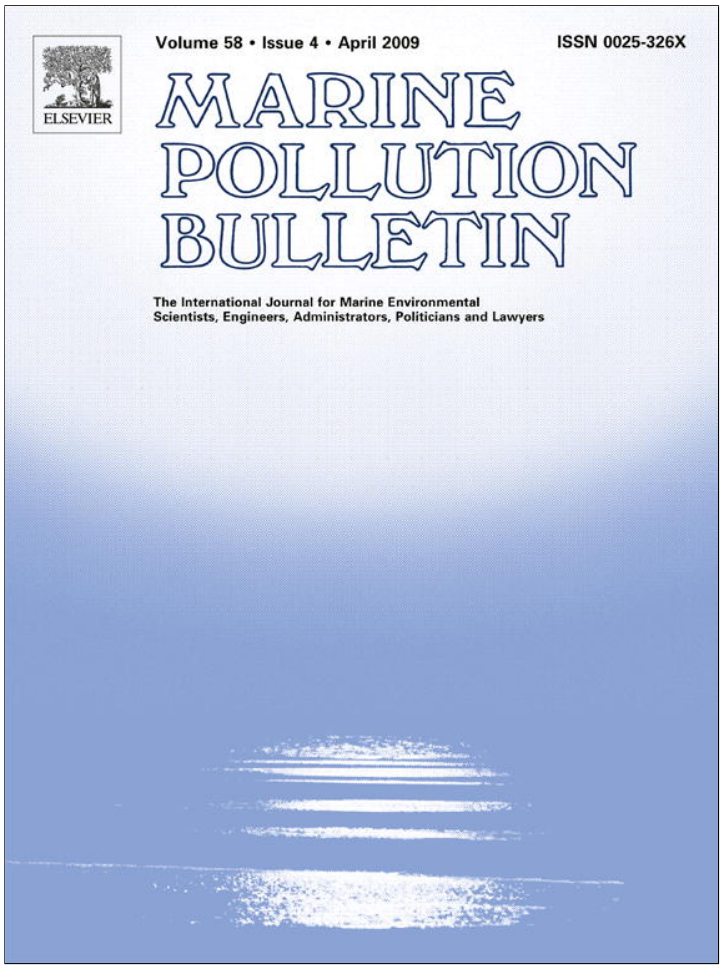

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Review

Comparative review of marine mammal guidance implemented during naval exercises

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ABSTRACT

This article reviews the types and effectiveness of marine mammal mitigation measures used during some naval activities worldwide. The three main standard methods used to mitigate the potential impacts of naval sonar sound on marine mammals are (1) time/area planning (of exercises/active sonar use) to avoid marine mammals; (2) implementation of operational procedures (e.g. 'soft start' – where sound levels are gradually increased over time); and (3) monitoring of animals for the purpose of maintaining an 'exclusion zone' around the sound source. Suggestions towards a minimum worldwide mitigation standard are made.

1. Introduction

Naval exercises occur on maritime ranges that can encompass many thousands of square kilometres. Exercises can be national or multi-national, of varying size in terms of numbers of combatant units, and may include a variety of activities designed to simulate air, sea-surface and subsurface battle conditions. These activities generate varying intensities of sound, from mechanical and propeller sound from ships and low-flying aircraft, to sound from missile launches, gun discharges, active sonar, and explosives detonations, such as for ship-shock trials, which are undertaken to determine a ship's ability to withstand damage caused by nearby explosions. These activities are not always restricted to defined exercise ranges, although high-end training generally does occur within ranges to ensure safety of the public and participants (S. Cole, pers. comm.). Sources are generally mobile, such as high-power modern mid-frequency active sonar systems, which have been in operation since the 1960s, and low-frequency active sonar systems, which were introduced in the 1980s.

Active sonars use a range of source levels and frequencies (Table 1). Although not indicated here, mid- and low-frequency ranges have an overlap – the UK Navy's Sonar 2087 is in the range of low and mid-frequency active sonar according to the US definition of 1 Hz–1 kHz for low-frequency and 1–10 kHz for mid-frequency active sonar systems (Department of Defense, 2007). There are estimated to be over 80 active sonar systems in use or development by NATO member countries (Jasny, 2005). Both mid- and low-frequency systems emit high-intensity sound

Abbreviation: ACCOBAMS, Agreement on the Conservation of Cetaceans of the Black Sea, Mediterranean Sea and contiguous Atlantic Area; ADCP, Acoustic Doppler Current Profiler; ASCOBANS, Agreement on the Conservation of Small Cetaceans of the Baltic and North Seas; AUTEC, Atlantic Undersea Test and Evaluation Centre; BUTEC, British Undersea Test and Evaluation Centre; CCC, California Coastal Commission; CINCFLEET, Commander-In-Chief Fleet; DoD, Department of Defense; EAXA, East Australia Exercise Area; EIAs, Environmental Impact Assessments; EIS, Environmental Impact Statements; EPBC, Environment Protection and Biodiversity Conservation Act; ESS, Environmental Scoping Study; IEER, Improved Extended Echo Range; IUCN, International Union for Conservation of Nature; JMC, Joint Maritime Course; JNCC, Joint Nature Conservation Committee; LFAS, Low Frequency Active Sonar; MAEMP, Maritime Activities Environmental Management Plan; MILOC, Military Oceanography Group; MMO, marine mammal observer; MMPA, Marine Mammal Protection Act; NATO, North Atlantic Treaty Organisation; NDE, National Defence Exemption; NMFS, National Marine Fisheries Service; NURC, NATO Underwater Research Centre; PAM, passive acoustic monitoring; PMRF, Pacific Missile Range Facility; RAN, Royal Australian Navy; RIMPAC, Rim of the Pacific exercise; RN, Royal Navy; RNoN, Royal Navy of Norway; SACLANT, Supreme Allied Commander Atlantic; SAKAMATA, Sea Animal Kind Area-dependant Mitigated Active Transmission Aid; SEA, Strategic Environmental Assessment; SOAR, Southern California Anti-submarine Warfare Range; SOCAL, Southern California; S2087, Sonar 2087; S2117, Sonar 2117; SONATE, Norwegian decision aid tool; TESS, Tactical Environmental Support System; UK, United Kingdom; UNCLOS, United Nations Law of the Sea Convention; USN, United States Navy; USWEX, Undersea Warfare Exercises; WAXA, West Australia Exercise Area.

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Table 1
Parameters of some naval sound sources.

	SQS-53C	SQS-56	SURTASS LFA	Ship shock trial (10,000 lb TNT)
Source level, dB re 1 μPa	235+	223	235	299
Ping duration, S	5	5	6–100	0.1
Ping energy	233	221	243	302
Duty cycle,%	4–8	6.2	10	Intermittent
Frequency, kHz	2.6, 3.3	6.8, 7.5, 8.2	0.1–0.5	Low/broad
Bandwidth	Narrowband	Narrowband	30 Hz	Broadband
Directionality	120 × 40	360 × 30	Horizontal	Omni-directional
Reference	Møhl (2004)	Møhl (2004)	Hildebrand (2005)	Hildebrand (2005)

into the ocean and listen for echoes that provide a 'sonic picture' of the environment. Such echoes include natural marine features as well as returning signals from anthropogenic sources, including some 380 submarine targets operated by around 45 countries (Tomaszeski, 2004). Active sonar is deployed from various platforms, including surface ships, helicopter and fixed-wing aircraft, sonobuoys, and submarines (Jasny, 2005).

Marine mammals rely on sound for all the fundamental biological and ecological aspects of their lives including navigation, prey location and capture, predator avoidance, and communication (including during migration and reproduction). Detailed reviews of mass strandings and non-stranding mortalities (where corpses are recovered at sea) of beaked whales and other cetacean species associated with mid-frequency active sonar are available (Parsons et al., 2008; Weilgart, 2007). The causal mechanism for mortality of individuals from naval sonar remains unknown, as does the extent of its impact. Although most incidents examined to date have involved beach strandings linked to offshore naval activities, it is clear that mortality may also occur at sea (Jepson et al., 2003; Espinosa et al., 2005). In addition to non-auditory physiological impacts (such as damage to body tissue and gas and fat embolism), documented impacts include masking of marine mammal acoustic signals (potentially resulting in loss of opportunities for foraging or reproduction, anxiety or stress, and non-detection of predators) and altered behaviour such as changes in vocalisation rate/amplitude and spatial avoidance of the region of naval trials (Tyack and Clark, 1998; Rendell and Gordon, 1999; Miller et al., 2000). In addition, blast injury has been documented in humpback whales *Megaptera novaeangliae* during construction operations (including explosions and drilling) (Todd et al., 1996). Whilst observations of death, injury and behavioural changes have been documented for odontocetes and mysticetes due to intense noise pollution, cumulative impacts are more difficult to study. The long-term consequences of intense noise pollution, particularly in areas of repeated use, remain largely unknown.

To date, most attention has been focussed on the operation of active sonar, and particularly mid-frequency active sonar, due to a link with cetacean mortality worldwide (Espinosa et al., 2005; Brownell et al., 2004; Fernández, 2006; Fernández et al., 2004; Fernández et al., 2005a; Fernández et al., 2005b; Freitas, 2004; Taylor et al., 2004). Strandings and mortality at sea resulting from active naval sonar have been associated particularly with beaked whales and other primarily (although not exclusively) deep-diving species (see Parsons et al. (2008) for a review). As a result, marine mammal mitigation guidance is often directed at active sonar, and this will form the focus of this review, except where otherwise stated.

This article reviews the mitigation guidance used to protect marine life during naval exercises (Table 2). It is based on the discloseable information available to the authors at the time of

Table 2
Some marine mammal guidance implemented during naval exercises.

Mitigation	Australia	Canada	France	Italy	Norway	NURC	Canary Islands	UK	Hawaii	SoCAL	RIMPAC 2006	NDE I, 2006	NDE II, 2007
Selection of area	Y	N	Y	Y	Y	Y	N	Y	N	N	N	N	Y
Buffer zone	Y	N	N	Y	N	N	N	N	N	N	N	N	N
Coastal exclusion	Y	N	N	N	N	N	Y	N	Y	Y	Y	Y	N
Det sys/database	Y	Y	N	Y	Y	Y	N	Y	N	N	N	N	N
Pre/post ded. Survey	Y	N	Y	Y	Y	Y	N/R	Y	Y	Y	Y	Y	Y
Increased lookout	Y	Y	Y	Y	Y	Y	N/R	Y	Y	Y	Y	Y	Y
Trained observers	N	N	N	N	N	N	N/R	Y	Y	Y	Y	Y	Y
Weather/sightability	Y	Y	N	N	N	Y	N/R	Y	Y	N	Y	Y	Y
PAM	Y	Y	Y	Y	Y	Y	N/R	Y	Y	Y	N	Y	Y
Other monitoring	Y	N	N	N	N	Y	N/R	N	Y	Y	Y	Y	Y
Min source required	N	Y	N	N	Y	Y	N/R	N	Y	Y	Y	Y	Y
Prop. conditions	N	Y	N	N	N	Y	N/R	N	Y	Y	Y	Y	Y
Soft start/ramp-up	N	Y	Y	Y	Y	Y	N/R	N	Y	N	N	N	N
Delay if cet obs'd	N	N	N	N	Y	Y	N/R	N	N	N	N	N	N
Repeat ramp-up	N	N	N	Y	Y	Y	N/R	N	N	N	N	N	N
Pwr dn if cet det	N	N	Y	N	Y	Y	N/R	Y	Y	Y	Y	Y	Y
Sonar off if cet det	Y	Y	Y	N	Y	Y	N/R	Y	Y	Y	Y	Y	Y
Exclusion zone	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
All marine mammals	N	Y	Y	Y	Y	N	N/R	Y	Y	Y	Y	Y	Y
Cow/calf pairs	Y	N	N	N	N	N	N/R	N	Y	Y	N	N	N
Other species	Y	N	N	N	Y	N	N/R	Y	N	N	N	Y	N
Stranding response	N	Y	N	N	N	Y	N/R	N	Y	N	Y	Y	Y
Reporting	Y	Y	N	N	N	Y	N/R	Y	Y	Y	Y	Y	Y
EIA	Y	N	N	N	N	Y	N/R	Y	Y	Y	Y	N	N
Excl. of spec. area	Y	N	N	Y	N	N	Y	Y	Y	Y	Y	Y	Y
Research	N	N	N	N	Y	N	N	N	Y	Y	N	N	N

Y, yes; N, no; N/R, not required; NDE, US National Defence Exemption.

writing. Access to guidelines can be challenging. Guidance undoubtedly exists which is not publicly available or which may have since been updated to differ from that presented here.

2. Existing mitigation measures

Guidance is developed individually by a country for use by their own Navy, and, on the whole, navies self-regulate and set their own mitigation strategies (Glassborow, 2006). The Royal Australian Navy (RAN) has produced extensive guidance under its Maritime Activities Environmental Management Plan (MAEMP). This is an overarching framework under which environmental management strategies, including Planning Handbooks, Planning Guides and Procedure Cards, have been developed. Marine Mammal Impact Mitigation Plans are available for Canadian Navy sea trials in 2002 and 2003. Guidance is available for all Norwegian military units that are operating active sonar in the 1–10 kHz band, with source levels exceeding 200 dB re 1 μPa, in Norwegian waters, including helicopter operated sonar and sonobuoys. Available guidance on the French Navy (Marine Nationale) activities is based on a brief developed for the scientific and technical committee pertaining to the Pelagos agreement (referring to the Ligurian Sea Cetacean Sanctuary) in 2006. Basic information on Italian Navy guidance in the Tyrrhenian Sea is available (Cerutti, 2005). The UK Royal Navy (RN) guidance pertains to Commander-in-Chief Fleet (CINCFLEET) interim command guidance for users of in-service active sonars to mitigate against marine mammal disturbance. Some further guidance is available for Sonar 2087 sea trials that took place between 2002 and 2006. No detailed guidance could be found for the Royal Netherlands Navy, although the authors are aware of limited mitigation efforts. Despite the freedom of information requests, documentation about mitigation measures during active sonar use was not obtainable from the German Navy.

Navy guidance in the US is not straightforward. In June 2006, the US Deputy Secretary of Defense provided a six month National Defense Exemption (NDE) from requirements of the Marine Mammal Protection Act (MMPA) for certain Department of Defense (DoD) mid-frequency active sonar activities to the Secretary of the Navy (Department of Defense, 2006a). During this period, specific guidance was set out on the use of mid-frequency active sonar during major exercises, within established ranges and operating areas (Department of Defense, 2006b). At the end of this NDE, in January 2007, a further Memorandum was provided to the Secretary of the Navy (Department of Defense, 2007). This memorandum included Improved Extended Echo Range (IEER) Sonobuoys (a new sensor system nearing deployment) as well as mid-frequency active sonar, for a further period of two years (Department of Defense, 2007), and retracted some of the measures required by the first exemption, such as a 12 nm coastal exclusion and special conditions for sonar use in low-visibility and significant surface ducting conditions. Two important court cases yielded additional requirements in 2008. Details of the history surrounding the cases, as well as mitigation measures imposed on the US Navy (USN), can be found in an appellate court ruling from February 2008 (NRDC v. Winter, 2008), which allowed completion of major exercises in southern Californian waters on the condition that certain mitigation measures are employed. At the same time, an injunction was imposed by a federal court in Hawaii requiring additional mitigation during USWEX (Undersea Warfare Exercises) around the Hawaiian Islands (OMI v. Gates, 2008).

The guidance of one country may be adopted by another during a joint exercise. In some circumstances, regional measures exist. The North Atlantic Treaty Organisation (NATO) has developed guidance for environmental protection during NATO led activities that identify sound as a potential impact upon wildlife (Fortescue et al., 2005). The NATO Underwater Research Centre (NURC) developed Human Diver and Marine Mammal Risk Mitigation Rules (NATO, 2006) following a mass stranding of Cuvier's beaked whales *Ziphius cavirostris* in Greece during 1996 (Frantzis, 1998). These Rules have periodically been updated, and whilst only applying to NURC activities, have formed the basis of guidance for other nations (Fortescue et al., 2005). In addition, the Scientific Committee of the Agreement on the Conservation of Cetaceans of the Black Sea, Mediterranean Sea and contiguous Atlantic Area (ACCOBAMS) has generated mitigation guidelines for sonar, use of explosives and for other active sound source activities (Pavan, 2007). As scientific rather than military guidance these are not considered further here.

As with seismic survey marine mammal mitigation measures (see Weir and Dolman, 2007), the mitigation guidance used during naval exercises often incorporates three main components: (1) time/area planning (of exercises/active sonar use) to avoid marine mammals; (2) implementation of operational procedures (e.g. 'soft start' – where sound levels are gradually increased over time); and (3) monitoring of animals for the purpose of maintaining an 'exclusion zone' around the sound source. The mitigation measures known to be operated during naval exercises, and associated information sources are summarised in Table 2 and are discussed in more detail below.

2.1. Avoidance of sensitive areas

Most naval guidance loosely defines sensitive areas as breeding, feeding or migration habitat for marine mammals, and/or focuses on the specific measures for beaked whales. While many guidance documents request more stringent mitigation procedures within such areas and suggest planning surveys to avoid sensitive times/areas, there is little rigorous definition of these areas and how they influence naval exercises. A 50 nm exclusion zone is clearly defined and implemented around the Canary Islands for Spanish Navy (Armada Española) vessels (Aguilar and Martín, 2007). The RAN imposes seasonal and source level restrictions within 30 nm of the coastline in its exercise areas off the west (WAXA) and east (EAXA) coasts of Australia, encouraging relocation of activities or retiming outside of sensitive seasons (Australian Defence Force, 2007). The RAN regularly conducts training activities in declared marine reserves and marine-protected areas, including the Great Barrier Reef Marine Park, but increases mitigation procedures while operating there (see Australian Defence Force (2007)). RNoN guidelines include avoiding areas and periods of high marine mammal density and known beaked whale habitats, as well as avoiding whale watching, areas of intense fishing and whaling activities, and some fish spawning grounds and maintenance of a 200 m buffer around aquaculture facilities. Italy and NATO emphasise avoidance of beaked whale habitats (including avoidance of complex seabed topography that beaked whales are likely to inhabit) and, along with the RN, impose measures to avoid protected whale 'sanctuaries'. The Italian Navy has one of the few guidance documents to impose a 'buffer' zone, keeping sonar use 5000 m outside the boundaries of 'important' areas (e.g. whale sanctuaries). The US uses a 1 nm buffer zone for LFAS (Low Frequency Active Sonar). The RN used buffer zones during S2087 trials between 2002 and 2006, when S2087 became in-service. Acoustic modeling determined the dimensions of the zones.

For mid-frequency active sonar exercises taking place in established ranges, the USN National Defence Exemption (NDE) specifies conditions of heightened risk for beaked whales – including rapid changes in bathymetry, the use of multiple ships or submarines over extended periods, the presence of channels and embayments, and the occurrence of significant surface ducts – and requires increased vigilance if avoidance is not possible; but it is questionable

how many areas would meet the USN's narrowly defined criteria. During the RIMPAC (Rim of the Pacific) 2006 exercise, all mid-frequency active sonar was banned within 25 km of the 200 m isobath around the islands, with the exception of three specified 'chokepoint' exercises that occurred within the deep-water channels between the islands, and a single exercise that took place in open water within an instrumented training range; for all these exercises, additional monitoring was required. For future USWEX in Hawaiian waters, avoidance of the Papahanaumokuakea Marine National Monument and most areas within 12 nm of the main islands is specified. For exercises off southern California, a court ordered the Navy to exclude sonar from within 12 nm of the coastline and from within the Santa Catalina Basin, which lies between San Clemente and Santa Catalina Islands. In the draft Environmental Impact Statements recently produced for its training ranges, the USN declines to include any geographic mitigation for mid-frequency active sonar exercises. Since 2002, courts have required the USN to avoid sensitive marine mammal habitat (including areas with vulnerable species and high densities of marine mammals) and marine-protected areas while operating SURTASS LFA, a low-frequency active sonar system (NRDC v. Evans, 2003; NRDC v. Gutierrez, 2008).

With the aim of determining sensitive habitats, the Royal Netherlands Navy has developed 'SAKAMATA' (Sea Animal Kind Area-dependant Mitigated Active Transmission Aid). This is a tool to assist command when planning and operating sonar use, providing guidance planning, monitoring and ramp-up (Benders et al., 2004), although no details are available on how this tool works or what sensitive areas it excludes from training. A decision aid tool (SONATE) is available for planning and operational use in Norway (Kvadsheim, 2008). SONATE provides historical and current data on the distribution of marine species and fishing activity for different areas and time periods, to ensure that operations are executed within the guidelines (Kvadsheim, 2008). The RN has recently developed a database called S2117, a computer decision aid, and its purpose is to provide command guidance based on underlying data sets on the distribution of marine mammal species and other relevant oceanographic information. The USN has developed a similar system. It is not clear from publicly available documents what actual guidance these systems provide for naval planners.

2.1.1. Environmental Impact Assessments/Statements (EIAs/EIS)

To enable the identification and evaluation of potential impacts from sound sources upon the environment, and the assessment of reasonable alternatives, an EIA or EIS is often a legislated requirement. Such a process is undertaken so that environmental uncertainties and consequences can be fully understood early in the decision-making process, with public transparency. Prior to any NURC experimental activity using high-level sound sources (other than normal navigation and standard ship-board equipment, e.g. Acoustic Doppler Current Profiler (ADCP), fathometer, etc.), the Scientist-in-Charge is required to prepare an Environmental Scoping Study (ESS). The RAN states that large-scale activities require specialist environmental review and clearance above that normally required by the Maritime Activities Environment Management Plan (MA EMP) (Australian Defence Force, 2007). Historical data, including stranding and sighting information are used by the RAN during exercise planning (Australian Defence Force, 2007). The latest guidance on "Managing the impact of RN acoustic Operations on the Marine Environment" (BR 4985 Volume V) has now been issued to the fleet and provides guidance on the planning and execution of acoustic operations, including the use of Global EIA for active sonar. EIAs have been undertaken for the global operation of the UK's Sonar 2087 (QinetiQ, 2003). At the time of writing, the USN is currently undertaking Environmental Impact Statements (EIS) for all ranges and operating areas off the US coast.

Assessing the cumulative impacts of exercises – typically a requirement of environmental impact documents – is challenging but vital given the frequent concentration of active sonar use in particular areas. As an example of the ongoing and regular use of a maritime exercise area, NATO conducted the Joint Maritime Course (JMC) military training exercise in coastal waters and in deeper waters to the North and West of Scotland between 1946 and 2006. The JMC occurred three times a year in March, June and November. Military jets, submarines, warships (including minesweepers and sub-hunters), landing craft, power boats and sonobuoys were utilised during these exercises. Many of these activities, and their combination over a 60-year time-frame, can potentially impact marine mammals (Parsons et al., 2000). The JMC has recently been replaced by the Joint Warrior exercise, a twice-yearly NATO event usually occurring in May and October. The west coast of Scotland is home to a diversity of marine species, including 24 species of cetacean, vulnerable basking sharks and internationally significant species of seabirds (Reid et al., 2001). To the authors' knowledge, there has been no EIA to fully assess the scale of cumulative environmental impacts from ongoing naval activities in this region.

2.1.2. Extent of application of guidance

Australian legislation applies to all Australian citizens anywhere in the world under the *Environment Protection and Biodiversity Conservation (EPBC) Act 1999*. RN guidance applies worldwide outside harbours to all Royal Naval ships, submarines and aircraft operating in-service active sonars (not including mine-hunting sonar) not covered already by other EIAs (Ministry of Defence, 2005). The Italian Navy is developing guidance to be applied in all Italian waters and elsewhere. The RNoN guidelines apply in Norwegian territorial waters, and foreign units are requested to operate these guidelines. Norwegian units outside of their own waters comply with the guidelines of the host nation (Kvadsheim, 2008). During SACLANT (NATO) Undersea Research Centre (NURC) sonar experiments, scientists must adhere strictly to the Centre's Instruction and Protocol for Human and Marine Mammal Risk Mitigation; when under NATO control, military units must follow NATO protocols and guidelines unless their own nation has stricter rules and protocols or the host nation imposes stricter rules; when not under NATO control, military units must follow their national or host nation's rules and protocols (Carron, 2004). It is currently unclear how widely the USN will impose measures that have been brought about by mid-frequency active sonar court rulings in California and Hawaii in 2008, but measures imposed by the court in the SURTASS LFA case apply to operations of that system worldwide. The USN's National Defence Exemption mitigation applies only to exercises taking place on established ranges and operating areas and to all major exercises regardless of where they occur; other forms of training, such as unit-level and sustainment exercises, which occur off range are not subjected to mitigation under the provisions of the National Defence Exemption (Department of Defense, 2007).

2.1.3. Avoidance of beaked whales

Given the particular sensitivity of beaked whales to mid-frequency active sonar, some efforts have been made in the available guidance to mitigate impacts on these species, particularly in avoiding sonar use in areas of complex seabed topography in which beaked whales are known to preferentially inhabit. For example, according to RAN guidelines, if the range prediction from modeling indicates that received levels will exceed 160 dB re 1 μPa @ 1 m at ranges greater than 4000 yd (3.66 km), then sonar transmissions in the direction of a seamount, steep gradient or other underwater terrain feature should be blanked (if practicable) or attenuated by 3 dB to 6 dB (if system controls permit) whenever

the ship is within 5 nm (9.26 km) to seaward of the steep grade or other feature. The French guidelines require a cessation of active sonar emissions in open bay areas or over particular (prescribed) seabed slopes. NURC requires avoidance of enclosed areas and coastal areas with complex, steep sea bed topography. For Italian Navy guidance in the northern Tyrrhenian Sea, sonar use should (i) avoid areas with steep (>5%) slopes and a bottom depth of 1000–2000 m; (ii) avoid acoustic trapping situations (e.g. canyons, bays, gulfs); and (iii) keep 5000 m outside the boundaries of 'important' areas (e.g. whale sanctuaries). The USN National Defence Exemption II provision relating to site planning (described above) is for the purposes of avoiding beaked whale habitat.

2.2. Operational procedures

2.2.1. Soft start

A soft start (or "ramp-up") is the technical term for the gradual introduction of the sound source, with the aim of providing any animals in the vicinity of the source with the opportunity to move away. It's efficacy is yet unproven. A requirement for a soft start is made in all guidance except by the USN, RN, and RAN, where (at least in the case of the RAN) equipment limitations may preclude this option. Where marine mammals are expected to be encountered, Norway requires sonar transmissions to be initiated under reduced speed or soft start conditions, depending on which is most appropriate for the operation. Where sort start is used, transmissions are started at a maximum source level of 200 dB, a maximum signal duration of 1 s, and a minimum 10 s signal interval, and are increased gradually to the desired source level during the next five transmissions. The maximum initial source level might be increased by 3 dB for every halving of the signal duration, or decreased for every doubling. For example; a 206 dB initial source level is acceptable if signal duration is 250 ms, but should be reduced to 194 dB if signal duration is 4 s. Transmissions of long duration (>10 s) signals shall be initialized with transmissions of short duration signals (e.g. 1 s) and gradually increased (Kvadsheim, 2008). During active sonar operation, soft start incorporates a gradual build-up of sound level and/or pulse duration over time, with the aim of warning marine mammals and allowing them to depart from the area of an exercise before the sonar pulses reach peak amplitude and/or duration. Naval soft start times are variable in duration: for example, 15–30 min for the Italian Navy and 30 min for NURC and the Royal Canadian Navy. The RN, French Navy (Marine Nationale) and USN (in Hawaii) start at 'low levels' to attempt to minimise disturbance. The Canadian Navy requires a ramp-up after 2 h of break in transmission. NURC provides the most comprehensive energy output requirements for soft start, including the level of acoustic output that should be added during each subsequent stage. It requires that the sonar source be increased gradually over a 30 min period from 150 dB re 1 μPa @ 1 m (or from the lowest possible setting if higher than 150 dB re 1 μPa @ 1 m). If transmissions stop for more than 30 min, the start-up procedure is to be repeated. Similar procedures are required for explosives use (NATO, 2006). Canadian Navy guidance for sea trials in 2003 specified that soft start begins at 160 dB re 1 μPa @ 1 m. In addition to its other requirements, the Italian Navy has soft start procedures for use with sonobuoys and helicopter-mounted sonars, with a 5 min ramp-up period to full power.

2.2.2. Minimising sonar sound propagation

An effective way to reduce overall sound levels in an area and to reduce the radius of possible impact is to minimise sonar source levels and therefore propagation. NURC, the USN and the Canadian Navy specify that the minimum source levels necessary to meet the scientific or technical objectives of the test or experiment should be used. NURC require a maximum continuous duration of sonar transmissions of less than 100 s, a duty cycle of less than 20% and a total cumulative exposure maximum of 3 h in 24 h. It is unclear whether the USN and Canadian Navy measures have resulted in any actual reductions in source levels.

2.2.3. Restrictions on sonar use – at night and in adverse weather conditions

Despite the ineffectiveness of visual monitoring for marine mammals at night and in adverse weather, the available guidance provides few limitations on using sonar during these conditions. NURC states that sonar operations should be limited at night. The RAN suggests that management at night is problematic, but should be dealt with by avoidance of critical habitat wherever possible, and Command is to make reasoned decisions based upon the most recent observations and reports of whale activity in the operating area. The use of optoelectronic and infra-red devices have been suggested to carry out short-range visual monitoring, as well as the use of passive acoustic monitoring (PAM) by the RAN, the USN, the Canadian, French and Italian Navies and the RN. The RAN Procedure Cards require the operators at sea to use judgment for night time operations based on observations prior to dusk. For the last six months in 2006, the USN was required to use additional detection measures and to suspend operations if, in the commander's judgment, the exclusion zone could not be effectively monitored; but according to the USN's after-action report for one affected exercise (RIMPAC, 2006), activities were never suspended despite extensive operations at night (US Navy, 2006).

2.2.4. Restrictions on sonar use – during surface ducting and other higher-risk conditions

Special measures have been applied during significant surface ducting conditions, when intense sounds can be expected to travel further. Before commencing sonar activities, RAN requires assessment of sonar propagation characteristics using TESS II (Tactical Environmental Support System). TESS is an automated information system, which provides a full spectrum of meteorology and oceanography (METOC) and tactical information to support all naval warfare missions. For six months of USN training in 2006, the May 2008 Hawaii USWEX, and SOCAL major exercises in 2008, an expanded exclusion zone was or is to be observed during significant surface ducting conditions. In addition, during SOCAL exercises in 2008 (included in the current injunction but temporarily suspended pending outcome of the USN's Supreme Court petition), there is a mandatory 6 dB power-down condition. During the March 2008 Hawaii USWEX, an incremental power-down was required in the presence of higher-risk factors (including surface ducting, multiple ships, steep bathymetry, and canyons).

2.2.5. Report back and adaptive management

Reporting of onboard monitoring enables a record of sightings to be maintained and facilitates possible evaluation of the effectiveness of the mitigation guidelines. Without undertaking evaluation of the mitigation procedures, adaptive management cannot be implemented. The RN reports observations to the UK Hydrographic Office, and the data are used to inform and improve the overall strategy. In the event of any approach by a whale or dolphin within the designated exclusion zones (safety zone around the vessel) while transmitting active sonar, RAN ships have to report the incident to Fleet Headquarters for investigation. The NURC Scientist-in-Charge has to include copies of completed recording and sightings forms in a post-cruise report and supply originals to the Marine Mammal Risk Mitigation project office. Sightings by Canadian Navy bridge staff are forwarded to the Department of Fisheries and Oceans and are included in the OBIS-SEAMAP system. After some exercises, the USN reports to the National Marine Fisheries Service (NMFS) and California Coastal Commission (CCC).

2.3. Detection and exclusion zone procedures

Exclusion zone procedures are various operational responses to the presence of marine mammals within a pre-determined radius of the sound source. The implementation of real-time mitigation is dependent on the detection of animals within the exclusion zone using visual and/or acoustic methods.

2.3.1. Species for which procedures apply

The Canadian, French, Italian Navies, NURC and USN include all marine mammal species within their mitigation measures (to varying extents). As an exception, NURC excludes some species under the following clause: 'small, generally fast moving marine mammals are known to be attracted to certain sound sources and are not harmed by approaching the source'; the authors, therefore, assume that the guidance does not apply to dolphins. RAN mitigation measures for active sonar apply to all marine mammals and other marine megafauna including sharks and turtles, although dolphins and porpoises riding the bow wave are excluded due to 'practical observation difficulties'. There are no requirements by USN for dolphins and porpoises if they continue to bow ride after 'initial avoidance procedures' (although not specified, we assume that the avoidance procedures refer to reductions in transmission levels within 1000 yds or shutting down of the source within 200 yds) (Department of Defense, 2007). RNoN mitigation measures apply to marine mammals and a number of fish species.

2.3.2. Visual detection

Visual monitoring is the primary method of animal detection in all regions (Table 2). Notwithstanding external influences (such as weather conditions and darkness), the efficacy of visual detection depends on factors including the number of marine mammal observers (MMOs) present, their experience, the regularity of their breaks (i.e. concentration span), their dedication, their objectivity (crew member or independent third-party), their enthusiasm and their level of training (Weir and Dolman, 2007). There is currently no standard for training of observers (see for example, Parsons et al., in press). Whilst naval guidance includes a requirement for visual observations, no regions specify the need for independent civilian-trained MMOs. NATO Underwater Research Centre requires trained observers with binoculars and the use of spotting aircraft/helicopters where available. The RN uses crew members trained by the Navy's Maritime Warfare School to carry out marine mammal observer duties. Details of watch duration and extent are not provided. The RAN ships maintain dedicated lookouts at all times, who are briefed to search for marine mammals (Australian Defence Force, 2007). Under the USN National Defence Exemption (June 2006), Navy watchstanders are to undertake National Marine Fisheries Service (NMFS)-approved training, while under USN National Defence Exemption II (January, 2007), all lookouts are to undertake USN training and review NMFS Marine Species Awareness Training (MSAT) material. For major exercises off southern California, USN watchstanders are required by the court to receive training directly from NMFS.

Given the known limitations of ship-board monitoring, aerial surveillance is required in some regions of US. The USN was required to conduct aerial surveillance before, during and after chokepoint and near-coastal training during the RIMPAC 2006 exercise and extended that requirement for all chokepoint training on its established ranges over the following six months. For major exercises off California, a federal court required the Navy to conduct dedicated aerial monitoring for one hour before the start of any MFA sonar use and to continue monitoring with participant aircraft during each exercise; another court established the same requirement for major exercises off Hawaii.

2.3.3. Detection equipment, including passive acoustic monitoring (PAM)

Most guidance (including the RAN, French and Italian Navies) acknowledge the potential value of real-time passive acoustic monitoring (PAM) for improving the detection of marine mammals (via passively listening for the sounds emitted by marine mammals) and consequently increasing the efficacy of mitigation measures. The Canadian Navy uses PAM, including sonobuoys and towed hydrophones. A marine mammal real-time acoustic detection and classification software system has been developed in Canada (Theriault and Bottomley, 2003; Glessing and Hood, 2006). The Royal Netherlands Navy developed a high frequency passive acoustic towed array system called Delphinus that aims to detect beaked whales (Glassborow, 2006). Norway uses passive acoustic sensors. NURC uses gliders and floaters, devices that travel through the ocean ahead of the sonar collecting environmental and potentially passive acoustic data, to make sure no sensitive marine mammals are between the sound source and the shore (Glassborow, 2006). The USN is required to use PAM from all available platforms, and increasing pressure has been placed on the USN to develop the PMRF's (Pacific Missile Range Facility) and SOAR's (Southern California Anti-submarine Warfare Range) underwater bottom-mounted hydrophone arrays for monitoring marine mammals.

2.3.4. Pre-source watch

The RAN, French and Italian Navies specify a pre-source watch (the watch carried out for marine mammals prior to starting up the sonar source) of 30 min (Table 2). Although time duration is not specified, the RAN may also conduct pre-source watches via aerial surveys where assets are available. Pre-exercise monitoring of 60 min, including dedicated aerial monitoring, is required during USN major exercises off southern California and USWEX in Hawaii.

2.3.5. Exclusion zone

The exclusion zone (or 'safety zone') is usually defined as the radius around the sonar source within which real-time mitigation measures are implemented if animals are detected. Exclusion zones vary considerably and can be larger for naval sonar than for seismic surveying, where a 500 m exclusion zone is standard. The Canadian Navy designates 1 nm (1.85 km) for baleen whales and 1 km for other marine mammals. The Italian Navy designates 1500 m for all marine mammals. NURC guidance is more complex, designating 2000 m for beaked whales and endangered species, once normal operations have commenced. It designates 2000 m for mysticetes, odontocetes and pinnipeds for impulsive sources. In addition, it limits received levels for coherent sources, where for small odontocetes: 3 kHz = 186 dB; 3–20 kHz = 181 dB; 20–75 kHz = 178 dB; and for mysticetes and large odontocetes: 100 kHz = 160 dB. The RNoN operates a 200 dB re 1 Pa @ 1 m limit (Glassborow, 2006). The RAN has the largest designated exclusion zone at 4000 yd (3.66 km), or 160 dB re 1 Pa at 1 m, 'blanking' (blocking the signal at least 45° either side of the bearing to the whale/s,) of a whale(s) to 2000 yd (1.83 km), or more stringent protocols in areas of critical habitat (Australian Defence Force, 2007). The RNoN exclusion zone extends for 100 m maximum (area inside the 200 dB isobar). Although it operates an exclusion zone, the available French Navy guidance doesn't specify a distance.

USN NDE II mid-frequency active sonar guidance mandates a reduction in operating level when animals approach to within 1000 yd (0.91 km), a further reduction at 500 yd (0.45 km) and a shut-down at 200 yd (0.18 km); these measures were also a requirement during the RIMPAC 2006 exercise. Measures imposed for USWEX off Hawaii included a slightly more precautionary exclusion zone, requiring a power-down of 6 dB at 1500 m, 10 dB

at 750 m and shut- down at 500 m. Operation is not to commence for 30 min after the last observation of the animal(s) or until after 2000 yd (1.8 km) distance from the last sighting. The USN applies restrictions to helicopter dipping sonar within 200 yd (0.18 km) of marine mammals or 500 m during USWEX in Hawaii. For major exercises off southern California, the Navy is required to observe a 2200 yd (1.98 km) shut-down zone; but, pending Supreme Court review, the Navy is temporarily allowed to follow the less protective NDE II measure if a marine mammal is sighted at a critical point of an exercise (such as when contact has been made with a target submarine).

2.3.6. Soft start delay

Unlike in industrial seismic surveys where a delay to source activation if marine mammals are present within the exclusion zone is a standard mitigation measure applied in all regions (Weir and Dolman, 2007), only NURC appears to implement a similar delay to the commencement of sonar operation.

2.3.7. Shut-downs (stop work procedure)

The RAN, RN, Canadian, French Navies, NURC and USN require a shut-down of the source whenever designated species (see Section 3.3.1) approach within the exclusion zone, although the RAN and NURC do not implement this for all marine mammal species. Norway operates a shut-down or reduction in power for marine mammals that enter the 100 m exclusion zone. NURC and Italian guidance both specify that if transmissions stop for more than 30 min, the start-up procedure is to be repeated.

2.3.8. Stranding response and other incidents

The Canadian guidance during 2003 sea trials specified that any marine mammal incidents including strandings that occurred after the first transmission and within two weeks of the last transmission in the trial area would be followed up and investigated by DRDC (Defence Research and Development Canada) Atlantic Staff. In the case where there has been: (1) a suspected incident concerning a NURC experiment and recreational or professional divers or marine mammals, or (2) a mass stranding in the NURC operating area (even if no NATO units are involved) or in the vicinity of a NURC experiment outside of the normal operating area, the Incident Action Team (IAT) will be activated. If there is possible NURC involvement in an incident, all records of exercise are obtained, a board of enquiry is convened, outside experts may be consulted and a report is produced. RAN policy is to report any incident, and then to participate in any investigation through a strandings incident review panel as required by the Commonwealth Regulator. USN undertakes to co-ordinate with NMFS if a stranding occurs during or immediately after mid-frequency active sonar use associated with training activities.

3. Naval guidance limitations

3.1. Operational procedures

3.1.1. Soft starts

The effectiveness of soft start for at least some species has been the subject of considerable debate (see Parsons et al., in press, for considerations of limitations with regard to seismic surveys). Some sonar systems are not designed for soft start. Beyond these basic shortcomings, the practice has certain limitations in its application. Existing guidance on how to operate a soft start are largely ambiguous and state only that power should be built up slowly over time. Because naval sonar can vary in pulse duration as well as sound level, naval soft start guidance should provide specific information on the required increase in both parameters over time.

3.1.2. Monitoring in adverse conditions

All current guidance depends predominantly on visual monitoring to detect animals at the surface. Whilst some navies require consideration of previous detection history prior to sunset, effectively no mitigation is in place for active sonar use occurring at night or in adverse weather conditions. It is well documented that detection of small marine mammals with low surface profiles is strongly determined by sea state (Barlow, 2006; Baird, 2005; Clarke, 1982) Night-time visual monitoring via infra-red/night-vision binoculars are suggested by the RAN, RN and USN despite an effective range at best of only a few hundred metres (C. Weir, pers. obs.).

3.2. Detection and real-time mitigation procedures

3.2.1. Visual detection

In addition to the limitations described above, visual detection is also currently hindered by the lack of appropriate training programs for, and independence of, marine mammal observers. The regional guidance specify little in their requirements for marine mammal observers and none define the frequently used terms 'trained', 'experienced', and 'qualified'. There may be a conflict of interests where marine mammal observers are crew members, as is usually the case on military vessels.

3.2.2. Species included

All marine mammals utilise sound and are potentially affected by intense sound sources associated with naval activities such as active sonar and explosives. Although some regions currently offer no protection to dolphins and porpoises (Table 2), there is evidence that small odontocetes are impacted from mid-frequency active sonar (Rendell and Gordon, 1999; Southall et al., 2006; Hohn et al., 2006). All species of marine mammal should, therefore, be included in naval mitigation measures.

3.2.2.1. Level of knowledge of species. The International Union for Conservation of Nature (IUCN) Red List classifies a number of marine mammal species as endangered, vulnerable, near threatened, lower concern or data deficient. Lack of knowledge might be the biggest challenge in obtaining effective protection of marine species. Without adequate knowledge of the distribution, abundance and trends of populations, applying management measures is difficult. However, Barlow and Gisiner (2006) stated that surveys to detect population-wide declines in beaked whale abundance do not hold much promise in the short term due to lack of precision in estimates of population sizes. Significantly, a review of US large-ship surveys found that the percentage of precipitous declines that would not be detected for beaked whales was 90% (where a precipitous decline was determined as a 50% decrease in abundance in 15 yr) (Taylor et al., 2007). These approaches to abundance estimation are therefore clearly not suitable to accurately assess changes in abundance of deep-diving elusive whales.

3.2.3. Exclusion zone

Defining an exclusion zone is a fundamental component of the real-time mitigation measures used during naval activities. However, the basis for defining exclusion zones remains unclear in most cases. Early considerations based on the likelihood of temporary or permanent hearing loss as an index of potential harm (e.g. National Research Council, 2003) came about due to suggestions that these were the main physiological impacts that could be expected (Ketten, 1995). This has led to exposure guidelines that considered sound exposure levels of up to 180 dB re 1 μPa @ 1 m to be a suitable standard for protection of cetaceans. A Noise Exposure Criteria was recently published, based on a scientific review conducted by a panel of US scientists (Southall et al., 2007). However,

the Criteria, and its application, have considerable short comings (Parsons et al., 2008; Southall et al., 2007).

3.2.4. Pre-shoot watch

The 30 min pre-shoot watch was originally defined by the UK's Joint Nature Conservation Committee (JNCC) for seismic surveying being undertaken on the UK's continental shelf (<200 m) waters. Although 30 min might be adequate for detecting shallow-diving shelf species, it may not be appropriate as a sole mitigation measure in deep-water areas where the known dive times of some species (e.g. sperm whale, beaked whales) regularly equals or exceeds this duration. Given that naval vessels can travel at 18 knots whilst using active sonar, more ground can be covered over a shorter time period than seismic vessels that are restricted to survey speeds of 4–5 knots.

3.2.5. Source shut-downs

Given the evidence that small odontocetes may be sensitive to disturbance from active sonar (Rendell and Gordon, 1999; Southall et al., 2006; Hohn et al., 2006), and the additional evidence of damage (Espinosa et al., 2005; Brownell et al., 2004; Fernández, 2006; Fernández et al., 2004; Fernández et al., 2005a; Fernández et al., 2005b; Freitas, 2004; Taylor et al., 2004), it is appropriate for naval guidelines to apply a shut-down procedure for all cetacean species. As in New Zealand seismic surveys, specific shut-down procedures should be considered for mother and calf pairs, where calves might be more sensitive to, and less able to avoid, anthropogenic sound than adults. Following a shut-down procedure, it is unclear in most guidance whether sonar use can resume immediately that the animals depart the exclusion zone or whether a further 30 min clearance period is required. Most guidance available does not stipulate that a full soft start is required following shut-down for marine mammals. Potentially, this means a temporary pause in sonar use simply as an animal passes through the designated exclusion zone, with the source suddenly activated again at full volume. This does not appear to be a precautionary use of the source given that animals may remain in the locality of the source when full power resumes.

3.2.6. Passive acoustic monitoring (PAM)

Although PAM is recognised as a potentially valuable detection technique within all available guidance, its full potential use in sonar mitigation is not yet realised. There are a variety of PAM systems that can be used to detect cetaceans (e.g. towed arrays, bottom-mounted hydrophones, sonobuoys), and many naval frigates are already fitted with suitable listening devices. PAM will become more successful as a mitigation tool if it is able to: (a) reliably detect a significant number of vocalising marine mammal species within the exclusion zone; (b) reliably identify each marine mammal species (where guidelines are species selective); and, (c) provide a reliable range measurement to the animal. Use of PAM as a mitigation tool is currently limited by the fact that animals are not always vocal, the seasonality in vocal activity of some species (e.g. baleen whales), lack of knowledge regarding sounds produced by some species (e.g. beaked whales), difficulty in species identification, the variable detection range between species, lack of accurate range estimation (currently often based on operator interpretation) and the regular masking of lower frequencies (those used by baleen whales) by vessel noise.

The use of PAM is also constrained by the lack of guidance for its implementation and the lack of training programmes in its use. Establishing whether a marine mammal, or a particular species, is within a set radius of the sonar source often depends on the judgment of the PAM operator rather than on objective software. As pointed out by Barlow and Gisiner (2006), acoustic detection improves tremendously if an observer knows what to listen for, and the development of training programs for the use of PAM should be a priority.

3.3. General issues

3.3.1. Sensitive areas

All naval guidance, except for the Canadian trials in 2003, recognise that sensitive areas exist for marine mammals, but there is little rigorous definition of these areas and how they apply to naval exercise applications. Only the Canary Islands government has implemented broad scale geographic restrictions recognising the particular sensitivity of beaked whales and other species in its waters. Generally, naval guidance should be more explicit about the criteria for defining and implementing mitigation measures in sensitive habitats, including time/area planning. Specific recommendations towards effective spatio-temporal restrictions have been made (Agardy et al., 2007).

3.3.2. Other sources of disturbance

Naval exercises often incorporate a range of vessels, including warships, carriers, aircraft and submarines and a variety of events, such as missile and ordnance testing and "sinking" exercises. These activities also have the potential to disturb marine mammals, and guidance for minimising impact to marine mammals needs to address all activities related to naval activities and not simply active sonar use. For example, standoff ranges of closest approach to marine mammals should be developed for those vessels able to manoeuvre during naval exercises.

3.3.3. Ineffectiveness of existing mitigation techniques

While visual detection is a reasonable method for detecting some marine mammals in the vicinity of a naval activity (given favourable weather and daylight), it remains ineffective for certain species such as beaked whales and small inconspicuous animals such as *Kogia* whales and porpoises. These same species may be difficult to detect acoustically, for example the vocalisations of beaked and *Kogia* whales are poorly known (Barlow and Gisiner, 2006). All marine mammal species are currently poorly protected at night (Weir and Dolman, 2007). Where visual observations do occur at night they are only realistically likely to detect bow-riding dolphins due to the range limitations of night-vision equipment. The use of acoustic monitoring at night will detect only vocalising animals and is therefore very limited for species that are largely non-vocal or which are not vocalising at the time (Weir and Dolman, 2007; Parsons et al., in press). A further inefficiency of the existing mitigation methods is that the crew member must visually observe the marine mammal entering the exclusion zone before mitigation can be requested. This does not adequately mitigate for deep-diving species such as sperm and beaked whales that may dive ahead of the survey on the vessel's track line. For example, since sperm whales typically dive vertically during the first portion of their dive, animals seen to fluke and commence a dive ahead of the ship may remain submerged on the trackline and enter the exclusion zone without being visually detectable within the exclusion zone by the marine mammal observers. Simulation studies to quantify the effectiveness of mitigation measures are currently underway (R. Leaper, pers. comm.).

3.3.4. Enforcement of mitigation methods

It is not currently clear under what circumstances the naval mitigation measures summarised in Table 2 are a requirement under environmental legislation in each region. Guidance appears to be on an entirely self-regulatory basis by regional navies, and is frequently punctuated by clauses such as 'wherever practicable' ensuring that there is no rebuke should the suggested mitigation not be used. Experience in the US, as reflected in the USN's after-

action reports, indicates that some measures (such as power-down provisions) are seldom implemented when discretion is left to vessel commanders. Onboard monitoring (and a subsequent feedback system) of the effectiveness of guidance, evaluation of the mitigation procedures and repercussions for those naval vessels that fail to comply with the guidelines, e.g. soft starts below the required duration, are not known. Relevant environmental government departments should integrate themselves into the monitoring and enforcement process.

3.3.5. Regional application of guidelines

Although the guidance summarised in Table 2 is now being used within those geographic regions identified, the majority of the world's oceans are still open to naval activities without any marine mammal mitigation procedures in place. Some of the regional guidance is selective regarding inclusion of their own waters, for example the version of the Italian Navy guidance available only applies to the northern Tyrrhenian Sea (although it is reported that broader measures are proposed in future for all Italian waters and operations elsewhere (Cerutti, 2005)). RAN marine mammal management requirements are mandated regardless of location in the world, and operations in recognised marine-protected areas are subjected to additional scrutiny. In regions where no statutory legislation exists for the protection of marine mammals, many naval activities occur within sensitive habitats without any consideration of marine fauna. The UN Law of the Sea Convention (UNCLOS) sets out general obligations including that states have a due diligence obligation to adopt the necessary measures to ensure that activities within their maritime zones or under their control (e.g. in respect of vessels flying their flag on the high seas) do not cause harm to the environment and interests of other states, as well as to the environment outside national jurisdiction (Taylor et al., 2007). It is unclear whether any mitigation measures for the protection of marine species are undertaken beyond national jurisdictions.

4. Additional mitigation measures

Although a number of mitigation measures are currently used to mitigate the effects of other anthropogenic sound sources on marine mammals, these are not included in guidance for use during naval activities. There are a number of technologies and/or measures that could be developed for naval activities in the future.

4.1. Closed areas and spatio-temporal restrictions

The simplest way to mitigate the effects of naval activities on marine fauna is to avoid animals either in space or time (Agardy et al., 2007; Dolman, 2007). The designation of closed areas is most effectively implemented at the government level in each region as part of standard statutory guidelines, where the legislation applies to and is adopted equally by all marine users. For example, the Canary Islands impose a moratorium on Spanish naval activities within 50 nm of its coasts to the south and west of the Islands for the protection of beaked whales and other species. The RAN avoids known marine mammal congregation areas, likely beaked whale habitat, and critical habitat by excluding the activity at the planning stage. Spatio-temporal restrictions require knowledge on the distribution, density and seasonal occurrence of cetaceans in an area. In some regions the occurrence of marine mammals is well documented. However, this basic information is lacking for many parts of the world and for some species (e.g. beaked and *Kogia* whales). Species distributions often change over time (and climate change may be causing large-scale changes to distributions) and so frequent monitoring is required to ensure that guidance includes the appropriate spatio-temporal range to protect animals and at the same time does not unnecessarily limit naval activities in areas that animals have departed. In some regions worldwide there is little awareness of the potential effects of naval activities on marine mammals, and such countries should be strongly encouraged to consider marine mammals early during the planning process to consider implementing spatio-temporal restrictions.

4.2. Equipment modification/development

That mid-frequency active sonar has been associated with an increasing number of deaths of beaked whales and other species requires urgent investigation of 'safer' systems that operate using different characteristics than current systems. Norwegian and Dutch Navies are experimenting with characteristics of their mid-frequency systems, to mitigate impacts on beaked whales (Glassborow, 2006). The development of new technologies as an alternative to sonar to reduce the acoustic footprint should be encouraged. Adapting active sonars with more sensors and less power (Glassborow, 2006) has been suggested. In addition, sonobuoys that operate below 2 kHz and at a tenth to a hundredth of the power of ship mounted sonar (Glassborow, 2006) appear to be a viable alternative to extensive ship generated sonar use, although there is an environmental tradeoff of additional material being dumped at sea. Reducing the total amount of sound produced by reducing power to a minimum to meet requirements, by reducing the duration and/or by reducing the number of times a system transmits a sound, can reduce the radius of sound and therefore the potential impact. Equipment to improve visual monitoring during night and poor visibility should be developed, with potential uses of infra-red equipment and millimetre waves radar.

4.3. Additional monitoring platforms

NATO Underwater Research Centre guidance suggests conducting aerial surveys before initiating the sound source, when available. This could greatly aid the detection of marine mammals, particularly in sensitive areas, although with some environmental and fiscal costs. Such information can subsequently be used in the real-time planning of exercises. Aerial observations during exercises can aid assessment of marine mammal responses to the sound source. The use of additional, dedicated research vessels may also be useful to survey the areas ahead of naval vessels and provide advice on the occurrence of animals, particularly during very large-scale activities involving many ships and sources. Independent visual and acoustic observation surveys by scientists at the time of year the exercise is conducted may be an effective management tool.

4.4. Transparency in legislative compliance

In most cases, national or regional environmental legislation is non-existent, weak or does not adequately enforce measures to deal with ocean noise (see, for example, Scott (2007)). Both the RAN and USN undertake public comment during their development of naval guidance due to environmental requirements. The U.S. Marine Mammal Protection Act is one of the worlds most comprehensive and well-enforced laws aimed at protecting marine mammals. However, it is not fulfilling its precautionary promise when it comes to regulating for sound impacts and compliance has been slow and limited (see, for example, Horowitz and Jasny (2007)).

5. Guidance towards a worldwide navy standard

As reviewed above, the marine mammal mitigation guidance in use during naval exercises and operations worldwide shows variation in most parameters between regions. This lack of consistency

needs to be addressed so that a minimum 'best practice' with a scientific basis offering adequate protection to all marine mammal species is adopted worldwide. Guidance is also needed for the management of naval exercises in waters where no guidance currently exists, perhaps starting with those countries that are members of NATO. A series of recommendations came out of a paper presented to the NATO Military Oceanography Group (Fortescue et al., 2005), one of which was that 'NURC should be requested to act on behalf of MILOC as the NATO focal point to support marine mammal risk mitigation by promoting co-ordinated data standards, collection/data exchange/data basing, modelling, legal considerations, etc. and to maintain a composite database for NATO nations'. Such efforts should be co-ordinated, transparent and reported to appropriate conventions and regional agreements, including ASCOBANS (Agreement on the Conservation of Small Cetaceans of the Baltic and North Seas) and ACCOBAMS.

In the absence of standard international guidelines, naval activities in some areas, and on the high seas, presently appear to be carried out: (a) without any mitigation measures in place, or (b) using ad-hoc or incomplete guidance. Development of a realistic mitigation protocol must incorporate measures to: (1) ensure protection of marine mammal species, particularly endangered species and feeding/breeding/migrating concentrations; (2) reduce associated mortalities of beaked whales; and (3) protect all marine life (including turtles and fish) more generally. The most significant environmental gains are achieved at the planning stage (Ministry of Defence, 2005). It is currently unclear how the recent US court decisions from California and Hawaii are likely to change the future of guidance in the USN, and no doubt in other navies. The following points, some of which are already undertaken by some navies, are recommended for inclusion as a minimal 'best practice' mitigation procedure.

5.1. Avoiding densities of animals

- Designation of closed areas (seasonal and/or year round as appropriate) where scientific data support the occurrence of vulnerable species and/or key marine mammal breeding/feeding/migratory habitat.
- Avoidance of established marine-protected areas.
- Implementation of buffer zones around closed zones, where active sonar is prohibited during particular seasons or on a year round basis so that damaging or disturbing noise levels are not created (Agardy et al., 2007).
- Clear definition of closed areas and buffer zones in naval guidance, so that all operators are equally subject to and aware of restrictions.
- Limitations of sonar use during months with historical significant surface ducting conditions, and use of power-downs during significant surface ducting conditions at other times, to minimise disturbance.
- Avoidance of fronts and other major oceanographic features, which have the potential to attract concentrations of animals.
- Planning of naval exercises to avoid impacting entire habitats or migration paths, to reduce stranding potential and provide escape routes for marine mammals.
- Concentration of exercises to the maximum extent practicable in surveyed offshore habitat identified as being of low use by marine mammals.
- Undertaking of predictive habitat modeling to determine key habitat that should be avoided.
- Ground-truthing of model results by funding dedicated field surveys in high use exercise areas.
- Prioritising research in areas where naval exercises regularly take place and where the distribution, density and seasonality of cetaceans in an area are poorly known.

5.1.1. Beaked whale specific mitigation

Whilst naval impacts are not limited to beaked whales, the particular susceptibility of these species to mid-frequency active sonar means that additional measures are required to ensure their protection:

- Avoidance of naval activity in shelf edge and canyon habitat that beaked whales are likely to inhabit, particularly when it occurs close to shore.
- Development of passive acoustic monitoring techniques, including long-term static monitoring, and use of these in preparation of major exercises should be a requirement in order to detect beaked whale hot spots.

5.1.2. Mitigation of other marine species

- Avoidance of fish spawning grounds and of important habitat for fish species potentially vulnerable to significant behavioural change, such as wide-scale displacement within the water column or changes in breeding behaviour.
- Avoidance of key sea turtle foraging habitat, and seasonal restrictions to coastal naval activity during turtle nesting seasons.

5.2. Completion of EIAs

- Full and transparent EIAs should be developed for offshore exercise areas, to include long-term and cumulative impacts of large-scale and multi-national activities.
- Navies should employ rigorous standards of environmental review, including objective analyses of the sound levels emitted by the source at varying ranges, a comprehensive analysis of all reasonable alternatives and a thorough delineation of measures to mitigate impacts.
- Development of Strategic Environmental Assessments (SEAs) or National Environmental Management Plans (such as that produced by the RAN), to include information on the overall use of the sound sources (including outside of offshore exercise areas) is also required.
- There should be transparency and public input in the planning and drafting process.

5.3. Source modification and alternative design technologies

- Use of sonar and other active acoustic systems at the lowest practicable source level.
- Use of modeling to reduce or eliminate chokepoint exercises in near-coastal environments, particularly within canyons and channels, and other important habitat.
- Limitations to the use of active sonar in training through effective planning.
- Ongoing development of point sensors such as active sonobuoys as an alternative to hull generated active sonars.

5.4. Onboard mitigation procedures

- Mitigation measures should apply to all marine mammal species.
- The use of the lowest practicable volume should be defined and enforced.
- Sound transmission properties in surface ducting conditions should be accounted for, particularly in the waters near the shelf break to aid in choosing areas to limit the impacts of sonar.
- Development of a series of standardised worldwide exclusion zones based on a conservative and scientific basis rather than

on arbitrary designation. Exclusion zone values should be calculated by the operator prior to the application process, using site-specific transmission loss modeling based on source parameters and the bathymetry, water properties and sound velocity profiles of the water column within the prospect area. The exclusion zone value should be verified in the field at the start of the survey. During long duration surveys, the exclusion zone should be regularly recalculated. The criteria used to calculate exclusion zones should regularly be reviewed.

- Development of defined and well-implemented shut-down and delay measures when animals are detected in the area of naval activities, including where high-densities or vulnerable species (to be regionally defined) are encountered unexpectedly within the exclusion zone.
- Suspension or relocation of exercises when beaked whales or high-densities (to be regionally defined) of other species are detected until the animals have cleared the area.
- Suspension or postponement of chokepoint exercises during surface ducting conditions and scheduling of such exercises during daylight hours.
- At least one dedicated third-party observer should be on watch 24 h (max 4 h shift), requiring at least two (and preferably three) dedicated and qualified marine mammal observers on every vessel during large-scale exercises. Equipment including high-quality infra-red and night-vision binoculars should be provided to the marine mammal observers for night time observations.
- Ideally, sonar use should be prohibited at night since current mitigation techniques are inadequate to detect marine mammals.
- Because of the impact of adverse weather conditions on the visual detection of marine mammals, active sonar use during unfavourable conditions (at least Beaufort sea state $\geqslant 4$, swell $\geqslant 2$ m, visibility $\leqslant 1$ km) should be prohibited (both night and day). This measure is particularly important at night when visual observations are already hindered.
- Every vessel (irrelevant of geographical area and local conditions) should implement a soft start procedure for every use of the active sonar.
- There should be a dedicated pre-shoot watch of at least 30 min. In areas where water depths exceed 200 m, the watch should be at least 60 min to help increase the probability that deep-diving species are detected.
- There should be a delay to commencement of soft start for all marine mammal species observed within the exclusion zone. Soft start may not begin until 30 min after the animals depart the exclusion zone or 30 min after they are last seen.
- There should be a shut-down of the active sonar source whenever a marine mammal is seen to enter the exclusion zone. Following a shut-down, a full soft start is mandatory. Soft start should not begin until 30 min after the animals depart the exclusion zone or 30 min after they are last seen.
- Develop suitable guidance for the use of dedicated PAM to detect vocalising species.
- Modification of sonobuoys for passive acoustic detection of vocalising species.
- Use of aerial surveys and ship-based surveys before, during, and after major exercises.
- Disturbance from other vessels associated with the naval exercise (e.g. carrier ships, submarines etc.) should be minimised. Those vessels free to manoeuvre should aim to provide at least 300 m clearance around cetaceans (accepting that some animals may approach of their own accord), in consistency with standard recommendations for other maritime users.
- Where joint exercises are taking place, all nations should comply with the most stringent mitigation measures, even if these are not those of the Host Nation.
- Standardised, timely and public-access post-exercise reporting should be a requirement.

5.5. Other recommendations

- Naval activities to ensure protection of marine wildlife should remain inside regulatory frameworks.
- Marine mammal mitigation guidelines should be adopted by all navies, to ensure that marine mammals are protected worldwide and not simply in those (usually developed) countries where adequate resources and structure are available.
- Marine mammal observers must be qualified, dedicated and experienced. As a minimum this should require that a marine mammal observer has no other role on the ship, that they have first-hand field experience of the relevant marine mammal species in an area and that they have completed an appropriate training scheme. Training courses should incorporate an eye test, practical field training, extensive theoretical training (including underwater acoustics, marine species identification, distance measuring at sea and PAM modules), and ongoing assessments.
- Development of improved range/bearing data using PAM technology, and development of PAM guidelines for implementing mitigation measures based on acoustic detection and PAM training, particularly since mitigation measures may be based on the PAM operators' judgment.
- There should be improved and ongoing biological monitoring before, during and after naval exercises, to provide information on species occurrence, seasonal/temporal distribution, and reaction to active sonar sound.
- Timely, regular reporting to the appropriate government department, state coastal management authorities, and the public to describe and verify use of mitigation measures during testing and training activities.

6. Research requirements

- Retrospective analysis of strandings that have occurred in association with naval activities. Navies should be forthcoming with information about sonar and explosive use surrounding 'atypical' stranding events (defined by Frantzis, 1998).
- Cluster analysis of historic stranding events around naval facilities; probability analysis of likelihood of stranding beyond chance.
- Detailed necropsy training of researchers and veterinarians in areas of high naval use where strandings have been known (or likely) to occur.
- Information from Atlantic Undersea Test and Evaluation Centre (AUTEC), British Underwater Test and Evaluation Centre (BUTEC) and other naval monitoring facilities should be analysed with a view to investigating broad scale responses of species to real-time sonar use.
- Funding should be made available for dedicated and long-term studies to enable understanding of population status and possible population level effects, particularly in regularly used exercise areas.
- A commitment to investigate the effectiveness of mitigation measures undertaken is long overdue. Effort should be also be made to measure the efficacy of commonly used mitigation measures, particularly soft start.
- Establishment of long-term research, to be conducted through an independent agent, on the distribution, abundance, and population structuring of protected species in the study area, with the goal of supporting adaptive geographic avoidance of high-value habitat.

7. Conclusions

The guidance currently in use by navies to mitigate potential impacts from sonar on marine mammals throughout the world varies in parameters such as the exclusion zone radius, the marine mammal species included in mitigation, and delay/shut-down procedures. Relatively few aspects of current mitigation have a firm scientific basis and proven efficacy in the field, and there remains a total lack of effective mitigation during night and adverse weather. Recent US court cases have been successful in highlighting a number of these inadequacies. This review highlights a number of shortcomings in the existing mitigation guidance and makes recommendations towards improved standards of protection. Marine mammal mitigation measures should be utilised during all naval exercises by all nations. Where a number of nations are exercising together, the highest level of protection should be maintained. Area closures and avoidance of key marine mammal habitat remain the most effective and precautionary measures for active sonar and other intense naval sound sources. Areas of importance for marine mammals should be explicitly identified and such measures implemented. Given the particular sensitivity of beaked whales to mid-frequency active sonar, all navies have a responsibility to conduct their activities in a way that limits potential impacts on those species.

A number of navies have already undertaken considerable work to protect marine wildlife, demonstrating that environmental duty of care does not need to come at the expense of navy training. An ongoing commitment to managing activities and investigating impacts is required by all navies to continue to understand and to minimise impacts on marine wildlife.

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References

Agardy, T., Aguilar, N., Cañadas, A., Engel, M., Frantzis, A., Hatch, L., Hoyt, E., Kaschner, K., LaBrecque, E., Martin, V., Notarbartolo di Sciara, G., Pavan, G., Servidio, A., Smith, B., Wang, J., Weilgart, L., Wintle, B., Wright, A., 2007. A Global Scientific Workshop on Spatio-Temporal Management of Noise. Report of the scientific workshop. 44p.

Aguilar, N., Martín, V., 2007. Canary Islands Naval Moratoria. In: Agardy, T., Aguilar, N., Cañadas, A., Engel, M., Frantzis, A., Hatch, L., Hoyt, E., Kaschner, K., LaBrecque, E., Martin, V., Notarbartolo di Sciara, G., Pavan, G., Servidio, A., Smith, B., Wang, J., Weilgart, L., Wintle, B., Wright, A. (Ed.), A Global Scientific Workshop on Spatio-Temporal Management of Noise, Report of the Scientific Workshop, 44p.

Australian Defence Force. 2007. The Australia Defence Force Maritime Activities Environmental Management Plan (MAEMP) guidance. 7p.

Baird, R.W., 2005. Sightings of Dwarf (*Kogia sima*) and Pygmy (*K. breviceps*) Sperm Whales from the Main Hawaiian Islands. Pacific Science 59, 461–466.

Barlow, J., 2006. Cetacean abundance in Hawaiian waters estimated from a summer/fall survey in 2002. Marine Mammal Science 22, 446–464.

Barlow, J., Gisiner, R., 2006. Mitigating, monitoring and assessing the effects of anthropogenic sound on beaked whales. Journal of Cetacean Research and Management 7, 239–249.

Benders, F.P.A., Beerens, S.P., Verboom, W.C., 2004. SAKAMATA: A tool to avoid whale strandings. Abstract presentation to the International Workshop on Sound, London. 1p.

Brownell, Jr., R.L., Yamada, T., Mead, J.G., van Helden, A.L., 2004. Mass Strandings of Cuvier's Beaked Whales in Japan: US Naval Acoustic Link? Paper Presented to the Scientific Committee at the 56th Meeting of the International Whaling Commission, 29 June–10 July 2004, Sorrento, Italy. SC/56/E37.

Carron, M., 2004. NATO SACLANTCEN Marine Mammal Risk Mitigation Programme (Sound, Ocean and Living Marine Resources). Report of the ECS Sonar Workshop, Canary Islands. p. 59–62.

Cerutti, F., 2005. Italian Navy's RIMPAM Environmental Impact Reduction Procedures for Marine Mammals. Proc. Intergovernmental Conference "The Effects of Sound in the Ocean on Marine Mammals. Lerici, May 2005. CDROM published by NURC, La Spezia, Italy.

Clarke, R., 1982. An Index of Sighting Conditions for Surveys of Whales and Dolphins. Report of the International Whaling Commission, 32.

Department of Defense, 2006a. National Defence Exemption (NDE) from requirements of the Marine Mammal Protection Act (MMPA) for certain Department of Defence (DoD) Mid Frequency Active Sonar Activities. Memorandum to the Secretary for the Navy. Unpublished. 1p.

Department of Defense, 2006b. Mid Frequency Active Sonar Mitigation Measures during Major Training Exercises, or within Established Ranges or Established Operating Areas. Appended to Memorandum to the Secretary for the Navy. Unpublished. 3p.

Department of Defense, 2007. National Defence Exemption (NDE) from Requirements of the Marine Mammal Protection Act (MMPA) for certain Military Readiness Activities That Employ Mid Frequency Active Sonar Activities or Improved Extended Echo Ranging Sonobuoys. Memorandum to the Secretary for the Navy. Unpublished. 6p.

Dolman, S.J., 2007. Spatio-temporal restrictions as best practise precautionary response to ocean noise. Journal of International Wildlife Law and Policy 10, 219–224.

Espinosa, A., Arbelo, M., Castro, P., Martín, V., Gallardo, T., Fernández, A., 2005. New beaked whale mass stranding in Canary Islands associated with naval military exercises (Majestic Eagle 2004). In 19th Annual Conference of the European Cetacean Society and Associated Workshops, 2–7 April 2005, La Rochelle, France, p.95. La Rochelle: European Cetacean Society.

Fernández, A., 2006. Beaked whale (*Ziphius cavirostris*) mass stranding on Almería's coasts in southern Spain, 26–27 January 2006. Report of the University of Las Palmas de Gran Canaria, Canary Islands.

Fernández, A., Arbelo, M., Deaville, R., Patterson, I.A.P., Castro, P., Baker, J.R., Degollada, E., Ross, H.M., Herráez, P., Pocknell, A.M., Rodríguez, E., Howie, F.E., Espinosa, A., Reid, R.J., Jaber, J.R., Martin, V., Cunningham, A.A., Jepson, P.D., 2004. Pathology: whales, sonar and decompression sickness. Nature 428, 1–2.

Fernández, A., Edwards, J.F., Rodriguez, F., Espinosa de los Morteros, A., Herraez, P., Casstro, P., Jaber, J.R., Martin, V., Arbelo, M., 2005a. "Gas and fat embolic syndrome" involving a mass stranding of beaked whales (Family *Ziphiidae*) exposed to anthropogenic sonar signals. Veterinary Pathology 42, 446–457.

Fernández, A., Mendez, M., Sierra, E., Godhino, A., Herráez, P., Espinosa, A., Rodríguez, F., Arbelo, M., 2005b. New gas and fat embolic pathology in beaked whales stranded in the Canary Islands. In 19th Annual Conference of the European Cetacean Society and Associated Workshops, 2–7 April 2005, La Rochelle, France, p. 95. La Rochelle: European Cetacean Society.

Fortescue, P., Hole, S.O., Robichaud, R.M., Conforto Sesto, J.R., Theriault, J., Hensley, R., Weaver, N., Maughan, B., 2005. Marine Mammals and Active Sonar. A paper prepared for the NATO Military Oceanography Group, October 2005, 28 p. Available at: <http://stinet.dtic.mil/cgi-bin/GetTRDoc?AD=ADA475349&Location=U2&doc=GetTRDoc.pdf>.

Frantzis, A., 1998. Does acoustic testing strand whales? Nature 392, 29.

Freitas, L., 2004. The stranding of three Cuvier's beaked whales *Ziphius cavirostris* in Madeira archipelago – May 2000. ECS Newsletter 42 (Special Issue), 28–32.

Glassborow, J., 2006. Sensors and sensibilities: navies factor mammals into sonar use. Janes Navy international, September 2006. p. 28–32.

Glessing, B., Hood, J., 2006. Marine Mammal Detection Final Report. DRDC Atlantic CR 2005-271. Defence R&D Canada – Atlantic. 42p. Available at: http://cradpdf.drdc.gc.ca/PDFS/unc49/p525531.pdf.

Hildebrand, J.A., 2005. Impacts of anthropogenic sound. In: Reynolds, J.E. et al. (Eds.), Marine Mammal Research: Conservation beyond Crisis. The Johns Hopkins University Press, Baltimore, Maryland.

Hohn, A.A., Rotstein, D.S., Harms, C.A., Southall, B.L., 2006. Multispecies Mass Stranding of Pilot Whales (*Globicephala macrorhynchus*), Minke Whale (*Balaenoptera acutorostrata*), and Dwarf Sperm Whales (*Kogia sima*) in North Carolina on 15–16 January 2005 (2006) (NOAA Tech. Memo. NMFSSEFSC-53). Available at: http://www.nmfs.noaa.gov/pr/health/mmume/event2005jan.htm.

Horowitz, C., Jasny, M., 2007. Precautionary management of noise: lessons from the US marine mammal protection act. Journal of International Wildlife law and Policy 10, 225–232.

Jasny, M., 2005. Sounding the Depths II. The rising toll of sonar, shipping and industrial ocean noise on marine life. NRDC report. Available at: <http://www.nrdc.org/wildlife/marine/sound/sound.pdf>.

Jepson, P.D., Arbelo, M., Deaville, R., Patterson, I.A.P., Castro, P., Baker, J.R., Degollada, E., Ross, H.M., Herráez, P., Pocknell, A.M., Rodríguez, F., Howell, F.E., Espinosa, A., Reid, R.J., Jaber, J.R., Martin, V., Cunningham, A.A., Fernández, A., 2003. Gas-bubble lesions in stranded cetaceans: was sonar responsible for a spate of whale deaths after an Atlantic military exercise? Nature 425, 575–576.

Ketten, D.R., 1995. Estimates of blast injury and acoustic trauma zones for marine mammals from underwater explosions. In: Kastelein, R., Thomas, J.A., Nachtigall, P.E. (Eds.), Sensory Systems of Marine Mammals. De Spil Publishing, Woerden, Netherlands, pp. 391–407.

Kvadsheim, P.H., 2008. Guidelines for use of active sonars in Norwegian waters. On file with authors.

Miller, P.J.O., Biassoni, N., Samuels, A., Tyack, P.L., 2000. Whale songs lengthen in response to sonar. Nature 405, 903.

Ministry of Defence, 2005. Sustainable Development and Environment Manual JSP 418. Directorate of Safety and Claims. 602p.

Møhl, B., 2004. Sperm whale sonar rivals tactical sonar with source levels at 235 dB. In: Evans, P.G.H., Miller, L.A. (Eds.), Workshop on Active Sonar and Cetaceans, ECS Newsletter no. 42, pp 41-42.

National Research Council, 2003. Effects of Noise on Marine Mammals. In Ocean Noise and Marine Mammals. National Academies Press, Washington DC. pp. 83–108.

NATO, 2006. NATO Undersea Research Centre Human Diver and Marine Mammal Risk Mitigation Rules and Procedures Marine Mammal Risk Mitigation Project. September 2006. 30p. Available at: <http://solmar.nurc.nato.int/solmar/PDF/NURC-SP-2006-008.pdf>.

NRDC v. Evans, 279 F.Supp.2d 1129 (N.D. Cal. 2003).

NRDC v. Gutierrez, __ F.Supp.2d __, 2008 WL 360852 (N.D. Cal. 2008).

NRDC v. Winter, 527 F.Supp.2d 1216 (C.D. Cal. 2008), aff'd 518 F.3d 658 (9th Cir. 2008).

OMI v. Gates, F.Supp.2d, 2008 WL 564664 (D. Hawaii 2008).

Parsons, E.C.M., Birks, I., Evans, P.G.H., Gordon, J.C.D., Shrimpton, J.H., Pooley, S., 2000. The possible impacts of military activities on cetaceans in West Scotland. European Research on Cetaceans 14, 185–191.

Parsons, E.C.M., Dolman, S.J., Wright, A.J., Rose, N.A., Burns, W.C.G., 2008. Navy sonar and cetaceans: how much does the gun need to smoke before we act? Marine Pollution Bulletin 56, 1248–1257.

Parsons, E.C.M., Dolman, S.J., Jasny, M., Rose, N.A., Simmonds, M.P., Wright, A.J., in press. A critique of the UK's JNCC Seismic Survey Guidelines for minimising acoustic disturbance to marine mammals: best practise?

Pavan, G., 2007. Guidelines to address the issue of the impact of anthropogenic noise on marine mammals in the ACCOBAMS area. Report to the Third Meeting of the Contracting Parties. August 2007. 28p.

QinetiQ., 2003. Sonar 2087 and the Environment. Report prepared for the Defence Procurement Agency, Ministry of Defence. 32p.

Reid, J.B., Pollock, C.M., Mavor, R., 2001. Seabirds of the Atlantic Frontier, north and west of Scotland. Continental Shelf Research 21, 1029–1045.

Rendell, L.E., Gordon, J.C.D., 1999. Vocal response of long-finned pilot whales (*Globicephala melas*) to military sonar in the Ligurian Sea. Marine Mammal Science 15, 198–204.

Scott, K.N., 2007. Sound and cetaceans: a regional response to regulating acoustic marine pollution. Journal of International Wildlife Law and Policy 10, 175–199.

Southall, B.L., Braun, R., Gulland, F.M.D., Heard, A.D., Baird, R.W., Wilkin, S.M., Rowles, T.K. 2006. Hawaiian Melon-Headed Whale (Peponacephala electra) Mass Stranding Event of July 3–4, 2004. (NOAA Tech. Memo. NMFS-OPR-31). Available at: <http://www.nmfs.noaa.gov/pr/pdfs/health/stranding_melon-headedwhales_final_report.pdf>.

Southall, B.L., Bowles, A.E., Ellison, W.T., Finneran, J.J., Gentry, R.L., Greene Jr., C.R., Kastak, D., Ketten, D.R., Miller, J.H., Nachtigall, P.E., Richardson, W.J., Thomas, J.A., Tyack, P.L., 2007. Marine mammal noise exposure criteria: initial scientific recommendations. Aquatic Mammals 33, 411–521.

Taylor, B., Barlow, J., Pitman, R., Ballance, L., Klinger, T., DeMaster, D., Hildebrand, J., Urban, J., Palacios, D., Mead, J.G., 2004. A call for research to assess risk of acoustic impact on beaked whale populations. Paper presented to the Scientific Committee at the 56th Meeting of the International Whaling Commission, 29 June–10 July 2004, Sorrento, Italy. SC/46/E36.

Taylor, B.L., Martinez, M., Gerrodette, T., Barlow, J., Hrovat, Y.N., 2007. Lessons from monitoring trends in abundance of marine mammals. Marine Mammal Science 23, 157–175.

Theriault, James A., Bottomley, John., 2003; DRDC Atlantic Q-273 Sea Trial Marine Mammal Impact Mitigation Plan; DRDC Atlantic TM 2003-044, Defence Research and Development Canada – Atlantic.

Todd, S., Stevick, P., Lien, J., Marques, F., Ketten, D., 1996. Behavioural effects to underwater explosions in humpback whales (*Megaptera novaeangliae*). Canadian Journal of Zoology 74, 1661–1672.

Tomaszeski, S., 2004. Navy Generated Sound in the Ocean. Presentation at the First Plenary Meeting of the Advisory Committee on Acoustic Impacts on Marine Mammals. Bethesda, Maryland. 3–5 February 2004. Available at: <http://www.mmc.gov/sound/plenary1/pdf/plenary%201_tomaszeski.pdf>.

Tyack, P., Clark, C.W., 1998. Quicklook Phase II, Playback of Low-Frequency Sound to Gray Whales Migrating Past the Central California Coast, January 1998. (23 June 1998), pp. 22–25.

US Navy, 2006. 2006 Rim of the Pacific Exercise After Action Report: Analysis of the Effectiveness of the Mitigation and Monitoring Measures as Required under the Marine Mammal Protection Act (MMPA) Incidental Harassment Authorization and National Defense Exemption from the Requirements of the MMPA for Mid-Frequency Active Sonar Mitigation Measures. On file with authors.

Weilgart, L., 2007. The impacts of anthropogenic ocean noise on cetaceans and implications for management. Canadian Journal of Zoology 85, 1091–1116.

Weir, C., Dolman, S.J., 2007. Comparative review of the regional marine mammal mitigation guidelines implemented during industrial seismic surveys, and guidance towards a worldwide standard. Journal of International Wildlife Law and Policy 10, 1–27.