Presentation at the Second Plenary Meeting of the Advisory Committee on Acoustic Impacts on Marine Mammals

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Background on Assessing the Risk to Marine Mammals from Anthropogenic Sound

Advisory Committee on Acoustic Impacts on Marine Mammals

Plenary Meeting Two

28 April 2004

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Studies

1994 National Research Council (NRC). Low-Frequency Sound and Marine Mammals: *Current Knowledge and Research Needs*

1997 High Energy Seismic Survey Committee (HESS)

1998 HESS Follow-up meeting

2000 NRC. Marine Mammals and Low-Frequency Sound: *Progress Since 1994*

2003 NRC. Ocean Noise and Marine Mammals

2004 NRC. [Determining the Biological Significance of Marine Mammal Responses to Noise]

Study Formats

The NRC and HESS studies represent two different approaches to risk assessment.

- The NRC committees relied primarily on published material to frame the issues and identify the gaps in current knowledge. The prepared reports were peer-reviewed by at least eight external experts with review oversight conducted by a section of NRC not associated with the report development. The reports were published by the National Academy Press and widely circulated.
- HESS used the Expert Opinion format in which a group of acknowledged experts are brought together and through a more gestalt approach they reach consensus on certain bounds of a given problem. In the Expert Opinion format, a report may or may not be issued, and if it is, it will not be peer reviewed because the peers are the panel members.

HESS (High Energy Seismic Survey)

- The HESS process had its genesis in 1988 when the California State Lands Commission decided that an Environmental Impact Report needed to be prepared before it would consider applications for seismic activities in California waters.
- The first application under this new policy was not submitted until 1995 and it then took eight months for review
- In 1996 MMS brought together a broad cross-section of individuals representing government agencies, the offshore oil and gas industry, the geophysical industry, the commercial fishing industry, marine research, and environmental organizations to form the HESS Team. Team meetings were facilitated by The Mediation Institute.
- The goals were to reach consensus on the application review process, including environmental review, and develop a set of potential mitigation measures for high energy seismic surveys proposed in the State of California and Federal waters within the Team's proposed study area.

HESS (High Energy Seismic Survey)

- To provide scientific input on the mitigation issues, in June 1997 MMS convened a panel of nine nationally recognized experts on marine mammals and acoustics, including three individuals who are alternates to the present committee.
- The Committee addressed:
  - Safety Zones and Zones of Potential Harassment
  - Transmission Loss Models
  - Ramp–up
  - Monitoring
  - Priority Species for Protection

HESS (High Energy Seismic Survey)

Safety Zones and Zones of Potential Harassment

- NMFS had been using Interim Acoustic Criteria for marine mammal harassment of:
  - 70 dB over threshold defines behavioral reaction
  - 80 – 100 dB over threshold defines annoyance or TTS
  - 130 dB over threshold defines pain
  - 155 dB over threshold defines PTS
- The Expert Panel felt there was not enough known about marine mammal hearing processes to justify using these values for establishing safety zones and zones of potential harassment

HESS (High Energy Seismic Survey)

Safety Zones and Zones of Potential Harassment

- The Expert Panel recommended that 180 dB rms re 1 μPa be set as the level above which there was potential to cause serious physiological and hearing effects; i.e., the Safety Zone should go out to the 180 dB contour
- The Expert Panel discussed, but declined to make a +/- 10 dB differential exposure criterion for different species

HESS (High Energy Seismic Survey)

Safety Zones and Zones of Potential Harassment

- The Expert Panel recognized that some animals responded at 140 dB but felt that the transition between response and significant response would occur in the range between 140 and 180 dB.
- The Expert Panel chose 160 dB as the level of potential harassment

HESS (High Energy Seismic Survey)

Transmission Loss Models

- The Expert Panel recommended that modeling in the absence of local propagation data was sufficient to determine the 180 dB contour
- The 160 dB contour could be modeled for survey monitoring design, but needed to be verified with local propagation data within the first 72 hours of operations

HESS (High Energy Seismic Survey)

Ramp–up

- The Expert Panel considered ramp–up a desirable mitigation measure
- The panel recommended a research project to determine the effectiveness of ramp–up

Note that NMFS instituted ramp–up requirements of an increase of no more than 6 dB per minute

HESS (High Energy Seismic Survey)

Monitoring

- The Expert Panel recommended:
  - Multiple experienced observers (3) on the seismic vessel
  - Passive acoustic monitoring
  - Aerial surveys because of the recognition that the 160 dB potential harassment contour could be well beyond observable range from the seismic vessel

Note that the recent beaked whale workshop agreed that mitigation through shut down of seismic surveys when beaked whales were observed within the 180 dB contour was ineffective because detection probabilities for beaked whales within this contour was 1 to 2 percent

HESS (High Energy Seismic Survey)

Priority species for protection

- The Expert Panel recommended three levels of priority for marine mammals in the California coastal region:
  - High Priority
    - Blue, humpback, fin and gray whales
  - Second Priority
    - Sperm whale, elephant seal, other mysticetes
  - Third Priority
    - Other odontocetes and other pinnipeds

HESS Follow–up

NMFS reconvened the HESS Expert Group with some additional participation to address the following issue and questions:

- The HESS workshop report concluded that, without reference to frequency, above about 180 dB (+/- 10 dB) rms re 1 μPa it is no longer certain that marine mammals will not sustain permanent hearing damage from noise:
  - Does this panel agree?
  - Could a higher level be used for pinnipeds and odontocetes (except sperm whales) without undue risk?
  - Should frequency be considered when using this rule of thumb?
  - Should NMFS avoid using this rule of thumb in the interest of avoiding single-number criteria?

HESS Follow–up

- The panel decided that although experimental data were lacking, the criterion could be increased to 190 dB for pinnipeds
- The panel noted that their recommendations applied specifically to the types of sounds generated by seismic surveys
- Before these values could be applied to other types of sound, more work needed to be done on the interval over which the sound exposure is integrated

Low Frequency Sound and Marine Mammals – 1994

- Creation of the Committee was stimulated by the ATOC (Acoustic Thermometry of Ocean Climate) proposal to use high source level, low–frequency sound traveling along long–distance undersea paths to measure speed of transmission and thereby determine average temperature change in the world's oceans due to global climate change
- Committee charge was to review current knowledge and on–going research on the effects of low frequency (1 – 1,000 Hz) sound on marine mammals

Low Frequency Sound and Marine Mammals – 1994

The Committee concluded:

- Current data were insufficient to predict the effects of intense, low–frequency sound on any marine species
- Based on available information, sounds below 100 Hz were unlikely to be in a sensitive range for odontocetes and most pinnipeds
- Effects on mysticetes had the potential to be significant, but with no data on hearing sensitivity or received levels the effects could not be determined

Low Frequency Sound and Marine Mammals – 1994

- The Committee raised a concern that the 120 dB criterion which was being used at that time in some contexts as the level above which potentially harmful acoustic effects may occur was really more likely a detection or mild annoyance threshold and the short term changes in behaviors were not necessarily indicative of an adverse effect
- The Committee was concerned that the statutory term "harassment," undefined in regulation, was "being interpreted through practice to include any action that results in an observable change in the behavior of a marine mammal" (Swartz and Hofman, 1991)

Low Frequency Sound and Marine Mammals – 1994

- The Committee recommended several possible statute and regulatory changes:
  - Distinguish between different types of taking and streamline the permitting process for activities that did not kill or capture marine mammals with further streamlining for non-lethal activities having negligible impact
  - Regulate within the context of total human impacts on marine mammals which include fisheries, shipping, oil and gas industry, research activities, etc. with primary effort expended on those activities with the greatest potential for harm using Potential Biological Removal (PBR) as a common metric for all such activities

Low Frequency Sound and Marine Mammals – 1994

- Operating in a PBR context would allow removal of the "small" numbers requirement for an incidental take authorization
- Decentralize permitting for research involving marine mammals in the same manner permitting for research on all other species of animals and humans is decentralized to local Institutional Animal Care and Use Committees (IACUC-for animals) and local Institutional Review Boards (IRB-for humans)

Low Frequency Sound and Marine Mammals – 2000

- The name of the Committee which produced the 2000 report was the Committee to Review the Results of ATOC's Marine Mammal Research Program
- In addition to the ATOC MMRP review the Committee was tasked to review other relevant research focusing on the strengths and weaknesses of the data in answering questions regarding marine mammals and low frequency sound
- The Committee was also directed to identify where gaps in our knowledge continued to exist

Low Frequency Sound and Marine Mammals – 2000

- In response to the primary task, the Committee concluded that because of time limitations and experimental design deficiencies the MMRP was not able to demonstrate a lack of significant effects of ATOC transmissions on marine mammals
- The Committee noted that "simply not detecting reactions is not by itself sufficient evidence that there is no significant impact"
- The Committee concluded "there is *no cause for alarm* about short term effects of ATOC on dolphins and most seals…however, there *is cause for concern* because we cannot totally rule out short–and long–term effects of ATOC, particularly on baleen whales and sperm whales"

Low Frequency Sound and Marine Mammals – 2000

- The 1994 amendments to the Marine Mammal Protection Act incorporated Level A and Level B Harassment
- The Committee recommended that a threshold for Level A injury be related to the likelihood of causing TTS and the magnitude of the TTS and suggested that a sound producing a 10 dB or less TTS separated by non-exposure intervals of 24 hours would be below the Level A threshold

Low Frequency Sound and Marine Mammals – 2000

- The Committee recommended that Level B harassment be redefined as:
  - Has the potential to disturb a marine mammal or marine mammal stock in the wild by causing meaningful disruption of biologically significant activities, including but not limited to, migration, breeding, care of young, predator avoidance or defense, and feeding

- The Committee reiterated the recommendation of the 1994 Committee that the "small number" requirement be removed from the Incidental Harassment Authorization and maintain only the "negligible impact" criterion

Ocean Noise and Marine Mammals – 2003

- The Committee was tasked to:
  - Evaluate human and natural contributions to the ambient
  - Describe long-term trends in the ambient
  - Outline research to evaluate the impacts of ambient noise
  - Identify gaps in marine noise databases
  - Recommend research needed to develop a model of ocean noise

Ocean Noise and Marine Mammals – 2003

- **Basic Question**
  - What is the overall impact of man-made sound on the marine environment?

- **Committee Conclusion**
  - The overall impact is unknown, although there is cause for concern.

Ocean Noise and Marine Mammals – 2003

- **The Committee recommendations were designed to increase understanding of:**
  - the characteristics of ocean noise, ***particularly from man–made sources***
  - the potential impacts on marine life, ***especially those that may have population level consequences***

Biologically Significant Responses to Noise – 2004

The 2003 Report was in response to one of the recommendations of NRC 2000. The 2004 Committee is also a response to one of the 2000 Recommendations:

- MMPA definition of Level B harassment should be "limited to meaningful disruption of biologically significant activities that could affect demographically important variables such as reproduction and longevity"

Biologically Significant Responses to Noise – 2004

The Committee's task is to "produce a brief report that reviews and characterizes the current scientific understanding of when animal behavior modifications induced by transient and non–transient ocean acoustic sources, individually or cumulatively affect individuals in ways that have negative consequences on populations"

Biologically Significant Responses to Noise – 2004

Conceptual Approach

- Link acoustic stimuli to behavioral responses to functional outcomes of responses integrated over daily and seasonal cycles to life history models
- Acoustic stimuli → behavioral responses occur on time scale of hours
- Behavioral responses → functional responses occur on time scales of days to season
- Functional responses → population responses occur on time scales of years

Sound	Transfer Function 1	Behavior Change	Transfer Function 2	Life Function Impacted	Transfer Function 3	Vital Rates	Transfer Function 4	Population Effects
Freq Duration Level Source Duty Cycle Rise Time		Orientation Breathing Vocalizing Diving Resting Mother-Infant Spatial Relationships Avoidance		Life Migration Feeding Breeding Nurturing Response to Predator		Age–Specific ℓ_x m_x		Survival Children Grand-children
			Functional Modulation of Effects Time and Energy Budgets Homeostasis and Allostasis					
+++*	+	++	+	+	0	+	+++	+

*The indicators in the columns with observable features, i.e., sound, behavior, function vital rates, and population levels relate to how well those measurements can currently be made. The indicators in the columns headed by transfer functions relate to how well the "black box" nature of the transfer functions is understood. The indicators scale from "+++" (well known, easily observed) to "0" (unknown)

Transfer Function 1
Sound to Behavior

- Controlled exposure experiments
- Observational or correlational studies
- Expert Opinion panel
- Varies with
  - Species
  - Season
  - Location
  - Age and sex
- Because of limited data marine mammals need to be grouped by hearing capabilities/ear types

Transfer Function 2
Behavior to Life Function

- Two time scales – diurnal and seasonal
- Typical cycle of activities is diurnal
  - Approximate time of attachment duration of suction cup tags for controlled exposure, dose:response measurements
- Responses increase monotonically, but not linearly
- Habituation and sensitization
- Strong seasonal variations in behavior
- Sum diurnal responses over a defined season
- Determine interference with behavioral functions critical to survival, growth, and reproduction

Transfer Function 3
Life Function to Vital Rates

- Seasonal effects on age and sex classes
- Integrated over multiple years
- Changes in population dynamic parameters
- Sound as one more component of PBR – e.g., populations near carrying capacity can withstand greater anthropogenic sound induced impacts than populations already depleted

Transfer Function 4
Vital Rates to Populations

- When population modelers know ℓ_x (age–specific survival rates) and m_x (age–specific fertility rates), they can easily calculate the population–level effects

Functional Modulation of Effects

- Lost opportunities – e.g., in a population where acoustic communication is important for mating behaviors; or where acoustic contact is important for mother-offspring recognition
- Time or energy expenditure – e.g., extended migration path length to avoid multiple acoustic sources; masking of navigational cues
- Long term stress pushing animals beyond capabilities of physiological homeostatic mechanisms and long term energy imbalance creating allostatic overload

Summary

- Two approaches to marine mammal risk assessment have been used:
  - Expert Opinion
  - Peer–reviewed reports from NRC Committees
- Both approaches have emphasized
  - Lack of essential data
  - A precautionary approach in the absence of essential data
  - The absence of evidence of an effect is not evidence of the absence of an effect
  - A common metric should be developed for all effects of human activities on marine mammals and PBR has been suggested in several reports as this metric
  - Regulatory activities should be directed toward activities having the most significant effects on populations