

Possible effects of anthropogenic noise on the marine environment: an overview of U.S. actions

6.1. Introduction

For many years US Navy carries out research on auditory thresholds of marine mammals, aversive behavioural effects of human-made sound, threshold shift effects, etc. Also the degree and type of injurious effects from cadavers is studied. Aim of these studies is among other things to determine zone radii of potential effects due to anthropogenic noise. Dr. Rob Gisiner, Office of Naval Research, US Navy supplied the following review of US Navy marine mammal research.

6.2. Activities, Office of Naval Research

The United States Navy is deeply committed to environmentally responsible operation on the world's oceans. As part of that commitment the U.S. Navy has assumed a leadership role in stimulating research on the potential effects of noise from naval and other human activities on marine life.

Based on relevant U.S. laws and regulations such as the Endangered Species Act (ESA), Marine Mammal Protection Act (MMPA), and National Environmental Policy Act (NEPA) the Navy has identified several activities such as explosives use, sonars and ship noise that may have potential for adverse environmental impacts. The primary focus has been on low frequency (LF) sound below 1000 Hz , based on

- The relatively higher energy of such low frequency sound sources as large explosions and low frequency sonars,
- The tendency of low frequency sound to propagate for longer distances and thus affect a potentially greater area, and
- The fact that many animals known to be sensitive to, or to emit, low frequency sound are classified as endangered or depleted under ESA, MMPA or both (e.g. large baleen whales).

Primary funding for research on this topic has come from the Office of Naval Research, a basic and applied research funding agency which provides grants and contracts to naval and other government research facilities, universities, and other non-government research

institutions and corporations. Since 1988 ONR has devoted a significant portion of its overall budget to investigations of marine animal hearing, behavioral response to noise from human at-sea activities, and development of technologies to facilitate such studies. ONR also assists in the distribution of funds, and in program management of other Navy research programs created to provide information to the U.S. Navy. These research products are used to inform policy and guidelines to assess and mitigate possible impacts of noise from Navy activities. The overall goals of these programs are:

- To measure actual impacts from activities and compare them to predictions where predictive models are available,
- To develop impact monitoring and mitigation procedures that will minimize environmental impacts while enabling the Navy to fulfill its national defense mission, and
- To generate science-based planning tools, predictive models, and guidelines which ensure full and consistent implementation of the Navy's policy toward the marine environment.

6.3. U.S. Navy working groups

Organization of this effort, and communication of findings to the appropriate persons and organizations is achieved by several ad hoc working groups. Within the Navy the Living Marine Resources Working Group (LMRWG) coordinates activities of ONR, the Office of General Counsel and Judge Advocate General (OGC/JAG), Plans and Policy (N3/5), the office of the Assistant Secretary of the Navy for Installations and Environment (ASN I&E), and other relevant commands under the leadership of the Navy's operational environmental compliance command, CNO N45. Communications with other relevant federal agencies is achieved through the Interagency Coordinating Group (ICG) under the leadership of the Marine Mammal Commission. Communications outside government are achieved through a variety of forums, including the public press, scientific and professional organizations, the National Academy of Sciences, and project-specific public outreach meetings.

6.4. Marine mammal research

The Navy-sponsored research projects fall into three categories:

- Studies of hearing and other physiological effects of sound,
- Field and laboratory studies of behavioral responses to sources of anthropogenic noise, and

- Development of remote sensing tools, databases and predictive models, and other data and technology tools to enable assessment and mitigation of adverse effects from manmade noise.

In the category of hearing and physiological studies basic audiometric assessments ('hearing curves') for pinnipeds and toothed whales (odontocetes) have been completed, including assessments at different depths to account for any effects differential pressure might have on hearing performance. Some preliminary data on masking, and critical bandwidths have been obtained for these same taxonomic groups, as well as partial data on temporary threshold shift (TTS) from ongoing studies. Some taxa, such as sea turtles and fishes have had data generated by other programs or are subjects of studies in progress. Other taxa, such as baleen whales (mysticetes) and beaked whales (mesoplodonts and relatives), have not been readily available for conventional assessments, so alternative methods have been applied. For example, hearing performance can be approximated by examination of the anatomy of the ear (Ketten) or by monitoring the activity of the auditory nerve and auditory cortex by measuring the auditory evoked electrical potential (AEP) at the skin surface. In addition to a limited effort in learning more about general stress responses (e.g. immune system) current effort related to non-hearing physiological effects of noise is focused on non-hearing physiological effects on human divers, from which general models can be derived to predict effects on many other organisms, especially mammals. Results from human divers will also enable subsequent efforts with other organisms to be focused on those physiological systems which have proven most sensitive to noise, out of a large number of plausible but unverified physiological responses which include vestibular (balance organ) effects, resonance of lungs, swim bladders and other gas-filled spaces, effects on central and peripheral nervous tissue, entrainment of rhythms of cardiac and other intrinsically rhythmic tissues. Studies in preparatory or planning phases include studies of the effects of explosives noise on freshly dead marine mammal specimens obtained from strandings and similar accidental mortalities, studies of the population variability of hearing (age and sex differences in hearing performance within a population), and AEP procedures applied to live stranded baleen whales to provide better hearing data on baleen whales.

The largest effort in assessing the behavioral effects of anthropogenic noise is in field studies of loud low frequency sources with the potential to affect tens or even thousands of square miles of ocean. Foremost among these have been the large scale, multi-investigator studies of the Acoustic Thermometry of Ocean Climate (ATOC) and Low Frequency Active Surveillance Towed Array Sonar (LFA SURTASS) sources. Both studies are in their final stages of data analysis; combining aerial, shore, and shipboard visual surveys of the insonified areas, passive acoustic monitoring of the sources and marine animal vocal activity using a variety of monitoring systems, focal following of individual animals in the sound field, telemetry and recoverable data logger tagging of animals in the sound field; all conducted under conditions of strictly managed sound exposure. Although the data are not completely analyzed the preliminary evidence indicates an unexpectedly small, transitory localized effect or no effect from these sources. Similar directed playbacks of sound to a variety of animals including humpback

and sperm whales have elicited similarly inconsequential effects. Given the great variety of behavioral responses possible, the variety of sound sources and their potential significance to different animals, and the potential biological consequences of the responses, considerable further effort of this type will be needed before we can feel confident about making general statements about behavioral effects. The Navy plans to devote a considerable amount of effort to these types of field studies as a natural outcome of NEPA monitoring and mitigation activities. For example, the SEAWOLF submarine explosive shock test scheduled for next summer will have an extensive monitoring component that will shed considerable light on the effects of noise from large explosions. The potential role of controlled laboratory studies has been seriously neglected and deserves greater attention in the future.

Finally, in the area of new technology developments the Navy has had a number of very exciting and successful projects. ONR considerably advanced the state of the art in satellite tracking tags and developed a noninjurious dorsal fin saddle pack that enables wild and trained dolphins to safely and comfortably carry a variety of instrument packs including a video dive recorder with on-screen read-outs from a variety of other monitoring instruments. ONR also funded development of remote monitoring systems capable of recording heart rate and feeding events. Perhaps most important ONR funded development of several remote acoustic exposure recorders, which are playing an increasingly important role in more precisely determining real acoustic exposure of monitored marine mammals. Since marine mammals tend to be very vocally active a variety of passive acoustic monitoring systems have been developed to assess the impacts of human noise on vocal activity; including towed, bottom-mounted and sonabuoy systems. Perhaps the most impressive project was the employment of the Navy's deep water submarine monitoring system (SOSUS) to listen to the vocal activity of whales over millions of square miles of the world's oceans to reveal an unprecedented picture of the global movements of these far-ranging animals. These data, along with distribution and abundance data from a variety of sources, are being incorporated into a Global Information System (GIS) type mapping technology to enable Navy planners to avoid areas of high marine mammal density ("hotspots") and to predict possible effects of an activity at whatever spatial scale is appropriate.

6.5. *Final remarks*

While considerable work needs to be done to fully understand the impact of increasing anthropogenic noise in the marine environment the U.S. Navy is proud of its contributions to our understanding of this issue. An assessment of achievements to date and recommendations about future science needs was undertaken by a team of subject matter experts in February 1998. The report from that meeting should be publicly available in July 1998 to augment other excellent references such as Richardson *et al* Marine Mammals and Noise (1995). The Navy remains committed to playing a leadership role in advancing our knowledge of this critical environmental issue and using that knowledge to minimize the impact of naval activities on the marine environment.