MARINE MAMMALS AND ACTIVE SONAR

A paper prepared for the NATO Military Oceanography Group

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1 PURPOSE

The purpose of this paper is to "*provide a recommendation to MILOC MG 40 for MILOC engagement with marine mammal mitigation measures, paying regard to the limited resources and special role of MILOC.*" (Extract from the minutes of the 35th MILOC SG dated 1 November 2004.)

The paper does not provide a comprehensive review of the considerable amount of work in progress in this field. It is no more than a brief statement of common understanding of the issues with their potential significance to the MILOC community and an outline of ongoing actions to address the issues. Options and recommendations for MILOC engagement are presented in conclusion.

2 BACKGROUND

This section covers:

- Context, political, public and media concerns
- The history of marine mammal strandings and the implication that military sonars are an underlying cause
- Scientific opinion on the issue
- National and international political responses

Context, political and public concerns

Responsibility for protection of the natural environment is generally accepted by the governments of NATO nations and is firmly supported by public opinion. Governments also have to balance protection of the environment against the need to maintain military effectiveness. This requires continued research and development of weapons and sensors. Training and exercising are required to be able to operate in a range of environments.

Of the wide spectrum of possible adverse impacts on the marine environment resulting from military activity, impacts on marine mammals currently has a particularly high profile for a number of reasons:

- Populations of whales, dolphins and other marine mammals are under threat from a range of other pressures resulting from human activity.
- All species of cetaceans are listed on Annex IVa to the EU Habitats Directive. This provides protection to cetaceans from deliberate capture and killing, and deliberate disturbance to these species whether they occur inside or outside a Special Area of Conservation. Some species, which are more threatened, are given greater protection either generally or in designated conservation areas.
- A number of cetacean species are included in the IUCN Red List[1]; two are critically endangered and several others are endangered or vulnerable. The COSEWIC[2] marine mammal species at risk lists 8 endangered cetacean species/populations and another 9 as either threatened or of special concern.
- In recent years there have been a number of highly publicised incidents of mass strandings, involving several whale species, in which the nearby presence of naval

[1] IUCN, 2002.
[2] COSEWIC, 2004.

activity, or other activities involving the use of an underwater high-energy sound source, is a common factor.
- Relatively little is known about marine mammal susceptibilities; consequently there is pressure to adopt a highly precautionary approach.
- People tend to feel an affinity for marine mammals simply because they are mammals, but also because they appear to be intelligent. In conservation jargon they are "charismatic megafauna" and consequently command great public sympathy.

Marine mammals may be adversely affected other than by sonar transmissions. Disturbance of normal activity by shipping or naval operations, collisions and increased levels of background noise may cause stress, lack of breeding or feeding success, direct injury or death. Mass stranding incidents have particularly high visibility in the media and are very emotive.

History of marine mammal strandings

Table 1 lists incidents prior to 2005 involving at least two Cuvier's Beaked Whales, one of the species thought to be sensitive to sonar transmissions. Also included in the table is an indication of other species that stranded as part of the same event. Naval or seismic survey activity correlates with 40% of these strandings. Multiple-animal strandings of Cuvier's Beaked whales are relatively rare and therefore the correlation of multiple-animal strandings with naval operations is of particular interest.

There have been hundreds of other recorded strandings involving other species. A number of national and regional databases are maintained of marine mammal strandings, (table 1 is derived mainly from Smithsonian records), but currently there is no global compilation of this information.

This year (2005), active sonar has been linked by news media to mass whale deaths in North Carolina (Environmental News Service, January 2005) and mass dolphin deaths in the Florida Keys (Associated Press, March 2005).

Year	Location	Zc	Ssp	Msp	Ha	Kb	Bsp	Naval activity?
1914	United States (NY)	2						
1963	Italy	15+						
1965	Puerto Rico	5						
1968	Bahamas	4						
1974	Corsica	3	1 Sc					Patrol
1974	Lesser Antilles	4						Explosion
1975	Lesser Antilles	3						
1980	Bahamas	3						
1981	Bermuda	4						
1981	United Sates (AK)	2						
1983	Galapagos	6						
1985	Canary Islands	12+		1 Me				Manoeuvres
1986	Canary Islands	5		1 Me				
1987	Canary Islands	group		2 Me				
1987	Italy	2						
1988	Canary Islands	3		1 Me	1	2		Manoeuvres
1989	Canary Islands	19+		2 Me 3 Md				Manoeuvres
1991	Canary Islands	2						Manoeuvres
1991	Lesser Antilles	4						
1993	Taiwan	2						
1994	Taiwan	2						
1996	Greece	12 or 13						NURC LFAS trial
1997	Greece	3						
1997	Greece	8						
1998	Puerto Rico	5						
2000	Bahamas	8+2*	1 Sf	3 Md			3	US Navy exercise
2000	Galapagos	3						Ewings seismic
2000	Madeira	3						Manoeuvres
2001	Salomon Is.	2						
2002	Canary Islands	10		1 Me 3 Md				NATO Exercise
2002	Mexico	2						Ewings seismic
2004	Canary Islands	4						Majestic Eagle 04

Table 1. Strandings involving at least two *Ziphius cavirostris* (**Zc** = Cuvier's Beaked Whale). Adapted from Taylor *et al*, 2004.
Ssp: *Stenella* species. **Sc** = *S. Coeruleoalba* (Striped Dolphin), **Sf** = *S. frontalis* (Atlantic Spotted Dolphin). **Msp**: *Mesoplodon* species. **Me** = *M. europaeus* (Gervais' Beaked Whale), **Md** = *M. densirostris* (Blainville's Beaked Whale).
Ha: *Hyperoodon ampullatus* (Northern Bottlenose Whale). **Kb**: *Kogia breviceps* (Pygmy Sperm Whale). **Bsp**: *Balaenoptera* species.

* The 2000 Bahamas stranding also included two Ziphiid not identified to species.

Scientific opinion - Do sonars cause strandings?

Some environmental pressure groups have presented as fact that sonars can cause severe damage to cetaceans' internal organs and implied that such effects can occur at extreme range. While the impacts have almost certainly been over-emphasized in some publicity material and such factors as the difference between source level and received signal level brushed over, there is strong circumstantial evidence that military sonar transmissions are implicated in cetacean death and disturbance[3]. There is also anecdotal evidence that some species are apparently unaffected by, or even attracted to, certain sonar transmissions.

Observations suggesting adverse effects from naval sonars have been made since 1985[4] and the correlation between mass strandings and sonar operations is sufficiently well established for the US Navy/National Oceanographic and Atmospheric Administration report[5] of the 2000 Bahamas strandings to state,

> *"…tactical mid-range frequency sonars aboard U.S. Navy ships…were the most plausible source of [the] acoustic or impulse trauma [to the stranded whales]."*

Several scientific reports[6] have suggested that sonar use has caused mass strandings of beaked whales in the Canary Islands, Ionian Sea, the Bahamas and elsewhere (table 1). Also, vocal behaviour changes have been observed in sperm whales, pilot whales and fin whales caused by sonar[7].

There are four hypotheses about the injuries found in stranded cetaceans. In the first, researchers hypothesize that lesions in auditory organs are caused by sonar, explosions or shipping traffic[8]. The second hypothesis suggests other symptoms caused by exposure to loud sounds such as the possibility that acoustic waves may cause resonance in organs and body cavities causing injuries to them[9], but that was generally dismissed as a result of a 2002 workshop[10] on the topic. The analysis of the Bahamas stranding data failed to support the resonance hypothesis. The workshop found that resonance effects were:

> *"..not likely to have played a primary role in the Bahamas stranding for the following reasons: 1) tissue displacements at resonance are estimated to be too small to cause tissue damage; 2) acoustic pressure attributable to resonance is orders of magnitude less than the ambient pressures during diving; 3) tissue-lined air spaces most susceptible to resonance are too large in marine mammals to have resonant frequencies in the ranges used by either mid- or low frequency sonar; 4) lung resonant frequencies increase with depth, and tissue displacements decrease with depth, so if resonance is more likely to occur at depth it is also less likely to have an effect there; 5) based on experiments with terrestrial mammals, tissue damage is estimated to require higher exposure levels than most wild animals would receive from sonar, especially at the depths where lung resonant frequencies would match the sonars being used; 6) based on terrestrial mammals, the time required for acoustically-induced vibrations to damage tissues is usually longer than animals would experience from short (1 sec) sonar pings; 7) lung tissue damage has not been observed in any mass, multi-species stranding of beaked whales."*

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[3] Weiss (2001) Simmonds and López-Jurado (1991), Frantzis (1998), Jepson et al (2003).
[4] Watkins *et al*. (1985),
[5] Evans and England (2001)
[6] Vonk and Martin (1989), Frantzis and Cebrian (1999), Balcomb and Claridge (2001), Evans and England (2001),Jepson *et al.* (2003) and Fernández (2004).
[7] Watkins *et al*. (1985), Rendell and Gordon (1999) and Parsons *et al.* (2000).
[8] André and Degollada, (2003)
[9] Balcomb and Claridge, (2001).
[10] NMFS, (2002).

The report goes on to recommend a number of research issues that warrant further investigation.

As a basis for the third hypothesis, several researchers have found gas-bubble lesions in stranded cetaceans similar to those that occur in humans as a result of decompression sickness[11]. Researchers hypothesize that these bubbles occur either as a result of the effect of intense sound energy (around 210 dB re 1 µPa) on tissues supersaturated with nitrogen or because the sonar transmissions cause the animals to behave abnormally and to ascend too quickly to the surface. These effects have been seen more frequently, though not solely, in deep diving species and the inference is that this makes them more susceptible to stranding as a result of sonar transmissions.

A fourth and relatively new, alternative explanation has been suggested based on the observation that strandings appear to be correlated with high sea temperatures[12]. It is suggested that panicked animals suffer heat stress as a result of over-exertion in water that is too warm to effectively cool animals adapted to spend most of the time in cold water below the thermocline. Both "gas-bubble lesion" and "heat stress" hypotheses are consistent with the apparent susceptibility of deep diving species.

Acoustic seismic surveys have also been associated with cetacean strandings. The low-frequency, high-intensity pulses produced by air guns are believed to affect cetaceans in a similar way to low-frequency sonars.

It is quite possible that whales are killed when sonar operations take place but mass strandings are not recorded. Whether or not dead or injured animals are carried ashore may be a result of the patterns of ocean currents in a particular area. Nor do we have good knowledge of how oceanographic conditions (i.e. temperature) affect carcass sinking and/or resurfacing rate. This further amplifies the need to understand the effects of high intensity sound and is a strong argument for a precautionary approach.

Political and legal response at national and international levels

Political responses, and in the US legal rulings, have tended to adopt this precautionary position. In August 2003, in a temporary injunction, the US Federal Court ordered the USN to reduce the potential of harm to marine life from Low Frequency Active Sonar (LFAS) by negotiating limitations on its use with conservation groups. A settlement was reached in October 2003 in which the Navy agreed to limit the use of LFAS to areas and seasons in which there is least possibility of having an impact on marine mammals.

In October 2003, a petition bearing 83,500 signatures was presented to the NATO Secretary General asking NATO to cease using high-powered sonars.

> *"We request that NATO comply with the UN Law of the Sea Convention and commission an independent Global Environmental Assessment on the impact of LFAS and other high-intensity active sonars on marine life and on the cumulative and synergistic impact of several nations simultaneously deploying these technologies. According to a Las Palmas, Canary Islands University report, 15 whales died around Sept. 24, 2002 of brain hemorrhage, most likely caused by "strong acoustic signals" emitted by navy ships. All deployment of high intensity active sonars should be stopped until the assessment is completed and evaluated."*

[11] Crum and Mao, (1996); Houser *et al*, (2001), Jepson *et al*, (2003).
[12] Cole, (2005).

NATO representatives received the petition on behalf of the Secretary and met with members of the European Parliament and concerned scientists representing the European Coalition for Silent Oceans[13] who initiated the petition. The Coalition represents more than 40 European environmental organizations.

In October 2004 the European Parliament passed a resolution calling for a moratorium on the operation of "high-intensity naval active sonar". The resolution expresses concern over strandings and mortalities associated with the use of mid-frequency sonar and over the other impacts that military sonar may have on marine mammals and ocean wildlife. It urges member states to take action on the issue. Among other things, it calls on them to develop international agreements, through a Multinational Task Force, for regulating noise levels in the world's oceans; to monitor, investigate, and report mortality events associated with sonar use; and to "immediately restrict the use of high-intensity active naval sonars in waters falling under their jurisdiction." It also calls on the European Commission to assess the environmental impacts of current deployments in European waters.

Also in 2004, the Canadian Parliament was presented with a petition to "use its power and influence and urge the navies of the world to cease any sonar activities harmful to whales and enact legislation to prohibit the harmful use of this technology in the marine environment."[14] The petition did not result in any enacted legislation, but caused an increase in awareness with the Canadian Parliament.

As a result of the Canadian Species at Risk Act[15] (SARA), brought into force in 2002, there is a requirement to formulate recovery strategies for species listed as endangered by COSEWIC. Draft recovery strategies[16] for four endangered species have identified naval active sonar as a threat. There are requirements under SARA to protect both the species and their habitat. The impact on Canada's naval operations is yet to be determined.

In the same year, the Spanish Minister of Defense imposed a moratorium on the use of naval active sonars within 50 NM of the Canary Islands. As a general rule for Spanish Naval exercises, there is a go/no-go policy depending on the presence of beaked whales.

[13] www.silentoceans.org
[14] Gov. of Canada, 2004.
[15] Statutes of Canada C-5, 2002.
[16] DFO, (2005a), DFO, (2005b).

3 SIGNIFICANCE (To MILOC and maritime operations)

This section underlines why this is important to MILOC and the wider military maritime community under the following headings:

- Potential impact on ASW and associated exercises/operations
- Potential for impact on other active sonar systems
- Need to establish risk mitigation procedures during exercises

Potential impact on ASW and associated exercises/operations

Due to the strong effect on public opinion of cetacean strandings after naval exercises, this has become a significant political issue. As a consequence governments are inclined towards conservation measures including the banning of military activities in some sensitive areas.

Although the early focus on impact was directed towards Low Frequency Active Sonar (LFAS), the circumstantial evidence suggests that operational mid-frequency active sonars also give cause for concern. A number of NATO countries have shifted their research efforts to focus on mid-frequency active sonars in recent years[17].

Following the European Parliament's 2004 Resolution there is even the risk of a more extensive moratorium on sonar use covering most European and North American waters. Therefore it is clear that political responses to mass strandings can affect the operational effectiveness of NATO navies.

NATO is committed to compliance with appropriate environmental requirements in the conduct of maritime exercises and training at sea. Modern day norms and evolving international standards and agreements dictate that military operations at sea and environmental protection must be viewed as complementary actions, rather than mutually exclusive events. In light of this perspective, NATO and several national authorities have provided guidance for mitigation of the impact of operations on marine mammals, to be employed by operational commanders as applicable during the planning and execution of maritime training and exercises.

Potential for impact on other active sonar systems

Although there is no evidence of significant harm being caused by high-frequency sonars (above 3kHz), such as echo sounders, survey equipment and mine hunting sonars, some nations have already imposed voluntary restrictions on the use of such systems in potentially sensitive areas. German survey ships, for example, will not operate high-frequency sonars in Antarctic waters.

Torpedo firings, shock tests, and use of SUS charges may also become restricted by measures imposed to control levels of underwater sound.

Need to establish risk mitigation procedures during exercises

Unless it can be clearly demonstrated that reasonable measures are being taken to avoid harm to marine mammals, pressure groups will use political and/or legal pressure to stop the use of active sonar.

[17] Gisiner and Hastings, 2004.

Emerging NATO Environmental Protection (EP) policy and guidance clearly indicates that forces operating under its control are expected to act as good stewards of the environment within the constraints of mission accomplishment. As noted in STANAG 7141

> *"While meeting their military mission, NATO Forces should be committed to taking all reasonably achievable measures to protect the environment".*

Clearly, an effective mitigation measure is to not use implicated sonar systems in areas of the ocean which have populations of apparently susceptible species, migration paths, or recognized marine mammal protection areas. NATO guidelines[18] include the following statement:

> *"If a potentially significant impact on marine mammal migration, calving, breeding or feeding is assessed, consider either relocation of the planned OPAREA or rescheduling of the operation as feasible. Active acoustic operations should not be conducted for training or exercise purposes within recognized marine sanctuaries as indicated on navigational charts"*

But to be effective, without being overly restrictive, planners and commanders will need access to better, more comprehensive and reliable data.

General principles of Environmental Protection (EP) regarding marine mammals are focused on collision avoidance and marine mammals' reactions to sound, taking into account the uncertainty regarding the biological impact that high levels of sound may have on the physiology of marine mammals. Ideally they would also take account of the relative sensitivity of different species. While the direct cause of strandings associated with military trials and exercises has not been proved, the link is sufficient to warrant both further investigation and the implementation of measures to minimise the likelihood of strandings in future. However, identifying the underlying cause is still crucial because it will have a profound influence on the design of effective mitigation measures.

Guidelines for collision avoidance with marine mammals are considered relatively straightforward, as they are tied directly to the exercise of prudent seamanship.

[18] Marine Mammal Risk Mitigation Guidelines for Training and Exercises, in draft, v4.

4 RESPONSE TO DATE BY NATIONS AND NATO

The following is by no means a comprehensive review of all nations' responses to this issue. It is biased towards those nations whose representatives have contributed to this paper. Certainly there is much more being done by more nations than are listed, but it does at least serve to give an overview of the kinds of activities being undertaken.

NATO/NATO Underwater Research Centre (NURC)

The Marine Mammal Risk Mitigation (MMRM) project, "Sound Oceanography and Living Marine Resources" (SOLMAR), was initiated following the recommendations of SACLANTCEN panels on Bioacoustics and Marine Mammal Environmental and Risk Mitigation Procedures, convened in 1998[19]. The panels were formed in response to the unusual mass stranding[20] of Cuvier's beaked whales, *Ziphius cavirostris*, in Kyparissiakos Gulf, Greece following a Centre sonar experiment in 1996.

Although it could not be established whether or not the use of active sonar was directly or indirectly linked to the stranding, NURC began to devise specific mitigation and monitoring protocols for use in future exercises using acoustic sources.

The SOLMAR project was established as a multinational, multidisciplinary joint research project. SOLMAR works closely with the Italian Navy, the Genoa Aquarium, the Central Institute for Scientific Research and Applied Technology of the Sea (ICRAM), an Italian Ministry of Environment agency for public dissemination of the scientific results of the project, CIBRA (U. Pavia), Italian National Research Council (CNR), University of Genova and has either formal or informal joint research programs with the US, UK, and other NATO nations.

When this project started, little information existed about the marine mammal population in the Mediterranean Sea and other NATO-interest areas. Likewise, little was understood about the impact of sound on these animals. The first tasks of the project were the development of

- A network of scientists with knowledge of marine mammal distribution, behaviour, bioacoustics, and sonars,
- A database containing all available documents and data related to marine mammal distribution, behaviour, and associated bioacoustics information,
- A risk mitigation instruction containing policy and protocols to ensure that active acoustic research was planned and performed in an environmentally sensitive manner,
- Acoustic and visual tools to observe and measure focal whale behaviour during SOLMAR sea-trials.

In cooperation with its primary partners, NURC has carried out 10 experiments under the SOLMAR project (7 of which were multi-ship) since the year of its inception in 1999 for the following purposes: to collect basic marine mammal population information, to develop and refine visual and acoustic measurement techniques, to measure and determine normal marine mammal behaviour and to develop and test experimental acoustic protocols by exposing deep diving species to controlled low source level sonar to determine whether there were measurable changes in their behaviour.

The NURC Human Diver and Marine Mammal Risk Mitigation Rules[21], originally created in 1999, have been reviewed and updated annually. While these rules only apply to NURC

[19] SACLANTCEN M-133
[20] *Frantzis, 1998.*
[21] NURC Staff Instruction 77

sonar and other noisy operations, other countries and operational forces have used them as a prototype for creating their own rules. Over the last few years NURC MMRM team members have assisted NATO naval planners in Naples to select sites and guidelines for sonar operations in Mediterranean exercises.

As the NURC MMRM and other international research programs have begun to understand the habitats and behavior of marine mammals, especially those to which sonars seem to pose a greater risk, the focus of the project is evolving from a purely scientific program to a more applied one, with an emphasis on tools and devices which could be used by operational forces for planning and on-site risk assessment and mitigation.

The centre has gained considerable experience and developed tools for assessing and mitigating the possible impact of sound on marine mammals. The focus has been on species in the Mediterranean Sea with a specific interest in Sperm whales and Cuvier's beaked whales. NURC now plans to move its current risk-management tools to a Web server.

In March 2005, the Assistant Secretary General for Defence Investment answered the letter sent to SACEUR by several green institutions. That answer included the following statements:

> *"The NURC will be reviewing NATO's environmental protection instructions to make sure that the issue of sonar transmissions is highlighted and is considered in the planning of all military exercises. Recommendations will be made available to appropriate NATO elements responsible for these instructions"*
>
> *"...NATO Strategic Commands have introduced rules for all sonar operating forces, which come under their command, such as the Standing Naval Forces".*

2005 has been an important year for the MMRM program at NURC. A training Guide to the Marine Mammals of the Mediterranean Sea has already been issued on the web in English and Italian as a prototype document for use by NATO forces. An Environmental Scoping Tool Kit prototype has also been released for evaluation by scientists at NURC and NATO naval planners.

In May 2005, NURC co-hosted an Intergovernmental Conference on the Effects of Sound in the Sea on Marine Mammals. Representatives of most NATO nations and Australia presented their work and developed a plan to produce a prototype set of guidelines for operational forces to use when performing noisy operations. Work is progressing in the development of cetacean species habitat models (to be used as part of the NATO AML) and on-site risk mitigation tools (such as passive detection devices, and possibly non-acoustic devices). In the autumn the project will test four different types of stationary devices (Naval Oceanographic Office EARS buoy, Cornell University Pop-Up buoys, and two NURC vertical arrays) and one towed recording device (NURC) tuned to listen for the species considered most at risk in the Mediterranean Sea, *Ziphius cavirostris*. This whale is almost always involved in mass strandings associated with naval exercises.

STANAG 7141 (Joint NATO Doctrine for Environmental Protection during NATO Led Operations and Exercises) and CM 469 (NATO Military Principles and Policies for Environmental Protection) have been reviewed by NURC. CM 469 is too high level and general to need amendment but changes may be recommended to the STANAG.

Canada

Canada has a number of current activities. Operationally, a Standard Operating Protocol (SOP) on marine mammal observation was added to the Environmental Management Systems

in 2004. Sightings by bridge staff are forwarded to Fisheries and Oceans Canada's national databases and for inclusion in the OBIS-SEAMAP system. An interim precautionary protocol for the use of the AN/SQS-510 active sonar is in review and is expected to be in place before the end of 2005.

Risk Awareness (RA) tools have been developed for both Atlantic and Pacific fleets. Habitat data for the system developed for MARPAC (Maritime Forces Pacific) is stored in an AML format. Discussions on migrating the MARLANT (Maritime Forces Atlantic) habitat and risk data to AML format are underway. A previous research effort considered the requirements for Command Decision Aids[22].

Two concurrent efforts are underway to consider acoustic detection of marine mammals. Within DRDC Atlantic's applied research program, effort on the detection, classification, and localization of marine mammals is ongoing. The initial focus species is the northern right whale. Through this effort, DRDC Atlantic organized and hosted a 2003 international workshop on passive acoustic localization. A similar follow-on workshop is being held in November 2005 in Monaco. The second effort has a much shorter time horizon, and is investigating autonomous and towed sensor technologies (gliders, moored systems, stealth buoys, towed arrays, etc) combined with transient-detection signal processing generated by other projects.

The current effort on detection, classification, and localization of northern right whales as well as a small effort to look at noise impacts on Beluga whales also serves to build expertise and an understanding of the general complexities.

A new proposed effort will likely see the evaluation of multiple detection modalities (passive acoustics, X-band radar, etc) through an international Navy research organization collaboration with industrial oil and gas producers. Another new effort will further the understanding of animal hearing through a mixture of experiments and finite-element modeling of the animal head and ear.

Netherlands

SAKAMATA (Sea Animal Kind Area-dependant Mitigated Active Transmission Aid)[23] is a commercially available tool developed by TNO Physics and Electronics Laboratory in The Netherlands. This is a tool to assist command when planning sonar use or actually using the sonar in the operational field. It provides the command and operators with tools for "careful mission planning," implementation of "marine mammal monitoring," and of "ramp-up schemes."

The IRMA software tool is also being developed. This is an identification and registration tool and a version is being developed for PDA so that all records can be digitally logged from the bridge.

Norway

In response to allegations that herring and killer whales have been scared away from certain areas as a result of sonar exercises and to proposed NATO rules for use of sonars during exercises, which may make it difficult to utilize new LF sonars in Norwegian coastal waters, Norway has been undertaking research to ensure that such new rules and regulations are based on scientific findings.

[22] Theriault (2004).
[23] Benders et al. (2004)

This project will support development of a set of rules and regulations for the use of (LF) active sonars in Norwegian waters where the new frigates will operate and a geographical data base that will contain all available information on distributions of economically and biologically important species of fish and sea mammals in Norwegian waters and their sensitivity to sonar. Distribution data for Norwegian areas exists and is stored at the Institute for Marine Research (IMR). However, the data is not readily accessible for this purpose; it needs to be converted, re-structured and correctly formatted. This database will be made available for planning and operational use.

A decision aid (SONATE) is under development for planning and operational use. This tool relies heavily on the accessibility of such a database within the decision aid.

To establish the extent of scientific knowledge in this area Norway has established a national forum of military and civilian experts. This Expert Group for Sonar Effects on Marine Life had its first meeting in October 2003. Collaboration with other nations' labs and institutions (TNO, dstl, NURC etc.) is also helping to achieve this goal.

The Expert Group recommended that the project undertake four field studies. The following controlled exposure experiments have been performed:

- The effects of sonar signals on survival and development of fish larvae and fish fry
- Behavioral and physiological effects of sonar exposure on herring (Norwegian spring-spawning herring)
- Behavioral effects of sonar exposure on killer whales and minke whales
- The effects of sonar exposure on seals (hearing and diver's disease)

Spain

After the mass stranding of 2002, the Spanish MoD funded and initiated collaborative research with the Regional Canarian Government and Universities. The University of Las Palmas research team found the presence of gas bubbles in stranded cetaceans' tissues and formulated the hypothesis of decompression sickness related to the strandings.

After the new mass stranding of summer 2004, the Spanish MoD banned the use of active sonar in waters within 50 NM around Canary Islands.

Currently the Navy Hydrographic Office is working on the preparation of a cetacean population database to be used with regards to Marine Mammals Risk Mitigation.

Recently the Canary Islands Regional Government and the Spanish MoD are seeking to undertake some collaborative research with NURC that will demonstrate publicly how NATO is concerned and involved in Marine Mammal Risk Mitigation.

There has been some scientific collaboration with the Sea Mammal Research Unit (SMRU) in the UK to develop models of cetacean habitat preference.

UK

Research into cetacean abundance and distributions
The Department for Environment, Food and Rural Affairs (DEFRA) has primary responsibility within the UK for monitoring marine mammal bycatch, conducting assessments of the distribution of cetaceans in United Kingdom waters and for regulating risk mitigation measures in the conduct of seismic surveys. DEFRA has conducted a number of surveys which have addressed population biology of harbour porpoises; trends in turtle and cetacean

strandings around the UK coastline; estimation of small-cetacean bycatches in UK fisheries; analysis and mitigation of cetacean bycatch; and further development of a dolphin exclusion device for fishing gear.

Over the last year, DEFRA has part funded an international project (SCANS II - Small Cetacean Abundance in the North Sea and North East Atlantic) to survey the abundance of whales, dolphins and porpoises in the North Sea and European Atlantic waters. UK funding represents about 14% of the total cost while other funding has come from the EU, other EU States and ASCOBANS (the Agreement on the Conservation of small Cetaceans of the Baltic and North Seas). This project will be carried out by the Sea Mammal Research Unit (SMRU) at St Andrews University, a world leader in its field, which holds data on global marine mammal distribution, as well as distribution in UK waters by species and period of observation.

The UK Joint Nature Conservation Committee (JNCC) has produced an atlas of cetacean distribution in north-west European waters which contains distribution information for all species occurring in UK waters. This information can be accessed on www.jncc.gov.uk

The UK MoD is funding research into cetacean distribution. This research is conducted by various academic and civilian institutions, including Aberdeen University, the Sea Mammals Research Unit (SMRU) at St Andrews University, and the Biscay Dolphin Research Programme. A component of that research involves observational surveys at sea.

Royal Navy ships continue to collect observations of marine mammal sightings during normal operations. Those sightings are recorded and passed to the UK Hydrographic Office (UKHO). The UKHO also exchanges data with other organizations and their database now holds several thousand observations of cetaceans.

Environmental Protection Policy
UK MoD Environmental Policy already requires that:
"…the Ministry will:
- *carry out environmental policy appraisals of all new or revised policies and equipment acquisition programmes and environmental impact assessments of all new projects and training activities;"*[24]

The Royal Navy's Maritime Warfare School is developing a series of modules covering environmental risk mitigation to be included in various training courses.

Environmental Impact Assessments (EIAS)
MoD funded EIAs include a global assessment of the impacts from S2087 LFAS and smaller scale studies for specific trials areas and major exercises. Guidelines on risk mitigation during LFAS trials currently rely heavily on experienced marine mammal observers.

The Ocean Eye Project is a three year programme, partly funded by UK MoD, designed to support efforts to reduce impacts on cetaceans by:
- scientific validation of visual search as a mitigation strategy
- identifying the aptitudes and skill set necessary for effective observation
- investigating the environmental factors that affect observer performance
- development of needs oriented training for marine-mammal observers

The project uses a ship's bridge simulator to accurately recreate a range of field conditions in a cost effective way.

[24] Secretary of State for Defence, SHEF Policy Statement. (July 2000)

Environmental Risk Mitigation Capability (ERMC) and IWC AML
ERMC is a system under development to meet the RN requirement for a robust, repeatable and transparent method to assess the potential impact of sonar activity on marine life. It will build on proven EIA and modeling techniques, assimilating a range of inputs (the platform's capabilities, characteristics of receptor affected, local environmental conditions) to provide objective advice on mitigation measures during the conduct of sonar operations. The system is intended to use both risk management predictive tools and mitigation tools integrated with observed and forecast conditions to update the advice as operating parameters change and will provide a real-time operational capability.

Alternatives to visual observation exist with a mixture of effectiveness. Passive acoustics, active acoustics, X-band radar, and IR are all being investigated. Work is also progressing in the UK to develop a passive acoustic marine mammal detection system to work alongside, and potentially to integrate with, the ERMC. The prototype Marine Mammal Acoustic Detection System (MMADS) is able to detect and classify vocalizing animals but the problem of establishing the position of an animal remains.

US

The Office of Naval Research (ONR) has commissioned research to determine the causal mechanisms of sonar-related beaked whale strandings. ONR is funding various research projects including passive acoustic detection methods, distribution mapping, anatomical studies etc.

A database of beaked whale sightings and strandings has been developed by the US. A Worldwide marine mammal sighting database, OBIS-SEAMAP (**S**patial **E**cological **A**nalysis of **M**eg**a**vertebrate **P**opulations), is maintained by Duke University and can be accessed via the Web.

LMRIS (Living Marine Resources Information System) is being developed by Angela D'Amico of SPAWAR. The aim for this system is to be an online database of mammal literature, density estimates and other relevant information for use by the US military.

Significant resources have been devoted to tagging experiments including development and deployment of D-TAG's. These are very sophisticated, having hydrophones and sensors to measure depth, pitch, roll and yaw. Some tags also measure oceanographic parameters such as Temperature, Salinity and are providing very good complimentary oceanographic information.

Computer-based Decision Aids
Computer-based Decision Aids (DA) are being developed in the US and several other NATO countries[25]. The following is a brief summary of efforts in addition to those described above:

- ESME (Effects of Sound on the Marine Environment)[26], being developed in the United States, is probably the most extensive acoustic impact risk modelling effort. Its goal is to develop an "update-able" integrated model that provides meaningful measures of risk using the best available science. The project brings together a wide selection of content experts in order to build a risk model. The project faces challenges in achieving its goals because of the limited databases related to the acoustic environment (seabed characteristics, etc) and biological information (habitat, abundance, behaviour), uncertainty in physical models and biological data, and the definition of relevant risk metrics. ESME will be featured in a 2005 Special Issue of the Journal of Ocean Engineering. A benchmark release of the model is expected in 2005.

[25] Theriault. (2004).
[26] Gisiner. (2004).

- The US Navy is also due to release another tool, PMAP (Protective Measures Assessment Protocol)[27] that provides "situational awareness for at-sea training." It is not restricted to acoustic impact awareness, but applies to a wide range of activities.
- In Canada, Maritime Forces Atlantic's Formation Environment[28] has a toolset for the identification of risk areas associated with planned training missions in east-coast Canadian waters. This tool, similar to PMAP, is not restricted to acoustic impact, but also includes risk mitigation measures associated with gun firings and towed equipment entanglement in fishing nets. Maritime Forces Pacific has a similar, but different, set of risk awareness tools.
- AIM (Acoustic Integration Model) is a commercial system available from Marine Acoustics, Inc. "AIM was designed to model the movements and behaviors of acoustic sources and receivers. These receivers are virtual animals and have been dubbed animats. The AIM model interfaces with an acoustic propagation model that simulates the acoustic field produced by the acoustic source(s). The animats can be programmed to simulate natural responses, including reactions to the sound field. The acoustic history of each animat is recorded, a valuable and important output. The model allows multiple Monte Carlo model simulations to estimate the impact of various scenarios[29].
- A recent paper[30] from Australia presented a model to predict the marine mammal received levels and statistical fluctuations. This work, supported by the Australian Defence Science and Technology Organization (DSTO), fits into and is a critical component in solving the larger problem of predicting the impact of active sonar transmissions.

Each of the approaches listed is directed towards a decision aid. Some present qualitative information and guidance while others strive to provide a quantitative risk assessment. The quantitative measure is often based on an influence zone, probability of impact, or some other physically derived value. However, the uncertainty due to the biological knowledge deficiencies (impact mechanisms, habitat, abundance, and behavioral characteristics) when combined with the physical-acoustics knowledge deficiencies (seabed characteristics, etc) and the natural environmental variability makes this a very difficult goal to achieve.

[27] Stone. (2004).
[28] Thomson. (2004).
[29] National Research Council. (2003).
[30] Duncan et al. (2004).

5 CONCLUSIONS

Adapting activity to minimise risk requires that an estimate of the extent and level of that risk can be made. In the case of marine mammals and sonar operations, estimating risk with any degree of confidence is extremely difficult because of the lack of reliable information on species distributions (including the difficulty of detecting the presence of animals in real time), their physiological and behavioural sensitivity to sonar transmissions, and the biological significance of the impact.

Regardless of the approach used, there are requirements for information on marine mammal distribution and abundance. Knowledge of the distribution of marine mammals by species and period (ideally distribution data compiled on a monthly basis) is at best sketchy for most parts of the world. The lack of comprehensive marine mammal information, and any associated database, could lead to arguments that this shortfall will minimise the effectiveness of any operational planning to avoid areas of known marine mammal activity such as migratory routes and breeding grounds. On the other hand, adopting a precautionary approach with the current level of knowledge probably means placing unnecessarily stringent constraints on naval operations. For example it can be foreseen how in the future there could be a go/no-go decision to be taken before naval exercises based on the presence of beaked whales in the area.

As a result of the "Intergovernmental Conference: Effects of Sound in the Ocean on marine Mammals[31]", a number of clear knowledge gaps have been identified. There is a need for research to improve our knowledge or expertise in the following areas:

- Species distributions including seasonal variability
- Population levels and the environmental factors encouraging aggregations of animals
- Species' susceptibility to pressures; both physiological and behavioural responses, direct or indirect, and a better understanding of their ultimate effects
- Means of detecting the presence of marine mammals and establishing their location – important if using stand-off ranges to mitigate risk
- Means of monitoring marine mammals to demonstrate that mitigation is effective

Lack of comprehensive datasets is a problem for forces which may be required to operate anywhere around the globe; however, there are numerous experts, or organizations, who have specific knowledge of mammals within their particular areas of interest and part of the answer must be to bring that fragmented knowledge together. NATO, through MILOC, could serve to facilitate data exchange standards and provide for the distribution of habitat information to member nations.

Individual countries will continue their efforts on risk management or decision aids regardless of the MILOC direction. However, there is an opportunity for the NATO MILOC community to show leadership in developing a NATO baseline model – in much the same manner as it has with the NATO Allied Environmental Support System.

[31] Intergovernmental Conference, 2005a and Intergovernmental Conference, 2005b.

6 RECOMMENDATIONS

1. As representative of military active sonar users, MILOC should take an interest and must be engaged.

2. MILOC should communicate across NATO that cetacean strandings could lead to major negative operational effects for NATO members (such as a broad moratorium on sonar use).

3. NATO should establish a means to collate national policies and restrictions on MMM.

4. NATO should provide high level guidance on all aspects concerned with MMM, including legal, PR, limitations on military operations and direction for scientific research.

5. A major effort should be made by NATO to show its involvement in and concern for Marine Life protection. This effort should focus on areas where mass strandings have occurred and public opinion is therefore more likely to be against NATO naval exercises.

6. Continued research and development is required to advance and refine NATO understanding and appreciation of marine mammal behavioural patterns, not just with regard to the impact of military sonars, but also of their migration patterns and habitats in order to better plan less intrusive military exercises.

7. NATO should support development of the technology for early detection of cetaceans, particularly beaked whales, by NATO naval units.

8. Nations should be encouraged to develop and maintain databases, preferably using a NATO standard format, and should contribute new information and the data they currently hold to a central NATO database of marine mammal sightings.

9. In support of 8 above, Alliance nations should encourage all naval units to report sightings of marine mammals and MILOC should endorse a common reporting format for such observations.

10. NURC should be requested to act on behalf of MILOC as the NATO focal point to support marine mammal risk mitigation by promoting coordinated data standards, collection/data exchange/databasing, modelling, legal considerations, etc. and to maintain a composite database for NATO nations.

11. NATO should endorse recommended changes to STANAG 7141 (Joint NATO doctrine for environmental protection during NATO led operations and exercises).

12. A formal working group with a representative from the major NATO organizations with a vested interest should be formed and funded to centrally address the Marine Mammal and Human Diver Risk Mitigation problem.

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