 200 nautical miles from the baselines from which the breath of the territorial sea is measured[47]). Under Art 60(1) LOSC, the coastal State has specified exclusive rights in the EEZ in relation to, *inter alia*, "installations and structures for the purposes provided for in article 56 and other economic purposes". Art 56 LOSC refers to, *inter alia*, "the production of energy from the water, currents and winds". Thus it is arguable that Art 208(1) LOSC, despite the title of the article,[48] may be interpreted to include structures at the sea surface within the EEZ for, say, energy generation or fish farming.[49] This is relevant since such structures have potential to generate ocean noise.[50]

Art 208(2) LOSC states that: "States shall take other measures as may be necessary to prevent, reduce and control such pollution". This provision refers to States in general, rather than to coastal States specifically. The meaning of "other measures" is not entirely clear. However, Art 208(2) LOSC does refer to "such pollution", i.e. the pollution described in Art 208(1) LOSC. One possible interpretation is therefore that, say, flag States of vessels operating under licence in the coastal State's zone (e.g. conducting seismic surveys or servicing installations) likewise have a duty to prevent, reduce and control the pollution.[51]

Art 208 LOSC also makes links to regional and global regimes. Under Art 208(3) LOSC, the laws, regulations and measures referred to in Art 208(1) & (2) LOSC are to be "no less effective

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[46] The basis for this view is that the LOSC has a separate provision (Art 209) that applies to "activities in the Area" (i.e. all activities of exploration for, and exploitation of, the resources of the seabed and ocean floor and subsoil thereof, beyond the limits of national jurisdiction [see Art 1(1)(3) & (1) LOSC]).
[47] Arts 55 & 57 LOSC.
[48] The title of Art 208 LOSC is: "Pollution from seabed activities subject to national jurisdiction".
[49] See also: S. Rosenne, A. Yankov & N.R. Grandy (eds.), *United Nations Convention on the Law of the Sea 1982: A Commentary* vol IV (Dordrecht: Martinus Nijhoff, 1991), p 226.
[50] E.g. see section 3.7.3 of the *OSPAR Quality Status Report 2000 for the North-East Atlantic*; available at: http://www.ospar.org (last visited 25.02.03).
[51] See also: S. Rosenne, A. Yankov & N.R. Grandy (eds.), *United Nations Convention on the Law of the Sea 1982: A Commentary* vol IV (Dordrecht: Martinus Nijhoff, 1991), pp 144 & 145.

than international rules, standards and recommended practices and procedures". It is assumed that the term "international" as used here refers to action at both regional and global levels. Under Art 208(4) LOSC, States are to "endeavour to harmonize their policies in this connection at the appropriate regional level". Under Art 208(5) LOSC, States are to establish global and regional rules, standards, practices and procedures, especially "through competent international organizations or diplomatic conference".

Art 214 LOSC deals with enforcement. States are required to (a) enforce their laws and regulations adopted in accordance with Art 208 LOSC and (b) implement "applicable international rules and standards".

In terms of implementation of Art 208 LOSC, it is clear that some States have indeed taken measures in respect of ocean noise from the type of source covered by Art 208 LOSC.[52] However, it is less clear whether this action represents implementation of Art 208(1) & (2) LOSC or whether it is instead motivated by distinct and separate nature conservation duties. For example, the United Kingdom government has issued draft "Guidance Notes" to industry on procedures for, *inter alia*, geological surveys on the UK continental shelf.[53] The proposed procedures are partly aimed at reducing the impact of seismic surveys on marine mammals. However, the Guidance Notes are intended to implement the EC Habitats Directive.[54] The stated aim of this directive is to "contribute towards ensuring bio-diversity through the conservation of natural habitats and of wild fauna and flora"[55] rather than to implement Art 208(1) LOSC.

As far as Art 208(5) LOSC is concerned, the only relevant global treaty is MARPOL. However, its limited scope has already been discussed above. Certain regional treaties are far more relevant. All of the treaties underlying regional seas initiatives[56] (with one exception[57]) define "pollution" to include "energy".[58] Each of the treaties in turn includes a

[52] For material on the application of US environmental legislation to ocean noise, see for example: http://www.nrdc.org/wildlife/marine/sound/sdinx.asp (last visited 25.02.03).
[53] Draft *Guidance Notes for Procedures for Geological Surveys and Shallow Drilling under the Offshore Petroleum Activities (Conservation of Habitats) Regulations 2001*, July 2001; available at: http://www.og.dti.gov.uk/environment/consultations.htm (last visited 25.02.03).
[54] Council Directive 92/43/EEC of 21 May 1992 on the conservation of natural habitats and of wild fauna and flora, OJ L 206, 22.7.92, p 7; available at: http://europa.eu.int/comm/environment/nature/legis.htm (last visited 25.02.03). The UK has sought to implement this directive in relation to oil and gas activities on the UK continental shelf through the Offshore Petroleum Activities (Conservation of Habitats) Regulations 2001, SI 2001 No. 1754; available at: http://www.legislation.hmso.gov.uk/si/si2001/20011754.htm (last visited 25.02.03).
[55] See: Art 2(1), EC Habitats Directive.
[56] See Appendix B of this paper. The term "regional seas initiatives" as used here includes initiatives both within and outside the UNEP Regional Seas Programme.
[57] Cartagena Convention - there is no definition of "pollution".

brief framework provision on pollution from seabed activities, or similar.[59] An analysis of these provisions reveals some interesting variations between treaties. There is not space here to provide a comprehensive analysis. However, two examples are given:

(a) **OSPAR Convention**: The contracting parties have a duty to take steps to prevent and eliminate pollution from "offshore sources".[60] This term means "offshore installations and offshore pipelines from which substances or energy reach the maritime area".[61] The term "offshore installation" is in turn defined by reference to "offshore activities".[62] This latter term is defined as those activities carried out "for the purposes of the exploration, appraisal or exploitation of liquid and gaseous hydrocarbons" (emphasis added).[63] This evidently restricts the scope of the duty to act to prevent and eliminate pollution. It was assumed above that the term "seabed activities" in Art 208(1) refers to exploration and exploitation of the natural resources of the seabed and subsoil. Beyond hydrocarbons, there are several such natural resources for which exploration or exploitation may create noise pollution, e.g. aggregates, sedentary species (on the continental shelf)[64] and non-hydrocarbon minerals. Yet pollution from exploration and exploitation of such resources would not be covered by the "offshore sources" duty in the OSPAR Convention.

(b) **Bucharest Convention**: Each contracting party is to take measures in respect of "pollution ... caused by or connected with activities on its continental shelf, including the exploration and exploitation of the natural resources of the continental shelf" (emphasis added).[65] Under the LOSC, the continental shelf "comprises the seabed and subsoil of the submarine areas that extend beyond its territorial sea ...".[66] Therefore, it would appear that the above duty in the Bucharest Convention does not apply to the territorial sea of the contracting parties.

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[58] OSPAR Convention - Art 1(4); Helsinki Convention - Art 2(1); Bucharest Convention - Art II(1); Nairobi Convention - Art 2(b); Kuwait Convention - Art I(a); Barcelona Convention - Art 2(a); Jeddah Convention - Art 1(3); Noumea Convention - Art 2(f); Lima Convention - Art 2(a); Abidjan Convention - Art 2(1); Antigua Convention - Art 3(1)(d).
[59] See Appendix C of this paper.
[60] Art 5.
[61] Art 1(k).
[62] Art 1(l).
[63] Art 1(j).
[64] See Art 77(4) LOSC.
[65] Art XI(1).

Four of the twelve regional seas treaties also have annexes or supplementary protocols on seabed activities (or similar). The OSPAR Convention and Helsinki Convention include annexes on pollution from "offshore sources"[67] and "offshore activities"[68] respectively. However, in both cases there is an emphasis on substances.[69] In the case of the OSPAR Convention, this emphasis is surprising in view of the assertion in the convention that the term "offshore sources" means "offshore installations and offshore pipelines from which substances or energy reach the maritime area" (emphasis added).[70] The term "offshore installations" is defined broadly as "any man-made structure, plant or vessel or parts thereof, whether floating or fixed to the seabed, placed within the maritime area for the purpose of offshore activities" (emphasis added).[71] Depending on the interpretation of "placed within", the term "offshore sources" could potentially cover vessels conducting seismic surveys.

In the case of the Helsinki Convention, the annex defines "offshore activity" as "any exploration and exploitation of oil and gas by a fixed or floating offshore installation or structure including all associated activities thereon" (emphasis added).[72] The term "exploration" is in turn defined as including "any drilling activity but not seismic investigations" (emphasis added).[73] Combining these provisions, it is arguable that seismic surveys could still be included as an "offshore activity" on the basis that they are activities associated with exploration. However, it would additionally be necessary to show that a vessel conducting such surveys was a "floating offshore installation or structure".

The discussion above illustrates the influence of definitions. Further to this, it is worth highlighting how the location of definitions within the convention or the annex can affect their influence. In the case of the OSPAR Convention, the definitions are located in the body of the convention itself. Thus the duty in the convention on contracting parties to "take ... all possible steps to prevent and eliminate pollution from offshore sources" is directly constrained by the definition of "offshore sources" in the convention. In the case of the Helsinki Convention, the

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[66] Art 76(1) LOSC.
[67] OSPAR Convention, Annex III.
[68] Helsinki Convention, Annex VI.
[69] Regarding the OSPAR Convention, Annex III, see, *inter alia*, Arts 4 and 10. Regarding the Helsinki Convention, Annex VI, see, *inter alia*, Regulations 4 and 5.
[70] Art 1(k).
[71] Art 1(l).
[72] Annex VI, Reg 1(1).

definitions are located in the annex and are stated as being "[f]or the purposes of this Annex".[74] In other words, and in contrast to the definitions in the OSPAR Convention, they do not affect (expressly, at least) the provision in the main body of the treaty which calls on contracting parties to "take all measures ... to prevent pollution ... resulting from exploration or exploitation of ... the seabed and the subsoil ...".[75]

The Barcelona Convention is supplemented by a *Protocol for the Protection of the Mediterranean Sea against Pollution Resulting from Exploration and Exploitation of the Continental Shelf and the Seabed and its Subsoil* ("the Barcelona Protocol").[76] The protocol defines "exploration activities" to include, *inter alia*, "seismological activities" and "surveys of the seabed and its subsoil".[77] Though several provisions apply generally to pollution (which in turn includes energy[78]) or to "activities" (which in turn includes "exploration activities"), the section in the protocol that addresses particular types of pollutants in turn[79] does so under the heading "wastes and harmful or noxious substances and materials"; not surprisingly in view of this declared scope, there is no mention in this section of pollution by forms of energy. Overall then, it is clear that in the detail, the Barcelona Protocol focuses on substances and materials rather than on energy.

The Kuwait Convention is supplemented by a *Protocol concerning Marine Pollution Resulting from Exploration and Exploitation of the Continental Shelf* ("the Kuwait Protocol").[80] The protocol defines "offshore operations" broadly to include, *inter alia*, "operations ... for the purposes of exploring of oil or natural gas".[81] Several provisions apply generally to pollution (which in turn includes energy) or to "offshore operations". However, with one exception, those provisions that go into detail on particular forms of pollution address only pollution by oil, sewage, garbage and chemicals.[82] The one exception refers expressly to "seismic operations". That provision requires each contracting State to "take appropriate measures to ensure that

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[73] Annex VI, Reg 1(3).
[74] Annex VI, Reg 1.
[75] Art 12(1).
[76] Adopted in 1994 but not yet entered into force; available at: http://www.unepmap.org/ (last visited 05.03.02).
[77] Art 1(d)(ii).
[78] Art 1(e).
[79] Section III.
[80] Adopted in 1989 and entered into force in 1990; available at: http://sedac.ciesin.org/pidb/texts/acrc/ProtKuwait.txt.html (last visited 25.02.03).
[81] Art I(13).
[82] Arts IX, X, & XI(1).

seismic operations in the Protocol Area shall take into account the Guidelines issued by the Organization".[83] It is not known whether any guidelines have in fact been issued.

Mention should also be made of the implementation at the regional level of the second element of Art 208(1) LOSC. It is noteworthy that, with three exceptions, the provisions of the treaties underlying regional seas initiatives do not expressly cover "artificial islands, installations and structures under their jurisdiction, pursuant to articles 60 and 80" other than those associated with the exploration and exploitation of the seabed and subsoil.[84]

The three exceptions are the Lima Convention, the Abidjan Convention and the Antigua Convention. The Lima Convention refers to "[p]ollution from any other installations and devices operating in the marine environment";[85] the Abidjan Convention refers to, *inter alia*, "pollution ... from artificial islands, installations and structures under their [i.e. the contracting parties'] jurisdiction";[86] and the Antigua Convention refers to "[p]ollution caused by ... any other arrangement or installation that operates in the marine environment".[87]

Taking a different approach, the OSPAR Convention and the Jeddah Convention include an article dealing with "pollution from other sources" and "pollution from other human activities", respectively.[88] For example, the article in the OSPAR Convention states that:

> The Contracting Parties shall cooperate with a view to adopting Annexes, in addition to the Annexes mentioned in Articles 3, 4, 5 and 6 above, prescribing measures, procedures and standards to protect the maritime area against pollution from other sources, to the extent that such pollution is not already the subject of effective measures agreed by other international organisations or prescribed by other international conventions.

[83] Art XI(2). The "Organization" referred to is the one established by Art I(c) of the Kuwait Convention, i.e. the "Regional Organization for the Protection of the Marine Environment", headquartered in Kuwait.
[84] See Appendix C of this paper.
[85] Art 4(c).
[86] Art 8.
[87] Art 6(1)(b).
[88] OSPAR Convention - Art 7; Jeddah Convention - Art VIII. See also Art 13 of the Noumea Convention. (Art VIII of the Kuwait Convention is entitled "Pollution from other human activities" but in fact relates only to pollution from "land reclamation and associated suction dredging and coastal dredging".)

Questions arise as to the identity of the “competent international organizations” mentioned in Art 208(5) LOSC. In respect of Art 207(4) LOSC, on land-based sources, Rosenne *et al*. state:[89]

> The plural term “competent international organizations” in this article ... recognizes that in dealing with land-based sources of pollution of the marine environment no particular universal or regional international organization has exclusive competence. As knowledge and technology process, it is becoming increasingly understood that different types of land-based pollution require different functional and legal approaches. In the nature of things, this can implicate different international organizations, both global and regional.

Rosenne *et al*.,[90] in relation to Art 208(5) LOSC and its use of the term “competent international organizations”, state that their comments made in connection with article 207 LOSC are applicable. Thus it is arguable that at the regional level such organisations include the various commissions (or similar) established by some of the treaties underlying regional seas initiatives,[91] and that at the global level such organisations include the International Maritime Organization and the United Nations Environment Programme.

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[89] S. Rosenne, A. Yankov & N.R. Grandy (eds.), *United Nations Convention on the Law of the Sea 1982: A Commentary* vol IV (Dordrecht: Martinus Nijhoff, 1991), p 133.
[90] *Ibid*., p 146.
[91] E.g. see: OSPAR Convention (Art 10), Helsinki Convention (Art 19), Bucharest Convention (Art XVII), Kuwait Convention (Art XVI), Jeddah Convention (Art XVI).

Conclusion

At the global level, only MARPOL establishes rules and standards in relation to operational pollution from "fixed or floating platforms", but its application to such structures is strictly limited. Similar strict limitations may well remain even if the scope of MARPOL is extended to cover noise pollution. At the regional level, the situation is more promising thanks to the twelve treaties underlying regional sea initiatives. Such treaties (with one exception) define pollution to include energy, and each includes a brief framework provision on pollution from seabed activities (or similar).

Four of the twelve treaties also have annexes or supplementary protocols on seabed activities (or similar). In all four cases, the emphasis in the annex or protocol is currently on pollution by substances, rather than by energy. However, in all four cases there is scope for improving the profile of ocean noise, whether by arguing for insertion of an additional provision on ocean noise or by arguing for measures to be taken with the instrument as it stands. Of the remaining eight treaties, there is clearly scope for protocols addressing pollution from seabed activities including, *inter alia*, ocean noise.

Few of the regional seas treaties address the second element of Art 208(1) LOSC, i.e. pollution from "artificial islands, installations and structures under their jurisdiction, pursuant to articles 60 and 80" beyond those associated with the exploration and exploitation of the seabed and subsoil. However, five of the treaties do contain framework provisions that could be applied to such pollution (e.g. via additional annexes or protocols). The remaining seven treaties have no such framework provision; political will could in the first instance be tested by seeking such a provision.

It should not be forgotten that several regional seas initiatives operate in the absence of an underlying treaty.[92] In those cases, there is still scope for influencing their agenda. However, in respect of all regional sea initiatives, it should be borne in mind that the various initiatives are currently, or are soon likely to be, taking action to implement the Global Programme of Action (see above).[93] This action with respect to land-based activities may be seen as either an

[92] Arctic; East Asian; North-West Pacific; South Asia; South West Atlantic. See: http://www.unep.org/unep/program/natres/water/regseas/regseas.htm and http://www.arctic-council.org/files/pdf/artic_environment.PDF (last visited 25.02.03).

[93] See GPA (Part III) and Report of the First Intergovernmental Review Meeting on the Implementation of the Global Programme of Action for the Protection of the Marine Environment

opportunity for, or a hurdle to, additionally seeking action in relation to Art 208 LOSC and ocean noise in particular.

Finally it should be noted that, in the absence of action at the regional or global level, States should still be encouraged to take unilateral action with regard to noise as a pollutant. As noted earlier, Art 208(1) LOSC requires coastal States to adopt laws and regulations. In terms of standards, the only qualification regarding such domestic legislation is that it must be "no less effective than international rules, standards and recommended practices and procedures" (Art 208(3) LOSC). This qualification is relevant once regional or global instruments exist. But in the absence of such instruments, a coastal State nonetheless has the duty to adopt legislation.

3.2 Pollution from activities in the "Area"

The "Area" is defined in the LOSC as "the seabed and ocean floor and subsoil thereof, beyond the limits of national jurisdiction".[94] Pollution from activities in the Area is addressed by Arts 209 & 215 LOSC, as well as elsewhere in the LOSC and in other instruments.[95] The term "activities in the Area" is defined in the LOSC as "all activities of exploration for, and exploitation of, the resources of the Area".[96] The term "resources" is in turn defined as "all solid, liquid or gaseous mineral resources *in situ* in the Area at or beneath the seabed, including polymetallic nodules".[97] In other words, the term "activities in the Area" has a very specific meaning.

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from Land-Based Activities (Annex III [*Outline Information on Regional Seas Activities*]); available at: http://www.gpa.unep.org (last visited 25.02.03).

[94] Art 1(1)(1) LOSC.

[95] See: (a) Part XI of the LOSC; (b) Agreement Relating to the Implementation of Part XI of the United Nations Convention on the Law of the Sea of 10 December 1982; available at: http://www.un.org/Depts/los/convention_agreements/texts/unclos/closindxAgree.htm (last visited 25.02.03); (c) Regulations on Prospecting and Exploration for Polymetallic Nodules in the Area, approved by the Assembly of the International Seabed Authority on 13 July 2000 (annexed to document ISBA/6/A/18); available at: http://www.isa.org.jm/ (last visited 25.02.03); and (d) Recommendations for the guidance of the contractors for the assessment of the possible environmental impacts arising from exploration for polymetallic nodules in the Area (published as ISBA/7/LTC/1/Rev.1* and Corr.1); available at: http://www.isa.org.jm/ (last visited 25.02.03).

[96] Art 1(1)(3) LOSC.

[97] Art 133(a) LOSC.

Art 209 LOSC focuses on both standard setting at the international level and adoption of laws and regulations at the national level. The former is particularly relevant because of the international nature of the Area and its resources. Art 209(1) LOSC states:

> International rules, regulations and procedures shall be established in accordance with Part XI to prevent, reduce and control pollution of the marine environment from activities in the Area. Such rules, regulations and procedures shall be re-examined from time to time as necessary.

Art 209 LOSC is complemented by, *inter alia*, Art 145 LOSC in Part XI. Art 145 LOSC requires, *inter alia*, that "[n]ecessary measures shall be taken in accordance with this Convention with respect to activities in the Area to ensure effective protection for the marine environment from harmful effects which may arise from such activities". Art 145(a) LOSC requires that to this end the Authority shall adopt appropriate rules, regulations and procedures for:

> the prevention, reduction and control of pollution and other hazards to the marine environment, including the coastline, and of interference with the ecological balance of the marine environment, particular attention being paid to the need for protection from harmful effects of such activities as drilling, dredging, excavation, disposal of waste, construction and operation or maintenance of installations, pipelines and other devices related to such activities;

Art 145(a) LOSC refers not only to pollution but also to "other hazards". Thus if there were doubt about whether ocean noise is covered by the definition of "pollution of the marine environment" in Art 1(1)(4) LOSC, it could instead be considered as falling under "other hazards". Though many of the activities listed in Art 145(a) LOSC have the potential to generate ocean noise, it is less clear whether the list extends to activities early on in the exploration process (e.g. seismic surveys). However, the listed activities are those meriting "particular attention" rather than exclusive attention.

Though exploitation is many years away, prospecting and exploration are taking place now.[98] The International Seabed Authority ("the Authority") has so far sought to implement Arts 209 &

[98] See for example document ISBA/8/A/5, paras 36-37; available at: http://www.isa.org.jm/ (last visited 25.02.03).

145 LOSC in respect of polymetallic nodules. In 2000 the Assembly approved Regulations,[99] and in 2001 the Legal and Technical Commission prepared Recommendations.[100] Space does not permit an analysis of these instruments in respect of ocean noise. However, two points will be made.

First, the Regulations do apply, *inter alia*, to prospecting.[101] This is significant because the definition of "activities in the Area" in Art 1(1)(3) LOSC does not refer to prospecting and hence it is unclear whether Arts 209 & 145 LOSC apply to this activity. Yet (a) prospecting for resources is likely to involve noise-generating seismic surveys and (b) prospecting is recognised by the LOSC as a human activity that is undertaken in relation to resources of the Area.[102] The Authority's readiness to regulate prospecting is therefore promising from the point of view of control of ocean noise.[103]

Secondly, and in contrast to the previous point, the Recommendations include "bottom and sub-bottom acoustic ... without the use of explosives" amongst a list of activities which are deemed to have no potential for causing serious harm to the marine environment. Though the list appears to be primarily influenced by US domestic legislation,[104] it may also reflect the emphasis in Art 145(a) LOSC on activities more closely associated with the latter stages of exploration and beyond.

The discussion so far has focused on the legislative jurisdiction of the Authority. However, a State acting in the capacity of a flag State or sponsoring State has a power to apply environmental laws and regulations that are more stringent than those established by the Authority. Thus Annex III LOSC Art 21(3) states that:

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[99] Regulations on Prospecting and Exploration for Polymetallic Nodules in the Area, approved by the Assembly of the International Seabed Authority on 13 July 2000 (annexed to document ISBA/6/A/18); available at: http://www.isa.org.jm/ (last visited 25.02.03).

[100] Recommendations for the guidance of the contractors for the assessment of the possible environmental impacts arising from exploration for polymetallic nodules in the Area (published as ISBA/7/LTC/1/Rev.1* and Corr.1); available at: http://www.isa.org.jm/ (last visited 25.02.03).

[101] See Part II of the Regulations.

[102] See: Art 160(2)(f)(ii) LOSC; 162(2)(o)(ii) LOSC; Annex III LOSC.

[103] The activities constituting prospecting must, however, be considered in context. Many of these activities may equally fall within "marine scientific research" ("MSR"), covered mainly by Part XIII of the LOSC. The Authority has no express control over MSR. As such, an entity conducting such activities may instead opt to describe its work as "MSR" rather than as "prospecting", and hence evade any regulations imposed by the Authority.

[104] *United States Deep Seabed Mining Regulations for Exploration Licences* (15 CFR Part 970), s. 701; available at: http://www.access.gpo.gov/nara/cfr/cfr-retrieve.html#page1 (last visited 25.02.03).

> No State Party may impose conditions on a contractor that are inconsistent with Part XI. However, the application by a State Party to contractors sponsored by it, or to ships flying its flag, of environmental or other laws and regulations more stringent than those in the rules, regulations and procedures of the Authority adopted pursuant to article 17, paragraph 2(f), of this Annex shall not be deemed inconsistent with Part XI.

Annex III LOSC Art 17(2)(f) relates to the Authority's duty to "adopt ... rules, regulations and procedures ... on ... mining standards and practices, including those relating to ... the protection of the marine environment".[105] As such, it is not focused expressly on pollution. However, it is reasonable to assume that the principle of unilateral action established by Annex III LOSC Art 21(3) applies by implication to rules, regulations and procedures of the Authority adopted to prevent, reduce and control pollution. Of note, the reference to "ships flying its flag" is broad enough to apply to prospectors.

Art 215 LOSC relates to enforcement jurisdiction. It states that:

> Enforcement of international rules, regulations and procedures established in accordance with Part XI to prevent, reduce and control pollution of the marine environment from activities in the Area shall be governed by that Part.

Under Part XI and Annex III, the Authority, State Parties and international organisations have duties with regard to ensuring compliance.[106] The Authority is also provided with express powers in this regard.[107] Some such powers and duties have been elaborated on in the Regulations.[108] It is not known whether the Authority has yet exercised its enforcement powers in relation to prospectors or contractors undertaking exploration.

Conclusion

The legal framework provided by the LOSC appears broad enough to apply to noise pollution caused by activities in the Area. Furthermore, an international organisation (the International

[105] See Annex III LOSC Art 17(1).
[106] See: Arts 139 LOSC; Art 153(4) LOSC; and Annex III LOSC Art 4(4).
[107] See for example Art 153(5) LOSC.
[108] See for example: Reg 3(4)(d)(2); Reg 11(3)(f); Reg 29(4); and Regs, Annex 4, section 14.

Seabed Authority) has been established with an express duty to adopt rules, regulations and procedures for the prevention, reduction and control of pollution of the marine environment. Despite doubt over whether the term "activities in the Area" includes prospecting, the Authority has shown its readiness to regulate prospecting through the Regulations. Preliminary indications from the Recommendations, however, suggest that the Authority may not regard seismic surveys, at least those conducted without the use of explosives, to have potential for causing serious harm to the marine environment. It remains to be seen how the Authority will (a) regard other potential sources of ocean noise from activities in the Area and (b) address such sources in view of its legislative and enforcement jurisdiction. However, the Authority should meanwhile be encouraged to take the impact and regulation of ocean noise seriously. It should also be remembered that flag States and sponsoring States may apply environmental laws and regulations that are more stringent than those adopted by the Authority.

3.3 Pollution from vessels

This is addressed by Art 211 LOSC and by Art 217 LOSC *et seq*. Art 211 LOSC deals with standard setting. Art 211(1) LOSC requires States "acting through the competent international organization or general diplomatic conference" to "establish international rules and standards to prevent, reduce and control pollution of the marine environment from vessels ...". It is generally acknowledged that the competent international organisation is the International Maritime Organization.[109] This duty has been implemented in respect of some forms of pollution.[110] However, it has not yet been implemented in respect of ocean noise.

Of note, Art 211(1) LOSC also requires States to "promote the adoption ... wherever appropriate, of routeing systems designed to minimize the threat of accidents which might cause pollution of the marine environment, including the coastline, and pollution damage to the related interests of

[109] See, for example: (a) S. Rosenne, A. Yankov & N.R. Grandy (eds.), *United Nations Convention on the Law of the Sea 1982: A Commentary* vol IV (Dordrecht: Martinus Nijhoff, 1991), p 200 & 201; (b) R.R. Churchill & A.V. Lowe, *The Law of the Sea*, 3rd edition, Melland Schill Studies in International Law (Manchester: Manchester University Press, 1999), pp 346-347; and (c) E. Franckx (ed.), *Vessel-source Pollution and Coastal State Jurisdiction* (The Hague: Kluwer, 2001), pp 19-20.

[110] Notably: (a) the forms of pollution covered by the annexes to MARPOL; and (b) organotins used in anti-fouling systems (under the 2001 International Convention on the Control of Harmful Anti-fouling Systems on Ships). Note too that a draft International Convention for the Control and Management of Ships' Ballast Water and Sediments is currently under consideration by IMO.

coastal States". This formulation suggests that the "pollution damage to the related interests of coastal States" must arise from threat of accidents. If so, the applicability of this part of Art 211(1) LOSC to ocean noise is doubtful, in that ocean noise is more typically a product of routine operations rather than of accidents.[111] The IMO's *General Provisions on Ships' Routeing*[112] appear to support the former interpretation, since the term "routeing system" is defined as "[a]ny system of one or more routes or routeing measures aimed at reducing the risk of <u>casualties</u> ..." (emphasis added).[113]

Art 211 LOSC goes on to place duties on flag States and give qualified powers to coastal States. Under Art 211(2) LOSC, flag States are to adopt laws and regulations for the prevention, reduction and control of pollution of the marine environment from their vessels, and these are to have at least the same effect as that of "generally accepted international rules and standards established through the competent international organization or general diplomatic conference". In the current absence of such rules and standards in respect of ocean noise from vessels, the impact of this duty is clearly limited. Nevertheless, the duty on flag States to adopt laws and regulations remains applicable, and flag States should therefore be encouraged to take unilateral action with regard to noise as a pollutant.

Under Art 211(4) LOSC, a coastal State may adopt laws and regulations for the prevention, reduction and control of marine pollution from foreign vessels in its territorial sea.[114] However, such regulations "shall not apply to the design, construction, manning or equipment of foreign ships unless they are giving effect to generally accepted international rules or standards".[115] Since some solutions to ocean noise from vessels are likely to lie in design, construction or equipment and IMO rules and standards in this area do not currently exist, the coastal State must currently find other ways of managing ocean noise in its territorial sea.

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[111] In this respect, ocean noise shares similarities with many other forms of pollution from vessels, e.g.: operational oil pollution, operational chemical pollution, air pollution, pollution by sewage, garbage, ballast water and anti-fouling chemicals.

[112] 7th edition, 1999. Based on Resolution A.572(14) (as amended), and "established pursuant to regulation V/8 of the SOLAS Convention" (i.e. the 1974 International Convention for the Safety of Life at Sea, as amended).

[113] Para 2.1.1; see also para 1.1.

[114] See also Art 21(1)(f) LOSC, under which a coastal State may adopt laws and regulations relating to innocent passage in respect of "the preservation of the environment of the coastal State and the prevention, reduction and control of pollution thereof".

[115] Art 21(2) LOSC.

One possibility is the adoption by the coastal State of laws and regulations in respect of "the regulation of maritime traffic".[116] For example, a coastal State may wish to establish a prohibition on vessel movements in an acoustically-sensitive area. However, any laws and regulations adopted by the coastal State for the prevention, reduction and control of pollution are not to hamper innocent passage.[117] Measures for the regulation of maritime traffic in the territorial sea have been established in the past (e.g. around Orkney in the United Kingdom); hence such measures are not automatically to be construed as hampering innocent passage. A coastal State does not, with some exceptions, need the approval of IMO for such measures in its territorial sea.[118] In practice, however, a coastal State may prefer to obtain such approval in order to improve the efficacy of the measure and perhaps to be reassured that innocent passage is not deemed by other States to have been hampered.

Under Art 211(5) LOSC a coastal State may adopt laws and regulations for the prevention, reduction and control of marine pollution from foreign vessels in its EEZ. However, such laws and regulations must conform to and give effect to "generally accepted international rules and standards established through the competent international organization or general diplomatic conference".[119] This implies that in the absence of international rules and standards on ocean noise, the coastal State may not adopt laws and regulations for the prevention, reduction and control of such noise from foreign vessels in its EEZ.

However, Art 211(5) LOSC is supplemented by Art 211(6) LOSC under which the coastal State may, in certain circumstances, take "mandatory measures" in "special areas" within its EEZ. At the outset, other States concerned must be consulted through the IMO. Next the proposal must be submitted to the IMO for its consideration. The role of the IMO is to determine whether (a) "the international rules and standards ... are inadequate to meet special circumstances" and (b) the particular part of the EEZ in question "is an area where the adoption of special mandatory measures for the prevention of pollution from vessels is required for recognized technical reasons in relation to its oceanographical and ecological conditions, as well as its utilization or the protection of its resources and the particular character of its traffic".

[116] Art 21(1)(a) LOSC.
[117] Art 211(4) LOSC.
[118] See: (a) paras 3.14-3.16 of *General Provisions on Ships' Routeing*; and (b) Art 22(3)(a) LOSC.
[119] Art 211(5) LOSC.

If the IMO makes this determination, the coastal State may then "adopt laws and regulations for the prevention, reduction and control of pollution from vessels implementing such international rules and standards or navigational practices as are made applicable, through the [IMO], for special areas". In principle, the coastal State may also adopt additional laws and regulations, subject to agreement by the IMO. In relation to ocean noise: (a) there is no reason in principle why a coastal State should not submit a proposal for a special area in view of concerns about ocean noise (in view of the broad definition of "pollution" in the LOSC and the inadequacy of international rules and standards on ocean noise) and (b) if the IMO agreed to the identification of a given area as an ocean noise special area, the onus would therefore be on the coastal State to propose appropriate laws and regulations.

As noted above, some solutions to ocean noise from vessels are likely to lie in vessel design, construction or equipment. However, Art 211(6)(c) LOSC specifies that any additional laws and regulations adopted by the coastal State for the special area "may relate to discharges or navigational practices but shall not require foreign vessels to observe design, construction, manning or equipment standards other than generally accepted international rules and standards". In the absence of generally accepted international rules and standards on these matters, the power of the coastal State is therefore restricted. The coastal State may instead wish to propose "navigational practices", e.g. a prohibition on vessel movements in an acoustically-sensitive area. As with any additional measure for an Art 211(6) LOSC special area, such a prohibition would require agreement from the IMO. However, it is not clear whether a proposal to prohibit vessel movements to minimise the impact of operational pollution would be accepted in view of the implied non-application the IMO's *General Provisions on Ships' Routeing* to operational pollution (see above).

Looking beyond Art 211 LOSC, there are two tools developed by the IMO that may be of assistance. The first is routeing measures (notably in respect of zones other than the territorial sea, e.g. the EEZ and the high seas). However, the implied lack of application of the IMO's *General Provisions on Ships' Routeing* to operational pollution has already been mentioned. It is arguable that the scope of the General Provisions should be clarified in order to facilitate a broader application of routeing systems.

The second, and currently more promising, tool is that of "particularly sensitive sea areas" ("PSSAs"). By Resolution A.927(22), the IMO Assembly in 2001 adopted *Guidelines for the*

Identification and Designation of Particularly Sensitive Sea Areas ("the PSSA Guidelines").[120] The PSSA Guidelines identify noise as an operational pollutant from vessels.[121] They define a PSSA as:[122]

> an area that needs special protection through action by IMO because of its significance for recognized ecological, socio-economic, or scientific reasons and because it may be vulnerable to damage by international shipping activities.

The criteria for the identification of a PSSA are laid down in the Guidelines.[123] In order to be identified as a PSSA, the area in question should meet at least one of the listed criteria and should additionally "be at risk from international shipping activities".[124] The listed ecological criteria are uniqueness or rarity, critical habitat, dependency, representativeness, diversity, productivity, spawning or breeding grounds, naturalness, integrity, vulnerability, and bio-geographic importance.[125] In principle, using at least one of these criteria, coupled with demonstrating a risk from international shipping activities, there is no reason why a State should not submit a proposal for a PSSA in view of concerns about ocean noise.

However, the question arises as to what may in turn be done to manage a noise problem. On that point, the PSSA Guidelines take two approaches. Initially, they state that "associated protective measures for PSSAs are limited to actions within the purview of IMO and include the following options", listed as:[126]

> 6.1.1 designation of an area as a Special Area under Annexes I, II or V, or a SOx emission control area under Annex VI of MARPOL 73/78, or application of special discharge

[120] See Annex 2 to Resolution A.927(22). The PSSA Guidelines are stated to "supersede chapter 3 of the Annex to resolutions A.720(17) and A.885(21)". The annex to Resolution A.720(17) contains *Guidelines for the Designation of Special Areas and the Identification of Particularly Sensitive Sea Areas*, of which chapter 3 addresses PSSAs. Annex I to Resolution A.885(21) contains *Procedures for the Identification of Particularly Sensitive Sea Areas and the Adoption of Associated Protective Measures*, of which chapter 3 addresses *Application by a Proposing Member Government for Identification of a PSSA and the Adoption of Associated Protective Measures*.
[121] See para 2.2. See also para 1.2.2, para 1.2.11 and Table 1 of the annex to Resolution A.720(17); these parts have not been superseded by Resolution A.927(22).
[122] Para 1.2.
[123] Section 4.
[124] Para 4.4. Factors to be taken into consideration in deciding whether the area is "at risk from international shipping activities" are listed in section 5.
[125] Para 4.4.
[126] Section 6.1.

restrictions to vessels operating in a PSSA. [...]

6.1.2 adoption of ships' routeing and reporting systems near or in the area, under the International Convention for the Safety of Life at Sea (SOLAS) and in accordance with the General Provisions on Ships' Routeing and the Guidelines and Criteria for Ship Reporting Systems. For example, a PSSA may be designated as an area to be avoided or it may be protected by other ships' routeing or reporting systems;

6.1.3 development and adoption of other measures aimed at protecting specific sea areas against environmental damage from ships, such as compulsory pilotage schemes or vessel traffic management systems.

Later the Guidelines state:[127]

(a) The application [by the proposing Member Government(s)] should identify the proposed [associated protective] measures which may include:

(i) any measure that is already available in an existing instrument; or
(ii) any measure that does not yet exist but that should be available as a generally applicable measure and that falls within the competence of IMO; or
(iii) any measure proposed for adoption in the territorial sea or pursuant to Article 211(6) of the United Nations Convention on the Law of the Sea.

(b) These measures may include ships' routeing measures; discharge restrictions; operational criteria; and prohibited activities, and should be specifically tailored to meet the need of the area at risk.

In a PSSA established to manage ocean noise, the objective should clearly be to reduce or eliminate ocean noise from vessels. To reduce or eliminate ocean noise, options include, *inter alia*, (a) setting speed restrictions, (b) prohibiting vessels or certain categories of vessel from using the area, (c) applying special restrictions on the "discharge" of noise (e.g. decibel limits), and (d) requiring the use of certain equipment (e.g. propeller nozzles). Of these, "(a)" is likely to be the least problematic. With respect to "(b)", the implied non-application of the IMO's *General*

[127] Section 7.4.2.1.

Provisions on Ships' Routeing to operational pollution has already been mentioned. With respect to "(c)" and "(d)", there are vessel design/construction implications.[128] However, it is also unclear what is meant when the PSSA Guidelines (as cited above) refer to "any measure that does not yet exist but that should be available as a generally applicable measure and that falls within the competence of IMO" (emphasis added).[129]

Conclusion

There are currently no "generally accepted international rules and standards established through the competent international organization or general diplomatic conference" in respect of noise pollution from vessels. Such rules and standards could potentially be introduced by (a) extending the scope of Art 1(1) of MARPOL appropriately and then drafting a new annex on ocean noise or (b) drafting a new stand-alone treaty (as has been done with the 2001 International Convention on the Control of Harmful Anti-fouling Systems on Ships). Of course, significant political will would be necessary to bring about either of these multilateral options. Meanwhile, however, flag States should still be encouraged to take unilateral action with regard to noise as a pollutant.

The legislative power provided to coastal States under Art 211(4)-(6) LOSC is currently more promising, and coastal States should be encouraged to make use of these powers in respect of ocean noise. In the territorial sea, the coastal State's legislative powers are relatively strong on account of the sovereignty it enjoys in that zone. However, coastal States are nonetheless constrained here by the current lack of generally accepted international rules and standards on vessel design, construction and equipment in respect of ocean noise. They may nonetheless undertake "the regulation of maritime traffic" (e.g. by establishing prohibitions on vessel movements in acoustically-sensitive areas) to the extent that innocent passage is not hampered. Subject to the same constraint, they may take other measures to preserve their environment or to prevent, reduce and control pollution (e.g. placing restrictions on vessel speed through certain areas, in order to reduce noise pollution).

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[128] Note though that para 3.8.3 in chapter 3 of the Annex to Resolution A.720(17) (albeit now superseded) states that "[o]ther measures which could be considered [in a PSSA] include special construction requirements ...".

[129] See para 7.4.2.1(a)(ii). It is unclear who has the task of judging whether a measure "should be available", and what criteria are to be used in reaching this judgment. Secondly, the term "generally applicable" is not used in the LOSC. In contrast, the terms "applicable" and "generally accepted" are used in Part XII of the LOSC (notably in Art 211 and in Arts 213, 214, 216-220 & 222), and much has been written on these terms.

In the EEZ, in comparison to the territorial sea, the coastal State's legislative powers are relatively weak. The current absence of "generally accepted international rules and standards established through the competent international organization or general diplomatic conference" in respect of noise pollution from vessels renders the coastal State unable to legislate in general in respect of its EEZ under Art 211(5) LOSC. Instead, Art 211(6) LOSC provides the coastal State with the option of seeking "special area" status for particular parts of the EEZ, but only where specified criteria are judged by the IMO to have been met. This option is available in respect of ocean noise. In current circumstances, measures proposed by the coastal State may relate "to discharges or navigational practices". In contrast to routeing measures for the territorial sea, any routeing measures for special areas in the EEZ are subject to IMO approval.

Two IMO tools may be of assistance: routeing measures and "particularly sensitive sea areas" ("PSSAs"), both of which may also apply beyond areas under national jurisdiction. However, it is strongly arguable that IMO-approved routeing measures do not, because of the wording of the IMO's *General Provisions on Ships' Routeing*, address operational noise pollution. This weakness is incompatible with the IMO's increasing desire to use routeing systems and reporting systems to help protect the environment. PSSAs show more promise. There is no reason why a State should not submit a proposal for a PSSA in view of concerns about ocean noise. The scope for routeing measures as an associated protective measure may be limited, in view of the point made above. However, there is scope for speed restrictions and perhaps for special construction requirements. There is currently a resurgence of interest by States in PSSAs, and States should be encouraged to establish and manage PSSAs in respect of ocean noise concerns.

4. Conclusion

This paper has analysed the regulation of ocean noise from the point of view of noise as a pollutant. It has focused on just three categories of pollution, referred to in Part XII of the LOSC as (a) pollution from seabed activities subject to national jurisdiction, (b) pollution from activities in the Area, and (c) pollution from vessels. The conclusion varies depending on which of these sources is considered. With regard to pollution from seabed activities subject to national jurisdiction, there are twelve regional seas treaties with strong potential to cover noise pollution, albeit that over the next few years the focus in respect of many of these treaties is likely to be the regulation of land-based activities. Unilateral action by coastal States is also possible. In relation to pollution from activities in the Area, the International Seabed Authority has already demonstrated its willingness to regulate for environmental protection, though noise pollution appears to have been somewhat overlooked so far. Unilateral application by sponsoring States and flag States of more stringent environmental legislation is also a possibility. With regard to pollution from vessels, there is need for “generally accepted international rules and standards” in respect of noise pollution in order to give more meaning to flag State legislative duties and coastal State legislative powers. In the meantime, unilateral action by flag States is possible. Furthermore, some action by coastal States in respect of their territorial seas and exclusive economic zones is also possible, as is action by States to establish and manage “particularly sensitive seas areas” in response to ocean noise concerns.

Appendix A - Some international instruments of actual or potential relevance to protection of cetaceans from ocean noise (other than specifically in relation to pollution)

Global

Instrument	**Adopted**	**Entry into force**
International Convention for the Regulation of Whaling	1946	1948
Convention Concerning the Protection of the World Cultural and Natural Heritage	1972	1975
Convention on Wetlands of International Importance especially as Waterfowl Habitat	1972	1975
Convention on the Conservation of Migratory Species of Wild Animals ("Bonn Convention")	1979	1983
United Nations Convention on the Law of the Sea [see, *inter alia*: Parts V, VII and XI; and Art 194(5) of Part XII]	1982	1994
Convention on Biological Diversity	1992	1993

Regional

Instrument	**Adopted**	**Entry into force**
Convention on the Conservation of European Wildlife and Natural Habitats	1979	1982
Convention on the Conservation of Antarctic Marine Living Resources	1980	1982
Protocol on Environmental Protection to the Antarctic Treaty - Annex V	1991	not yet

Instruments adopted under Bonn Convention:		
Agreement on the Conservation of Small Cetaceans of the Baltic and North Seas	1992	1994
Agreement on the Conservation of Cetaceans of the Black Sea, Mediterranean Sea, and Contiguous Atlantic Area	1996	2001
Regional sea conventions:		
Convention for the Protection of the Marine Environment of the North-East Atlantic [see, *inter alia*, Art 2(1); see also Annex V *On the Protection and Conservation of the Ecosystems and Biological Diversity of the Maritime Area*; and Appendix 3 on *Criteria for Identifying Human Activities for the Purpose of Annex V*]	1992	1998
Convention on the Protection of the Marine Environment of the Baltic Sea Area [see, *inter alia*, Art 15]	1992	2000
Convention on the Protection of the Black Sea against Pollution [see, *inter alia*, Art V(5)]	1992	1994
Convention for the Protection and Development of the Marine Environment of the Wider Caribbean Region [see, *inter alia*, Arts 4(1) & 10]	1983	1986
Convention for the Protection, Management, and Development of the Marine and Coastal Environment of the Eastern African Region [see, *inter alia*, Arts 4(1) & 10]	1985	1996
Convention for the Protection of the Marine Environment and the Coastal Region of the Mediterranean [see, *inter alia*, Arts 4(1) & 10]	1995	not yet
Regional Convention for the Conservation of the Red Sea and Gulf of Aden Environment [see, *inter alia*, Art III(1)]	1982	1985
Convention for the Protection of the Natural Resources and Environment of the South Pacific Region [see, *inter alia*, Arts 5(1), 13 & 14]	1986	1990

Convention for the Protection of the Marine Environment and Coastal Area of the South-East Pacific [see, *inter alia*, Art 3(1)]	1981	1986
Convention for Co-operation in the Protection and Development of the Marine and Coastal Environment of the West and Central African Region [see, *inter alia*, Arts 4(1) & 11]	1981	1984
Convention for Cooperation in the Protection and Sustainable Development of the Marine and Coastal Environment of the Northeast Pacific [see, *inter alia*, Art 6(2)]	2002	not yet
Protocols pursuant to regional seas conventions:		
Protocol Concerning Protected Areas and Wild Fauna and Flora in the Eastern African Region	1985	1996
Protocol for the Conservation and Management of the Protected Marine and Coastal Areas of the South-East Pacific	1989	1994
Protocol Concerning Specially Protected Areas and Wildlife to the Convention for the Protection and Development of the Marine Environment of the Wider Caribbean Region	1990	2000
Protocol Concerning Specially Protected Areas and Biological Diversity in the Mediterranean	1995	1999
European Community law:		
Council Directive (21.5.1992) on the conservation of natural habitats and of wild fauna and flora (92/43/EEC) OJ L 206, 22.7.92, p 7	1992	

Appendix B - Treaties underlying regional seas initiatives

Treaty	**Adopted**	**Entry into force**
Convention for the Protection of the Marine Environment of the North-East Atlantic ("OSPAR Convention") Available at: http://www.ospar.org/eng/html/convention/	1992	1998
Convention on the Protection of the Marine Environment of the Baltic Sea Area ("Helsinki Convention") Available at: http://www.helcom.fi/helcom/convention.html	1992	2000
Convention on the Protection of the Black Sea against Pollution ("Bucharest Convention") Available at: http://www.blacksea-environment.org/	1992	1994
Convention for the Protection and Development of the Marine Environment of the Wider Caribbean Region ("Cartagena Convention") Available at: http://www.cep.unep.org/pubs/legislation/cartxt.html	1983	1986
Convention for the Protection, Management, and Development of the Marine and Coastal Environment of the Eastern African Region ("Nairobi Convention") Available at: http://www.unep.ch/seas/main/eaf/eafconv.html	1985	1996
Kuwait Regional Convention for Co-operation on the Protection of the Marine Environment from Pollution ("Kuwait Convention") Available at: http://sedac.ciesin.org/entri/texts/kuwait.marine.pollution.1978.html	1978	1979
Convention for the Protection of the Marine Environment and the Coastal Region of the Mediterranean ("Barcelona Convention"; [1995 amendment not yet in force]) Available at: http://sedac.ciesin.org/pidb/texts/mediterranean.pollution.1976.html	1976	1978
Regional Convention for the Conservation of the Red Sea and Gulf of Aden Environment ("Jeddah Convention")	1982	1985

Available at: http://www.unep.ch/seas/main/persga/convtext.html		

Convention for the Protection of the Natural Resources and Environment of the South Pacific Region ("Noumea Convention") See: http://sedac.ciesin.org/pidb/texts/natural.resources.south.pacific.1986.html	1986	1990
Convention for the Protection of the Marine Environment and Coastal Area of the South-East Pacific ("Lima Convention") Available at: **Error! Bookmark not defined.**	1981	1986
Convention for Co-operation in the Protection and Development of the Marine and Coastal Environment of the West and Central African Region ("Abidjan Convention") Available at: **Error! Bookmark not defined.**	1981	1984
Convention for Cooperation in the Protection and Sustainable Development of the Marine and Coastal Environment of the Northeast Pacific Available at: http://www.unep.ch/seas/main/nep/nepconve.html	2002	not yet

Appendix C - Selected provisions of regional seas treaties

Treaty	Provision (emphasis added)
OSPAR Convention	**Article 5** **Pollution from offshore sources** The Contracting Parties shall take, individually and jointly, all possible steps to prevent and eliminate pollution from offshore sources in accordance with the provisions of the Convention, in particular as provided for in Annex III. **Article 1** **Definitions** For the purposes of the Convention: [...] (j) "Offshore activities" means activities carried out in the maritime area for the purposes of the exploration, appraisal or exploitation of liquid and gaseous hydrocarbons. (k) "Offshore sources" means offshore installations and offshore pipelines from which substances or energy reach the maritime area. (l) "Offshore installation" means any man-made structure, plant or vessel or parts thereof, whether floating or fixed to the seabed, placed within the maritime area for the purpose of offshore activities. (m) "Offshore pipeline" means any pipeline which has been placed in the maritime area for the purpose of offshore activities. [...]
Helsinki Convention	**Article 12** **Exploration and exploitation of the seabed and its subsoil** 1. Each Contracting Party shall take all measures in order to prevent pollution of the marine environment of the Baltic Sea Area resulting from exploration or exploitation of its part of the seabed and the subsoil thereof or from any associated activities thereon as well as to ensure that adequate preparedness is maintained for immediate response actions against pollution incidents caused by such activities. 2. In order to prevent and eliminate pollution from such activities the Contracting Parties undertake to implement the procedures and measures set out in Annex VI, as far as they are applicable.

Bucharest Convention	**Article XI** **Pollution from activities on the continental shelf** 1. Each Contracting Party shall, as soon as possible, adopt laws and regulations and take measures to prevent, reduce and control pollution of the marine environment of the Black Sea caused by or connected with activities on its continental shelf, including the exploration and exploitation of the natural resources of the continental shelf. The Contracting Parties shall inform each other through the Commission of the laws, regulations and measures adopted by them in this respect. 2. The Contracting Parties shall cooperate in this field, as appropriate, and endeavour to harmonize the measures referred to in paragraph 1 of this Article.
Cartagena Convention	**Article 8** **Pollution from sea-bed activities** The Contracting Parties shall take all appropriate measures to prevent, reduce and control pollution of the Convention area resulting directly or indirectly from exploration and exploitation of the sea-bed and its subsoil.
Nairobi Convention	**Article 8** **Pollution from sea-bed activities** The Contracting Parties shall take all appropriate measures to prevent, reduce and combat pollution of the Convention area resulting directly or indirectly from exploration and exploitation of the sea-bed and its subsoil.
Kuwait Convention	**Article VII** **Pollution resulting from exploration and exploitation of the bed of the territorial sea and its sub-soil and the continental shelf** The Contracting States shall take all appropriate measures to prevent, abate and combat pollution in the Sea Area resulting from exploration and exploitation of the bed of the territorial sea and its sub-soil and the continental shelf, including the prevention of accidents and the combating of pollution emergencies resulting in damage to the marine environment.
Barcelona Convention	**Article 7** **Pollution resulting from exploration and exploitation of the continental shelf and the seabed and its subsoil** The Contracting Parties shall take all appropriate measures to prevent,

	abate, combat pollution of the Mediterranean Sea area resulting from exploration and exploitation of the continental shelf and the seabed and its subsoil.

Jeddah Convention	**Article VII** **Pollution resulting from exploration and exploitation of the bed of the territorial sea, the continental shelf and the sub-soil thereof** The Contracting Parties shall take all appropriate measures to prevent, abate and combat pollution in the Sea Area resulting from exploration and exploitation of the bed of the territorial sea, the continental shelf and the sub-soil thereof, including the prevention of accidents and the combating of pollution emergencies resulting in damage to the marine environment.
Noumea Convention	**Article 8** **Pollution from sea-bed activities** The Parties shall take all appropriate measures to prevent, reduce and control pollution in the Convention area resulting directly or indirectly from exploration and exploitation of the sea-bed and its subsoil.
Lima Convention	**Article 4** **Measures to prevent, reduce and control pollution of the marine environment** The measures adopted by the High Contracting Parties to prevent and control pollution of the marine environment shall include, *inter alia*, measures designed to minimize to the fullest possible extent: [...] (c) Pollution from any other installations and devices operating in the marine environment, in particular measures for preventing accidents and dealing with emergencies, ensuring the safety of operations at sea, and regulating the design, construction, equipment, operations and manning of such installations or devices.
Abidjan Convention	**Article 8** **Pollution from activities relating to exploration and exploitation of the sea-bed** The Contracting Parties shall take all appropriate measures to prevent, reduce, combat and control pollution resulting from or in connection with activities relating to the exploration and exploitation of the sea-bed and its subsoil subject to their jurisdiction and from artificial islands, installations and structures under their jurisdiction.
Antigua Convention	**Article 6** **Measures to prevent, reduce, control and remedy pollution and other forms of deterioration of the marine and coastal**

	environment 1. The Contracting Parties shall adopt measures to prevent, reduce, control and remedy pollution and other forms of deterioration of the marine and coastal environment, including: [...] (b) Pollution caused by ships and any other arrangement or installation that operates in the marine environment ...

Annex 2. Guidelines for commercial cetacean-watching activities in the ACCOBAMS area

RESOLUTION 1.11

GUIDELINES FOR COMMERCIAL CETACEAN -WATCHING ACTIVITIES IN THE ACCOBAMS AREA

The Meeting of the Parties to the Agreement on the Conservation of Cetaceans of the Black Sea, Mediterranean Sea and contiguous Atlantic area,

Considering

- that cetacean-watching activities for commercial purposes are increasingly being developed in the ACCOBAMS area and require to be regulated;
- that commercial cetacean-watching activities, where properly conducted, do contribute to the building of education and awareness on cetaceans and their habitat;

Noting :

- *that the International Whaling Commission, at its 48th annual meeting (1996), adopted the Scientific Committee's recommendations on the general principles for the management of whale-watching (IWC Resolution 1996-2);*
- *that the Workshop on the Legal Aspects of Whale Watching, held in Punta Arenas, Chile, in 1997 and sponsored by IFAW (International Fund for Animal Welfare), drafted the Options for the Development of Legislation or Guidelines Related to Whale Watching;*
- the code of conduct for cetacean watching drafted under the Agreement between France, Italy and Monaco on the Mediterranean Sanctuary for Marine Mammals;
- that legislation or guidelines applying to cetacean-watching activities have been adopted by a number of countries;

Acknowledging

- that under Article II.1, of ACCOBAMS the Parties shall prohibit and take all necessary measures to eliminate any deliberate taking of cetaceans, including harassing or attempting to engage in any such conduct;
- that under Chapter 2 of Annex 2 to ACCOBAMS, when necessary, the Parties shall develop guidelines and/or codes of conduct to regulate or manage activities which create interactions between humans and cetaceans, such as touristic activities;
- that under Chapter 1.c) of Annex 2 to ACCOBAMS the Parties shall require impact assessments to be carried out in order to provide a basis for either allowing or prohibiting the continuation or the future development of activities that may affect cetaceans or their habitat in the ACCOBAMS area, including tourism and cetacean-watching, as well as establishing the conditions under which such activities may be conducted;

- that under Article III.8.c) of ACCOBAMS, the Meeting of the Parties makes recommendations to the Parties as it deems necessary or appropriate and adopts specific actions to improve the effectiveness of ACCOBAMS;

Aware that it is desirable that other guidelines be developed in the near future to specifically address cetacean watching activities for research or non-commercial recreational purposes;

1. *Recommends* the Contracting Parties to take into consideration the Guidelines annexed below when drafting or updating their domestic legislation on cetacean watching;

2.* Asks *the Scientific Committee to develop these Guidelines on the basis of the evolution of scientific knowledge

ANNEX 1 [to Resolution 1.1.1]

GUIDELINES FOR COMMERCIAL CETACEAN-WATCHING ACTIVITIES IN THE ACCOBAMS AREA

Point 1
Scope of the Guidelines

These Guidelines address cetacean-watching activities carried out for commercial purposes and subject to the jurisdiction of the Parties to ACCOBAMS.

Point 2
Impact assessment

1. Before allowing cetacean-watching activities, the Parties shall require an assessment on their impact on the favourable conservation status for cetaceans.

2. The impact assessment shall be based on the best available scientific information.

3. No cetacean-watching activity are authorized if there are threats of significant adverse impact on the behavioural patterns or physiological well-being of cetaceans, having regard to the number and effect of existing cetacean-watching operations.

4. Based on the results of the impact assessment, the Parties should establish special conditions to carry out cetacean-watching activities.

5. The impact assessment shall be repeated at periodic intervals.

6. The impact assessment shall be carried out under the special procedure established by the Parties.

Point 3
Permit

1. Any commercial cetacean-watching activity should be carried out under a permit granted by the competent authority.

2. Every applicant for a permit for a vessel or aircraft cetacean-watching operations should submit to the competent authority an application in writing setting out:

   a) the type, number and speed of vessels or aircraft intended for use and the maximum number of vessels or aircraft the operator proposes to operate at any time;
   b) information relating to the noise level of each vessel or aircraft both above and below the sea;
   c) the area of operation;
   d) the base of operation;
   e) the duration and frequency of trips;
   f) the species of cetaceans with which the operation will have contact and the kind of contact;
   g) the method of location of cetaceans;
   h) the maximum number of passengers to be taken on board;
   i) the persons in command of the vessel or aircraft;
   j) the educational materials provided to the passengers;
   k) the altitude of the aircraft.

3. No permit should be granted if the competent national authority is not satisfied that:

   a) the operator and the staff who come into contact with cetaceans have sufficient experience with cetaceans;
   b) the operator and the staff have sufficient knowledge of the local area and of sea and weather conditions;
   c) the operator and the staff who come into contact with cetaceans have no convictions for offences involving the mistreatment of animals;
   d) the operation proposed has sufficient educational value to the public.

4. The competent national authority may at any time suspend or revoke a permit, or restrict the operation authorized by a permit, where:

   a) the holder contravenes or fails to comply with any statutory requirement relating to cetacean-watching or any condition specified in the permit;
   b) to suspend, revoke or amend a permit is necessary, on reasonable grounds, for maintaining the favourable conservation status for cetaceans.

Point 4
Behaviour around cetaceans

The following conditions should apply where cetacean-watching activities are being carried out:

a) vessels and aircraft should be operated so as not to disrupt the normal movement or behaviour of cetaceans;
b) contact with cetaceans should be abandoned at any stage if they show signs of becoming disturbed or alarmed;
c) no cetacean should be separated from a group;
d) no rubbish or food should be thrown near or around the cetaceans;

e) no sudden or repeated change in the speed or direction of vessels or aircraft should be made except in the case of an emergency;
f) where a vessel stops to enable the passengers to watch a cetacean, the engines should be placed in neutral;
g) no aircraft should be flown below 150 metres above sea level;
h) no vessel should approach within 50 metres of a cetacean;
i) no vessel should cut off the path of a cetacean
j) no cetacean should be prevent from leaving the vicinity of the vessel;
k) a vessel less than 300 metres from cetaceans should move at a constant speed no faster than the slowest cetacean in the vicinity;
l) a vessel departing from the vicinity of cetaceans should proceed slowly until the vessel is at least 300 metres from the nearest cetacean;
m) aircraft should be operated is such a manner that, without compromising safety, the aircraft's shadow is not imposed directly on cetaceans;
n) only one vessel or aircraft at any one time should be allowed to stay in the watching area;
o) the presence in the watching area should be limited to around 15 minutes for vessels or 2 minutes for aircraft, especially if other vessels or aircraft are waiting for their turn;
p) no vessel should approach within 100 metres of any cetacean that is accompanied by a calf;
q) vessels should approach a cetacean only diagonally from the rear side;
r) activities such as swimming with cetaceans should be specifically authorised and regulated;
s) cetaceans should not be in any other way disturbed or harassed.

Point 5
Training and special quality mark

1. The Parties should organise training courses for operators and staff and grant them a certificate

2. The Parties should allow the use of a special quality mark to the operators who have behaved in conformity with the applicable regulations or guidelines, have obtained a training certificate and have a qualified guide on board.

Point 6
Sanctions and remedies

1. The Parties should impose sanctions of sufficient gravity to deter violations of the present Guidelines, including the suspension or revocation of permits.
2. Those who are responsible of violations should be required to compensate the damage in the form of restitution or mitigation.

Annex 3. Documented examples of cetacean disturbance by boat traffic

(Adapted from: S.J. Dolman, E.C.M. Parsons and M.P. Simmonds 2002. Noise Sources in the Cetacean Environment. Paper presented to the Scientific Committee at the 51st Meeting of the International Whaling Commission (IWC/SC 54/E7)

Bottlenose dolphins, *Tursiops* spp.

Although bottlenose dolphins are known to display positive reactions to boat traffic, approaching boats to ride on the bow-wave (Shane *et al.* 1986) and associating with fishing vessels (Corkeron, 1990), they are also known to display negative reactions to vessel traffic. Scientific literature summarising these reactions is described below.

Location: Cardigan Bay, Wales.

- In August 1999 land-based observation sites were used to monitor bottlenose dolphin behaviour, including their behaviour around boat traffic.
- Generally dolphins displayed neutral behaviour around boats (neither attracted nor deterred). However, dolphins displayed a significant attraction to dolphin-watching boats, and were significantly deterred from kayaks.
- Size of bottlenose dolphin group did not affect the dolphins' reactions to boat traffic.

Ref: Gregory and Rowden 2001.

Location: Perth, Australia.

- Decrease in dolphin feeding and resting behaviour was correlated with the presence of dolphin watching boats ($p<0.01$ and $p<0.05$ respectively). In addition, travelling behaviour increased with presence of tour boats ($p<0.01$).
- In the presence of boats, duration of behaviours decreased ($p<0.01$ feeding & resting, $p<0.05$ socialising).
- Mean group size increased with the presence of tour boats ($p<0.01$)

Ref: Crosti and Arcangeli 2001.

Location: Sarasota, Florida, USA.

- Dolphins displayed longer intervals between inhalations/exhalations when a boat approached within 100m.
- Intervals between inhalations/exhalations increased as the dolphins' distance from boats decreased
- Dolphins displayed significant changes in underwater behaviour when boats approached including: changes direction, decreased distances between animals and increased swimming speeds.
- Approaches of boats to dolphins in shallow waters increased the probability of a change in behaviour.

Ref: Nowacek *et al*. 2001.

Location: Clearwater, Florida, USA.

- Dolphin foraging behaviour was compared between two sites with differing densities of boat traffic. No measurable differences in the amount of time dolphins dedicated to foraging behaviour was recorded between the sites.
- Habitat use by foraging dolphins did, however, differ between weekend and weekday periods at the site with a higher density of boat traffic.
- Preferred feeding areas included boat channels during low boat traffic periods (weekdays: 0.67± 0.03 vessels per km^2), which disappeared in higher traffic periods (weekends: 1.71± 0.08 vessels per km^2).
- At the lower traffic density site (weekdays: 0.17± 0.01 vessels per km^2; weekends 0.53± 0.03 vessels per km^2) vessel traffic densities were not high enough to evoke a measurable response.
- Dolphins reduced the use of their primary foraging habitats in periods of high boat activity, i.e. dolphins altered habitat use directly to avoid boat traffic, or as a result of their prey avoiding boat traffic.

Ref: Allen and Read 2000.

Location: Port Phillip Bay, Victoria, Australia.

- Whistle production by bottlenose dolphins was significantly greater in the presence of commercial dolphin swim-tour boats. The behaviour exhibited by the dolphins prior to the arrival of the boats did not affect this increased rate of vocalisations.

Ref: Scarpaci *et al.* 2000.

Location: Moray Firth, Scotland.

- Forty-two cases of dolphin/boat interactions were observed in the Moray Firth. In seven cases the boat stopped; in 35 cases the boat passed through the dolphin group without stopping.
- The total number of surfacings (within a radius of 100m) before and after the boat had approached within 50m was recorded. This was compared to surfacing rates in a control (non-boat impacted) group. There was a highly significant decrease in surfacing rate after boats had passed through the dolphin groups.
- Comparisons were made between approaches by dolphin-watching boats and other types of boat. In 17 of the 22 cases where dolphin-watching boats approached groups, fewer surfacings were recorded, which was statistically significant. In 7 of the 12 cases of approaches by other boats a decrease in surfacing rate was recorded and an increase in 4 cases. There was no significant difference in surfacing rates after the approach of non-dolphin-watching boats but the sample size for this group of vessels was small.

Ref: Janik and Thompson 1996.

Location: Sarasota, Florida, USA

- Preliminary analyses suggested that boat traffic affected bottlenose dolphin distribution, behaviour and energy requirements.
- Significantly fewer dolphins were seen in boat channels on weekends (periods of high vessel traffic) than on weekdays, suggesting a shift in distribution to avoid boat traffic.

Ref: Wells 1993.

Location: Cardigan Bay, Wales.

- The responses of bottlenose dolphins were observed when exposed to speedboats and playbacks of sounds produced by speedboats.
- Observed responses included shorter surfacing periods and longer dive times observed from vessels at distances of 150-300m.
- The authors suggested that quieter boats travelling at high speeds disturb dolphins more than slower, larger boats that emit higher intensity noise. The noise produced by a high speed boat only rises above ambient levels shortly before its closest point of approach, eliciting a startle response.

Ref: Evans *et al.* 1992.

Location: Ensenada De La Plaz, Mexico.

- No quantifiable adverse responses to boat traffic in Ensenada De La Plaz were recorded.

Ref: Acevedo 1991.

Beluga whales, *Delphinapterus leucas*

Location: St. Lawrence Estuary, Canada.

- In 1991 beluga whale vocal behaviour was monitored before and after exposure to noise from a small motorboat and a ferry.
- Vocal responses were observed in all trials but were more pronounced when exposed to the ferry.
- Responses included: (i) a progressive reduction in calling rate, (ii) brief increases in falling tonal calls and three pulsed-tone call types, (iii) an increase in the repetition of specific calls, and (iv) a shift in frequency bands used by vocalising animals from 3.6kHz to 5.2-8.8 kHz when vessels were close (within 300m) to the whales.

Ref: Lesage *et al.* 1999.

Location: Arctic

- Vocal behaviour recorded in beluga whales exposed to the noise produced by a large vessel and an icebreaker ship, altered after exposure. The beluga whales remained vocal and emitted a large proportion of falling tonal, chirp trains, “morse” tonal calls and noisy pulsive calls, thought to be alarm calls.
- These alarm calls were produced when the vessels were at a distance of 85km.
- Avoidance behaviour began to be observed when vessels were 45-60km away. Received, broad-band (20Hz – 1kHz) noise levels from the shipping at this distance were 94-105 dB re 1μPa.
- Group integrity and surfacing/diving behaviour also changed.
- The beluga whales travelled up to 80km away from the vessel’s course and remained displaced for 1-2 days.

Ref: Findley *et al.* 1990.

Location: St. Lawrence Estuary, Canada

- Beluga whales changed direction to avoid shipping traffic and increased swimming speed.
- Reactions were stronger when the shipping traffic made sudden changes in speed or direction.

Ref: Edds and MacFarlane 1987.

Location: Bristol Bay, Alaska

- Beluga whales stopped feeding and swam down river in response to motorboats, even when levels of received noise were low.
- The beluga whales showed stronger reactions to vessels with outboard motors than other vessels.
- The beluga whales exhibited reactions despite received sound levels being so low the researchers considered that they would be barely perceptible to the beluga whales.

Ref: Stewart et al. 1982, 1983.

Location: MacKenzie Estuary, Canada,

- Beluga whales avoided tug boats and oil auxiliary vessels even though they were further than 2km away.
- The beluga group split up and remained separate for several hours

Ref: Fraker 1977a,b; 1978.

Location: Bristol Bay, Alaska

- Beluga whales, *Delphinapterus leucas*, feeding in Bristol Bay, Alaska were not displaced from their feeding site despite being harassed by speedboats.

Ref: Fish and Vania 1971.

Porpoises

Species type: Finless porpoise, *Neophocaena phocaenoides*
Location: Hong Kong.

- The presence of boats caused a significant increase in finless porpoise dive times. It was suggested that the longest dives were in response to speed and passenger boats.
- Porpoises were observed surfacing tens of metres in front of, or alongside, high-speed ferries.
- Porpoises were observed leaping, apparently as an avoidance reaction in response to approaching boat traffic.

Ref: Beasley and Jefferson 2000.

Species type: Harbour porpoise, *Phocoena phocoena*
Location: Shetland Isles, Scotland

- Harbour porpoises in south-east Shetland avoided shipping traffic of all sizes.
- The occurrence of shipping vessels in an area could lead to porpoises departing the area completely.
- Porpoises were more likely to avoid infrequent vessels than routine vessels such as regular ferry services.

Ref: Evans et al. 1994.

Species type: Harbour porpoise, *Phocoena phocoena*
Location: Bay of Fundy, Canada.

- Harbour porpoises were significantly more frequently observed swimming away from the survey ship route than towards it.
- The avoidance behaviour was more frequent for animals sighted within 400m of the survey vessel.

Ref: Polacheck and Thorpe 1990.

Species type: Vaquita, *Phocoena sinus*
Location: Gulf of California, Mexico.

- Vaquita surfacing duration and respiration rate decreased in the presence of boats.

Ref: Silber et al. 1988.

Species type: Dall's porpoise, *Phocoenoides dalli*
Location: Pacific Ocean

- Dall's porpoises, *Phocoenoides dalli,* are attracted to boat traffic (Jefferson *et al.,* 1991).
- In Japanese waters, Dall's porpoise mothers with calves actively avoid boat traffic (C. Perry pers. comm. 2002)

Species type: Finless porpoise, *Neophocaena phocaenoides*

Other Odontocete Cetaceans

Species type: Boto *Inia geoffrensis*
Tucuxi *Sotalia fluviatilis*.
Location: Loreto Yacu river, Colombia

- Preliminary evaluation of the effect of boat activity on the vocal activity of dolphins has led to concern about the effect of intense boat traffic on surfacing dolphins and on their vocal behaviour, especially at confluences.
- Botos seem to be adapted to boat traffic even though many fishermen recognise that they strike a dolphin at least once a year, especially in the Orinoco region.
- Tucuxis avoid boats and seem to be more affected by traffic.

Ref: Omacha, pers. Comm. 2002.

Species type: Pacific humpback dolphin, *Sousa chinensis*
Location: Moreton Bay, Australia

- The rate of Pacific humpback dolphin, *Sousa chinensis*, whistling significantly increased when boats entered an area.
- Click train or burst pulse rates were not affected.
- Whistling rates increased when boats came within 1.5 km of the dolphins.
- Groups with no calves produced significantly fewer whistles.
- It was suggested that mother-calf pairs were most disturbed by transiting boat traffic.

Ref: Van Parijs and Corkeron 2001.

Species type: Sperm whale, *Physeter macrocephalus*
Location: Kaikoura, New Zealand

- Resident animals typically showed fewer reactions to whale watching vessels and their responses were less pronounced than those of transients.

- These results may indicate habituation by resident sperm whales.
- Transient sperm whales are influenced by whale watching vessels.

Ref: Richter et al.*, 2001.*

Species type: Hector's dolphins, *Cephalorhynchus hectori*
Location: Porpoise Bay, South island, New Zealand.

- Land-based survey stations observed changes in Hector's dolphin behaviour around a dolphin-watching boat in Porpoise Bay: a small (4km^2), shallow (<18m) bay.
- Dolphins were not displaced from the Bay as a result of the dolphin-watching activities.
- Analysis of dolphin orientation towards the dolphin-watching boat showed that dolphins initially orientated towards and approached the boat. However, as the encounter progressed dolphins became less interested.
- By 70 minutes into any particular encounter dolphins were either actively avoiding the dolphin-watching boat or were equivocal towards it.
- Dolphin groups were significantly more tightly bunched when a boat was in the bay.

Ref: Bejder *et al*. 1999.

Species type: Short-finned pilot whales, *Globicephala macrorhynchus*
Risso's dolphins, *Grampus griseus*
False killer whales, *Pseudorca crassidens*
Killer whales, *Orcinus orca*
Pantropical spotted dolphin, *Stenella attenuata*
Clymene dolphin, *Stenella clymene*
Spinner dolphin, *Stenella longirostris*
Striped dolphin, *Stenella coeruleoalba*
Rough-toothed dolphin, *Steno bredanensis*
Melon-headed whale, *Peponocephala electra*
Fraser's dolphin, *Lagenodelphis hosei*
Atlantic spotted dolphin, *Stenella frontalis*
Bottlenose dolphin, *Tursiops truncatus*
Pygmy/dwarf sperm whales (*Kogia spp*.)
Beaked whales (*Ziphidae*)

Location: Gulf of Mexico, USA.

- Analyses of cetacean avoidance reactions to survey ships and aircraft were recorded from 1992-1994 in the Gulf of Mexico.
- 73% of pygmy/dwarf sperm whales (*Kogia spp*.) and beaked whales (*Ziphidae*) (n=15) demonstrated avoidance reactions. None of the animals showed positive reactions to vessels.
- 15% of large delphinids (n=80; short-finned pilot whales, *Globicephala macrorhynchus*; Risso's dolphins, *Grampus griseus*; false killer whales, *Pseudorca crassidens*; and killer whales, *Orcinus orca*) showed avoidance reactions. Only one of six pilot whale groups and 12 of 30 Risso's dolphin groups showed a positive reaction (attraction) towards the survey vessel.

- 6% of small delphinids (n=264; pantropical spotted dolphin, *Stenella attenuata*; clymene dolphin, *Stenella clymene*; spinner dolphin, *Stenella longirostris*; striped dolphin, *Stenella coeruleoalba*; rough-toothed dolphin, *Steno bredanensis*; melon-headed whale, *Peponocephala electra*; Fraser's dolphin, *Lagenodelphis hosei*) showed avoidance reactions, but 90 % of small delphinids approached or bowrode the survey vessel.
- 33% of striped dolphins moved to avoid the survey ship.
- 91% of Atlantic spotted dolphin (n=22; *Stenella frontalis*) demonstrated positive responses towards the survey vessel (attracted towards/bowrode the ship).
- 88% of bottlenose dolphin (n=88; *Tursiops truncatus*) groups displayed positive reactions towards the survey vessel.
- For all cetacean species, animals that were "resting" or "milling" showed greatest susceptibility to disturbance.

Ref: Würsig *et al.* 1998.

Species type: Indian humpback dolphin, *Sousa plumbea*
Location: Algoa Bay, South Africa

- Indian humpback dolphins, *Sousa plumbea*, appeared to be highly susceptible to disturbance by inshore boat traffic.
- The behaviour of Indian humpback dolphins in Algoa Bay, South Africa, was not affected by the presence of bathers or surfboats. However, powerboats did cause changes in behaviour and when these vessels were present avoidance reactions were observed by the dolphins in 95.3% of occasions.
- Females with calves were also observed forming alliances with other females when disturbed by boat traffic, the females interposing themselves between the approaching boat and calves in a protective fashion.
- On numerous occasions animals were seen actively avoiding vessels.
- Areas most heavily used by inshore boat traffic were seldom visited by humpback dolphins.
- Recommended that the behavioural responses of humpback dolphins to powerboat traffic be monitored, in particular the effect of vessel and engine size, underwater noise production and nature of vessel approach.
- Also recommended a comparison of boat noise with dolphin and dolphin prey species acoustics to determine if acoustic interference occurs.

Ref: Karczmarski *et al*. 1997, 1998.

Species type: Short-finned pilot whale, *Globicephala macrorhynchus*
Location: Canary Islands
- Significantly longer dive times were recorded from pilot whales in response to the presence of whale-watching vessels.
- Inter-animal distances also decreased as a response to whale-watching vessels.
- Incidences of behaviour associated with aggression also increased during these periods.

Ref: Heimlich-Boran *et al*. 1994.

Species type: Northern bottlenose whale, *Hyperoodon ampullatus*

Location: Northwest Atlantic

- Northern bottlenose whales, Hyperoodon ampullatus, frequently approach stationary or slow moving vessels.
- The whales may also circle and stay in close proximity of vessels for more than an hour.

Ref: Reeves *et al*. 1993.

Species type: Ganges River dolphin, *Platanista gangetica*
Location: River Ganges, Nepal

- Ganges River dolphin, *Platanista gangetica*, did not display changed behaviour in the presence of rowing boats or canoes.
- River dolphins did, however, avoid areas where motorised ferries were active.

Ref: Smith 1993.

Species type: Sperm whale, *Physeter macrocephalus*
Location: Kaikoura, New Zealand

- Sperm whales demonstrated avoidance behaviour to commercial whale-watching vessels at a distance of 2km.

Ref: Cawthorn 1992.

Species type: Sperm whale, *Physeter macrocephalus*
Location: Kaikoura, New Zealand

- Sperm whale, *Physeter macrocephalus*, behaviour altered in close proximity to whale-watching vessels: surface durations were reduced and respiration rate increased.
- Frequency of dives without flukes being raised also increased.
- Vocalisations were not affected by the presence of boats.
- Some whales appeared to be tolerant of the presence of boats and remained in the area despite repeated boat encounters.

Ref: Gordon et al. *1992.*

Species type: Killer whale, *Orcinus orca*
Location: British Columbia, Canada.

- Killer whales, *Orcinus orca,* in Johnstone Strait did not display obvious avoidance reactions to boat traffic within 400m of the animals.
- Although they did not exhibit obvious avoidance reactions to boats, killer whales swam faster and moved to less confined waters.
- Swimming speeds adopted by these whales were not linked to engine type or boat size.

Ref: Kruse 1991.

Species type: Boto, *Inia geoffrensis*
Tucuxi, *Sotalia fluviatilis*
Location: Amazon river, Peru

- Boto, *Inia geoffrensis*, and Tucuxi, *Sotalia fluviatilis*, demonstrated avoidance reactions and were temporarily displaced by boats.

Ref: Leatherwood *et al*. 1991.

Species type: Black dolphin, *Cephalorhynchus eutropica*
Location: Chile

- Chilean Black dolphins, *Cephalorhynchus eutropica*, tended to avoid boat traffic. However, on some occasions animals would approach vessels.

Ref: Crovetto and Medina 1991.

Species type: Narwhal, *Monodon monoceros*
Location: Arctic

- Narwhals, reacting to the noise produced by a large vessel and an icebreaker ship, ceased vocalising.
- Reactions were, however, temporary and normal behaviour resumed even though received broad-band noise levels were as high as 120 dB re 1µPa.
- However, avoidance reactions were recorded by some animals and these could be displaced over considerable distances.

Ref: Findley *et al*. 1990.

Species type: Squid-eating cetaceans
Location: East Coast, USA.

- Densities of squid-eating cetaceans were reduced in the Northwest Atlantic within several kilometres of shipping vessels.

Ref: Sorensen *et al.* 1984.

Species type: Striped dolphin, *Stenella coeuruleoalba*
Spotted dolphin: *Stenella attenuata*
Location: Tropical Pacific Ocean

- Striped and spotted dolphins approached by a research vessel tried to evade, increased their swimming speed and the group became more densely packed, when the vessel came within 200m

- The dolphins started to display evasive manoeuvres when the boat was more than 11km from the group.

Ref: Au and Perryman 1982.

Species type: Baird's beaked whale, *Berardius bairdii*
Location: Tokyo Bay, Japan.

- It was suggested that postwar decreases in Baird's beaked whale, *Berardius bairdii*, catches in Tokyo Bay were the result of increased boat traffic and changes in the distribution of these species. However, the declines in numbers of this whale species may have been due to the impacts of commercial whaling rather than to the effects of boat traffic.

Ref: Nishiwaki and Sasao 1977.

Species type: Sperm whale, *Physeter macrocephalus*
Location: Whaling grounds

- Sperm whales in whaling areas began to react to the presence of a vessel from a distance of 15km.

Ref: Gambell 1968.

Humpback whales, *Megaptera novaeangliae*
Location: Australia

- As a rule of thumb, doubling the speed of a vessel doubled the range over which whales detected or first reacted to it?. The response was as much a function of the rate of change of noise as its steady level.
- Rapid increases in noise produced more responses.

Ref: McCauley and Cato, 2001.

Location: US
- The acoustic profiles of several whale-watching boats and the responses of humpback whales to them were studied, with the loudest vessels producing the strongest reactions from the whales.
- Whilst they concluded that the noise caused by the whale-watching boats as long as they obeyed the US "stand-off distance" of 91 m should not cause any harm to the auditory systems of the whales they noted that "the ramifications of behavioural changes induced by the presence of boats are open to assessment".

Ref: Au and Green 2000.

Location: Trinity Bay, Newfoundland, Canada.

- Humpback whales appeared tolerant of transient blasting activity and frequent vessel traffic.
- The whales were affected (numbers decreased) by continuous dredging activity concurrent with vessel traffic.
- There was a significant decrease in the return rate of humpback whales to the feeding grounds disturbed by industrial activity, indicating abandonment of the disturbed area which is a possible long-term effect of exposure to blasting.

Ref: Borggaard *et al*. 1999.

Location: Hawaii

- Humpback whale song structure was studied when whales were approached by boats. Although largely the song structure and characteristics were not greatly affected, the duration of some song elements changed.

Ref: Norris 1994.

Location: West Indies

- Some humpback whales avoided boat traffic on the breeding grounds; in particular mothers with calves were sensitive to the approach of boats.

Ref: Clapham and Mattila 1993.

Location: Hawaii

- When a boat approached within 0.5 miles of humpback whales, significant decreases in the amount of time spent at the surface and increases in dive duration were recorded.
- In addition, humpback whales changed direction, avoiding vessels.
- These effects persisted for more than 20 minutes after the vessels had departed.

Ref: Green and Green 1990.

Location: Hawaii

- Humpback whales moved out of a preferred area on days when fast boats operating parasailing rides occurred nearby.

Ref: Green 1990.

Location: Cape Cod, Massachusetts, USA

- Humpback whales that are approached by whale-watching vessels travelling at a slow speed and according to established guidelines for whale-watching display no “adverse reactions”

- Boats that approached within 30m or approached quickly/pursued whales caused the whales to display changes in behaviour.

Ref: Schilling *et al*. 1989.

Location: Hawaii

- Boat traffic speed, numbers, and direction changes were correlated with changes in observed humpback whale behaviour including respiration rates, diving intervals, swimming speed and aerial behaviour (e.g. breaching).
- Humpback whales generally avoided boat traffic.
- Aggressive behaviours were sometimes directed towards vessels.
- Frequencies of surfacing without blows and dives where flukes were not raised increased as the result of exposure to boat traffic.
- Behaviours were elicited when vessels were from 1-0.5 km away.
- Reactions were stronger from groups with a calf or small groups, as opposed to large groups of whales.
- The researchers concluded that exposure to boat traffic is stressful to humpback whales.

Ref: Bauer 1986; Bauer and Herman 1986; Bauer *et al.* 1993.

Location: Cape Cod, Massachusetts, USA

- Twenty-five years of anecdotal observations of whale behaviour near whale-watching vessels were reported upon.
- Humpback whales, *Megaptera novaeangliae*, approached whale-watching vessels more closely in recent times than they did in the past when the whale-watching industry was newer.
- Whales often moved away from whale-watching vessels in response to strong or rapidly changing vessel noise. This avoidance reaction was particularly strong when boats approached whales directly.

Ref: Watkins 1986.

Location: Hawaii

- The presence of boat traffic was correlated with an absence of nursing humpback whales in the coastal waters of Maui

Ref: Glockner-Ferrari and Ferrari 1985.

Location: Alaska

- Observations on humpback whales in the 1970s, suggested that they moved away from vessel traffic and cruise ships at a distance of several kilometres.
- In addition respiration rates and diving durations were altered.

- Behaviour interpreted as aggressive or "threat" behaviour tended to be recorded in the vicinity of boat traffic.

Ref: Dean *et al.* 1985

Location: Alaska

- The departure of humpback whales from Glacier Bay, Alaska, was reported to be correlated with increases in boat traffic over the previous ten years.

Ref: Johnson 1983.

Location: Alaska

- Behaviour exhibited by humpback whales changed according to distance of the whales from the boat traffic.
- Whales responded to vessels by diving for longer, spending less time at the surface and making evasive movements even when the vessels were more than 3km away.
- At less than 2km distance, dive times increased, surface times decreased and swimming speeds slowed.
- It was hypothesised that humpback whales adopted two avoidance strategies:

(a) Horizontal avoidance when vessels were 2-4km away (decreased dive durations, longer surfacing intervals, increased swimming speeds).

(b) Vertical avoidance when vessels were within 2km (increased dive durations, decreased swimming speeds, reduced surfacing durations) i.e. animals try to stay submerged.

- Whales were also displaced from preferred feeding sites by the presence of boat traffic.
- It was also noted that approaching vessels triggered displays of aerial behaviour (leaping and tail/flipper slapping).

Ref: Baker *et al.* 1982, 1983.

Location: Hawaii

- The presence of humpback whales, *Megaptera novaeangliae*, was inversely correlated with the amount of boat traffic.

Ref: Kaufman and Wood 1981.

Location: Alaska

- A tanker passing within 800m of feeding humpback whales did not disrupt the whales or cause changes in behaviour.

Ref: Watkins *et al*. 1981a.

Location: Hawaii

- On rare occasions humpback whales "charge" towards a boat and "scream" underwater, apparently as a threat display towards boats.

Ref: Payne 1978.

Minke whales, *Balaenoptera* spp.

Species type: Antarctic minke whale, *Balaenoptera bonaerensis*
Location: Antarctica

- Antarctic minke whales, *Balaenoptera bonaerensis*, showed no significant reaction to the approach of a survey vessel. It should be noted, however, that the sample size for this experiment was very small and it would be difficult to prove a significant reaction with such a small sample size.

Ref: Borchers and Haw 1990.

Species type: Common minke whale, *Balaenoptera acutorostrata*
Location: St. Lawrence Estuary, Canada

- Minke whales, *Balaenoptera acutorostrata,* changed direction to avoid shipping traffic and increased swimming speed.
- Reactions were stronger when the shipping traffic made sudden changes in speed of direction.

Ref: Edds and MacFarlane 1987.

Species type: Common minke whale, *Balaenoptera acutorostrata*
Location: Cape Cod, Massachusetts, USA

- Twenty-five years of anecdotal observations of whale behaviour near whale-watching vessels were reported upon.
- In recent years, minke whales, *Balaenoptera acutorostrata,* approached whale-watching vessels less frequently than before, initially showing curiosity towards whale-watching vessels.

Ref: Watkins 1986.

Species type: Antarctic minke whale, *Balaenoptera bonaerensis*
Location: Antarctica

- Antarctic minke whales, *Balaenoptera bonaerensis,* have been reported to approach slow moving or stationary vessels.

- There was no evidence of minke whales approaching vessels travelling at survey speeds and some avoidance behaviour was noted.

Ref: Tillman and Donovan 1986.

Species type: Common minke whale, *Balaenoptera acutorostrata*
Location: Tokyo Bay, Japan.

- It was suggested that postwar decreases in minke whale, *Balaenoptera acutorostrata* catches in Tokyo Bay were the result of increased boat traffic and changes in the distribution of these species. However, the declines may have been due to the impacts of commercial whaling causing a decline in numbers of these whale species rather than effects of boat traffic.

Ref: Nishiwaki and Sasao 1977.

Bowhead whales, *Balaena mysticetus*

Location: Beaufort Sea

- Bowhead whales avoiding boat traffic do so when receiving only relatively low levels of vessel produced noise. A 13m diesel powered boat produced an avoidance reaction in a bowhead whale with a received noise level of only 84 dB re μ1Pa. This received level was c. 6dB above the ambient noise level

Ref: Richardson 1995.

Location: Beaufort Sea

- Bowhead whales, *Balaena mysticetus*, exhibited various reactions, including changes of observed behaviour and alteration of diving and respiratory behaviour, when approached by a variety of vessel types.
- Bowhead whales 0.5km to the side or behind a vessel seemed unaffected and on occasions approached within 100-500m of the vessel when the vessel was not manoeuvring towards the whales.
- These whales tolerated broadband noise levels of up to 110-115dB re μ1Pa.
- It was suggested that bowhead whales actively engaged in mating/social behaviour may be less responsive to boat traffic.
- One radio-tagged bowhead whale was approached by a small boat for a period of three days. Dive times were reduced when the boat approached within 500m for a period of 90-150 minutes. For a period of three days after the approaches by the small boat, diving behaviour returned to normal and the whale remained in the general area that the vessel was operating in.

Ref: Wartzok *et al*. 1989.

Location: Beaufort Sea

- Aversion behaviour was exhibited by bowhead whales, *Balaena mysticetus,* when exposed to shipping vessel noise 6-13dB above ambient noise levels.

Ref: Miles *et al*. 1987.

Location: Bering Sea

- Bowhead whales in the Bering Sea exhibited negative responses and moved away from vessels approaching to within 0.4-0.6km of the whales.

Ref: Kibal'chich *et al*. 1986.

Location: Beaufort Sea

- Bowhead whales exhibited avoidance reactions when vessels approached within 0.8-3.4 km.
- The whales demonstrated shorter dive and surface times as the result of the presence of shipping.
- Initially the whales increased speed, presumably attempting to outpace an oncoming vessel, then altered course and swam away from the vessel's course line.
- Subtle changes in surfacing and blow durations and frequencies were noted as the result of the sounds produced by idling diesel engines 3-4km away.
- Whale groups became scattered, with the inter-animal distance increasing from 7.5 (c. 110m) to 37 (c. 0.6km) whale lengths.

Ref: Richardson *et al*. 1985a, 1985b.

Right whales, *Eubalaena* spp.

Species type: Southern right whale, *Eubalaena australis*
Location: Australia

- Southern right whale mothers interposed themselves between their calves and boat traffic in Australian calving grounds.

Ref: Ulmann 1995.

***Species type: Northern right whale,* Eubalaena glacialis**
Location: Bay of Fundy, Canada

- Northern right whales may be approached by a slowly moving vessel but move away from faster vessels.
- During mating and feeding right whales are less responsive to the presence of small vessels unless these vessels change speed or direction abruptly.

Ref: Goodyear 1989.

Species type: Northern right whale, *Eubalaena glacialis*
Location: Cape Cod, Massachusetts, USA

- Northern right whales, *Eubalaena glacialis*, became silent and consistently moved away from whale-watching vessels, diving quickly.

Ref: Watkins 1986.

Species type: Southern right whale, *Eubalaena australis*
Location: Argentina

- Southern right whales displayed variable reactions to boat traffic. Some vessels elicited avoidance reactions, whilst others did not respond even when boats approached to within a few metres.

Ref: Cummings *et al.* 1972; Payne *et al.* 1983.

Species type: Southern right whale, *Eubalaena australis*
Location: Australia

- Although Southern right whale mother-calf pairs did not actively avoid approaching small boats, the mother "adopted a low profile" similar in response to reactions exhibited by disturbed gray whales.

Ref: Robinson 1979.

Species type: Southern right whale, *Eubalaena australis*
Location: South Africa

- Southern right whales displayed variable reactions to boat traffic. Some vessels elicited avoidance reactions, whilst there was no response to other boats.

Ref: Donnelly 1969; Saayman and Tayler 1973.

Gray whales, *Eschrichtius robustus*

Location: Mexico

- Gray whale vocal behaviour changed when exposed to the sound of an outboard motor and the sound of a drillship. Call rate increased after exposure to the former and decreased after exposure to the latter.
- No avoidance reaction was evident during the underwater playbacks and some whales approached the amplifiers playing sound from outboard motors.
- The average received levels of calls (loudness) increased in response to actual boats or playbacks of boat noise, suggesting that the animals vocalised louder possibly to avoid calls being masked by boat noise.

Ref: Dalheim 1987.

Location: Mexico.

- Gray whales abandoned San Diego Bay as the result of exposure to intense shipping activity and dredging.
- The gray whales returned only after vessel traffic decreased.

Ref: Bryant *et al*. 1984.

Location: Mexico.

- Gray whales exhibited short-term escape when approached by boat traffic in breeding lagoons.
- Responses were stronger when exposed to fast or erratically moving vessels.

Ref: Swartz and Cummings 1978; Swartz and Jones 1978, 1981.

Location: Chukotka, Western Russia

- Summering gray whales displayed avoidance reactions and moved away if a vessel was within 350-550m, but no avoidance reactions occurred in response to distant vessels.

Ref: Bogoslovskaya *et al.* 1981.

Location: San Diego, USA.

- Gray whales abandoned San Diego Bay as the result of exposure to vessel traffic.
- The gray whales returned only after vessel traffic decreased.

Ref: Reeves 1977.

Location: Mexico

- Migrating gray whales disturbed by vessels exhale under water, only exposing their blowholes to inhale. This behaviour is also observed when animals are threatened by the presence of killer whales.

Ref: Hubbs 1965; Hubbs and Hubbs 1967.

<u>Location: East Pacific</u>

- During a gray whale migration, whales changed their course at a distance of 200-300m to avoid boat vessels in their path.

Ref: Wyrick 1954.

Fin whales, *Balaenoptera physalus*

Location: Cape Cod, Massachusetts, USA

- Fin whales displayed reduced inter-surfacing and dive intervals and fewer exhalations per surfacing when boat traffic was nearby.

Ref: Young 1989; Stone *et al*. 1992.

Location: St. Lawrence Estuary, Canada

- Fin whales changed direction to avoid shipping traffic at distances of 1km or greater.
- In addition the whales increased their swimming speed and the dive duration.
- Reactions were stronger when the shipping traffic made sudden changes in speed of direction.

Ref: Edds and MacFarlane 1987.

Location: Cape Cod, Massachusetts, USA

- Fin whales reacted strongly to boats producing noise levels of a similar frequency to those used by the fin whales (15-100Hz).

Ref: Watkins 1986.

Location: Prince William Sound, Alaska, USA

- Fin whales ignored whale-watching boats that remained more than 100m away.
- If boats approached slowly at a steady speed no reaction was noted by fin whales.

- If boats changed their speed or course rapidly or put their engine into reverse the whales avoided the boats.

Ref: Watkins 1981b; Watkins *et al.* 1981.

Other Mysticete cetaceans

Species type: Blue whale, *Balaenoptera musculus*
Location: St. Lawrence Estuary, Canada

- Blue whales, *Balaenoptera musculus*, changed direction to avoid shipping traffic.
- Surfacing and respiration patterns were generally not affected, however, when boats approached close to whales, diving behaviour became erratic and inter-surfacing intervals decreased.
- Reactions were stronger when the shipping traffic made sudden changes in speed of direction.

Ref: Edds and MacFarlane 1987.

Species type: Bryde's whale, *Balaenoptera edeni*
Location: Peru

- Bryde's whales were reported to approach slow moving or stationary vessels.
- The whales did not approach vessels travelling at survey speeds however.

Ref: Tillman and Donovan 1986.

Species type: Bryde's whale, *Balaenoptera edeni*
Location: Gulf of California

- Bryde's whales actively approached moving research vessels.

Ref: Cummings *et al*. 1986.

Species type: Bryde's whale, *Balaenoptera edeni*
Location: East Pacific

- Bryde's whales did not show any response to a boat approaching slowly at a steady speed.

Ref: Watkins 1981a.

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