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Working Group III: Proposals for Hydroacoustic Methods with Minimal Environmental Impact

Report by Robert J. Hofman[1]

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WORKING GROUP CHARGE

The group presumed that its charge was to identify ways for avoiding or minimizing the possible impacts of research involving the use of active acoustic devices on marine mammals, diving birds, and other biota in the marine area south of 60 °S, i.e. the marine area to which the provisions of the Protocol to the Antarctic Treaty on Environmental Protection apply. The group recognized that fishing and related activities south of the Polar Front or Antarctic Convergence, including that in the Antarctic Treaty Area, are governed by the Convention for the Conservation of Anarctic Marine Living Resources. The group considered the following questions

1. What are the goals of impact assessment and mitigation - e.g., to:
• avoid population and ecosystem level effects?
• minimize possible harmful effects on individual animals? or
• prohibit any potential adverse effects on individual animals?
2. What kinds and uses of acoustic devices are of concern?
3. What are the relative risks and benefits of the various devices and uses?
4. What are the critical uncertainties and how might they best be resolved?
5. What risk is acceptable - appropriately precautionary - given the uncertainties?
6. What reasonably can be done to avoid possible adverse population and ecosystem level effects and to minimize any possible harmful impacts on individual mammals, birds, and other biota?

With regard to the last question, the group used as a reference guide the measures discussed in the draft report - titled "Impacts of Marine Acoustic Technology on the Antarctic Environment" - provided by Dr. O'Brien, the convener of the SCAR *ad hoc* Group on Marine Acoustic Technology and the Environment.

QUESTIONS CONSIDERED

1. What are the goals of impact assessment and mitigation?

During discussion of this question it was recognized that, given the uncertainties described below, the only way to assure that human sources of sound do not adversely affect individual animals in the Antarctic marine environment would be to prohibit all ship traffic and low level aircraft flights, as well as all use of hydroacoustic devices, in the seas adjacent to as well as south of 60 °S. Further, it was pointed out that, among other things, Article 3 of the Environmental Protocol states that activities in the Antarctic Treaty area shall be planned and conducted to avoid:
• detrimental changes in the distribution, abundance or productivity of species or populations of species of fauna and flora;
• further jeopardy to endangered or threatened species or populations of such species; or
• degradation of, or substantial risk to, areas of biological, scientific, historic, aesthetic, or wilderness significance [emphasis added].

The group therefore concluded that the basic goals should be to avoid possible population- and ecosystem- level effects, and whenever feasible to minimize adverse effects on individual animals .

2. What kinds and uses of acoustic devices are of concern?

A variety of acoustic devices are used in both routine ship operations and research in the Antarctic. They include single beam echo sounders (fathometers) and side scan sonars used to monitor water depth and detect hazards to navigation; multi-beam echo sounders and side scan sonars used for seafloor mapping; variable frequency sonars used to detect and assess the distributions and abundance of krill and other fishery resources; air guns and other high energy sound sources used for geophysical seismic profiling; and low energy sound sources used to trigger release and enable recovery of bottom anchored current meters and other equipment used in oceanographic research.

A number of variables affect the nature and significance of the

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possible effects of these devices on marine mammals and other biota. The variables include the frequencies, intensities (loudness), and rise- and fall-times of the sounds produced by the devices; sea surface conditions, bottom type, water depth, and other factors (e.g., temperature and salinity) determining the transmission paths and extinction rates of the sounds; the species, ages, sex, numbers, activities and hearing ranges of animals present in areas where they will be exposed to the sounds; the length of time and frequency that animals are exposed to the sounds; and the location and movement of the sound source relative to the animals and topographic features interfering with the animals' ability to avoid or escape the sound. For example, exposure to high intensity (loud) sounds with rapid rise- and fall-times, such as those produced by underwater volcanic explosions and detonation of large explosive charges, can cause tissue and organ damage and kill animals within critical distances, while exposure to sounds of the same frequencies and duration at greater distances may cause nothing more than temporary startle responses. Further, animals seem less likely to be aware of and to respond to many sounds when they are engaged in activities such as feeding and breeding requiring focused attention, than when they are engaged in activities like surface resting and swimming not requiring particularly focused attention. Likewise, some animals exposed frequently to certain sounds may become accustomed to the sounds and stop responding to them, while others may become sensitized to the sounds and respond to them more and more intensively over time. Also, some animals may respond differently to particular sounds if the sources are moving versus stationary, if they are in deep, offshore waters versus shallow, coastal waters or embayments, and if the source is between them and an escape route to open water.

3. What are the relative risks and benefits of the various devices and uses?

As noted above, the likelihood or risk of an animal being affected physically or psychologically by a particular sound source can vary depending upon the species, age, sex and activity of the animal, and when, where, how, how long, and how frequently it is exposed to the sound, as well as by the nature of the sound itself. High-intensity, low-frequency sounds generally have the potential for affecting the greatest number of animals because they can ensonify larger areas than lower intensity, higher frequency sounds. Also, the hearing ranges of most marine animals tend to be in the low to mid-frequency ranges. Further, impulse sounds that occur infrequently and are random in time appear to be more problematic than constant sounds, at least in part because they can not be anticipated and cause startle effects. Based solely on the nature and typical duration of the sounds produced by the aforementioned kinds of acoustic devices, the likelihood of their use affecting biologically significant numbers of marine mammals and other biota in the seas around Antarctica can be viewed as a continuum ranging from near zero for short-duration acoustic release devices and high-frequency echo sounders, to potentially significant for extended use of low frequency air guns and low- to mid-frequency range fish finders, multi-beam echo sounders, and side scan sonars.

When considering the risks of potentially affecting marine biota, it also is necessary to consider the benefits of the research and other uses of the acoustic devices in question. For example, the benefits of avoiding ships running aground and the possible attendant loss of human life and fuel contamination of the environment through use of echo sounders and side scan sonars will outweigh the effects of those devices on marine organisms, except in cases where there is reason to believe that highly endangered or unusually large numbers of animals could be affected adversely. Similarly, the likelihood of at least marine mammals being affected adversely by acoustic releases of oceanographic instruments probably is less than the likelihood of them being entangled and killed or injured if lines attached to surface floats are used to locate and retrieve instruments. Likewise, fisheries cannot be regulated effectively without reliable information on the distribution and abundance of the resources, and in most cases use of acoustic devices to obtain this information will be both more cost-effective and less likely to affect non-target species than other sampling techniques, e.g., multiple net hauls.

As noted in the answer to question 6 below, a number of things can be done to reduce the likelihood of population- and ecosystem-level effects and to minimize possible adverse effects on individual animals.

4. What are the critical uncertainties and how might they best be resolved?

As indicated in the reports of working groups I and II and in several of the invited presentations made during the first two days of this workshop, there are experimental data showing that some fish and their eggs and larvae can be killed by exposure to certain high-intensity sounds. There also is circumstantial evidence that exposure to certain sounds can cause tissue and organ damage sufficient to cause mal-adaptive behaviour and possibly kill beaked whales and other marine mammals. Further, there is circumstantial evidence and some experimental data indicating that exposure of marine mammals, birds and fish to high intensity sounds in their hearing ranges can cause both temporary and permanent hearing threshold shifts. Also, there are observational and experimental data indicating that exposure to sounds at and above their hearing threshold levels can cause changes in swimming speed and direction, surfacing and dive times, and other behaviour of several marine mammal species. It is not known what frequencies, intensities, and exposure times will cause unrecoverable tissue and organ damage in different species and age/size groups. Likewise, it is not known what if any degree of hearing damage or behavioural disturbance will cause decreases in the survival or productivity of the affected animals or the populations and ecosystems of which they are a part.

Ideally, studies would be designed and carried out to determine the frequencies, levels and exposure times of sounds that will cause organ and hearing damage, and biologically significant behavioural responses in all of the species and age-sex classes of animals that potentially could be affected by use of hydroacoustic devices and other human activities in the Antarctic. Given the number of species and age-sex classes of animals that could be affected, this would be prohibitively costly if not impossible any time in the foreseeable future. An alternative would be to select and carry out directed exposure trials on captive and free ranging members of the species and age-sex groups thought most likely to be sensitive to the sounds of concern, and representative of the various species and age-sex groups that could be affected. While such studies would be desirable, it is important to keep in mind that only a small number of species and age-sex groups could be studied. Also, it would be difficult to justify studies designed to intentionally cause mortality, injury, and significant disruption of biologically important behaviour. Further, it would be difficult if not impossible to evaluate all of the variables noted earlier that could affect the nature and likelihood of adverse effects.

Another possible alternative would be to carry out sufficient surveys to characterize the distributions, abundance, and productivity of the species and populations thought most likely to be affected by the activities in question and then monitor them periodically to look for possible cause-effect changes. Given the size of the area and the number of species and populations that could be affected, and the difficulty and cost of conducting assessment surveys in the Antarctic, this too would be impracticable. Further, changes that might be detected could be due to natural variation, global climate change, fishery-related ecosystem changes, or other human activities rather than use of hydro-acoustic devices.

Several more practical and cost-effective things also could be done to help resolve the uncertainties. One would be to establish a database by requiring that trained observers be carried on all ships using high intensity acoustic devices in the Antarctic Treaty Area to determine and record the species, numbers, and activities of birds and mammals present on and within visual range of the track lines of the ships. In some situations it also might be reasonable to require that the locations of vocalizing marine mammals be monitored passively to augment and assess the veracity of the visual sightings. These data then could be analysed to look for patterns and changes in patterns associated with the ships' activities and use of acoustic devices. If any species or age-sex groups become accustomed or sensitised to the sounds or related activities, changes in the distribution or activity patterns may become apparent. For example, if animals become accustomed to the activities there may be an increase in sighting rates and a decrease in apparent avoidance behaviour. Conversely, if animals become sensitized to the activities, sighting rates may decrease while apparent avoidance behaviour increases.

With regard to the last point, it is important to keep in mind that it will not be possible to make reasoned judgments regarding the possible causes of any observed changes in the variables being monitored unless there are good records of the nature and frequency of all human activities in and near where the changes are observed.

5. What risk is acceptable - appropriately precautionary - given the uncertainties?

As noted earlier, any activity that could have adverse population- or ecosystem-level effects, or degrade the scientific or other values of Antarctica, would be contrary to the provisions of the Environmental Protocol. Further, some countries may have domestic laws or regulations with more restrictive provisions. In the United States, for example, the Marine Mammal Protection Act requires that incidental taking authorization be obtained for research and other activities that could inadvertently kill, injure, or harass marine mammals in either U.S. waters or by U.S. citizens or vessels on the high seas. The Act provides that authorization can be granted only if the taking will have negligible effects on the affected species or populations and a monitoring and reporting program is in place to confirm that animals are taken only in the numbers, places, and ways authorized. The U.S. Antarctic Science, Tourism, and Conservation Act has similar provisions that apply to birds and other biota as well as marine mammals in Antarctica.

6. What realistically can be done to avoid possible adverse population- and ecosystem-level effects and to minimize any possible harmful effects on individual marine mammals, birds, and other biota?

The available data suggest that the current level and frequency of ship-based research in the Antarctic Treaty Area is unlikely to be having adverse population- or ecosystem-level effects. It is possible, however, that repeated or increased levels of activities in certain areas could cause and be causing localized ecosystem changes by affecting local populations or important habitats and habitat components. For example, repeated or increased frequency of activities in important marine mammal and penguin feeding areas might affect prey availability and/or cause animals to avoid or abandon the areas.

The report of the SCAR *ad hoc* Group on Marine Acoustic Technology and the Environment, mentioned earlier, identifies six things (a-f below) that can be done to reduce the risk to Antarctic wildlife from high power, low frequency sound sources. The Working Group reviewed and, with some modification and clarification, endorsed these measures. As modified, they are:

a. Use the minimum source levels and the least adverse frequencies necessary to meet the research objectives.
As noted earlier, the size of the area ensonified and thus the number of animals potentially affected by sounds produced by acoustic devices are due in part to the frequencies and intensities of the sounds. For example, high intensity, low frequency sounds will travel greater distances without attenuation and therefore affect larger areas than lower intensity, higher frequency sounds. Also, the hearing ranges of many marine mammals and other marine organisms are in the low- and mid-frequencies, meaning they are more likely to hear and be affected by sounds in these frequencies. Thus, anything that can be done to reduce the source levels and avoid using frequencies in the hearing ranges of the animals present in the areas where the research is being conducted will reduce the likelihood of affecting biologically significant numbers of animals.

b. Use "soft starts" whereby power is increased gradually.
Conceptually, ramping-up or increasing the output of acoustic devices gradually, over 15 to 30 minutes, will make animals aware of the presence and increasing intensity of potentially aversive sounds, thus giving them the opportunity to take

evasive actions. It also is possible, however, that some animals may be attracted to the sounds, and/or not take evasive action before the sounds reaches harmful levels. Even so, the potential benefits of soft starts likely outweigh the potential risks. Therefore, soft starts should be a requirement, whenever possible, until there is evidence to the contrary. Further, animals within sighting distance should be observed during start-up and the resulting data analysed to prove or disprove the hypothesis that most if not all species and age-sex classes will move away from potentially aversive sounds before they reach harmful levels.

c. Lay out track lines whenever possible to avoid blocking access to open water
Animals may respond differently to sound sources when both are in open ocean areas than when the animals are in shallow, near-shore waters and the source is between them and open water. In the first case, animals may simply ignore or slowly move away from the source as it approaches. In the latter case, animals may perceive the source as blocking escape to open water and, in a panic, be more vulnerable to predation, attempt to dive under the source and be exposed to higher intensity sounds, move into and be trapped in shallower, near-shore waters, or simply flee at maximum swimming speed in advance of the approaching source. Therefore track lines should be laid out whenever possible to avoid trapping animals between the sound source and shorelines, icebergs, or shallow underwater ridges or shoals.

d. Operate whenever possible during daylight hours and shut down the sound sources if cetaceans of concern are observed in or near the estimated zones of potential adverse effect.
The best available data indicate that exposure levels below 180 or 190 dB re 1 μPa @ 1 m are unlikely to kill, injure, or damage the hearing of any cetacean. Exposure to lower level sounds may affect behaviour, but if the exposure is inferquent and of short duration (see below), should have no long-term effects on either survival or reproduction. Therefore, before initiating research involving the use of acoustic devices, the potential zones of influence of the devices should be estimated, taking into account source levels, frequencies, and oceanographic conditions (e.g., water depth, temperature and salinity) affecting transmission paths and transmission loss. Whenever possible, the research should be conducted during the summer months when there is daylight, with good visibility, so that cetaceans in or approaching the estimated zones of influence can be seen. A cost-benefit analysis should be done before the research is initiated to determine the situations when the equipment should be shut down or put on standby if cetaceans are seen in or approaching the estimated zone of influence. Generally, the decision rule should be to shut down the equipment when highly endangered species or concentrations of animals are encountered, but not do so when occasionally encountering individuals or small groups of common species and suspending the research would prevent or seriously compromise meeting the research objectives.

e. Research should be planned to minimize repeat coverage of areas, both within years and in consecutive years.
As noted earlier, the likelihood of affecting significant numbers of animals is dependent upon the length of time and frequency that animals are exposed to sounds of concern, as well as the characteristics of the sound and the environment. To minimize the lengths of time and frequency that animals are exposed to sounds from research involving the use of acoustic devices, such research should be planned, whenever possible, to avoid repeat coverage of the same areas, both within years and in consecutive years. Consultations should be undertaken during the planning stages to determine whether other countries or research groups have conducted or are planning to conduct similar research in the area of interest. The research should be coordinated and the results shared, to the maximum extent feasible, to avoid repeated studies of the same areas.

f. Research should be planned and carried out, whenever possible, to avoid biologically important areas and times.
The likelihood of encountering and affecting significant numbers of animals will depend in part upon where and when the research is conducted. For example, the likelyhood of encountering significant numbers of penguins and seals will be greater near their terrestrial breeding colonies in the spring and summer breeding seasons than in other areas and at different times of the year. Available data on known breeding, feeding, and concentration areas and times of Antarctic wildlife should be examined during the planning stages of acoustic research, and the research should be designed whenever possible to avoid such biologically important areas and times. As indicated earlier, the research should be suspended if highly endangered or larger than anticipated numbers of animals are encountered.