Acoustic Risk Mitigation in the Mediterranean Sea. Current situation and recommendations.

Pavan G.

CIBRA - Centro Interdisciplinare di Bioacustica e Ricerche Ambientali
Università di Pavia, Via Taramelli 24, 27100 Pavia, Italy
Email gpavan@cibra.unipv.it

ABSTRACT
The knowledge that man-made noise can affect marine mammals and the need for a regulatory system to mitigate such effects has increased over the past few years, mainly within the context of military sonar and seismic surveys. In the absence of specific laws, and given the fact that underwater noise is a transboundary pollutant, in the Mediterranean waters the EU Habitat Directive is the framework for developing a regulatory system that complies with the recommendations expressed by international organizations (ACCOBAMS, IWC, European Parliament).
To limit the impact of sonar operations, the NATO Undersea Research Centre (NURC) developed a Marine Mammals Risk Mitigation Policy, and other protocols/guidelines are being developed by EU Navies about the use of sonar and explosives during exercises. The Italian Navy, concerned about marine mammals since 1995, has developed and adopted in year 2005 its own policy for mitigating the effects of sonar operations.
Nevertheless, underwater anthropogenic noise remains largely unregulated and both scientific research and new legislation are needed to address the current environmental concerns and to provide viable management and mitigation solutions.

Introduction

In the Mediterranean Sea marine life is threatened by habitat degradation due to intense human activities such as fisheries, ship traffic, pollution, and coastal development. In addition to being affected by chemical pollution, cetaceans can be affected by noise pollution.
At present, noise is an ubiquitous form of marine pollution, especially in areas of heavy maritime traffic and developed coasts. Intense underwater noise is generated by airguns widely used for geophysical explorations for the oil and gas industry as well as for academic and administrative purposes, by high power sonar, either military or civil, by ship traffic, by shoreline and offshore construction works, and by a series of other commercial, military and industrial sources. The knowledge that man-made noise can affect marine mammals and the need for a regulatory system to mitigate such effects has increased over the past few years, mainly mainly as it relates to military sonars and seismic surveys.

Noise pollution can cause marine mammals to abandon their habitat and/or alter their behaviour by direct disturbance or by masking their acoustic signals over large areas (Payne & Webb, 1971; Hildebrand, 2004, 2005); higher levels could directly affect their hearing capabilities by producing either temporary or permanent hearing losses (Simmonds and Lopez-Jurado, 1991; NRC, 2000; NRC, 2003; Gordon et al., 2004). All these effects may be critical for the survival of marine mammals. As previously indicated, some high energy sound sources can even trigger mortality events, as recently evidenced by several dramatic and well documented atypical mass strandings (mass strandings are defined as 2 or more animals stranded in the same area) of beaked whales (e.g. Greece 1996, Bahamas 2000, Canary Islands 2002. See: D'Amico, 1998; Frantzis, 1998; Evans and England, 2001; NOAA, 2001; Dep't of the Environment, 2002; Evans and Miller, 2004; Fernández 2005).
Although atypical mass strandings represent the most dramatic class of incidents related to acute sound exposure, at least for certain marine mammal species, it should be remembered that the effects of repeated non lethal exposures and of increased noise levels are generally unknown but may potentially have significant long term effects. Furthermore, the biology of "disturbance" and

the effect of noise on the fecundity of marine mammals and their prey species is not well understood. Fundamental research on marine mammal acoustics, on their habitats and habits, as well as on their prey, is thus needed to address this very complex issue.

Impacts on other marine organisms

While most interest in anthropogenic noise has focused on marine mammals (mainly cetaceans and pinnipeds) and a few other vertebrates (e.g. sea turtles), there is increasing concern regarding the impact of such noise on fishes and marine invertebrates. Despite increasing interest in the effect of sounds on fishes and its economic implications, this issue has only been addressed on a limited scale.

Although it is known that noise can deafen fish and otherwise seriously impact them (McCauley et al., 2003; Popper et al. 2004), little concern has been given to the ecological implications of such effects and few mitigation procedures address fish or spawning aggregations; despite ethical concern that is rarely expressed, this issue will need exploration in the future also taking into consideration the effects on the trophic web.

Marine Mammals Risk Mitigation Policies

Because the occurrence and use of sources of potentially harmful anthropogenic noise are likely to increase in the coming years and new sound sources are continuously being introduced the question of how to mitigate the harmful effects of these noise sources is pressing. Acoustic Risk Mitigation procedures have been developed or are being developed by navies, administrations, and commercial companies. Generally these are concerned with avoiding exposing animals to sound pressures that can cause direct damage of their hearing system, or produce other types of physical damage that may lead to impairment of vital functions or to death, or that could disrupt their behaviour so that their survival could be threatened. Mitigation procedures, however, are not consistent between regions, and are often based on perceived “common sense” rather than real knowledge of risks, and may often be only applied sporadically.

Best current mitigation practices generally call for noise producers to 1) avoid areas with high density of marine mammals, 2) monitor the operational area to verify that no animals are present before starting acoustic emissions, and 3) observe the area while emitting sounds to check that no animals are within or are approaching the exposure area.

The implementation of these measures would require: 1) creation of databases of marine mammals’ spatial and seasonal distribution so that harmful activities can be planned in areas and periods where animals are less likely to be encountered, 2) visual and passive acoustic monitoring to ensure that marine mammals are distant enough from any active acoustic source(s) or to any source to be activated, 3) slow increase (ramp-up) of acoustic power to theoretically allow marine mammals sufficient opportunity to leave the ensonified area and 4) continuous research to improve monitoring and mitigation techniques.

The implementation of these points seems to be straightforward, though the efficacy of measures 2 and 3 are unproven and disputed in terms of their effectiveness (though passive acoustic monitoring holds some promise for certain species). With relation to ramp up it should be noted that in some cases this procedure can result in substantially more sound energy being produced in the marine environment making it important that its efficacy be measured and its costs balanced by efficacy.

A key point of any mitigation process is the ability to model, and to verify actual values of the emitted acoustic field (Turner et al., 2006) and to define a 3D range (exclusion zone) where animals should not be present to avoid exposure to a harmful noise dose. Linked to this is the ability to detect animals within the exclusion zone, or entering or approaching it, with sufficient time to apply mitigation measures such as shutting off the acoustic source(s). Although the effects of factors such as weather conditions, visual team size and animal behaviour on sightings probabilities for different species of marine mammals is well known the obvious impact that these will have on the risk of an

animal being with the exclusion zone and not being detected is not considered in any current mitigation procedures.

One crucial and still open question is the definition of acceptable threshold levels, and thus related 3D ranges, for short-term exposure to sounds of high-intensity. Estimated threshold values for direct auditory damage differ by orders of magnitude from thresholds related to behavioural responses, such as those that have led to the atypical mass stranding of beaked whales (Cox et al., 2006) in the Bahamas in 2000.
Once 3D ranges are established, trained Marine Mammal Observers and Bio-Acousticians should be dedicated to the implementation of these monitoring and mitigation measures within a regulatory framework. Monitoring measures may include the survey of the area before, during and after the activities to evaluate any possible effect, including changes in the population density, behaviour, or anomalous strandings. This could require establishing cooperation with local experts and organizations, such as stranding networks and other local authorities/agencies.
Mitigation measures may include: restriction of operations to daylight hours; a gradual increase (ramping up) of sound sources; cessation of emission (shut-down) if mammals are detected within the designated exclusion zone; shut-down or delay of operations if weather or sea conditions make monitoring impossible or unreliable; restrictions on boat traffic in the area; power limits; and seasonal or geographic restrictions based on the activities and distribution of the animals. Reducing the emission level (power-down) to reduce the ensonified area to that which can be monitored effectively in bad weather or limited visibility could be also considered.

Marine mammal mitigation measures currently in use worldwide show considerable variation and there are increasing numbers of studies that are relevant to monitoring and mitigation, suggesting a need for reconsideration of the rationale and effectiveness of existing methods.
Further, new detection technologies (e.g. thermal imagery, remote sensing, infrared, radar, etc.) including low-impact whale-finding sonar (themselves a source of noise), should be evaluated and developed for mitigation needs and as anti-collision tools.
No definitive methods currently exist for predicting or determining with high confidence whether there are marine mammals in a given area; spotting them at the surface and listening to their underwater sounds are currently the two most widely used techniques. But these techniques may fail: observers can only work in daylight with good weather conditions, and while acoustic monitoring can be done 24/24h, it requires suitable equipment and detects vocalizing animals only. Animals can be difficult to spot, some species can dive for long periods, of an hour or more, or they can be silent, at least in the observation period, or produce emissions out of the range of the detection equipment. Together with careful planning to avoid known key habitats and other areas of high marine mammal density, an integration of different techniques and proper observation periods seems to be the most successful solution to date: trained and experienced observers equipped with suitable acoustic equipment can greatly improve the probability of detecting marine mammals.
Furthermore, passive acoustics is one of the tools to be used, with great potential for improvements, for (a) expanding knowledge about marine mammal distribution and habitat preferences (i.e. with surveys), (b) evaluating the effects of sound exposure on animals' behaviour, and (c) monitoring underwater noise levels.

Although no risk mitigation measures can completely eliminate the risks associated with high power sound sources, such as military sonars and airguns, a regulatory system to enforce thoughtful and prudent planning with mitigation actions can significantly reduce these risks.

Towards a regulation system in EU waters

The implementation of a regulatory system should be based on the best scientific knowledge about marine mammals sensitivity to noise, about the habitats they use for critical parts of their life cycle, and when scientific data are not available, on the implementation of the precautionary principle. Such regulatory systems should also be readily adaptable to the incorporation of new information as it becomes available, from both conservative and liberal points of view.

Marine mammals are difficult animals to study in the wild and relatively little effort has been directed towards understanding this problem. Consequently large data gaps exist in relation to both marine mammal populations and the effects of noise, which combined result in substantial uncertainty in the effects of noise on marine mammal populations, especially in the long term. There is the potential for irreversible harm to occur before it is detected. The precautionary principle whose application is specifically required by the EU Parliament Motion, dictates that in the face of uncertain knowledge, precautionary management measures should be implemented. Operationally, this might involve using pessimistic assumptions within the bounds of likely values for particular parameters of interest. However, these assumptions should become less restrictive as research is directed to reduce uncertainty in key areas.

In the US it is mandatory to comply with the Marine Mammal Protection Act (MMPA) and with the Endangered Species Act (ESA) for any action with a potential impact on marine life; for this reason the implementation of mitigation measures is designed to balance scientific, industrial and military needs with the protection of marine resources. The permit system is managed by National Marine Fisheries Service (NMFS) and by other US Agencies, depending of the type of permit.
For an overview of how underwater sound is regulated worldwide, see McCarthy, 2004.

In the absence of specific laws, and given the fact that underwater noise is a transboundary pollutant, in the Mediterranean waters the EU Habitat Directive is probably the best framework for developing a regulatory system that complies with the opinions expressed by international organizations (ACCOBAMS Recommendation 2.7, Resolution 2.16, Recommendation SC 4.3; the recommendations of the 56° and 58° IWC meetings, held in 2004 and in 2006), by the European Parliament (Motion B6-0089/04), and with the United Nations Convention on the Law of the Sea (UNCLOS) that consider underwater noise a form of pollution of the marine environment.
The European Union Habitat Directive states that it is not permissible to deliberately disturb in the wild any creature which is listed in Annex IV (a), where all Cetaceans (and several other marine mammals) are listed. In addition to species protection, the Habitats Directive also makes provision for the site-based protection of a range of marine mammal species (listed in Annex II), including bottlenose dolphins and harbour porpoises and all species of seal. To achieve this, Special Areas of Conservation (SAC), as well as Marine Protected Areas (MPA) should be proposed and designated as key tools for marine mammals protection.

A strong position has been taken by the European Parliament with the resolution on the potentially harmful environmental effects of high intensity active naval sonars (Motion B6-0089/04).
The resolution states that the nature and extent of the risks involved requires the precautionary approach, as enshrined in the EC Treaty, be applied; if scientific doubts exist, action which might harm biodiversity and wildlife must be avoided. This means that the lack of a complete information base must not be used as a pretext to prevent appropriate precautionary action, in particular where there is clear evidence of a significant threat to biodiversity.

The Parliament called on the Commission to bring forward, as soon as possible, a thematic strategy on the marine environment, based on the following elements:

- the 'precautionary principle', including the evaluation of the long-term effects of policies and actions;
- the concept of sustainability, including establishing benchmarks for protection and conservation objectives as well as action targets;
- a Strategic Environmental Assessment, in order to integrate environmental and biodiversity considerations into mainstream decision-making;

The motion calls the EU and its Member States:

- to adopt a moratorium on the deployment of high-intensity active naval sonars until a global assessment of their cumulative environmental impact on marine mammals, fish and other marine life has been completed;
- to actively pursue, in the framework of NATO and other international organisations, the adoption of moratoriums and restrictions on the use of high-intensity active sonars in naval operations and the development of alternative technologies;
- to immediately restrict the use of high-intensity active naval sonars in waters falling under their jurisdiction;
- to monitor and investigate in a transparent manner mass strandings and deaths of marine mammals in EU waters which are associated with the use of intense anthropogenic noise and to communicate the findings to the Commission;
- to conduct a study of the potential impact on the marine environment of the deployment of high-intensity active naval sonars and to provide an assessment, on the basis of information from the Member States, of the impact of current practices in European waters;
- to set up a Multinational Task Force to develop international agreements regulating noise levels in the world's oceans, with a view to regulating and limiting the adverse impact of anthropogenic sonars on marine mammals and fish;

Even though dedicated laws about underwater noise are not yet available yet, it is important to act in a precautionary way and give these animals, together with marine turtles and other zoological groups, protection against noise.

The NATO approach

The NATO Undersea Research Center (NURC), located in La Spezia - Italy, runs a multinational, multidisciplinary Marine Mammal Risk Mitigation research project (formally referred to as SOLMAR (Sound Oceanography and Living Marine Resources)), that resulted in the development of the NATO Marine Mammals Risk Mitigation Policy (NATO Staff Instruction 77-04 and revisions). While this policy was initially conceived for sonar research and development at NURC, it is being considered as a reference and resource for NATO Navies and NATO exercises that involve active sonars.

The Marine Mammal Risk Mitigation Project started in 1999 to support the NURC commitment to conduct marine research in an environmentally responsible manner and to provide scientific data, guidelines and dedicated tools to the NATO Navies and to the scientific community.

One of the goals is the development and refinement of the tools and/or procedures to minimise the probability of marine mammals being within a zone near a sonar source prior to and during its use. It also seeks to improve the understanding of anthropogenic noise characteristics which are aversive and potentially harmful to animals. The project includes the development of a set of comprehensive databases of oceanography, ecosystem dynamics and living marine resources in the Mediterranean Sea to support the development of models for predicting the presence of marine mammals based on seasonal and environmental parameters. The Project website (http://solmar.nurc.nato.int/) is a rich resource of information on the project itself, for education and training, and provides basic tools for the understanding of the noise issues.

The Italian situation

As specific national rules are lacking, in Italy the legal reference framework is the Habitats Directive. The Office of Protected Marine Resources (Ministry of the Environment), is in charge for authorizing seismic surveys and for providing basic guidelines to minimize impact on marine fauna. But no office in charge of controls exists, and the effectiveness of the whole regulatory system is unclear.

In support of a stronger implementation of mitigation procedures, a recent law (L. 8 febbraio 2006, n. 61) allows extending Italian jurisdiction beyond the national waters, creating special Ecological Protection Zones.

The Italian Navy's Policy

The Italian Navy, concerned about the impact of sonars on marine mammals since 1995 (Nascetti et al., 1996) was one of the first Navies that adopted restrictions on the use of sonars in areas known for the presence of marine mammals and in particular in the Cetacean Sanctuary (Ligurian Sea); to broaden the implementation of such measures, the IT Navy has recently developed and adopted a policy (RIMPAM) to mitigate the effects of sonar operations in compliance with UNCLOS directives and the EP Resolution B6-0089/04 (Cerutti F., 2005).

It is based on the same, widely accepted, principles of the NATO Policy but with slightly different threshold levels and different models for sound propagation. Key points of the Policy are the adoption of two thresholds, 150 dB and 180 dB, estimated at the receiving subject, respectively for disturbance and damage; the adoption of a compromise for propagation loss estimates of 15xLog distance, and a greater attention for seafloor depth lower than 75 meters where the propagation is assumed cylindrical. Also, the maximum single emission duration is 100 s, the max duty cycle 20% and max total transmission time is 3 hours/day. Operative areas must be chosen according to available databases held at the Hydrographic Institute to minimize the potential encounters with marine mammals, to maintain a 5km distance from Marine Protected Areas and from potential beaked whales' habitats characterized by steep seafloor. Also, position and movement of the naval units should never block a possible escape corridor. Before any sonar activity all the units should look and listen for at least 30 minutes to be sure no marine mammals are within a 1.5km radius. Once the area is declared clear, at least 15 minutes ramp-up is required.

When helicopters are concerned, other than visual observation, two minutes of passive listening and then a ten minutes ramp-up is required. The Policy recommends to avoid deploying active sonobuoys at less than 1.5km from a marine mammal.

During active emissions continuous monitoring, both visual and acoustic, should be carried out; in case a marine mammal is detected within a 5km radius, sonar emission should be reduced to minimum or ceased, communication given to all units in area, and naval units should be manoeuvred to avoid passing at less than 2km from the marine mammal. Emission can be resumed only when the animal is detected or estimated to be beyond the 5km limit. In case of sonar deployed by helicopters, sonar emission should be stopped if a marine mammal is detected within 500m from the source.

The Italian Policy is extremely conservative in both the planning and operative phases; it is aimed at avoiding impacts on protected areas and on potential habitats for sensitive species such as beaked whales; it also includes rules to be followed in case of unexpected impacts.

During all operational phases, the Policy contemplates the use of any available mean to reveal the presence of marine mammals, including the use on any available passive acoustic system. Even if it is conservative, this is the weakest point of the Policy as the passive acoustic monitoring is not implemented with dedicated tools with proven detection efficacy, but is based on a combination of different tools with limited bandwidth.

To further increase its efficacy the Policy should indicate the minimum detection capabilities required for the passive acoustic detection of marine mammals; dedicated tools and additional resources should then be used to match those requirements.

Research, Legislation and Education

Regardless of the high attention of the noise issue and the efforts to develop and implement mitigation policies, anthropogenic noise remains largely unregulated in the marine environment and thus both scientific research and new legislation are needed to address the current environmental concerns and to provide viable management and mitigation solutions.
Specific laws and the designation of organizations committed to overseeing their implementation are now required, along with support for research, education and training to build knowledge and expertise such that mitigation rules and technical tools can be designed, implemented, verified and improved.

The primary objective of mitigation is to decrease environmental risk by reducing the likelihood of exposures that have the potential to lead to physical damage, and by promoting measures that minimize behavioural disturbance that could lead to effects on vital parameters such as growth, survival, or reproduction. A key goal is to protect at the population level. To this end, consideration needs to be given to defining strategies that address possible chronic, cumulative, and synergistic effects.

At present, there are no specific legal provisions to limit sound production underwater. Instruments such as the Habitats Directive lay down general prohibitions on deliberate disturbance which must be implemented through measures enacted at the national level if at all.
Individual States are urged – but not explicitly required - to adopt measures related to underwater noise and to justify these by reference to the principle of precaution now legitimated in EP motion. Such measures could, like any other legal measure, be challenged in the national administrative courts. The Authorities involved would then have to demonstrate the reasonableness/lawfulness of the measure concerned by reference to the scientific case.
In practice, the limiting factor in the application of the Habitat Directive to the noise issue is that one is required to demonstrate that damage has occurred before intervention can take place.

A regulatory system should be implemented to develop a strategy based on prevention and on the precautionary principle. The implementation of a regulatory system requires a series of steps and synergistic actions to promote education, awareness and research. Much effort should be devoted to developing a legal framework where underwater noise is recognized and regulated as a real threat.
In this context, the creation of Special Areas of Conservation (SACs) and Marine Protected Areas (MPAs) that take noise pollution into account should ensure protection of areas of critical and productive habitats, and particularly of vulnerable and endangered species.
The designation of SACs and MPAs can be used to protect marine mammals and their habitats from environmental stressors including the cumulative and synergistic effects of noise. In these areas, noise levels should not be allowed to exceed ambient levels of more than a given value, including the contributions from sources that are located outside of the MPA but whose noise propagates into MPA boundaries. This would require additional research to establish baseline noise data and evaluate thresholds for noise levels that can be considered acceptable; i.e. can be tolerated without any significant negative effect.

From a scientific point of view basic and applied research is required in several areas. Research on the effects of sound on marine mammals, and their biological significance is needed. Research to be able to predict spatial and seasonal distributions and abundances to support planning of activities in

areas and times when impacts can be reduced, and research to improve and evaluate the effectiveness of operational mitigation measures (including visual and acoustic real time detection technologies) is also necessary. Specific research is required to identify and quantify the actual and potential risk for individual species, such as beaked whales.
It is also important to develop more effective ways to monitor the presence and behaviour of animals as part of current mitigation so that such monitoring data can be used for evaluating impacts and mitigation effectiveness. In this context, the interpretation of biological significance of null findings from impact assessments is problematic, and highlights the need for consideration of statistical power, experimental design and appropriateness of response variables.
Dedicated funding is required to support research, management and conservation issues as well as to continuously refine and update mitigation rules and tools.

Suggested priority actions, to be undertaken by the scientific community and by all subjects involved in noise producing activities, include:

a) conduct more complete analysis of past and present stranding data, including obtaining more information on whether or not there were noise activities in the area at the time of the stranding, for both naval sonars and seismic surveys. Full disclosure of noise events by noise producers is necessary for a thorough analysis of such data.
b) create or improve regional and worldwide databases to model marine mammals' presence, distribution, density, preferred habitats, as well as to map and model seasonal movements and seasonal specific behaviours.
c) improve planning capabilities to more safely plan noisy activities (databases, geographical information systems, environmental models, habitat models, remote sensing technologies)
d) develop an international/worldwide network of underwater noise monitoring stations, to collect baseline noise data, to keep track of the changes in the underwater noise levels, monitor cetaceans, and monitor for unusual events.
e) create datasets to assess the global extent of industrial, military and academic activities that use high power sound sources.
f) investigate acoustic exposure criteria by taking into account signal duration and repetition, energy, frequency, directionality, and bandwidth and behavioural and physical effects on animals. Exposure criteria designed to prevent injury should be based on well-defined measures for potential injury, including injury mediated by a behavioural response, and or hearing threshold shifts.
g) develop a "noise budget" model where the synergistic and cumulative effects of noise sources are taken into consideration.
h) develop an "acoustic comfort" model to define a range of noise levels above the natural background that can be tolerated with negligible effect.
i) clearly define a standard for measuring units and create equivalence tables, where applicable.
j) review and evaluate available information on the impacts of human-generated sound on marine mammals at the individual and population level and on other components of the marine environment, including the prey field.
k) collect baseline whale population and ecosystem data before any seismic/sonar operation has started. In case of field development and associated seismic surveys that may extend over decades, pre-exposure baseline data need to be assembled with a long-term focus.
l) create or improve stranding networks and involve related institutions so that monitoring for unusual events and the analysis of carcasses to reveal acoustic related trauma can be undertaken. This will involve substantial capacity building throughout the region in terms of necropsy facilities and techniques.
m) support education and training to produce qualified personnel such as marine mammal observers, marine biologists, bioacoustic experts, veterinarians, law officials, etc.

n) create specialist teams to examine problems related with the noise issue; in particular improve training for marine mammal observers and bio-acousticians to be employed for monitoring and mitigation in the field.
o) improve marine mammal detection tools to be used for (1) creating distribution databases, (2) assessing marine mammal presence, distribution and density in areas where surveys are to be planned, (3) detecting and monitoring marine mammal activity and movements for mitigation purposes during seismic/sonar operations.
p) investigate current mitigation techniques to evaluate and improve their effectiveness; develop new monitoring technologies (improved or new sensors: passive acoustic, thermal, radar, low power whale-finding sonars, remote sensing) and mitigation methods.
q) improve passive acoustic techniques, including towed arrays, bottom deployed hydrophones, sonobuoys, and acoustic recording tags.
r) develop alternative sonar/seismic technologies with lower impact; design sound sources (sonar, airgun) to minimize the irradiated acoustic energy. In seismic surveys, improve airgun design to better concentrate acoustic energy where it is required for geophysical needs, towards the seafloor, and reduce unnecessary long-range dispersion on the horizontal plane; reduce unnecessary high frequencies and sharp transients.
s) reduce shipping noise by adopting quieting technologies (NOAA 2007), by encouraging good maintenance of engines, by better designing new ships, by encouraging speed restrictions and alternative lanes, especially in sensitive habitats, etc.
t) create a funding/rewarding system to transparently support all the mentioned activities and encourage the development of self-regulated activities.

Many of the above actions are already being developed but more coordination and synergy is required. In this context it is important to involve all the subjects working in the sea environment to create a broad awareness of the acoustic pollution problem and of all the procedures and actions that can be adopted to mitigate negative effects.
As a first step all subjects should be urged to voluntarily adopt basic mitigation procedures and develop the ability to carry out an environmental impact assessment (EIA) of their own activities.

In the marine environment many anthropogenic noise sources contribute to the overall noise level and it is thus important to identify which of those noise sources should be regulated and which should merit attention for other types of mitigation.
Specific activities are known to have a strong impact on the marine environment, and those activities are the first to be regulated. But in the wide context of the noise issue, it is important to consider that all noise sources should require attention. Recent data (Green et al 1994, Andrew et al. 2002; NOAA 2005; McDonald et al., 2006) show that shipping noise has increased in the last decades to levels that may have an impact on marine mammal populations, and shipping industry should be encouraged, or regulated if necessary, to reduce the noise irradiated by engines and propellers (NOAA 2007) and to modify shipping lines to avoid MPAs and sensitive areas such as breeding grounds, feeding grounds and migratory corridors.

To summarize, these are the sources and activities to be taken into consideration within the context of the ocean noise issue:

- Ship traffic (cargo ships, high speed ferries, any type of motorboat, whale watching boats)
- Military sonars
- Civil sonars
- Airguns and Sparkers, including arrays
- Explosives, including the blasting of residual war weapons, shipshock events to test hull integrity and other military exercises, decommissioning of offshore structures
- Construction/demolition works on harbours/coast, including pile drivers, jack hammers, etc.
- Offshore construction/demolition works

- Coastal industries
- Ports
- Drilling and oil/gas extraction offshore platforms
- Offshore wind farms
- Oceanographic instruments (bottom and sub-bottom profilers, side-scan sonars, current meters, underwater modems, acoustic thermometry experiments, etc.)
- Echosounders and other acoustic navigation aids and instruments
- Pingers (used on fishing nets) and Acoustic Harassment Devices (AHD)

Although all these sources should be evaluated and monitored individually for their acoustic emission features, for their contribution to the ocean noise budget and for any synergistic effects, a few major categories of noise producing activities are considered here as requiring mitigation. This does not mean, however, that the others do not require attention and specific regulations (e.g. limits to ships' and motorboats' noise emission underwater).

Monitoring and reporting are two key activities for the implementation of mitigation procedures and for evaluating their effectiveness.
Accurate and unbiased data is required to document any possible effect on the local fauna and to assess the effectiveness of the adopted mitigation rules. In case this can't be done adequately by observers undertaking mitigation, independent monitoring programs should be setup.

Summary

Although we know that anthropogenic sound in the ocean is a serious threat, we do not have sufficient information at this time to understand the full extent of the problem. One of the biggest challenges faced in regulating the effects of noise is our ignorance of the characteristics and levels of sound exposures that may pose risks to marine mammals in the long term. Given the current state of our knowledge we must therefore take a precautionary approach in the regulation of noise.
We must also expand our efforts to protect and preserve marine mammals by instituting and using effective mitigation measures – such as geographic exclusion zones – now, to keep marine mammals at a distance from noise sources that have the potential to harm or kill them.
While most interest in anthropogenic noise has focused on marine mammals (mainly cetaceans and pinnipeds) and a few other vertebrates (sea turtles), there is increasing concern regarding the impact of such noise on fishes and marine invertebrates. This issue will need exploration in the future also taking into consideration the effects on the trophic web.

Acoustic impacts on the marine environment need to be addressed through a comprehensive and transparent management and regulatory system. This should address chronic and acute anthropogenic noise, long-term and short-term effects, cumulative and synergistic effects, and impacts on individuals and populations.
Only through a combined approach based on precaution, mitigation, and research, we can assure that these very special resources will be here for the enjoyment of future generations.
Designated agencies should identify and implement mitigation measures that are effective for noise-producing activities as a part of research programs that includes systematic study of the effectiveness of various mitigation and conservation tools. In addition, management should be extended to unaddressed sources and activities that have the potential to produce adverse effects.
Even though dedicated laws about underwater noise are not yet available, it is important to act in a precautionary way and give these animals, together with marine turtles and other zoological groups, protection against noise. To achieve this, Special Areas of Conservation (SAC), as well as Marine Protected Areas (MPA) should be proposed and designated as primary key tools for marine mammals protection.

Acknowledgements

A thank is due to the NURC and to all the staff working there for the opportunity to work with them in the Marine Mammal Risk Mitigation (SOLMAR) Project and for having been hosted on their oceanographic ships.
A special thank is due to the IT Navy, in particular to the Stato Maggiore Marina Reparto SPMM, for the support and cooperation given within the institutional framework of the NURC SOLMAR Project and of the agreement with the University of Pavia.

Selected references

This list provides an overview of the scientific literature concerned with the underwater noise and its impact on the marine environment. It is not exhaustive, but includes the most relevant reviews on the topic and some papers that address specific issues cited in the present paper.

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RECOMMENDATION SC4.3

Anthropogenic Noise

The Scientific Committee recommends that Parties and non Parties carefully consider and act upon the recommendations and guidelines developed and endorsed by the Scientific Committee (SC4/Doc 18) in order to regulate and mitigate underwater anthropogenic noise in the ACCOBAMS area. It notes that this work has taken into account the work on noise undertaken by *inter alia* the International Whaling Commission Scientific Committee, the US Marine Mammal Commission, the US National Marine Fisheries Service, and other governmental and non governmental organizations.

It notes that an important component of these recommendations and guidelines is the development of a permit system. It recognises that the development of permit systems is complex and may take considerable time. Given this, it strongly requests the Parties to act in accordance with the following principles as soon as possible:

a) *Noise should be considered a potentially significant threat to marine mammals and other marine wildlife; this threat can range from continuous noise exposure (disturbance, masking, site avoidance, etc.) with long-term effects to acute exposure with potential short-term harmful and even lethal effects. Particular attention should be given to habitats that host sensitive species such as beaked whales.*

b) *Priority should be assigned to high quality research to map the range of noise doses to which animals are exposed and to define the noise exposure doses that may have impacts on marine mammals welfare and survival. Specific research is also required to characterize all those human activities that produce or may produce underwater noise.*

c) *Consideration of the effects of underwater noise should be included in Environmental Impact Assessments and in the consequent design of mitigation procedures for any activity with the potential of introducing noise underwater.*

d) *Underwater noise levels should be considered a quality parameter when assessing habitats, zoning MPAs and other issues related to marine life. This should be considered a priority in critical habitats and whenever noise may affect essential behaviour (e.g. feeding, reproduction, nursing).*

e) *Underwater noise should be regulated and reduced; specific laws will be required to set limits to the noise irradiated underwater by ships and motorboats, whatever their function, and by any other noise-producing activity- especially high priority should be accorded to high power sources (seismic and sonar) and both offshore and coastal construction works.*

The Scientific Committee also encourages the development of quieter and environmentally safer acoustic technologies and the use of best available control technologies and other mitigation measures in order to reduce the impacts of man-made noise sources in the Agreement area.