MARINE MAMMAL POPULATIONS AND OCEAN NOISE

DETERMINING WHEN NOISE CAUSES BIOLOGICALLY SIGNIFICANT EFFECTS

Committee on Characterizing Biologically Significant
Marine Mammal Behavior

Ocean Studies Board

Division on Earth and Life Studies

NATIONAL RESEARCH COUNCIL
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able to inform the other in important ways (see Caswell and John, 1992). Some candidate populations for such a study are the Puget Sound killer whales (Krahn et al., 2002), the North Atlantic right whales (*Eubalaena glacialis;* Waring et al., 2003), bottlenose dolphins in Sarasota Bay (Wells, 2003), the gray seals of Sable Island (Austin et al., 2004), and the northern elephant seals of Año Nuevo Island (LeBoeuf et al., 2000). All those have been studied extensively, and individual animals have been identified and resighted over multiple years. For most of the populations, the demographics are well defined; in some, the effects of major environmental stressors, such as an El Niño or the North Atlantic Oscillation, have been observed (Fujiwara and Caswell, 2001; Greene and Pershing, 2004). Such complex interdisciplinary modeling has been undertaken by the National Center for Ecological Analysis and Synthesis at the University of California, Santa Barbara.

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Rational Management with Incomplete Data

The committee's task statement requires placing this scientific review within the context of management.

> Recognizing that the term "biologically significant" is increasingly used in resource management and conservation plans, this study will further describe the scientific basis of the term in the context of marine mammal conservation and management related to ocean noise.

As noted in this report, the full predictive model is at least a decade away from coming to fruition, and the management requirements involved in addressing concerns over ocean-noise effects on marine mammals are extremely pressing. Efforts are under way to address the long-term goal of producing the predictive model outlined here, but an interim plan is needed. One strategy is to implement a management regimen that uses available data, agreed upon management goals, and a conservative approach to the insufficiencies of the available data. The regimen should encourage data acquisition to reduce uncertainty. At the workshop the NOAA Fisheries Potential Biological Removal (PBR) model was discussed as such an example.

The three acts of Congress most relevant to regulating exposure of marine mammals to noise are the National Environmental Policy Act of 1969 (NEPA), the Marine Mammal Protection Act of 1972 (MMPA), and the Endangered Species Act of 1973 (ESA). The NEPA focuses on environmental analysis of "the relationship between local short-term uses of man's environment and the maintenance and enhancement of long-term productivity." The goal of the MMPA is to "replenish any species or population stock which has diminished below its optimum sustainable level," but its basic regulatory tool involves a prohibition on "taking" marine mammals, where *take* is defined as "to harass, hunt, capture or kill, or attempt to harass, hunt, capture or kill." Similarly, the ESA aims to "conserve endangered species and threatened species and the ecosystems upon which they depend," but it also relies on a prohibition of taking individual animals. The prohibition on taking marine mammals made sense when the dominant conservation problems involved directed hunting and animals incidentally killed by commercial fishing. It is much more difficult to relate harassment takes to population effects.

A number of the workshop panelists agreed that the concept of Potential Biological Removal (PBR) (Taylor et al., 2000) as developed by scientists at NOAA Fisheries, and the concept of the revised management procedure (Cooke, 1994) as developed by scientists associated with the International Whaling Commission, represented the best current approaches to management of human effects on marine mammals under conditions of inadequate data. This chapter reviews the PBR concept and suggests how harassment and other takes could be incorporated into it. The PBR concept is attractive because it is based on a small number of clearly defined and easily understood variables. The limits of acceptable population impact determine the allowable removals. Extensive modeling and sensitivity analysis confirmed that the selected parameter values ensured, with high probability, that the population impacts would be within the prescribed bounds. Anyone who feels that the allowed removals are set either too low or too high can present new data and interpretation in peer-reviewed publications that NOAA Fisheries uses in stock assessments and establishment of PBR.

FINDING: Development of a model, such as the PCAD model, to inform regulatory decisions is critical for a full understanding of the biological significance of anthropogenic noise on marine mammal populations, but a more immediate solution is necessary.

RECOMMENDATION 6: A practical process should be developed to help in assessing the likelihood that specific acoustic sources will have adverse effects on a marine mammal population by disrupting normal behavioral patterns. Such a

process should have characteristics similar to the Potential Biological Removal model, including

- **Accuracy,**
- **Encouragement of precautionary management—that is more conservative (smaller removal allowed)—when there is greater uncertainty in the potential population effects of induced behavioral changes,**
- **Being readily understandable and defensible to the public, legal staff, and Congress,**
- **An iterative process that will improve risk estimates as data improve,**
- **An ability to evaluate cumulative impacts of multiple low-level effects, and**
- **Being constructed from a small number of parameters that are easy to estimate.**

POTENTIAL BIOLOGICAL REMOVAL

The 1994 reauthorization of the MMPA introduced a new regime to determine when the number of animals killed or seriously injured by commercial fisheries poses a risk to marine mammal stocks. It involves estimating the number of animals that could be "removed" from a marine mammal stock without stopping the stock from reaching or maintaining its optimal sustainable population (16 U.S.C. 1362(3)20). The number is called the PBR. Under this regime, every fishing vessel is required to register with NOAA Fisheries. As long as the operators of the vessel register, accept an observer on board, report every marine mammal that they find killed or seriously injured, and comply with the requirements of regulations adopted under a take-reduction plan, all the requirements under the MMPA have been met. In effect, they are exempt from the prohibition on harassment.

For each marine mammal stock, the number of animals killed or seriously injured is compared with the PBR. If NOAA Fisheries learns of sources of mortality, such as a ship strike, the animals are added to the total, but there is no systematic effort to monitor nonfishing kills.[1] If the number

[1]From the Marine Mammal Commission's 2002 report to Congress: "The Commission also questioned the Service's decision to include data on fishery- and other human-related

of animals taken is above the PBR, the regimem calls for a take-reduction team to be formed and to determine ways to reduce the take. The take-reduction team is required to recommend management actions that will reduce the take to below the PBR within 6 months and to the zero-mortality goal within 5 years. A rule establishing 10% of the PBR as zero mortality was published in the July, 20 2004, *Federal Register*.

The calculation of the PBR provides an example of a model designed for management and decision-making. The criteria used for this model are these (Taylor et al., 2000):

- Input parameters are based on available data.
- Uncertainty is incorporated into the model. Managers must make decisions despite uncertainty, but decisions grow more conservative with greater uncertainty.
- There is a mechanism for demonstrating that decisions based on the model meet the MMPA management goals.

Before 1994, the MMPA prohibited any kills of marine mammals in stocks that were below an optimal sustainable population (OSP). The MMPA defines OSP on the basis of the theory of density-dependent population growth. The OSP is defined as the maximal net productivity level (MNPL), which is the population size that theoretically yields the greatest growth rate. The MMPA characterized populations that fell below the MNPL as depleted. During the first 20 years of the MMPA, however, it proved difficult to estimate the parameters required to determine when a population reached the critical point of depletion. Given that uncertainty and the draconian consequences of a "depleted" designation, few populations were designated as depleted, and depletion designations did not fare well in court.

The PBR model was developed in response to the difficulty in parameter estimation. The PBR model selected inputs on the basis of the

mortalities and serious injuries only when incidents could be confirmed. In the Commission's view, requiring confirmation runs counter to the precautionary principle built into the Marine Mammal Protection Act and would tend to result in underestimates. Similarly, the Commission took issue with conclusions in some assessment reports, particularly those for the Alaska region, that certain effects were not occurring because they had not been observed. The Commission cautioned that such conclusions of no-effect should be based, in part, on monitoring effort being made to detect such effects."

experience that the three parameters most easily estimated for most marine mammals were abundance, the uncertainty of abundance, and maximal growth rate. The PBR is calculated as follows:

$$PBR = 0.5 N_{min} R_{max} F_r$$

where N_{min} is the minimum population estimate, R_{max} is the maximal population growth rate, and F_r is a recovery factor ranging from 0.1 to 1.0. Qualitatively, it should be clear that the larger the population and the faster it is capable of growing, the more animals can be removed from the population without impeding its recovery. The equation for PBR was not derived from population modeling, however, but through modeling to evaluate its ability to meet, with a 95% probability, the following management goals based on the MMPA (Taylor et al., 2000):

- Healthy populations will remain above OSP numbers for the next 20 years.
- Recovering populations will reach OSP numbers after 100 years.
- Populations at high risk will not be delayed in reaching OSP numbers by more than 10% beyond the predicted time that is based on an absence of human-induced mortality.

Biologists at NOAA Fisheries tested various values for the input parameters to decide on the values most likely to meet management goals.

The PBR model incorporates two features that are desirable in a model to be used for management decisions (Taylor et al., 2000). It uses parameters that are readily available, and it is conservative when there is uncertainty. For example, the use of the minimal population estimate takes an immediately conservative approach while research to refine the population estimate is stimulated. That is particularly true when the take is near the PBR and the minimal population estimate leads to a PBR well below that calculated by using the mean population estimate. The validity of the PBR is based on how well the result meets explicit management objectives.

EXTENSION OF PBR

PBR should be extended in two ways. First, it needs to incorporate mortality outside the regulated fishing industries. Second, it needs to consider effects on populations that result from the summation of multiple sublethal impacts on individuals. Although the PBR regime was initially developed to regulate commercial fisheries, it cannot achieve the goals of the MMPA if activities other than fisheries contribute to mortality and these takes are not counted accurately and tallied with the fishery takes. For example, NOAA Fisheries has instituted a costly scheme of using professional monitors on vessels to count animals that are entangled in fishing gear, and fisheries are required to report deaths and serious injuries. In many fisheries, however, animals may be killed or injured in lost gear, and this is unlikely to be detected by monitoring on the fishing vessels (Laist, 1996). Similarly, animals immobilized in fishing gear may be taken by predators or may become disentangled after injury or death and not be counted. The regulations requiring reporting of lethal takes and serious injuries are limited to fisheries, so the accounting of takes in nonfishery activities is not as accurate.

The NOAA Fisheries stock assessments are improving their reporting of takes in such activities as vessel strikes, but without a reliable mechanism for monitoring and reporting it is nearly impossible to estimate the number of takes in a given activity. There may be additional uncounted lethal takes from a variety of sources, including exposure to intense noise.

The potential for such takes of Cuvier's beaked whales in association with naval sonar was reflected in the NOAA Fisheries 2002 stock assessment for Cuvier's beaked whales in the western North Atlantic. The assessment lists 46 fisheries-related beaked whale deaths from 1989 to 1998, 53 beaked whales stranded from 1992 to 2000, and 14 beaked whales stranded in the Bahamas in association with a naval sonar exercise. The assessment points out other associations between mass strandings of beaked whales and the presence of naval vessels (NMFS, 2002, pg. 50)

> Although a species-specific PBR cannot be determined, the permanent closure of the pelagic drift gillnet fishery has eliminated the principal known source of incidental fishery mortality. The total fishery mortality and serious injury for this group is less than 10% of the calculated PBR and, therefore can be considered to be insignificant and approaching zero mortality and serious injury rate. This is a strategic stock because of uncertainty regarding stock size and evidence of human induced mortality and serious injury associated with acoustic activities.

The stock assessment states that the stock is strategic because of acoustic activities, now that the fishery rate is low. This is a clear example of where the PBR mechanism cannot protect marine mammals unless NOAA

Fisheries develops a mechanism for accurate reporting of all sources of human-induced mortality.

FINDING: During the last decade, the PBR mechanism has proved to be a successful model to account for the cumulative effects of lethal takes and serious injuries in commercial fisheries. However, as currently implemented, the PBR mechanism cannot adequately protect marine mammals from all sources of human-induced mortality until all such mortality is included in a revised and expanded PBR regime.

RECOMMENDATION 7: Improvements to PBR are needed to reflect total mortality losses and other cumulative impacts more accurately:

- **NOAA Fisheries should devise a revised PBR regime in which all sources of mortality and serious injury can be authorized, monitored, regulated, and reported in much the same manner as is currently done by commercial fisheries under Section 118 of the MMPA.**
- **NOAA Fisheries should expand the PBR model to include injury and behavioral disturbance with appropriate weighting factors for severity of injury or significance of behavioral response (cf. NRC, 1994, p. 35).**

The PBR is intended as a mechanism to trigger regulatory action when the cumulative effects of taking reach some threshold. It uses the number of individuals removed from the population as the unit for assessing cumulative effect. Individuals are taken when they are killed, but taking also includes serious injury, minor injury, and behavioral disturbance. Rather than the current practice of counting serious injury as equal to death and injury as equivalent to no effect, it would be appropriate to develop a severity score for each kind of take defined by the MMPA. A severity score estimates the proportional effect of a given take activity compared with that of a lethal take. A precise estimate of the proportion would require integration of behavioral effects into demographic models—one of the most challenging aspects of the PCAD model. However, it may be possible to set several categories of severity for injury and behavioral harassment. Two categories per order of magnitude would probably provide appropriate precision (for example, 1, 0.3, 0.1, 0.03, 0.01, 0.003).

The visible signs of injury listed by NOAA Fisheries[2] include injuries of obviously varied severity. They include

- Loss of or damage to an appendage, jaw, or eye; these injuries affect the long-term ability of an animal to swim, feed, or see.
- Entanglement in fishing gear; it may take days or weeks for an animal to free itself from a serious entanglement, which may also leave long-term injuries.
- Bleeding, laceration, swelling or hemorrhage; some of these may reflect a serious injury, but they often resolve in a few days with little long-term consequence.

To address Recommendation 7, NOAA Fisheries could convene an expert panel of veterinarians to assign injury severity scores for those and other symptoms. For example, it seems likely that the first category might score 0.3, the second category 0.1, and the third category 0.01. Although some of the animals with the symptoms may have more or less severe effects, as long as the severity score is at least as great as the effect on the average animal compared with being killed, the scoring should be conservative for use in the PBR. The research necessary to validate that would involve following the outcomes of injured animals for their ability to survive, grow, breed, and provide parental care.

Just as the cumulative effects of nonserious injuries cannot be ignored, so an analysis of cumulative effects must add the adverse effects of behavioral harassment. Behavioral harassment is likely to be both less severe and more common than injury. That makes it all the more important to evaluate the cumulative effects on a stock of all harassment takes in addition to injury and lethal takes. For example, the dominant model of effects of noise posits different zones of influence at different distances from the source (Figure 4-1).

Assigning a severity score to harassment would involve a process similar to that used for injury but would require experts in behavioral ecology instead of veterinary care. Assuming that harassment is not involved indirectly in causing injury or death (as may occur with effects of military sonar on beaked whales), the primary effects of harassment involve the loss of opportunities, time, and energy. If the proposed activity occurs at a critical time or in a critical place when a specific activity must occur (for example, it disrupts a critical feeding trip of a phocid seal or disturbs a breeding site during a short season), the severity score will be higher. Thus, for a species for which the cost of a lost breeding season reflects the postponement to the next season and for an individual expected to have well in excess of 10 breeding seasons, the severity of loss of a breeding season might be set at 0.1; if the expectation is well in excess of 30 breeding seasons, the severity of loss of a breeding season might be set at 0.03. For activities that are expected to expose animals for shorter times during less critical periods, the time and energy lost may dominate interpretation of severity. One of the most pronounced behavioral responses of a marine mammal to noise involves the response of beluga whales to icebreakers in the Arctic. Beluga whales may respond to an icebreaker at many tens of kilometers (LGL and

[2]http://www.nmfs.noaa.gov/prot_res/PR2/Fisheries_Interactions/MMAP.htm

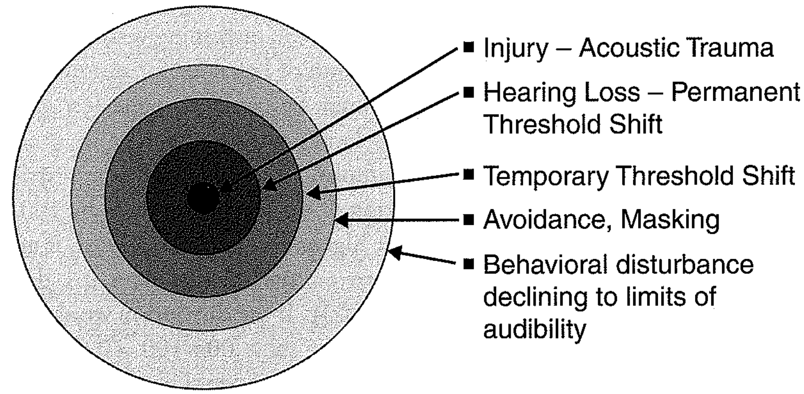

FIGURE 4-1. Close to an intense source, sound may be loud enough to cause death or serious injury. Somewhat farther away, an animal might have less serious injury, such as hearing loss. Temporary threshold shifts occur at greater distances. Animals may avoid exposures at even greater distances or they may not move from the area but still be affected through masking of important auditory cues from the environment. They may show just observable behavioral disturbance at distances comparable with the limit of audibility. The different distances for the different effects define different areas for each zone.
SOURCE: Modified from Richardson and Malme, 1993.

Greeneridge, 1986; Cosens and Dueck, 1988; Finley et al., 1990). Their normal behavior is disrupted for several days, and they may have an increased metabolic rate as they swim away from an oncoming vessel. Other animals in other settings may show disruption of behavior for minutes to hours. In those cases, the severity score may be based on time lost and excess energy expended. Many species have seasonal changes in their behavioral ecology, with seasons lasting around 100 days, so a first approximation might divide the expected duration of disruption, in days, by 100. The result could be rounded to the next higher severity score. Thus, if an activity would be expected to disrupt an animal for less than 0.1 day (2.4 hr), the severity would be 0.1/100 = 0.001. If the disruption would be expected to last minutes, the severity might be set a .003/100 = 0.00003. As with the severity score for injury, an expert panel could be convened to establish severity scores for different kinds of behavioral disruption.

Severity scores can be used in the calculation of PBR by multiplying the number of animals affected by each severity (N) times the severity score (S) itself, and then tallying all of the N*S values. Table 4-1 illustrates the expectation that the higher the severity score, the fewer animals expected to be impacted, but in addition it illustrates how leaving out the cumulative effects of injury and harassment may underestimate cumulative impacts. In this hypothetical example, with an unrealistic assumed density of 1 animal/3.14 m^2, there is 1 lethal take, the equivalent of 1 lethal take in 10 injuries, and the equivalent of 1 lethal take in 100 cases of behavioral harassment. If PBR is to correctly tally cumulative impacts, it cannot completely ignore effects with severity of <1.

TABLE 4-1 Arbitrary Ranges and Severity Levels to Illustrate the Relation Between Severity of Effect and Numbers of Animals Affected (for most species, a two-dimensional approximation is appropriate)

Effect	Range (m)	Severity (S)	Relative Area (πr^2)	Number of Animals (N)	(N)*(S)
Death or serious injury	1	1	3	1	1
Injury (such as hearing loss)	10	0.01	314	100	1
Behavioral Disturbance	100	0.0001	31,416	10,000	1
TOTAL					3

DETERMINATION OF NONSIGNIFICANT IMPACT

The proposed modifications of the PBR model cannot be accomplished easily or quickly. The original PBR model was the result of many years of development and analysis. Prior sections of this report have emphasized the long time-line for acquiring the data and understanding necessary for a full implementation of the PCAD model. Compliance with the current regulatory interpretations of the NEPA, the MMPA, and the ESA is fraught with uncertainty regarding the use of sound sources in the marine environment and as the 2000 National Research Council report noted, regulations are more effective when they target critical disturbances.

The statement of task for this study was initially framed as identify biologically significant effects, but from a regulatory perspective it is more important right now to suggest a process for identifying activities that do *not* reach a de minimis standard for biological significance. Such activities would be exempt from the normal permitting process.

To assist regulatory agencies in meeting the requirements of the MMPA, a formalized, intelligent-decision system for risk assessment that uses current research expertise could offer the following advantages:

- It could provide a rapid and more simple authorization procedure, reducing the burden on applicants and regulators.
- It could provide a tally of each effect in a format that could account for cumulative effects.
- It could stimulate the generation of data required to make determinations in a format that makes the data readily available for the next applicant.
- It could improve decisions by improving available data.
- It could encourage others to report problems (such as, strandings) and to identify unexpected potential problems.
- It could set conditions for permits on the basis of location, time, and ecological conditions.
- It could maintain permanent records of every application.
- It could require applicants who apply and fail to meet a de minimis standard to obtain permits as under the current system.
- It could institute an adaptive system to improve data incrementally, and to reflect updates from annual reviews.

An Internet-based system, described in Figure 4-2 could assist producers of sound in the sea to determine whether proposed activities

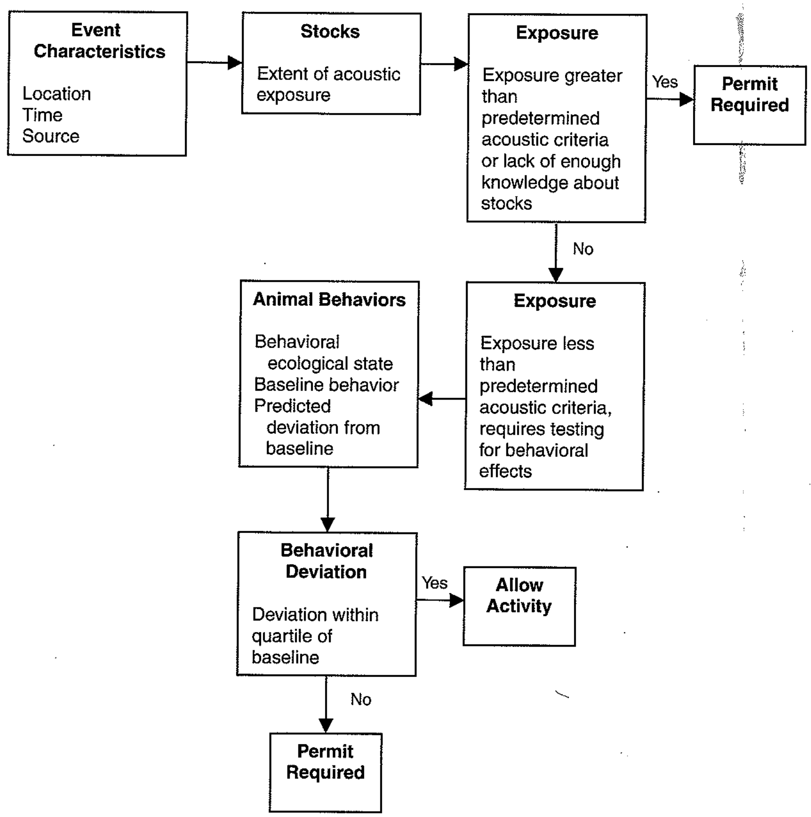

FIGURE 4-2. Diagram of a possible system for determination of whether behavioral changes cross a de minimis threshold.

require a permit or may be considered exempt from permitting. Essentially, such a process would allow regulators to establish de minimis standards that identify activities that have a low probability of causing changes in marine mammal behavior that would lead to significant population effects. This system would be populated initially with rules that, given our current state of knowledge, can best be attained through expert opinion. Although the model presented is based on animal exposure to sound, it is equally applicable to other types of activities affecting marine mammals.

In the initial stage of the process for applying for the de minimis exemption, for any kind of effect on marine mammals, the applicant would state the location and time of the proposed activity. The spatial scope of most effects is relatively easy to define. Sound travels so well in water that determining the scope of acoustic effects requires more information. For acoustic effects, the applicant would also state the acoustic characteristics of the proposed source: for example, source level, rise time, spectrum, directionality, and time course of operation.

Because most marine mammal populations are below their OSP, the system should be conservative in the face of uncertainty, that is, it should avoid the type of error that would lead to the loss of a valued resource (NRC, 1995). Such conservativeness might be reflected in a requirement for a specified level of knowledge about the distribution of animal populations, known as stocks for management purposes, within hearing range of the source. If enough is known about the stocks and their distribution, the system would move to the next stage; if not, it would reject the application for "no significant effect" determination unless the applicant could obtain and enter the required information.

The initial format of this part of the system would be based on a geographical information system (GIS). It could build on several continuing efforts to develop GIS systems that store information about the distribution and abundance of stocks (such as the Ocean Biogeographical Information System Spatial Ecological Analysis of Megavertebrate Populations, http://seamap.env.duke.edu) with geographical data on sound propagation. The common database described in Recommendation 3 could be used to populate this part of the system. The raw sighting data used by NOAA Fisheries for stock assessments would be a major component of the marine mammal element of the GIS for US waters. The acoustic information could be used to define how the sound would spread from the proposed site.

The initial stage in evaluating whether potential effects of a sound source cross the de minimis threshold would use the NOAA Fisheries acoustic criteria described in Chapter 3. For each species in the area, the exposure to sound from the planned sources is evaluated in terms of the criterion threshold for sound pressure level or energy level for the functional hearing group to which the species belongs. If the probability that individuals are exposed above the threshold level for acoustic effects is less than, for example, 0.001, the species would pass the proposed de minimis standard for direct acoustic exposure.

Animals experiencing exposures below the direct acoustic-effects threshold may still have behavioral reactions that could lead to population consequences. The next step is to determine the level of effect on life functions (Box 4-1).

BOX 4-1
Considerations for Evaluating Marine Mammal Disturbances by Specific Activities

Determining biologically significant disturbance would necessarily evaluate a number of behaviors and their ecological contexts in regard to the proposed activities. Below are some behaviors that theoretically can be disrupted by noise, and some considerations in the determination of significance of the disruptions. The examples are illustrative only and should not be construed as a complete catalog of potentially biologically significant behavioral disruptions.

Migration. For migration, the standard might state that neither the path length nor the duration of migration could be increased into the upper quartile of the normal time or distance of migration. Fully one-fourth of the population exceed this value normally, so this is likely to be a conservative criterion. With enough data on time and length of migration, the applicant could then use response models or estimates of the scope of the effect to evaluate whether they meet the criterion. For example, if the effect of the activity extends for only a small duration of migration or a small part of the migratory path, such data alone might be sufficient. For migrating gray whales, in which case avoidance can be quantitatively related to a received level of sound, more-detailed analyses might be applied to a measure to account for the reduced uncertainty.

Feeding. For feeding behavior, the standard might be related to whether the disturbance will decrease energy reserves into the lower quartile of normal variation, as measured during a period appropriate for the proposed activity and season and the species affected. For example, female marine mammals can be divided into capital breeders, which postpone reproduction until they have stored enough energy to carry infants through to weaning, and income breeders, which continue to make foraging trips during lactation (Costa, 1993). Different periods would be integrated for the different classes and different energy measures, such as energy stores or reserves vs. daily energy balance.

The behavior of marine mammals varies by species, age-sex class, location, season, and time. The effect on life functions of a given change in behavior will also depend on those variables. The effect can be modulated

Breeding. Different standards for disruption of breeding behavior should be considered for females and males. The ability of a female to select a mate, breed, gestate, and give birth to a viable offspring is so essential to populations that there should be very low tolerance of disturbances that might affect these activities. The disruption of male reproductive behavior is probably less likely to have population effects than would disruption of female reproductive behavior, although disruption of male behavior should not reduce the pool of potential mates from which females can choose by more than 25%. This might be estimated from known changes in male call characteristics in response to noise, if the typical distribution of males and disturbance-caused movements of females are sufficiently known, the scope of disturbance could be estimated.

Nurturing and Parental Care. Very low thresholds should be considered for any disturbance that might separate a dependent infant from its caregivers. Examples include analyzing whether noise or disturbance responses might cause the infant and caregivers to separate too far to resume their activities. On longer time scales, the program could analyze whether the disturbance might reduce the nutrition from lactation to less than the lower quartile of normal. Both the duration of nursing bouts and the distribution of intervals between bouts may be important. It is possible that males in some species, such as Baird's beaked whales (*Berardius bairdii;* Kasuya et al., 1997), may be important for parental care and infant survival. Undisturbed social structure may be particularly important for infant survival. For example, bottlenose dolphin calves raised in large, more stable groups have higher survival than those raised in smaller, less stable groups (Wells, 1993).

Predator Avoidance. For behavioral changes that alter the response to predators, very low thresholds are recommended if there is the chance that the disruption will increase the vulnerability of an animal to predation. Many marine mammals depend on social defenses from predation (Mann et al., 2000).

by interannual ecological changes, such as El Niño or the North Atlantic Oscillation. Because the science is not mature enough for predictive modeling from behavior of individuals to population effects, a simple interim criterion based on normal variation of undisturbed behavior could be used. The baseline behavior against which behavioral changes are measured should be mapped onto the time and location of the proposed activity as closely as possible. Where other contexts, such as the phase of the interannual cycle, are known to affect behavior, they should be taken into account.

The de minimis criterion should be robust and conservative in the face of small samples and ignorance of shape of the distribution of baseline behavior. It should also be set at a level that meets management goals. A reasonable starting point would be a quartile level (upper or lower, as appropriate), but the value selected for this criterion should be tested with the same kinds of models used to evaluate the performance of the calculation of PBR (Taylor et al., 2000).

In all cases in which the proposed system yields a "no-significant-impact" determination and the applicant does not have to prepare a permit application, NOAA Fisheries should require the applicant to register the activity, monitor for effects, and report observed effects to the system to improve the knowledge base for future determinations. Approved stranding networks should enter all stranding data. The Internet-based system could be queried for any planned activities, and anyone could look for correlations between activities and strandings. After accumulating data for a few years, the database would allow epidemiological research that should be able to identify such problems as the effects of mid-range tactical sonar on beaked whales in less than the 35 years that it took to make this particular connection.

Experts and managers should meet annually, at least initially, to evaluate the performance of the system and to revise decision criteria on the basis of new information. Such a system, if applied to all activities, would provide rich opportunities for epidemiological analyses of the data to identify hot spots and linkages between human activities and marine mammal mortality or morbidity.

Any cases of lethal take or serious injury should be reported immediately and should be added to the take that is compared with the PBR. Any such take should disqualify the activity for the "no significant impact" determination and for regulation under the de minimis standard. Any applicant who provides false information to the system in an attempt to avoid permitting requirements should be disqualified from using the system and be subject to prosecution.

FINDING: Current knowledge is insufficient to predict which behavioral changes in response to anthropogenic sounds will result in significant population consequences for marine mammals. The PCAD model and proposed revisions to the PBR will take years to implement. In the interim, those who introduce sound into the marine environment and those who have responsibility for regulating takes resulting from such activities need a system whereby reasonable criteria can be set to determine which sounds will have a nonsignificant impact on marine mammal populations. Collectively, there are sufficient expert knowledge and extensive databases to establish such a system and to set the non-significant-impact criterion conservatively enough that there can be broad agreement on it.

RECOMMENDATION 8: An intelligent-decision system should be developed to determine a de minimis standard for allowing proposed sound-related activities. An expert-opinion panel should be constituted to populate the proposed system with as many decision points as current information and expert opinion allow. The system should be systematically reviewed and updated regularly.

Appendix B

Acronyms

AIM	Acoustic Integration Model
ATOC	Acoustic Thermometry of the Ocean Climate
CEE	Controlled Exposure Experiment
ESA	Endangered Species Act
ESME	Effects of Sound on the Marine Environment
FWS	US Fish and Wildlife Service
GIS	Geographic Information System
IBM	Individual-Based Model
LFA	Low-Frequency Active
MMPA	Marine Mammal Protection Act of 1972
MNPL	Maximum Net Productivity Level
NCEAS	National Center for Ecological Analysis and Synthesis
NEPA	National Environmental Policy Act of 1969
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration

NRC	National Research Council
ONR	Office of Naval Research
OSP	Optimum Sustainable Population
PBR	Potential Biological Removal
PCAD	Population Consequences of Acoustic Disturbance
PTS	Permanent Threshold Shift
SPAWAR	Space and Naval Warfare Systems Center
SURTASS	Surveillance Towed Array Sensor System
TTS	Temporary Threshold Shift

Appendix C

Workshop Agenda and Participants List

Predicting Population Consequences of the Disturbance by Noise on Marine Mammals
National Academy of Sciences
Lecture Hall
2101 Constitution Avenue NW
Washington, DC
March 5-6, 2004

Friday, March 5, 2004

Open Session

Opening remarks, committee introductions, review of workshop format
Douglas Wartzok—Florida International University, Chair
Joanne Bintz—Study Director, Ocean Studies Board

Introduction to Task Statement and Model

PANEL I—INDIVIDUALS TO POPULATIONS
Session Introduction—**Katherine Ralls**
Shripad Tuljapurkar, Dean and Virginia Morrison Professor of Population Studies, Stanford University
Bill Morris, Associate Professor, Department of Biology, Duke University