Abstract

Title of Dissertation.	ECOLOGICAL RISK TO CETACEANS FROM ANTHROPOGENIC OCEAN SOUND: CHARACTERIZATION ANALYSIS USING A PROFESSIONAL JUDGMENT APPROACH TO UNCERTAINTY
	Amanda Ann Truett, Doctor of Philosophy, 2007
Dissertation directed by:	Joseph Mihursky, Ph.D. University of Maryland Center for Environmental Science, Chesapeake Biological Lab, Solomons Island
	Michael Fogarty, Ph.D. Woods Hole Oceanographic Institution

The recommendations of anthropogenic ocean sound impact criteria by an expert community of scientists have been monitored over the 10–year period from 1996 - 2006. This dissertation approaches this topic in three ways; **1:** by content analyzing 94 peer-reviewed publications specific to this topic (representing 20 countries and 27 species of cetaceans, and virtually all oceans), from which up to fifteen variables were coded for exploratory analysis, **2:** by an anonymous Internet survey questionnaire administered to 91 of the 119 authors of these 94 publications, one that was designed to identify common patterns and points of departure in how these expert scientists currently independently and anonymously characterize their data on the species they study, and **3:** Logistic regression analysis to help determine the functional relationship, or measure of association (risk) between anthropogenic ocean sound and impacts to cetaceans and fish.

Results indicate an increasing risk of disturbance behaviors in response to increasing anthropogenic sound levels, and that observed free-ranging populations (n >1486 animals) have lower behavioral thresholds to anthropogenic sound than observed captive individuals (n = 25 animals). Empirical estimates indicate a .945 probability that the sound threshold for free-ranging animals lies below the 180dB rms NMFS status quo criterion. Survey data suggests a significant increase in the concern over global ocean sound over the 10-year period – with 51% of criteria recommendations dropping from the 180dB rms status quo to 140dB p-p and below, representing more than a 50% shift toward the 100dB rms average ambient assumed in this study. It is concluded that these empiricists demonstrated a cooperative strategy which is in the early stages of adaptive management favoring integrating solutions to sustainability problems by way of collective management, and advocate precautionary behavior. Communications strategies are identified and discussed and recommendations include open data base collaborations.

This project thus demonstrates the utility of a transparent international data base instrument and suggests a broader strategy for greater scientific leadership in guiding policy toward achieving sustainable management of living marine resources.

ECOLOGICAL RISK TO CETACEANS FROM ANTHROPOGENIC OCEAN SOUND: CHARACTERIZATION ANALYSIS USING A PROFESSIONAL JUDGMENT APPROACH TO UNCERTAINTY

By

Amanda Ann Truett

Dissertation submitted to the Faculty of the Graduate School of the
University of Maryland, College Park in partial fulfillment
Of the requirements for the degree of
Doctor of Philosophy
2007

Advisory Committee:

Professor Joseph Mihursky, Co-Chair
Professor Michael Fogarty, Co-Chair
Professor John Robinson
Professor Miranda Schreurs
Professor Thomas J. Miller

Dedication:

To all those yet unborn.

Hunkapi

Acknowledgements:

To all those whose lives have touched this work, thank you for making this the second most enriching experience of the past half-century of my life.

TABLE OF CONTENTS

List of Tables....................vi
List of Figures....................viii
Introduction....................1
Chapter I. Ecological Risk and Protective Policy....................6
The Marine Mammal Protection Act....................8
The Bureaucracy: “Harassment” Redefined....................13
Professional Judgment....................14
The Concerns of Scientists Regarding Ocean Sound....................15
Chapter 2. History and Literature Review....................20
The conflict....................20
Ocean Sound Science....................27
The Directions of Whale Research....................31
Cetacean evolution and adaptation to the seas....................33
The Question of Why Whales Strand....................36
Habitats and risk....................37
Marine Mammal Commission response....................44
The role of National Marine Fisheries Service....................45
Sound Exposures and Effect Characteristics....................46
Chapter 3. Methods....................51
Overview....................51
Statements of hypotheses....................51
Importance of the study....................52
Statistical goals....................52
Social/Political importance....................53
Publication selection....................53
Expert scientist population....................54
Literature Analysis....................55
Anthropogenic Ocean Sound Survey....................58
Questionnaire Construct....................58
Research Limitations and Assumptions....................60
Limitations....................60
Assumptions....................61
Expert Scientist Participation....................62
Data preparation....................63
Kolmogorov-Smirnov two-sample test....................64
Logistic Regression Analysis....................64
Threshold Probability Estimation....................66
Chapter 4. Results....................67
Publication Data....................67
The Kolmorogov-Smirnov two-sample test results....................70
The Internet Ocean Sound Survey Results....................71
Sustainable Ocean Sound Levels....................72
Maximum Standard” Anthropogenic Ocean Sound Recommended by Expert Scientists....................74

Combining Publication Variable Analysis with the Internet Survey Variable Analysis. 77
Logistic Regression Results 77
Recommended Criteria 95
Not enough Information to suggest criteria” 96
Chapter 5. Risk Characterization. 98
On the Fraction of Non-Participation 101
Discussion 104
From a Socio-Governance Perspective 108
Social Construct 108
On Governance 110
Weaknesses of the Study 113
Closing Thoughts 114
Appendix A Species reported in 94 selected publications and 91 Internet survey responses 117
Appendix B Publication Variables by Numeric Code 119
Appendix C Published research content variables 125
Appendix D Letters of Invitation (to participate in Internet Survey) 128
Appendix E Anthropogenic Ocean Sound Survey Questionnaire 131
Appendix F Survey Comments by question number 140
Appendix G Logistic Regression Analyses (SAS) arranged by Acoustic Groupings: a. Publication data analysis; b. Survey “Sustainable” data analysis, and; c. “Maximum Standard” data analysis 165
G.1. Small Odontocete 165
G.2. Medium and Large Odontocetes 170
G.3. Mysticetes 175
G.4. Other unspecified cetaceans, marine animals 180
G.5. Fish 183
G.6. Total (All Species) 188
Appendix H: NMFS proposed exposure criteria management guidelines 193
Appendix I. Benders et al., (2005). Model for the ‘Identification & Registration of Marine Animals’ (I RMA) 200
Bibliography 201

LIST OF TABLES

Table 1. Acoustic Criterion for Each of the Proposed Alternatives (NMFS 2004) ... 45
Table 2. Selection of peer-reviewed publications and expert scientists ... 63
Table 3. Captive animals' observed behaviors resulting from SL dB P-P n=10 publications representing 25 animal observations ... 67
Table 4. Free-ranging observed behaviors resulting from SL dB P-P anthropogenic sound, n=17 publications representing >1486 animals ... 68
Table 5. Free-ranging observed behaviors resulting from RL dB P-P Anthropogenic sound, n=18 publications representing > 1356 animals ... 68
Table 6. Two-sample Kolmogorov-Smirnov tests of similarity between Captive animal Source Level data (CSL) and Free-ranging Source Level data (FRSL) ... 70
Table 7. Two-sample Kolmogorov-Smirnov tests of similarity between Source Levels and Received Levels on free-ranging animals only ... 71
Table 8. Two-sample Kolmogorov-Smirnov tests of similarity between Captive Source Level (CSL) data and Free-Ranging Received Level (FRRL) data ... 71
Table 9. Survey questions 14-16 on Sustainability ... 73
Table 10. Weighted data for "Sustainable" sound level ... 73
Table 11. "Maximum Standard" criterion recommended for sustainability survey results by NMFS Acoustic Groupings, RL dB P-P, N=102 ... 75
Table 12. Weighted data for "Maximum Standard" recommended criteria ... 76
Table 13. Small Odontocete Publication Logistic Regression Analysis ... 77
Table 14. Small Odontocete "Sustainable" Logistic Regression Analysis ... 78
Table 15. Small Odontocete "Maximum Standard" Logistic Regression Analysis ... 78
Table 16. Medium and Large Odontocete Publication Logistic Regression Analysis ... 80
Table 17. Medium and Large Odontocete "Sustainable" Logistic Regression Analysis ... 81
Table 18. Medium and Large Odontocete "Maximum Standard" Logistic Regression Analysis ... 81
Table 19. Mysticete Publication Logistic Regression Analysis ... 83
Table 20. Mysticete "Sustainable" Logistic Regression Analysis ... 83
Table 21. Mysticete "Maximum Standard" Logistic Regression Analysis ... 84
Table 22. Other "Sustainable" Logistic Regression Analysis ... 86
Table 23. Other "Maximum Standard" Logistic Regression Analysis ... 87
Table 24. Fish Publication Logistic Regression Analysis ... 89
Table 25. Fish "Sustainable" Logistic Regression Analysis ... 89
Table 26. Fish "Maximum Standard" Logistic Regression Analysis ... 89
Table 27. All Species Publication Logistic Regression Analysis ... 92
Table 28. All Species "Sustainable" Logistic Regression Analysis ... 92
Table 29. All Species "Maximum Standard" Logistic Regression Analysis ... 92
Table 30. Weighted Maximum Sound Levels dB P-P @ 1µPa by Acoustic

Grouping 95
Table 31. Parametric qualifiers as described in scientists' commentary (Appendix F Deemed necessary to accurately determine sustainable anthropogenic ocean sound criteria 96
Table 32. Survey response indicating scientific expertise 97
Table 33. Survey response indicating inability to recommend criteria 97
Table 34. Probability of the point below which the true threshold of anthropogenic ocean sound lies for free-ranging cetaceans based on observations of 1779 Animals 98
Table 35. "Maximum Standard" – Probability of the sound level above which Level A harassment is likely experienced by species studied, N=44 survey responses 98

LIST OF FIGURES

Figure 1. Captive Animals' Observed Behaviors Resulting from SL dB P-P n=11 Publications Representing 25 animals 68
Figure 2. Free-ranging observed behaviors resulting from SL dB pp anthropogenic sound, n=17 publications representing >1486 animals 69
Figure 3. Free-ranging observed behaviors resulting from RL dB pp Anthropogenic sound, n=18 publications representing > 1356 animals 69
Figure 4. "What lowest anthropogenic sound level range (re 1 μPa) do you think will have an unreasonable adverse effect of the long-term survival, growth, and reproduction of the cetacean or fish species that you have studied? N=95 74
Figure 5. "Maximum Standard" criterion recommended for sustainability survey results by NMFS Acoustic Groupings, RL dB P-P, N=102 76
Figure 6. Small Odontocete Publication data logistic curve 78
Figure 7. Small Odontocete "Sustainable" data logistic curve 79
Figure 8. Small Odontocete "Max Standard" data logistic curve 79
Figure 9. Small Odontocetes: Effect Odds Ratios and 95% Confidence Limits 80
Figure 10. Medium and Large Odontocetes Publication logistic curve 81
Figure 11. Medium and Large Odontocetes "Sustainable" logistic curve 82
Figure 12. Medium and Large Odontocetes "Maximum Standard" logistic curve for Medium and Large Odontocetes 82
Figure 13. Medium/Large Odontocetes: Effect Odds Ratios and 95% Confidence Limits 83
Figure 14. Mysticetes Publication logistic curve for 84
Figure 15. Mysticetes "Sustainable" logistic curve 85
Figure 16. Mysticetes "Maximum Sustainable" logistic curve 85
Figure 17. Mysticetes: Effect Odds Ratios and 95% Confidence Limits 86
Figure 18. Other "Sustainable" logistic curve 87
Figure 19. Other "Maximum Standard" logistic curve 88
Figure 20. Other: Effect Odds Ratios and 95% Confidence Limits 88
Figure 21. Fish Publication logistic curve 90
Figure 22. Fish "Sustainable" logistic curve 90
Figure 23. Fish "Maximum Standard" logistic curve 91
Figure 24. Fish: Effect Odds Ratios and 95% Confidence Limits 91
Figure 25. All Species Publication logistic curve 93
Figure 26. All Species "Sustainable" logistic curve 93
Figure 27. All Species "Maximum Standard" logistic curve 94
Figure 28. All Species: Effect Odds Ratios and 95% Confidence Limits 94

Introduction

> *"The point, in a certain sense, is the derivation of the properties of a phenomenon, and is an art that requires a bit of practice…to get an idea of what kinds of things are involved in physics problems. Some problems are more elaborate than others and in order to set up any of the laws of physics it is important to understand as well as possible more or less how things work. It's about the relationships of a phenomenon in one place to a phenomenon in another. The secret of all these things is to get what might be called a feeling for a phenomenon. This important aspect is usually forgotten when we read the book."*
>
> *Richard Feynman, Caltech 1962*

The evolution of scientific methodologies toward assessing the risk to ecological systems from human encroachment when uncertainty[1] is high is expanding to include combining empirical data analysis using methods such as meta-analysis with qualitative processes such as expert judgment (IPCC, 2007) when creating models for natural resource management. Quantifying and aggregating experts' interpretation of empirical data is believed to provide important input to decision makers justifying 'optimally defensible' choices of parameters and models in chemical plants and nuclear power plants (Cooke & Goossens, 2004). The application of qualitative risk assessment methodologies was shown to improve fisheries management in Western Australia (Fletcher, 2005); and the "Ecological Risk

1 The IPCC (2007) has classified uncertainty in several different ways according to it's origin. Two primary types are 'value uncertainties' and 'structural uncertainties'. Value uncertainties arise from the incomplete determination of particular values or results, for example, when data are inaccurate or not fully representative of the phenomenon of interest. Structural uncertainties arise from an incomplete understanding of the processes that control particular values or results, for example, when the conceptual framework or model used for analysis does not include all the relevant processes or relationships. Value uncertainties are generally estimated using statistical techniques and expressed probabilistically. Structural uncertainties are generally described by giving the authors' collective judgment of their confidence in the correctness of a result. In both cases, estimating uncertainties is intrinsically about describing the limits to knowledge and for this reason involves expert judgment about the state of that knowledge. A different type of uncertainty arises in systems that are either chaotic or not fully deterministic in nature and this also limits our ability to project all aspects of climate change (or other phenomena).

Assessment for Effects of Fishing Methodology" by the Australian Fisheries Management Authority begins its hierarchical approach largely with qualitative analysis of risk (Hobday et al., 2007).

This dissertation effort focuses on the marine acoustics discipline specific to cetaceans and fish, and presents a process-oriented approach to identifying how expert scientists interpret their empirical data on the effects that anthropogenic sound[2] may have on the sustainability[3] of these and potentially other marine biota for the purpose of guiding natural resource policy when uncertainty is high. Methods include meta-analyses of variables mined from peer-reviewed literature and the quantitative analysis of results of an Internet survey questionnaire delivered to the authors of that literature in an effort to ascertain how an international scientific community of experts view the impacts from anthropogenic ocean sound based on the best available science and professional scientific knowledge.

Professional-judgment approaches rely on the expertise of the scientists who generally make up expert (elite) panels, and in this case the panel consists of the 91 out of 119 scientists who are the authors of the 94 relevant peer-reviewed

---

2 This document has adopted the term 'sound' and not 'noise' in an effort to satisfy the broader community of physicists. Noise is a particular subset of sound, one which corresponds to a sort of irregular vibration of the eardrum that is produced by the irregular vibration of some object, the sound source (Feynman, 1966), and is not characteristically inclusive of all anthropogenic ocean sounds.

3 Elisabeth Mann Borgese's approach to sustainability (Pacem in Maribus, 1972) is defined as the evolution of nonviolent interdisciplinary governance accountable to multiple levels of human organization, guided by global human material equity, and supported by productive ecologies. Common use of the term "sustainability" began with the 1987 publication of the World Commission on Environment and Development report, Our Common Future. Also known as the Brundtland Report, this document defined sustainable development as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs." http://www.epa.gov/sustainability/index.htm.

publications included in this study[4]. Their publications relate changes in measures of the effecter (sound) to changes in observed behaviors of the species they study. The United States Environmental Protection Agency (USEPA) considers professional-judgment linkages between measures of effect and assessment end points as just as credible as empirical or process-based expressions, provided they have a sound scientific basis (USEPA, 1992a). The premise that expert scientists are better informed by the science is the basis from which professional-judgment extrapolations can be made between species, from laboratory data to field effects, and between geographic areas. When databases are inadequate to support empirical models and process models are unavailable or inappropriate, expert judgment helps fill the gap in assisting in decision making.

Although other stakeholder groups are instrumental in natural resource management problem formulations, priorities central to economic (in this case, commerce related to international trade via shipping, and oil exploitation) and political strategies (including defense via NATO sonar exercises) seem to influence outcomes which may be based on limited pure or natural science toward ecosystem approaches to ecological sustainability. This circumstance is particularly true when there are few scientific data, gaps in scientific data, inconsistent scientific data, and broad variations among observations resulting in apparent substantial uncertainty. In the case of anthropogenic ocean sound one consequence of that uncertainty, by default, is the persistence of the highly disputed NMFS 10-year status quo criterion of

4 Although all of these 94 publications were not specifically designed to address how anthropogenic sound affects cetaceans and fish, their basic research objectives were specific to cetacean and fish bioacoustics (see Appendix B) and served to identify experts in cetacean and fish bioacoustics research.

180 decibels (dB) root mean square (rms) re 1μPa[5], a criterion based on threshold shift data, determined through experiments on two captive odontocete species; 8 individual captive bottlenose dolphins and 2 individual captive beluga whales[6]. This criterion is disputed partially because data from threshold shift experiments using captive odontocetes are applied to open ocean criteria, which, in many cases, has resulted in measurable dissimilar effects on free-ranging cetacean species. This finding has also prompted concerns about potential effects to most marine mammal species, and other marine biota on which the effect of anthropogenic sound is largely unknown.

This dissertation sketches a collaborative framework across the disciplines of sociology, government and policy, and marine biology within the University of Maryland, and over a representative distribution of expert scientists across nations, habitats, and species. This project models an international (blind) interface instrument among the world authorities on cetacean bioacoustics for a general approach to measuring which levels of anthropogenic ocean sound expert scientists believe constitute impact to the species they study, what limits of exposure they believe are most likely sustainable for those species, and what exposure criteria they

5 Decibels are used to describe the ratio (on a logarithmic scale) between two quantities, in this case, the ratio of a received pressure level (RL) to the reference level 1 microPascal (μPa) rms (root mean square). "re"= "with reference to." This document will henceforth omit the "re 1 μPa" notation when referring to decibel levels measured in water. The in-air standard is referenced to 20 μPa and was chosen so that the threshold of hearing for a human with normal hearing would correspond to 0 dB at a frequency of 1000Hz (Chapman and Ellis, 1998) (the beginning of the mid-frequency range, which corresponds approximately to the second B above middle C on a piano; normal human conversation generally occurs at ~ 60 dB re 20 μPa.). The same sound pressure that acousticians label 0 decibels in air would be labeled 26 decibels in water (ANSI, 1969).

6 Finneran, J.J., and Houser, D.S., As reported at the US Navy Undersea Warfare Training Range proposal public hearing, November 2005, Chincoteague Island, VA (Truett, pers. observation).

recommend in developing sustainable global ocean policy regarding cetaceans and fish.

There are two hypotheses considered in this dissertation (as stated on pages 51 and 52) related to determining how anthropogenic sound effects cetaceans. Both hypotheses are based on considering empirical data and expert judgment. The first relates the functional relationship or a measure of association between cetacean behavior and anthropogenic ocean sound. The dependent variable in this study is described as the effect (outcome) behavior of observed cetaceans and fish (otherwise described as level of impact, disturbance, or harassment), and the independent variable is the anthropogenic sound level. The second hypothesis relates to the distribution characteristics of sound level data sets which have been published on captive animals, as compared to similar data sets which have been published on free ranging animals. This methodology combines quantitative analysis of empirical data sets with the qualitative interpretation of those data by the expert scientists who published them.

There are other hypotheses related to my data from variables not addressed at this time and from the aspect of the social/political sciences and I have included some information from those forthcoming papers within the context of this dissertation.

Chapter I. Ecological Risk and Protective Policy

Ecological risk assessment "evaluates the likelihood that adverse ecological effects may occur or are occurring as a result of exposure to one or more stressors" (USEPA, 1992a). Ecological effect characterizations evaluate stressor- response relationships or evidence that exposure to stressors causes an observed response. The current USEPA definition of stressor is "any physical, chemical, or biological entity that can induce an adverse response," in the species observed. The nature of any environmental stressor influences the types of analyses conducted.

An example, physical stressors resulting from the initial disturbance to biota from anthropogenic ocean sound, in the case of beaked whales, are clear, and in terms of risk are considered a primary effect on the "assessment endpoint" (e.g., strandings and death). There is, however, a growing concern about the sub-lethal, long-term, or secondary, effects, or a decline of populations of any animal that depends on acoustical perception as their primary sensor (for example, see MMC, NRC, NRDC). Exposure analyses should emphasize co-occurrence with associated physical stressors rather than direct contact alone. (e.g., 1. any form of startle behavior in the animal causing rapid changes in atmospheric pressures, such as ascent from normal depth limits, could cause physiological problems; and 2. species which are important food sources may abandon habitats, become increasingly vulnerable to predators or other niche/ecological pressures, unable to locate prey species or conspecifics, or otherwise be negatively effected, thus resulting in a ripple effect). For ecological stressors on the habitat or food sources, exposure analysis is an evaluation of sound field entry, and impacts measured through dispersal, survival, and reproduction (Orr et al., 1993).

Because marine acoustical stressors have become an increasing trend over time, database transparency is essential for greater certainty and management of risk. But when exposures and effects cannot be sufficiently quantified with confidence, risk may be assessed qualitatively based on professional judgments resulting from the best available science (Simberloff and Alexander, 1994).

Although routine risk assessments include quantitative data, quantifying risk is not always possible. When quantitative analyses are limited, it is better to convey conclusions (and associated uncertainties) qualitatively than to ignore them because they are neither easily understood or estimated, nor can be described by a system of numeric calculations and results (USEPA, 1998).

In addition to single-species tests, laboratory-based multiple-species tests are sometimes used to predict field effects. While these tests have the advantage of evaluating some aspects of real ecological systems, they also have inherent scale limitations (e.g., lack of ability of animals to escape the sound, or the animals' expectation of food rewards for tolerance, possibly leading to habituation, or disturbances to social structures or neonate care, etc.). Therefore, laboratory studies may not adequately represent features of the field system important to free ranging populations.

This study addresses these limitations utilizing two approaches; 1. the selection and analysis of variables common to the 94 peer-reviewed publications specific to ocean sound and cetaceans or fish; and, 2. distribution of a blind Internet survey to authors of the publications designed for interpretation of how these expert scientists view their data in terms of ecological risk of anthropogenic sound to the species that they study. In addition to descriptive parameters, three statistical functions were used for analysis within and between the resulting data sets; standard meta-analysis, the Kolmogorov-Smirnov two-sample test, and logistic regression. Therefore, a broad representation of all lines of evidence is represented in the publications selected and the Internet survey participation for this study.

The Marine Mammal Protection Act

The Marine Mammal Protection Act (MMPA), originally enacted in 1972, was amended with the objective to protect marine mammal species and population stocks from harmful human activities. The original rationale of the Act was to reverse the declining populations of whales as a result of the whaling industry, and the intent of the Act was to facilitate a "Zero Mortality Rate Goal" toward global ocean sustainability of marine mammals (MMPA 1972). In 1988, re-authorization proposals included a Marine Mammal Exemption Program that allowed the accidental "take" of marine mammals during fisheries operations. By 1995 the re-authorizations required the National Marine Fisheries Service (NMFS) to make annual reports of marine mammal mortality rates from fisheries operations, aimed at management based on a "Potential Biological Removal" of cetaceans which would result in an "Optimal Sustainable Population" or the number of animals that will result in maximum productivity of the species. By defining and regulating human activities described in terms of "impact" and "harassment" of marine mammals using standards which were believed functional for scientists and policy makers alike, it was assumed that a basis for sustainability could be achieved (Hofman, R.J. 2003 pers com.).

However, with a growing exploitation of the oceans and new modes[7] of anthropogenic impacts to marine biota, legislators, regulators, and other policy-making administrators necessarily turn to elite scientific communities to guide the development of new policy and management strategies which are believed to promote ecological balance of living marine resources.

In many cases, however, uncertainties that result from measurement and estimation error, model miss-specification and general lack of data diminishes statistical confidence (Harwood, 2000) in what scientists might recommend to managers in meeting their needs. Legislators press scientists to produce discrete criteria, but in many cases of field research criteria are derived from sparse data. To construct such a recommendation requires a translation from what the data *are* to what the data *mean*, an "organizational distance" (Underdal, 2000) over which effective communication strategies toward policy outcomes appear substantial, as found in the issue of anthropogenic ocean sound. Scientists making concrete policy recommendations which are represented as "scientific consensus" is an enterprise which seems inconsistent with the broader character of science and scientists due to their propensity to insist on high confidence of the correctness of their findings.

Potential impacts of anthropogenic ocean sound on marine mammals has been a topic of ongoing, intense debate both within the scientific community and among other stakeholder (economic and political) groups. Establishing an understanding of how cetaceans and fish are affected by and respond to human-induced rapid changes

7 Within the context of ocean sound, these may fall under the broader subset of pure science, commerce, homeland security, and minerals exploration, among others. For more information on the history of ocean sound, see McCarthy (2004), International Regulation of Underwater Sound: Establishing Rules and Standards to Address Ocean Noise Pollution.

in their environment, particularly regarding sound which is presumably the primary sensory modality in cetaceans (and possibly fish) is not trivial, although scientific uncertainty can usually be reduced by taking additional measurements and properly designed studies that will specify sample sizes large enough to detect important signals. Unfortunately, many studies have sample sizes that are too small to detect anything but gross changes (Smith and Shugart, 1994; Peterman, 1990). The controversy highlights situations (e.g., in free-ranging populations) where the power to detect difference is low, which seems to be in most cases of observing a species that is, for most of the time, unobservable (as are "proprietary" data sets). Meta-analysis[8] is one option to combine results from different studies to improve the ability to detect effects (Laird and Mosteller, 1990; Petitti, 1994), and has been applied to sound level variables and animal behavioral responses as reported in the publications reviewed for this dissertation.

Inherent variability among the published literature and their respective outcomes are likely due to a wide range of physical, spatial, and temporal characteristics of sound in the ocean (Mercado & Frazer, 1999; Pickard & Emery, 1996; Urick, 1983), a spectrum of hearing mechanisms and habitat preferences among different species of cetaceans (Ketten, 2000), opportunities for study, especially for free ranging animals, as well as substantial differences in research methodologies (Mann, 1999; Feyerabend, 2000). Many cetacean behavioral studies

8 In reviewing literature to determine the impact of a particular variable of interest one often finds a sizeable number of studies with a range of results, performed with different subjects, under a variety of conditions, and executed with varying degrees of expertise. Meta-analysis is the single best method to distill the essence of accumulated research findings (Isaac & Michael, 1997).

used methodologies viewed as unreliable, such as the *ad libitum*[9] method (Mann, 1999), and all of them include an impressive list of statistical applications, but reflect substantial variances in observed impacts to cetaceans from anthropogenic sound. Such variances among similar studies hinder meaningful comparisons among research projects and suggests an incommensurability that diminishes the applicability of results of one study to another based strictly on the content of the publication. All of these above described elements have contributed to the high degree of uncertainty from existing research results and conclusions about how sound ultimately affects cetaceans, their prey species, and their ecology, and for which the Internet survey may have parametrically defined data interpretation in the characterization of risk.

Individual interpretations of data may vary because of assumptions which may or may not be stated, realized, or considered. Assumptions, or supposition that something is true (Websters, 1983), are routine in reductionism, however, multiple interpretations of data result when various assumptive clusters (e.g. sets of ideas that inform our thoughts and actions) are viewed through different cultures or communities of humans (Brookfield, 1995). Discussions among scientists regarding levels of anthropogenic ocean sound seems to be rooted in extrapolations based on assumptions and how groups of individuals perceive or view which consequences of impacts from various sound levels are or are not acceptable (NMFS, 2000). Further debate stems from how the assumptions or groups of assumptions and accompanying extrapolations are made by either the scientists or regulators regarding sound and

9 Freely; at liberty; improvised.

whether the basis of impact should be to either individual marine mammals, species, populations, or ecosystems (NOAA, 2005; NMFS, 2005). There is significant uncertainty regarding all of these assumptions which arise from substantial data gaps. Therefore assumptions and assumptive clusters must be clearly stated, recognized, and accounted for if the research is to provide guidance. Further, if certain assumption clusters are adopted by focus groups or research teams, then the acceptance of these assumptions as truth likely increases and, in cases of uncertainty, are frequently extrapolated. Extrapolations such as these may diminish the instinctive reasoning that the assumptions being made may not fit the situation[10]. Such multiple interpretations are apparent in the case of impacts of anthropogenic sound on cetaceans and their habitats, which continues to fuel the debate (NMFS, 2005).

Historically, the competitive atmosphere within most ecological and behavioral sciences did not promote broad collaborative data sharing, presumably at least partially due to funding sponsorships and/or employment contract priorities and mandates. Each Principal Investigator manages the projects and the requisite publications ensue. But the data collected remain, for the most part, isolate. Open databases are, however, now being proposed among agencies, universities and researchers who seem to embrace this cooperative effort, a trend which is at least partially apparent in this case study. Leadership is implied within each project and is measured by different criteria among institutions including the governmental and economic sectors. The United Nations Convention on the Law of the Sea (UNCLOS,

10 One of the earliest records of a science/policy interface occurred in 343B.C. when, in Mieza's Gardens of Midas, Aristotle mentored 13 year old Alexander the Great, to, "…Make no assumptions – every situation is different. Organize and analyze the facts before drawing conclusions." (mpt.org/mpt/alexander/).

1983) provides a basis for governing science in the oceans, but not an explicit scientific basis for governing the oceans (Boesch, 1999; NMFS, 2006). As the potential for leadership within the scientific community emerges, there is evidence that the motivation to engage policy is increasing, and is measured through this dissertation.

The Bureaucracy: "Harassment" Redefined

The National Defense Authorization Act, enacted in November 2003, with the help of the expert scientific community, provided two definitions of marine mammal harassment for ''military readiness activities'' and ''scientific research activities conducted by or on behalf of the Federal government consistent with section 104 (c)(3)'' of the MMPA (1972). The first definition, termed Level A harassment, specifies (i) any act that injures or has the significant potential to injure a marine mammal or marine mammal stock in the wild. The second level, termed Level B harassment, specifies (ii) any act that disturbs or is likely to disturb a marine mammal or marine mammal stock in the wild by causing disruption of natural behavioral patterns, including, but not limited to, migration, surfacing, nursing, breeding, feeding, or sheltering, to a point where such behavioral patterns are abandoned or significantly altered (MMPA reauthorization, 2005). The Endangered Species Act (ESA) (ESA 1973) defines "take" as "to harass, harm, pursue, hunt, shoot, wound, kill, trap, capture, or collect, or to attempt to engage in any such conduct." Anthropogenic ocean sound is one such impact now known to impart disturbances described as harassment by the MMPA.

As of the time of this writing the original 1996 High Energy Seismic Survey (HESS) team and current NMFS Level A impact maximum standard criterion of 180 dB rms is under review and new criteria are in development by the NOAA. Although domestic and international regulatory, legislative, and judicial bodies have been involved in the evolution of the criteria development (Buck, 2005), the objective of establishing criteria for protective policy seems to have become blurred/overshadowed by a parallel objective of streamlining the policy and legal processes for impact exemption authorizations. This process has become a point of contention and antagonism related to this issue by a number of marine mammal scientists, non-governmental organizations, Departments of Defense, oil and gas exploration regulators, and in some cases, the shipping industry (commerce). The contention is reported to be due to a time lag from stakeholder application prior to activity commencement (seismic exploration, NATO exercises, commercial fisheries, scientific study, etc.) to the eventual issuance of exemption authorization by NMFS. This delay is due to legal requirements that NOAA inform the public and conduct environmental analysis under NEPA, ESA, and MMPA prior to issuing the authorization to incidentally take marine mammals (Steve Leathery, NMFS, pers. comm. 2006; MMC Advisory Committee Scientific Research Caucus Statement (MMC, 2006)). Any further adjustments in the sound criteria may further congest the bureaucracy, thus delaying time sensitive and economically important projects.

Professional Judgment

Professional scientific knowledge leading to professional opinion and judgment can be defined as “the capacity to synthesize vast and diffuse information that more or less clearly bears on the problem at hand in such a way that no element or set of elements is given undue importance" (Elster, 1983, as quoted from Malnes, 2006). Leadership by virtue of professional judgment includes the capacity of seeing things in a way, which afterwards proves to be true, even though it cannot be established at the moment, and of grasping the essential facts, discarding the unessential (Schumeter, 1934, cited in Skodvin & Andresen, 2006; Feynman, 1962). Truth is a more general superset of fact. Fact might be described as explicit measurements about the world which are true and can be directly verified as true. Truth, on the other hand, might be defined as the practice or value or ethic of stating facts truthfully, or the practice of not miss-representing facts.

But when called to advise on policy, scientists' recommendations are frequently overwhelmed by economic and political considerations (Boesch, 1999), where scientists are expected to inform politicians in a simple manner that can be readily understood, but the message must always be scientifically exact (Bolin, 1994a quoted from Malnes, 2006), and scientists must give a best estimate of the detail of risk that one would prefer to assess only in general terms (Houghton, 1990, as quoted in Malnes, 2006).

The Concerns of Scientists Regarding Ocean Sound

The current Alternative I (status quo) standard of 180 dB rms for Level A Harassment developed by the National Marine Fisheries Service (NMFS) (Appendix E) is now being challenged so aggressively through litigation by stakeholder groups (Natural Resources Defense Council, (NRDC) 2005) as a maximum standard which evidence suggests is not ecologically sustainable that the current stakeholder “consensus” is that exemptions will be granted, indefinitely, on a case-by-case basis (NRDC 2006), and for which science had been called into question. The NMFS states that the new criteria are being developed after careful consideration of current data and MMC Scientific Advisory Committee opinion, although after two years of stakeholder workshops and meetings the final statement by the Committee fell short of providing a maximum standard criterion, or any criteria. The existing proposed matrix (Appendix H) was generated from NMFS (Southall, 2006). However, concerns have been raised by other marine mammal scientists, many of whom are involved in acoustics research (NMFS, 2005). These include concerns related to the level of detail and accuracy the science must have before confidence can be achieved in recommending criteria; that the MMC “expert panel” is too small, is not representative of the wider marine mammal scientific community, and was not randomly selected from the population of cetacean scientists working within the marine acoustics discipline.

The following is a summary of a few of the questions and concerns which were raised and registered in Scoping Reports for the National Marine Fisheries Service, including those for the Environmental Impact Statement (EIS) for National Acoustic Guidelines on Marine Mammals, compiled in May, 2005 (NMFS, 2005):

1. Physics of sound must be standardized, such as when considering sound effects as it incorporates time, direction, and proximity.
2. Ecological sustainability depends on management decisions being made on an ecosystem basis. Doing so includes calculating synergistic and cumulative affects on all species. When such measures are not available,

acoustics matrices must include cumulative data from broad resources. In this case, these would include the spatial and temporal aspects of auditory, behavioral, and physiological variables using minimal inter-variable extrapolations.

3. Populations and social parameters of species must be factored into criteria development, such as energy-flux density[11] levels exposures of single adult captive specimens as compared to free ranging mother-calf pairs.

4. Effects of masking must be included.

5. Transparency is not evident within the scientific community or between the scientists and the policy making institution. At least some scientists believe that there is substantial bias away from the science in determining ocean sound criteria.

6. Human social dynamics must be standardized, such as for names, affiliations and research funding support sources for scientific advisory committees, and how the committee will interact with other policy forming agencies to provide sound criteria.

7. Limiting factor seems to be based on economics, not long term sustainability.

In summary, over the past ten years the perceived problems associated with this issue include; a) the maximum standard for anthropogenic ocean sound which is most likely sustainable cannot be determined with confidence due to data gaps and uncertainty in the scientific community, and scientists and policy makers do not agree

11 Energy flux density is the time integral of the instantaneous intensity. Units are ergs per square centimeter (Urick,1983).

on which maximum standard is sustainable for any given species in diverse habitats which remain largely unidentified; b) the process of determining sustainable anthropogenic ocean sound which has been implemented by policy makers is not satisfactory among broader stakeholders, much less within the scientific community; and c) the perception that a lack of funding results in a lack of data, and issues related to transparency impedes open communications, expanded research, and integrated databases in affecting sustainable ocean sound management.

Scholars of environmental governance propose that efforts toward cooperation for global or international resource management are not optimally productive when the numbers of participants are inappropriate for the task, such as those involved in the UNFCCC[12] (and UNCLOS III[13] (Miles, 2006)) where the number of actors may be too great. Nor can it easily arise from other available forums with too few actors, such as the G8[14], because their membership is too skewed (Victor, 2006). Former Canadian Prime Minister Paul Martin suggests that a forum of leaders from twenty key countries (L20[15]) is likely to offer the best chance of establishing international policy acceptable to most (Martin, 2005, as cited in Victor, 2006). This dissertation measuring professional judgment of anthropogenic ocean sound provided venue to 119 scientists representative of 20 countries for which ocean sound research has been published. Methods adopted by my study serve to quantify expert judgment which may help compensate for the ambiguities, account for assumptions, and minimize or

12 United Nations Framework Convention on Climate Change includes 196 countries.

13 United Nations Convention on the Law of the Sea includes 152 parties.

14 Group of Eight countries are France, United States, United Kingdom, Russia (as of 2006), Germany, Japan, Italy and Canada.

15 Leaders-20, www.l20.org

negate the incommensurability currently found among the existing published findings.

Chapter 2. History and Literature Review

The conflict

The current issue regarding ocean sound and any related ecological impacts began after several cetacean stranding incidents which seemed to coincide with anthropogenic ocean sound events such as those associated with military sonar exercises and seismic surveys, which occurred after enacting the MMPA in 1972. These incidents include cetacean strandings in the Canary Islands, Spain in 1985, 1988, 1989, and 1991 and resulted in the suggestion that there could be a military connection (Simmonds and Lopez-Juraco, 1991; Frantzis, 1998).

Public awareness of the issue escalated in January 1991 with The Heard Island Feasibility Test (HIFT) in the southern Indian Ocean. The Defense Department's Advanced Research Projects Agency (DARPA) funded the HIFT, which was intended to establish the limits of usable, long-range acoustic transmissions, and possibly could be applied to measuring changes in ocean temperature associated with global warming. A high-intensity, low-frequency[16] (tens to hundreds of Hz) sound (source pressure level (SPL) of 221 dB rms with a center frequency of 57 Hz @1 meter) was introduced into the deep sound (SOFAR[17]) channel near Heard Island in the southern Indian Ocean and was detected at 19 monitoring sites located on various research vessels over thousands of kilometers throughout the oceans as well as on the coasts of South Africa, Bermuda, India, Christmas Island, Samoa, Tasmania and California (Munk et al., 1994). Although there was no evidence of distress in the

16 Conventional science defines frequency ranges of sound as: low <1kHz, mid = 1-10kHz, and high > 10kHz (ANSI, 1969).

17 **SO**und **F**ixing **A**nd **R**anging – the SOFAR channel usually occurs at mid-latitude depths around 1200 meters and is a layer in which sound travels more slowly and transmission is unusually efficient for long distances. Sounds leaving this depth tend to be refracted back into it (Garrison, 2005).

local marine mammal population (as observed within 1 km of the source ship at transmission start time) in response to the acoustic transmissions (Bowles et al., 1994), the broad scope, potential use, and huge geographic regions affected by transmissions of this type, together with the aforementioned observed effects of noise on marine mammals escalated the debate over the potential impacts of human generated ocean sound.

The debate continued when, in 1992, scientists from the Acoustic Thermometry of Ocean Climate Program (ATOC) (later the North Pacific Acoustic Laboratory – NPAL) anticipated that basin-scale (entire ocean) measurements of the travel times of high intensity (195 dB) low-frequency sound (mainly 60-75 Hz) would be generated at depths of about 900 m over long-distance undersea pathways such as the SOFAR channel (NRC, 2000). By utilizing the SOFAR channel for ATOC transmissions from the Pioneer Seamount and Kauai to receivers in different parts of the Pacific Ocean, scientists could provide important information for determining if global oceans, the earth's main heat sink, are warming (Mulroy, 1991; NRC, 2000). However, these sound transmissions could negatively impact the lives of cetaceans, and have the potential for causing biologically significant effects and physiological stress to marine biota (NRC, 2005).

Other anthropogenic ocean sound events continued through activities carried out by the defense department such as in ship shock trials. In 1994 the USS John Paul Jones was involved in the detonation of up to 4500 kilograms of explosives to test the survivability of military ships to underwater explosions (Richardson et al., 1995). Again, the potential for injury to marine life was highlighted and the debate continued.

Concern substantially escalated about the potential effects of military operations on cetacean behavior and physiology with particular reference to the coincidence of their mass stranding concurrent with or following naval maneuvers when twelve whales stranded in Greece in 1996 (Frantzis, 1998). The Grecian episode, along with the total of twenty-four whales stranded in the Canary Islands on three occasions, and a previous four whales which stranded in the Lesser Antilles, established the coincidence of naval maneuvers around the time of the mass strandings (Van Bree and Kristensen, 1974), but cause and effect evidence is lacking as discussed by Balcomb & Claridge (2001).

As a consequence of events related to the ocean noise issues, in June 1996 a panel of nine experts in the fields of marine biology and acoustics sponsored by California's High Energy Seismic Source (HESS) Team convened at Pepperdine University and reached a consensus that not enough was known about marine mammal hearing and their responses to received levels greater than 180 dB rms. The panel determined that 180 dB rms should be identified as a safety zone for marine mammals in general. (http://www.surtass-lfa-eis.com/docs/180dBCriteria.pdf).

In July 1996, the Navy published in the *Federal Register* a notice on intent to prepare an environmental impact statement (EIS)[18] in accordance with the National

---

18 Environmental Impact Statement (EIS) - The EIS is used to document impacts of large and/or controversial projects where there are expected to be significant environmental changes produced. Impacts are defined as being significant based on scientific input, public controversy, or legal requirements. The EIS is intended to be a disclosure document, providing decision makers with a systematic evaluation of the environmental impacts of a full spectrum of practicable alternatives including the no

Environmental Policy Act (NEPA)[19], regarding planned worldwide deployment of a new low frequency active sonar system, Low Frequency Active - Surveillance Towed Array Sonar System, known as the SURTASS LFA[20] (http://www.surtass-lfa-eis.com/EIA/). The Navy received public comments on the proposal expressing concerns that not enough was known about the potential impacts of extreme sonar to marine biota to produce a reliable EIS. In response, the Navy provided support for a three phase experimental program, the Low Frequency Sound Scientific Research Program (LFS-SRP), to determine how representative marine mammals would respond to operation of the SURTASS LFA (Dept. of the Navy, 1999). One of the

---

action alternative. The Draft EIS describes all the alternatives being considered, and the expected impacts. Typically a preferred alternative is identified. The Draft EIS is circulated to the public for a minimum of 45 days. After the public review period is complete a Final EIS, which incorporates public input and response to questions raised by the public, is prepared. The Final EIS is circulated for comment for 30 days, after which the Record of Decision (ROD) is prepared. The ROD describes which alternative the agency has chosen to move forward on and why that decision was made. The ROD also identifies what mitigation will be implemented to compensate for the impacts of the proposed project.

19 The National Environmental Policy Act (NEPA) is the basic environmental protocol for the nation. NEPA is an umbrella statue that sets up a process to document potential environmental impacts (EIS) of proposed alternatives to help decision makers take environmental considerations into account in project selection. All Federal actions are subject to a NEPA review. NEPA also sets up a process to disclose information on the proposed project and solicit comments. Unlike other environmental laws, NEPA does not contain statues that help define project design. Rather, NEPA is a mechanism to identify and describe alternatives and their impacts, and possible ways to mitigate for those impacts. Every federal agency is required to have procedures for implementing NEPA.

20 SURTASS LFA sonar is a long-range, all-weather sonar system that operates in the low frequency (LF) band between 100 and 500 Hertz (Hz). It has both active and passive components. The active component of the system, LFA, is a set of 18 low frequency acoustic transmitting source elements (called projectors) suspended by cable from underneath a ship. The source level of an individual projector is 215 dB. These projectors produce the active sonar signal or ``ping." A ``ping," or transmission, can last between 6 and 100 seconds. The time between transmissions is typically 6 to 15 minutes. The average duty cycle (ratio of sound ``on" time to total time) is between 10 and 20 percent. The SURTASS LFA sonar signal is not a continuous tone, but rather a transmission of waveforms that vary in frequency and duration. The duration of each continuous frequency sound transmission is nominally 10 seconds or less. The signals are loud at the source, but levels diminish rapidly over the first kilometer. The passive, or listening, component of the system is SURTASS, which detects returning echoes from submerged objects, such as threat submarines, through the use of hydrophones on a receiving array that is towed behind the ship. The SURTASS LFA ship maintains a minimum speed of 5.6 kilometers (km) per hour (kph) (3 knots [kt]) through the water to tow the horizontal line hydrophone array (DOD Federal Register, 2002).

conclusions of the resulting EIS was that although critical issues about effects of sound on marine mammals and their habitats remain unanswered, under a set of proposed mitigation measures, such as geographic restrictions[21], monitoring mitigation[22], and ramp-up[23], there would be no significant adverse impacts on marine mammals as a consequence of the operational use of the SURTASS LFA (Dept. of the Navy, 2001). The EIS conclusion was based on a number of assumptions, one of these being that, based on the 1996 HESS expert panel consensus, exposure (received) levels below 180 dB rms posed zero risk of having biologically significant effects on any species or age-sex class of marine mammal (Hoffman, pers. comm. 2003).

In response to the above incidences, the Office of Naval Research (ONR) convened a workshop on the effects of anthropogenic noise in the marine environment and completed a report in June of 1999 (Dept. of Navy, 1999) calling for additional research. Then, in 2000, three beaked whales were found stranded in the Galapagos Islands within 500 km of the *Maurice Ewing,* a 2,000-tonne air-gun[24] vessel operated by Lamont-Doherty Earth Observatory at Columbia University, New

21 The geographic restrictions include limiting SURTASS LFA sonar received levels to not exceed 145 dB at known recreational or commercial diving sites; limiting SURTASS LFA sonar received levels to below 180 dB within 22 km (12 nm) of all coastlines (including islands) and in areas declared as Offshore Biologically Important Areas (OBIAs); and the use of sound pressure level (SPL) modeling to accurately gauge the 145 dB and 180 dB sound fields prior to commencing operations (DOD Federal Register, 2002).

22 The monitoring mitigation includes visual monitoring, the use of passive acoustic monitoring, and use of the high frequency marine mammal monitoring (HF/M3) sonar to detect marine mammals entering or within the 180-dB sound field (DOD Federal Register, 2002).

23 The startup of the HF/M3 sonar will involve a ramp-up from a low source level of approximately 180 dB to ensure there is no inadvertent exposure of local animals to received levels 180 dB and above (DOD Federal Register, 2002).

24 Also referred to as watergun. Seismic waterguns use compressed air to rapidly expel water from a water-filled chamber to generate a pressure wave toward the ocean floor. The water leaving the chamber creates a void behind it; the collapse of water into this void creates an acoustic signal (Finneran et al. , 2002b).

York (Dalton, 2003). On March 15 and 16, 2000, seventeen cetaceans of several species stranded in the Northeast and Northwest Providence Channels of the Bahamas Islands. Specimen samples were collected from four dead whales. Three whales revealed signs of bleeding in the inner ears and one whale had signs of bleeding around the brain (NOAA, 2001). An investigation team concluded that tactical mid-range frequency sonars (SPL up to 235 dB) aboard U.S. Navy ships that were in use during the sonar exercise in question were the most plausible source of the acoustic or impulse trauma experienced by the dead animals (NOAA, 2001).

In accordance with Civil L.R. 7-2, NRDC et al. (2002) challenged the NMFS approval of the exemption, challenging specifically, the Navy's central assumption that 180 dB rms is the minimum exposure level at which marine mammals will be injured (NRDC, 2002), yet on 15 July 2002, the U.S. National Marine Fisheries Service (NMFS) exempted the U.S. Navy's Low Frequency Active Sonar (LFAS) program from the requirements of the Marine Mammal Protection Act after determining that its operation would have a "negligible impact" on any species (Weiss, 2002). About ten weeks later, in September 2002, beaked whales stranded in La Paz, Baja Sur, Mexico in the Gulf of California (Dalton, 2003), and in the same month 15 Cuvier's beaked whales beached on the Canary Islands at the same time the U.S. destroyer *Mahan* was maneuvering in the area with ships from nine other members of the North Atlantic Treaty Organization (NATO)[25]. Autopsies of the

---

25 Nine Cuvier's beaked whales were found dead on 24–25 September 2002 on the Canary Islands of Fuerteventura and Lanzarote. Six beached whales were pushed back into the sea, and another two were seen floating lifeless in coastal waters. Ships from Belgium, Canada, France, Germany, Greece, Norway, Portugal, Turkey, the United Kingdom, and the United States were conducting a multinational exercise known as Neo Tapon 2002 designed to practice securing the Strait of Gibraltar. The Cuvier's beaked whale is a toothed cetacean that ranges from 5 to 8 meters in length. J. Socolovsky, "Investigation Points to

whales revealed brain damage consistent with an acoustic impact (Andre, 2002). On October 31, 2002, the U.S. District Court issued the Opinion and Order Granting Plaintiffs' Motion for a Preliminary Injunction (NRDC, 2002), However, on May 5th, 2003, another stranding incident occurred in the Haro Strait near Vancouver Island[26] (NOAA, 2004; Dept. of the Navy, 2004; Vedder, 2003; McClure, 2003; Anderson, 2003). On November 24th, 2003, President Bush signed P.L. 108-136, the National Defense Authorization Act for FY 2004 amending the MMPA to exempt military readiness activities from "specified geographical region" and "small numbers" requirements (Buck, 2005). On July 3, 2004, as many as 150 melon-headed whales were observed swimming in a tight circle in the shallow waters of Hanalei Bay, Kauai, Hawaii, an event which was coincident with use of mid-frequency sonar by six naval vessels prior to the start of the biennial Rim of the Pacific (RIMPAC) naval exercise (US and Japan) (Southall et al., 2006).

On August 24, 2004 NOAA published a notice that two one-year Letters of Authorization had been issued to the U.S. Navy to take marine mammals by harassment incidental to operation of the SURTASS LFA sonar system (69 Fed. Reg.

NATO Exercise in Mass Whale Beaching," Associated Press, 10 October 2002, posted at the Web site of the Environmental News Network, http:/www.enn.com/news/wire-stories/2002/10/ 10102002/ap_4866.

26 On 5 May 2003, the U.S. Navy's guided-missile destroyer USS Shoup tested mid-range sonar for five hours in the Haro Strait near Vancouver Island, sending out pings louder than 200 dB, which caused a pod of 22 killer whales and a minke whale to stop their feeding and form into a tight group as far from the sound as possible and then flee the region. The dead carcasses of eight harbor porpoises washed ashore in the days after this test, and subsequent investigations indicated that they had suffered severe trauma to their brains. [http://www.nwr.noaa.gov/mmammals/cetaceans/necropsypage.htm]; [http://ww.cpf.navy.mil/archive/first_release.htn]; Tracy Vedder, "This Is Another Smoking Gun," KOMO TV, 8 August 2003, http://www.komotv.com/news/printstory.asp?id=26542 (accessed 11 July, 2005); Robert McClure, "Tests on Marine Mammals to Look for Sonar Link to Injuries,"
Seattle Post-Intelligencer, 12 July 2003, http://www.seattlepi.nwsource.com/local/ 130609_sonar12.html (accessed 11 July 2005); Peggy Anderson, "Did Navy Tests Kill Porpoises?" CBSNEWS.com, 23 July 2003, http://www.cbsnews.com/stories/ 2003/07/23/tech/main564700.shtml (accessed 11 July 2005).

51996-51998). Following that authorization, on Jan 15 & 16, 2005, at least 36 whales beached themselves and died along the North Carolina shore (Hohn et al, 2006), when on Jan 14 & 15 the USS Kearsarge Expeditionary Strike Group, based in Norfolk, was conducting an anti-submarine exercise about 240 nautical miles from Oregon Inlet. On March 2, 2005, about 80 rough-toothed dolphins, nearly 30 of which died, beached the same day that a nuclear-powered submarine used two different types of active sonar to navigate over several days as it trained approximately 39 nautical miles southwest of the Florida Keys (Babson, 2005).

Ocean Sound Science.

One of the earliest records that sound existed in the ocean was noted in 1490 by Leonardo da Vinci (Urick, 1983). Ambient[27] sound was first observed and measured by Knudsen in 1948, and again in 1962 by G.M. Wenz. Ambient sound in the sea has been steadily increasing, and is expected to continue to do so (Ross, 1993). Anthropogenic ocean sound began to escalate during the industrial revolution in the mid to late 1800's and the accompanying combustion engine development and ocean vessel activity. World War I advanced the need for submarine technologies and the development of acoustic listening devices, and following the war, use of these devices expanded into fisheries, navigation, and exploration (Urick, 1983). World War II resulted in a more sophisticated technology for searching out the depths by way of echo-ranging (sonar).

27 Ambient sound can be defined as the noise associated with the background din emanating from a myriad of unidentified sources. Its distinguishing features are that it is due to multiple sources. Individual sources are not identified (although the type of noise source – e.g., shipping, wind - may be known), and no one source dominates the received field (NRC, 2003).

The physics of how sound moves through the ocean is relatively well known, but the impacts of anthropogenic sound on oceanic biota are not [Sound is a consequence of Newton's laws (Feynman, 1962); it is a branch of mechanics and has properties that are functions of the media through which sound travels]. Sound is a pressure wave which propagates out from its source and is characterized by wavelength (γ), speed (c), and frequency (f), where γ=c/f. Wavelength is the distance between waves in meters (m); frequency is the rate of oscillation (Hz, where 1Hz = 1 oscillation/second); and speed is a function of the density (and corresponding elasticity) of the medium (m/s) (Feynman et al., 1966). The sound field can be described in terms of *motion* variables such as displacement, velocity, or acceleration (Hastings, 2003).

It is important to make the distinction between velocity and speed, where velocity has a direction associated with it (such as a vector), and speed is a magnitude of velocity in distance per unit time. Path characteristics include spherical spreading and cylindrical spreading, each with different propagation losses associated with them. There are also *state* variables which include temperature, density, and amplitude, a pressure measurement (in Pascals, or "Pa" which includes compression and rarefaction) that can be converted to a sound pressure level or loudness in decibels (dB) (Hastings, 2003).

Sound levels drop rapidly as sound waves spread over an increasingly larger area. For example, in spherical spreading of sound for each doubling of distance the sound travels can expect to lose 6 dB of sound. Sound levels are reduced as sound energy is absorbed by water[28], but the sound frequency is critical because higher frequencies attenuate faster than lower frequencies (Southall, 2004). Acoustic impedance (a ratio of pressure to flow, in terms of resistance) has important implications for (sound) energy transport because the phase relationship between pressure and particle velocity is analogous to the power factor in an electrical circuit and indicates the extent of cooperation between the "effort" (i.e., pressure) and the "flow" (velocity) (Finneran et al., 2002a). The relationship between pressure and particle velocity at a point in space may be described by a specific acoustic impedance ratio (Finneran et al., 2002a).

Exposure of biota to sound fields depend on source level, source frequency spectrum, sound propagation conditions, and the depths of the sound source and receiving animal (Dept. of the Navy, 1999). As in air, sound undergoes attenuation and degradation, but the properties of water allow sound to travel with several hundred times less attenuation than in air (Rundus & Hart, 2002), so the sound travels much farther and faster. On average, sound travels 340m/s in air, and about 4.4 times faster, or 1500m/s, in water (Garrison, 2005). There is some variation in the speed that sound travels in water depending on the physical properties of the water such as temperature, density, salinity, and compressibility, where the "stiffer" the medium, the faster the speed of sound.

Sound travels faster at the warm ocean surface than it does in deeper, cooler water, and its speed decreases with depth along the thermocline eventually reaching a

---

28 An interesting attribute of acoustic energy in water was demonstrated by Iida et al., (1991) by correlating phases of sound pressure with natural convection heat transfer augmentation ratios, where increased sound pressure resulted in a heat transfer augmentation ratio of 1.8.

minimum at about 1000 meters, where it forms a "duct" known as the SOFAR channel (Hastings, 2003) that serves to "bend" the slower sound back into the channel. This characteristic is thought to be utilized by some cetaceans in transoceanic vocalizations, and likewise serves as a conduit for anthropogenic sound. These physical properties were justification for Federal Magistrate Judge Elizabeth D. LaPorte's injunction decision against the U.S. Navy because, "The extremely loud and far traveling naval sonar system maintains its sound pressure level of approximately 140 dB more than 400 miles from the [transmitting] vessel" and covers broad areas (NRDC, 2002).

The distance sound travels depends on variables such as wavelength, in that longer wavelengths (low frequency) go farther, and shorter wavelengths (high frequency) are absorbed or attenuated. Reverberation and scattering/backscattering from sound striking bubbles or particulate matter results in increased distortion of sound over long distances (Bradbury & Vehrencamp, 1998), but is measurable and sometimes useful in identifying some bottom substrates. Backscattering has also been measured while apparently being used by orcas during hunting for Chinook salmon (Au, et al. 2004). The physical properties of the ocean, along with geographic and topographic features result in the characteristics and propagation of sound being substantially different than in air. As a consequence, the derivation and adaptation through the evolution of the cetacean anatomy and physiology is profound compared to other mammals.

Changes in the distribution and activity patterns of marine mammals in response to anthropogenic sounds, later considered 'taking by harassment' (Swartz and Hofman, 1991), led to extensive research and substantial funding by the U.S. Office of Naval Research and the U.S. Mineral Management Service, among others. Recently, sources and types of sound introduced into the ocean have been grouped into six categories: shipping (with vessel traffic a major contributor), seismic surveying, sonars, explosions, industrial activity, and miscellaneous (NRC 2003).

The Directions of Whale Research

From 1667 to about 1812, most of the research concerning whales was about where to fish for them (especially sperm whales), anatomical features and resources, and the most effective procedures for killing them. In 1948, Ogawa and Artifuku noted that the acoustic system in the brains of the Cetacea is very well developed, although based on their understanding of the differences between odontocetes and mysticetes they noted that extrapolations of data from one to the other "are not justified" (Ogawa et al., 1948). In 1952, Kellogg and Kohler of the Oceanographic Institute, Florida State University, Tallahassee, noted the reactions of the “porpoise” to ultrasonic frequencies (Kellogg et al.,1952), and in 1953 they, along with Morris, published work related to porpoise sounds as sonar signals (Kellogg et al.,1953). In the earlier years publications began to appear in scientific journals and reports on topics ranging from waxy plugs in the external auditory meatus of the mysticetes (Purves, 1955; Nishiwaki, 1957; Ichihara, 1959), to the acoustic behavior of dolphins and other animals (Lilly, 1961[29]; Busnel, 1963; Schevill, 1964; Caldwell, et al.

29 While lifting an injured dolphin into a tank, John Lilly noted “the distress call, a crescendo-decrescendo gave rise to our suspicions that these animals have a very complex language and know how to use it for descriptive and predictive purposes.” (Lilly, 1961).

1965[30]), and the physiology of diving mammals (Elsner et al.,1964; Krogh, 1965; Ridgway, 1966). Auditory threshold data for the bottlenosed porpoise (*T. truncatus*) data from the U.S. Naval Ordinance Test Station was published by Scott Johnson in 1966, and the effects of stress upon the social distance in dolphins was recognized in 1968 by Richard Maier (Johnson, 1966; Maier, 1968). Also in 1968, from the journal *Zoologiskrevy*, an article appeared by Karl Fichtelius on "How to communicate with dolphins" (Fichtelius, 1968). Most of the publications through the 1960's related to the anatomy and physiology of whales, such as retia mirabilia[31] and cerebral circulation (Nagel et al., 1968), diving adaptations (Strauss, 1969), and lung volume (Olsen et al., 1969).

It was in the early 1970's when articles on the biological sonar and echolocation arose along with models which attempted to explain them (Bel'Kovich, 1970; Beamish, 1970; Schevill et al., 1971), and the beginning of the study of the songs of the humpback whales (Payne et al., 1971). It was then that the recordings and broadcast of humpback whale songs raised the visibility of cetaceans and the resulting "Save the Whales" campaign which created international unrest when Greenpeace carried out direct action in 1975 against Soviet whalers (Greenpeace, 2005), the dolphin-tuna problems (Perrin et al., 1972), as well as the Navy's marine mammal program (Wood, 1973). "Pingers" were introduced along with the reaction

30 The Marine Studios of Florida first captured bottlenose dolphins in 1938 from an inlet near St. Augustine. It was there that, in the early 1950's, the first captive-born dolphin was birthed. The Caldwells began their studies of dolphin whistles in 1965.

31 The retia mirabelia or 'wonderful nets' is a network of blood vessels which are thought to serve to protect vital organs from the effects of water pressure, and possibly to trap any bubbles of nitrogen which may form in the blood during ascents from deep dives. Retia in the thorax and around the spine are fed with blood from arteries in the body wall and supply blood directly to the brain through arteries in the spinal canal.

of sperm whales to them (Watkins et al., 1975), and in Russia it was found that dolphins had the ability to differentiate tone-pulse signals (Saprykin et al., 1975).

One of the earliest reported impacts of anthropogenic ocean sound on cetaceans were the result of seismic activity and oil and geophysical industry in the late 1970's and early 1980's from studies in Canada, Alaska, and California. It was found that distribution and activity patterns of beluga whales, ringed seals, bowhead whales, and gray whales could be affected by sounds associated with seismic profiling, drilling, and aircraft and ship operations, sometimes at distances in excess of 10 kilometers (Richardson et al., 1995). Since 1971 there have been speculations and predictions about impacts of anthropogenic sound on cetaceans (Payne et al., 1971).

Cetacean evolution and adaptation to the seas

The Order Cetacea are obligate marine mammals that successfully inhabit every ocean (and some rivers) in the world (Au, 2000), and include the whales, dolphins, and porpoises. Cetaceans are further divided into two suborders, the *Mysticetes* (baleen whales), and the *Odontocetes* (toothed whales). There are currently 86 recognized modern cetacean species (Smithsonian Institution, 2005), the evolution of which has to date been traced to the Eocene period (about 50 MYBP) from artiodactyls (even-toed ungulates) in the area of Pakistan and western India (Thewissen et al., 2001). The fossil record suggests that the transition from a terrestrial quadruped to an absolute aquatic occurred relatively quickly, in less than 15 million years (Nummela et al., 2004). Among the many adaptations that allowed cetaceans to live in ocean habitats was the evolution of various acoustical receiving capabilities of their ears. This development was needed to enable movement into the depths to capture prey and then surface again for air, resulting in physiological tolerance for substantial pressure differentials (Castellini et al., 2002).

The ear region of the earliest whales, the pakicetids, is distinctive in its shape and resembles that of other fossil cetaceans and modern whales indicating that the evolution of the modern aquatic ear likely took less than 8 million years (Thewissen et al., 2001). Thus is the basis for the cladistic origins of how cetacean ears transitioned from the archaeocetes through modern whales to accommodate sound transmission under water.

Modern whale ears are among the most derived (evolved) anatomical structures found in the Class Mammalia (Thewissen, 1998), with the outer and middle ears bearing little resemblance to their terrestrial ancestors and with an uncertain functionality because of a general lack of physiological data (Ketten, 2000). The cochlea portion of the inner ear, however, has the same fundamental organization as other mammalian species (Ketten, 2000), with the sizes of whales ranging from the largest animal on Earth, the blue whale (*Balaenoptera musculus*, 33.5m, 190,000kg) (Wilson et al., 1999), to the smallest odontocete, the vaquita (*Phocoena sinus*, 1.2m, 55kg) (Vidal et al., 1999). It is generally believed by scientists that it is the size of the whales' ears which allows for the scale and frequency that each of the species hears, with larger cochlea such as in the blue whale accommodating the lower frequencies (longer wavelengths), and smaller cochlea like that found in the ears of the vaquita responding to higher frequencies (shorter wavelengths) of sound (Ketten, 2000). These frequencies span a range of about 12 octaves, or roughly from 12.5 Hz for the blue whale, *Balaenoptera musculus*, to over 100 KHz for *Phocoenid* porpoises (Ridgway, 2000; Ketten, 2000; Au, 2000).

Typical source levels of cetacean vocalization (and sonar) has been estimated by Frankel (1994) for singing humpback whales to be between 170 and 175 dB rms. The calls humpbacks off Hawaii were measured to be 189 dB (Au et al., 2001). The average call source level for blue whales was calculated to be 186 dB (McDonald et al., 2001). Watkins et al., (1987) and Charif et al., (2002) recorded source levels for fin whales up to 186 dB. Mohl et al., (2000) found source levels for sperm whale clicks up to 223 dB. Therefore, if marine mammal vocalizations are generally at these levels, it is not unreasonable to speculate that these species have also evolved mechanisms to protect themselves and conspecifics from high source pressure levels, and therefore received pressure levels, via vocalizations. By comparison[32], large ship source levels range from 170 – 190, airgun array range from 235 – 255, and Low Frequency Active (LFA) sonar from 210 – 220 dB (Southall, 2004).

Of all the known species of modern whales, data have been published on the anatomy and various associations and/or applications of sound (effects/impacts) from well defined and controlled environments on 10 species that are small and easily confined (Nachtigall et al., 2000a). Other data have been presented on a few other species based on data collected during episodes of opportunistic passive listening, or with active acoustics for brief periods of time in a variety of open ocean environments around the globe. Although research in ocean bioacoustics is increasing, science

32 For an in-depth discussion of frequency ranges and source level of sound in the ocean, see W.J. Richardson et al. (1995), Marine Mammals and Noise; E. McCarthy (2004); NRC Ocean Noise and Marine Mammals 2003.

cannot currently predict the biological significance of anthropogenic sound on different cetaceans or other biota in various regions of the ocean (NRC, 2005).

The Question of Why Whales Strand

The stranding of whales has been an enigma for centuries. Scientific journal publications began to surface in the 1930's (Fraser, 1936). Strandings usually involve single individuals and have been observed on most coastlines around the world, but the occurrences of multiple animals (mass strandings) also occur. Available data reveal demographics such as age, gender, species of cetaceans involved, and seasonal, annual, and geographic trends (USC, 2005). Strandings data show that mass strandings appear to have increased in the past 25 years, particularly in the North Atlantic (USC, 2005). In some areas such as Nova Scotia, the incidence of recorded strandings increased from 1.9 strandings/year between 1970-1989 to 7.1 strandings/year between 1990-1998, and mass strandings of multiple male sperm whales have occurred three times (all since 1990) (Lucas et al., 2000). Goold et al., (2002) report that sperm whale strandings have been most dense, and have increased fastest, in the Hebrides, Orkney and Shetland Islands of Scotland beginning about 1970. The data support no firm conclusions but valid hypotheses include increased reporting and anthropogenic effects, which may be acting synergistically, but the increase in the British data is too dramatic to have been caused solely by a simple increase in sperm whale population size (Goold et al., 2002).

Strandings which are not the obvious results of bycatch mortalities have generated a spectrum of plausible ideas about the causes of cetacean strandings. Hypotheses include: lemming behavior (Brooks 1979); "burial", suicide and interspecies communication (Eaton, 1979); stress and disease (Geraci, 1979); neuropathology (Schimpff et al., 1979); parasitic infections (Geraci, 1979; Ridgway, 1979); geomagnetic sensitivity (Kirschunk et al., 1986; Klinowska, 1986); confusion to cetaceans, predominately odontocetes, possibly because of bottom topography, coastal configuration, and geomagnetic characteristics (Odell, 1987; Massuca et al., 1999); bio-accumulation of persistent organic chemicals and toxic metals (Meador et al., 1993; Stein et al., 2003); and most recently, lunar cycles (Wright, 2005), and solar activity (Vanselow et al., 2005). Navy sonar was determined to be the cause of strandings in the Bahamas (NOAA, 2001), therefore concern has arisen that similar intense anthropogenic ocean noise also may have caused or will cause similar strandings and deaths of endangered and protected cetaceans (NRC, 2000, 2003, 2005; McCarthy, 2004).

Habitats and risk

The United States Environmental Protection Agency published the *Guidelines for Ecological Risk Assessment* (EPA, 1998), which outlines a methodology for evaluation. A stressor is defined as any physical, chemical, or biological entity that can induce an adverse response (Framework, 1992). But when the United States Congress enacted the Marine Mammal Protection Act of 1972, concern was with over harvest. There was apparently no recognition that anthropogenic sounds associated with transportation, dredging and construction, offshore oil and gas development, geophysical surveys, ocean science studies, explosions, wind turbines, and Dept. of Defense exercises (much of which overlaps the acoustical ranges used by cetaceans) could have adverse or unacceptable effects such as masking[33], temporary threshold shift (TTS)[34], permanent threshold shift (PTS)[35], or non-auditory impacts[36] on marine mammals or other marine biota. Since then, research has produced a spectrum of data that reveal, at least to a degree, that sound can and does have immediate and direct impacts on cetaceans and other marine organisms and those impacts vary among species and individuals (NRC 2005).

For example, Air-gun pulses of about 200 dB severely affected fish distribution, local abundance and catch rates across the entire investigation area of 40 X 40 miles where trawl catches of cod and haddock and longline catches of haddock declined on average 50% and abundance and catch rates did not return to pre-shooting levels during the 5 day period after the seismic shooting stopped (Engas et al, 1996); At 166 dB of air-gun emissions a green and a loggerhead turtle exhibited a noticeable increase in swimming behavior, and at 175 dB, their behavior became increasingly erratic with probable avoidance (McCauley et al., 2000). Squid in cage trials showed a startle response (ink sac fire) and avoidance to the startup of an air-gun array from .9 to 1.5 kilometers away, displayed a noticeable increase in alarm behaviors at from 156-161 dB, and at 166 dB, had a significant alternation in swimming speed patterns, perhaps using the sound shadow near the water surface (McCauley et al., 2000).

---

33 Obscuring of sounds of interest by interfering sounds, generally at similar frequencies (Richardson et al., 1995).

34 Temporary threshold shift is a temporary increase in the threshold audible sound level presumed to be caused by temporary inactivation of the outer hair cells at a given frequency (NRC 2003).

35 Permanent threshold shift – prolonged exposure to noise causing permanent hearing damage (NRC 2003).

36 Tissue damage, such as that found in air bladders, lungs, or other air-filled cavities.

One question that remains outstanding is related to a “risk cascade” (Lipton et al., 1993). A risk cascade describes a series of interactions of exposures and effects resulting in secondary exposures, secondary effects, and finally, ultimate effects, also known as causal chain, pathway, or network (Andrewartha and Birch, 1984). Each of these may potentially function on either a short or long-term scale, the outcome on which one can only speculate. However, the nature of scientific inquiry can lead to extrapolations which are made based on available information from field studies, laboratory studies, structure-activity relationships, stressor-effects relationships, stressor occurrence (circumstances) if available, and provide a magnitude and direction of uncertainties.

Zacharias & Gregr (2005) point out that one must consider physical structures such as fish spawning areas, cetacean mating areas, as well as biological structures like rare and endangered species habitats, fish holding and feeding areas, and regionally significant populations. Limited field studies allow for the collection of correlative information such as behavioral change in response to specific sounds, and/or habitat avoidance. Less apparent is a causal relationship to mortality or potential population decline, and this is where substantial uncertainty lies. If avoiding impacts is the management goal, then predictions must be made of where the most vulnerable marine areas are with ecological classifications for all biota based on a number of untested assumptions regarding marine mammal sensitivity to anthropogenic sound and on a combination of existing and potential acoustic sources.

Few quantitative data exist to assess potential received levels or to predict impacts to different species of cetaceans in different habitats from various source types. Impacts seem to vary according to the specific context of each event such as the particular species involved, the location and geographic characteristics, the nature of the sound, and any prior experience the animals may have had with specific sounds (NRC, 2005). Marine biota evolved in an environment filled with sounds resulting from events such as plate tectonics and the associated volcanoes and earthquakes over the last 210 million years (Garrison, 2005). Most of the world's marine biota and fisheries are located on the continental shelves (Houde, pers. comm. 1999) and most cetacean studies are performed there. For example, on Canada's western continental shelf most of the existing data is based on humpback and sei (Gregr and Trites, 2001), fin (Charif et al., 2002; Croll et al., 2001), and blue whales (Croll et al., 2001) utilizing habitats such as inshore and some offshore feeding areas (Gregr & Trites, 2001; Zacharias & Gregr, 2005).

Although there are limited data on cetacean habitats, primary, secondary, and tertiary productivity maps may serve to facilitate a sort of time/area closure for the purposes of mitigating risk of anthropogenic sound to cetaceans. However, some species, such as humpback whales, are known to migrate seasonally to areas of far lower productivity for breeding. Others, like the belugas (Scheifele, 1997; Lesage et al., 1999; Erbe et al., 2000), seem to remain in the cooler waters near the polar oceans. For most species of cetaceans, however, data regarding the habitat selection and movement patterns are sparse. However, spatiotemporal prediction models of cetacean habitats have been proposed (Hamazaki, 2002). From such models and data come extrapolations to advance hypotheses.[37]

Whatever the location of the cetaceans or their food sources, the risks to individuals or populations likely include a stress level, defined as a deviation of environmental conditions beyond the expected range (Zacharias & Gregr 2005). Some cetaceans and a few examples of their food fish seem more sensitive to anthropogenic sounds than others. We can define sensitivity as the degree to which marine features respond to such stress measured by using one or more indicators (or species, communities, and habitats) that respond to one or more natural or anthropogenic stressors. These responses are potentially nonlinear and may include interactions between stressors. Sensitivity does not inherently assume the characteristics of fragility or intolerance (Zacharias & Gregr 2005), and there is continued speculation regarding the degree that sound causes biologically significant effects (NRC 2005) or if stress levels can be considered biologically significant. For example, stress has been defined (*in* Encyclopedia of Animal Behavior. 2005. ed. Marc Bekoff) as "an environmental effect on an individual which overtaxes its control systems and reduces its fitness or appears likely to do so," or a condition in which abnormal or extreme adjustments to behavior, psychology, or physiology are necessary to cope with the environment. An example of the different forms that apparent stress can look like is illustrated in studies on captive odontocetes such as

37 In identifying Vulnerable Marine Areas for cetaceans (VMAs) Zacharias & Gregr (2005) created a table of examples of "Valued Ecological Features" (VEFs) identified in the eastern North Pacific and their potential stress classes. In this table they include under "Community disturbance" the variables of, "direct mortality, indirect mortality, prey removal, vessel strikes, noise pollution, and vessel congestion." There is no cross reference between "vessel strikes and/or vessel congestion" and "noise pollution" implying that the presence of vessels have resulted in no "indirect or direct mortality" from acoustic impact on humpback (or other baleen) whales (Zacharias & Gregr, 2005).

those involving Masked Temporary Threshold Shift (MTTS). Finneran's (2002b) MTTS experiment used a 229 dB simple impulse sound, which indicated a 6-7 dB shift in a beluga but none in a dolphin, demonstrating threshold variations among odontocetes. Finneran noted, however, the subjects' behavioral reactions were otherwise consistent with those of the earlier studies: both subjects were often reluctant to return to the sound station following exposure to the seismic watergun impulse and sometimes vocalized after the exposure.

Nachtigall (2003) noted in a similar experiment using a 179 dB tone on a different animal that the reluctance of the dolphin to participate would indicate the animal was negatively impacted by the fatiguing noise. Although the animals recovered from any threshold shifts that they may have experienced as a result of the artificially synthesized sounds, a recovery that would indicate that there was no permanent physical damage to these animals, their behaviors during the experiments suggest that the sounds created an environment and reaction symptomatic of acute stress. Alternatively, Thomas et al., (1990) reported no statistical difference in behaviors and catecholamines[38] in response to simulated 137 dB rms oil drilling noise, and Croll et al., (2001) noted no obvious responses in the behaviors of fin and blue whales to a 180 dB rms, anthropogenic, LF (SURTASS) sound, indicating that if

38 Catecholamines are soluble chemical compounds produced from the adrenal medulla and the sympathetic nervous system. The most abundant catecholamines are epinephrine (adrenaline), norepinephrine (noradrenaline) and dopamine. High catecholamine levels in blood are associated with stress. Catecholamines cause general physiological changes that prepare the body for physical activity (fight-or-flight response). Some typical effects are increases in blood pressure, heart rate, and blood glucose levels.

any stress had occurred, it was not enough to interrupt their normal foraging behaviors.

There are few data with which to extrapolate the effects of stress on an individual to the impacts that stress might have on the population, particularly where cumulative impacts affect acceptable risk. Effects of stress might be estimated by way of "Total Maximum Daily Load" (TMDL)[39] of sound in cetacean habitats, and the impacts to populations might be considered acceptable via a sustainable Potential Biological Removal[40] (PBR) of a population. If the goal of risk management is to reduce the overall impacts of anthropogenic sound in the ocean (the current White House Executive Administration has voiced rather different goals[41]), then one of the mitigation tools could be the adoption of the Precautionary Approach to approving limits to potential impacts to the environment, "applying judicious and responsible management practices based on best available science and on proactive, rather than reactive, policies." (U.S. Commission on Ocean Policy, 2004). The Commission further stated, "...lack of full scientific certainty shall not be used as a justification for

---

39 A TMDL is the sum of the allowable loads of a single pollutant from all contributing point and nonpoint sources. The calculation must include a margin of safety to ensure that the water body can be used for the purposes the State has designated. The calculation must also account for seasonal variation in water quality. The Clean Water Act, section 303, establishes the water quality standards and TMDL programs (USEPA, 2005).

40 The concept of Potential Biological Removal in the MMPA defines acceptable levels of incidental mortality as considered precautionary in that it uses minimum population estimates to calculate the maximum number of animals that can be removed from the population without significantly affecting a population.

41 "The Bush administration is strongly opposing international efforts to restrict the Navy's use of active sonar anywhere in the world, putting it at odds with European allies and several key ocean-protection organizations. While allies have become increasingly concerned about a link between mass strandings of whales and nearby naval use of sonar, the new U.S. position, being finalized, puts national security first. 'The U.S. strongly opposes any international regulatory framework addressing military use of active sonar because of the potential to restrict the ability of individual States to balance the relevant security and environmental interest,' the new policy reads.,, (Cape Cod Times, February 28, 2005, p. A5).

postponing action to prevent environmental degradation." One of the bases for dealing with the existing uncertainty includes the alternative decision-making tools, such as, among other avenues, the use of expert judgment and to consider the context of specific cases in determining appropriate approaches (MMC, 2005).

Marine Mammal Commission response

The Omnibus Appropriations Act of 2003 (Public Law 108-7) directed the Marine Mammal Commission to "fund an international conference or series of conferences to share findings, survey acoustic 'threats' to marine mammals, and develop means of reducing those threats while maintaining the oceans as a global highway of international commerce." (MMC, 2005). In response, the Commission, working through the U.S. Institute for Environmental Conflict Resolution, Tucson, AZ, contracted with a team of professional facilitators to explore the potential for a multi-stakeholder policy dialogue that would focus on the impacts of anthropogenic sound on marine mammals (MMC, 2005). The facilitation team's assessment, which was completed in November 2003, identified stakeholder support for the Commission's plan to establish a federal Advisory Committee on Acoustic Impacts on Marine Mammals. Accordingly, the Commission invited representatives of the interested parties to serve on the Advisory Committee (MMC, 2005). Committee member stakeholder groups included representatives and their alternates for the mineral management (petrol) industry, NGO's, governmental, DOD, and a group of eight marine mammal scientists.

The Marine Mammal Commission hosted the final meeting of its Advisory Committee on Acoustic Impacts on Marine Mammals on 20-21 September 2005 in

Bethesda, Maryland. At the meeting, the Advisory Committee decided against a single, consensus-based report. Instead, each member was given the opportunity to submit a non-consensus statement to the Commission. Some members collaborated to produce multi-member statements. Each statement was limited to 30 pages. The compilation of these statements, along with a succinct summary of the Advisory Committee process, constituted the Advisory Committee's report to the Commission (this voluminous report can be viewed at www.mmc.gov).

The role of National Marine Fisheries Service

The NMFS has proposed a new set of management guidelines based on various exposure criteria. These include six "Alternative Actions" (Appendix H) which are being considered for determining the acoustic threshold at which both Level A and Level B harassment takes might occur (NOAA, 2005), and are summarized as follows:

Table 1. ACOUSTIC CRITERION FOR EACH OF THE PROPOSED ALTERNATIVES

Alternative	**Level A Harassment Criterion**	**Level B Harassment Criterion**
I (Status Quo)	180 dB rms re: 1μPa	160 dB rms re: 1μPa (impulse)
(continuous).		120 dB rms re: 1μPa
II	Highest average	lowest possible natural ambient.
III	TTS Onset	50% Behavioral Avoidance.
IV	PTS Onset minus 6dB	TTS Onset minus 6dB.
V	PTS Onset	TTS Onset.
VI	PTS Onset plus 6dB	PTS Onset minus 6dB.

Source: Dr. Brandon Southall, NMFS, 2004

The alternative actions would be based on the current noise exposure guidelines marine mammals would be divided into five functional hearing groups as follows for:

1) low-frequency cetaceans (all mysticetes, i.e., baleen whales);

2) mid-frequency cetaceans (all odontocetes, i.e., dolphins and porpoises, not included in the low or high frequency groups);

3) high-frequency cetaceans (harbor and Dall's porpoise, river dolphins);

4) pinnipeds under water (seals, fur seals and sea lions)[42];

5) and pinnipeds out of water.

A second set of criteria is also proposed for gray whales to account for extrapolations to help fill data gaps and areas of uncertainty.

Sound Exposures and Effect Characteristics

There are some areas of research where there is a higher level of confidence regarding the effects of sound on cetaceans and fish which has resulted from studies in the laboratory or from captive animals. These include studies related to threshold shifts and/or other responses to carefully measured sound bites (Nachtigall et al., 2003, 2004; Schlundt et al., 2000; Finneran et al., 2002b) most of which involves closely monitored behavioral changes, blood catecholamine levels (Thomas et al., 1990), hair cell enumeration over time (Smith et al., 2004; McCauley et al., 2002, 2003), and necropsies. Physiological studies and necropsies occur in the lab and reveal measurable physical changes. In studies on threshold shifts, sound source levels, which can be assumed to be virtually the same as received levels, are known and carefully regulated, although for necropsies sound sources are less well defined

42 Although not directly addressed in this study which is specific to cetaceans and fish, the survey would have grouped these last two groupings (4 and 5) as "other" for this dissertation.

and associated with strandings, which are opportunistic, time sensitive events, where the longer the stranding goes undetected or not recovered, the less likely any meaningful data can be extracted. Pinger studies are done near established fish farms or on small, well observed populations of small odontocetes (Kastelein et al., 2005; Monteiro-Neto et al., 2004), and seismic simulations have been done on captive fish in cages and have been recorded on video for review and archiving (McCauley et al., 2002). In these captive animal cases the variables are more easily controlled, there are fewer assumptions made, the results are relatively consistent among studies, and the scientists are in greater agreement about processes and outcomes.

This agreement is not the case for free ranging cetaceans and fish. Research on wild cetaceans in the ocean is difficult, and the few species that have been studied have provided a spectrum of responses to various sound sources and this variance confounds an understanding of how anthropogenic ocean sound impacts either individuals or populations. For example, humpback whales summer at high latitudes where they feed and winter at low latitudes where they aggregate for breeding and where males have been observed engaging in elaborate vocalizations. There are several hypotheses regarding the function(s) and critical nature of these “songs” (Frazer & Mercado, 2000; Au et al., 2001; Mercado & Frazer, 2001) and how anthropogenic ocean sound might impact the functions of these songs (Fistrup et al., 2003).

Richardson et al., 1990 study reported a clear overall tendency for bowhead whales (*Balaena mysticetis*) in the Canadian Beaufort Sea to “orient away” during most playbacks of 115 dB broadband drilling and dredging noises. Apparent call rates were lower during playbacks (but masking by playback noise was a factor). Many bowheads would react at distances of 4 - 10 km from the drill ship or 3-11 km from the dredge. Nowacek et al., (2004) found that North Atlantic right whales (*Eubalaena glacialis*) in the Bay of Fundy responded to RL 133 – 148 dB alert signals by swimming strongly to the surface, a response likely to increase rather than decrease the risk of collision with vessels. Croll et al., (2001) did not observe obvious responses of fin and blue whales (*Balaenoptera*) in the San Nicolas Island, CA to a loud (180 db and below) anthropogenic low frequency sound. Frankle and Clark (2000) found that 98 – 109 dB ATOC signals did not affect the abundance, but did cause a change in the distribution and short term behavior of humpback whales (*Megaptera novaeangliae*) in Kauai, Hawaii, but suggested that these apparent affects cannot be generalized to other species.

Small deep diving odontocetes such as beaked whales seem to experience the most obvious lethal impacts from anthropogenic acoustic episodes (NOAA, 2001), but most open-ocean experiments and simulations focus on observations of large mysticetes (Fistrup et al., 2003; Croll et al., 2001; Frankel & Clark, 2000, 2002; Bowles et al., 1994), primarily because the low frequencies of sounds thought to impact cetaceans (such as ATOC) are assumed to be within the hearing ranges of larger whales (Ketten, 2000). Therefore small odontocetes are assumed likely insensitive to low frequencies and not likely affected by them (Wursig and Greene, 2002; Ketten, 2000; Au et al., 1997) thus introducing the possibility of skewed interspecies results. Nevertheless, conclusions from sonar sounds include known stranding events involving small odontocetes in the presence of active U.S. Navy

SONAR exercises in the Bahamas Islands, Canary Islands, and the Mediterranean Sea (Jepson et al., 2003; Balcomb & Claridge, 2001; Frantzis, 1998). However, there was an apparent lack of observed similar impacts on much larger mysticetes which may have also been present during the military exercises and subject to the sonar, but could have been affected differently.

Small odontocetes also seem to respond differently to similar levels of anthropogenic sound, as noted by Wursig and Greene (2002) who found that 146 dB underwater sounds near a fuel receiving facility in western Hong Kong seemed irrelevant to nearby dolphins, but Buckstaf (2004) found a significant increase in Sarasota FL dolphin whistles in response to 113 – 138 dB sound from approaching boats. Lesage et al., (1999) observed a progressive reduction in beluga calling rates from 3.4 – 10.5 calls/whale/min to 0.0 or <1.0 calls while vessels were approaching. They also noted an increase in frequency bands from the whales when vessels were close to the whales. Watkins et al., (1985) reported sperm whales ceased calling in presence of military sonar; and Bowles et al., (1994) reported long-finned pilot whales and sperm whales ceased calling during broadcasts of low-frequency sounds during the Heard Island Feasibility Test. Rendell and Gordon in 1999 observed vocal response of long-finned pilot whales (*Globicephala melas*) to military sonar in the Liguarian Sea, where a pod of 45-50 whales significantly increased their whistling in response to sonar. Normal changes in whistle characteristics among some cetaceans are hypothesized to promote reunions, and a study by Nowacek et al., (2001) found interanimal distance within a group decreased in the presence of watercraft and likely are within visual if not physical contact during vessel approach, which may have been initiated by whistles. There may be cetacean compensation for signal masking, shared frequency bands and above ambient received levels, for maintaining communication in a noisy environment. Increased whistle production may be a tactic to reduce signal degradation (Richardson et al., 1995). Given the low level of effort and funding to date in scientific research, there continues to be substantial data gaps in our understanding of cetaceans and their critical habitats in the oceans, and the ultimate effects anthropogenic ocean sound might have on the long-term sustainability of cetaceans and their ecosystems.

Given the confines of their methodologies (Mann, 1999; Feyerabend, 2000), these scientists strive to concentrate efforts to understand causal mechanisms in the interest of exploration and exploitation in a competitive environment. The research model organized within this dissertation serves to facilitate a broader understanding of how expert scientists view the ecological risk to cetaceans and fish from anthropogenic ocean sound and make natural resource management recommendations by way of a professional judgment approach to uncertainty.

Chapter 3. Methods

Overview

The objective of this study is the characterization of ecological risk to cetaceans from anthropogenic ocean sound by applying quantitative methodologies to the analysis of qualitative interpretation of empirical data by expert scientists using the "Professional Judgment Line of Evidence Approach" guidelines established by the United States Environmental Protection Agency (USEPA, 1998), assuming a relationship between ecological risk and impact, and "take" as defined by the Marine Mammal Protection Act (MMPA) of 1972. There are two approaches; 1. the selection and analysis of variables common to the 94 peer-reviewed publications specific to ocean sound and cetaceans or fish; and, 2. distribution of the blind Internet survey to authors of the publications designed for interpretation of how these expert scientists view their data in terms of ecological risk of anthropogenic sound to the species that they study. In addition to descriptive parameters, three statistical functions were used for analysis within and between the resulting data sets; standard meta-analysis, the Kolmogorov-Smirnov two-sample test, and logistic regression.

Statements of hypotheses:

1. The independent variables, or anthropogenic sound levels, are not significant predictors of the outcome variable, animal behavior changes, when the dependent variable (logit) is binary, where

$H_0 : \beta_1 = 0$; Anthropogenic ocean sound levels are not significant predictors of cetacean behavior, and

$H_A : \beta_1 \neq 0$ Anthropogenic ocean sound levels are significant predictors of cetacean behavior.

Test statistic: Logistic Regression, defined as

$$\pi(X) = \frac{e^{\beta_0 \beta_1 x}}{1 + e^{\beta_0 \beta_1 x}}$$

where $(\beta_0 + \beta_1 x)$ = the linear function of *x* (ocean sound), and β_1 is related to the slope.

2. The sound level data distribution differs significantly between population samples of captive animals and free-ranging animals, where

H_0: The data distribution is common to both samples.

H_A: The data distribution is not common to both samples.

Test statistic: Kolmogorov-Smirnov two sample test defined as

$$\text{d} = \left| \frac{F_1}{n_1} - \frac{F_2}{n_2} \right|$$

where at P $\leq$ 0.05, any value for $n_1 n_2 D$ < Critical Value, and D is defined as the largest unsigned difference between the samples.

Importance of the study:

Statistical goals: To determine the measure of association or relative risk in the approximation of how much more likely, or unlikely, it is to expect changes in cetacean and fish behavior as anthropogenic ocean sound levels change. To better understand differences in the shape and location of the data distributions between sound source levels and sound received levels of captive individuals and free-ranging populations.

Social/Political importance: To establish a record (caucus/consensus) in international expert judgment regarding maximum sustainable anthropogenic ocean sound; to demonstrate the utility of a transparent international instrument of communication within and between institutions in support of greater scientific leadership in guiding policy toward achieving sustainable management of living marine resources; to provide an Internet database to the scientific community.

Publication selection.

I reviewed more than 4000 titles resulting from searches in archived databases from Science Citations Index (ISI Web of Knowledge) Elsevier's Science Direct, Natural History Museum of Los Angeles County and university libraries using keywords, (cetacean OR whale OR dolphin OR porpoise OR fish) AND (acoustic OR ocean noise OR ocean sound OR anthropogenic ocean sound). Additional studies were collected by direct electronic solicitations for publications through lists generated from the Office of Naval Research, requests to Principal Investigators from the Environmental Consequences of Underwater Sound (ECOUS) Symposium (2003), the Society of Marine Mammalogy Conference (2003-2005), and the NMFS scientific research exemption list. The searches yielded 428 publications. These abstracts were further scanned to eliminate studies not specific to relationships between ocean sound and cetaceans and/or fish, and with an effort to balance for representation among species, geographic research locations, methodologies, funding sources, and representative nations. Multiple publications by single authors were narrowed by taking the most recent and most relevant publication(s) of the author(s). One hundred nine publications were finally selected for analysis, and considered representative of the best available science and scientists who are respected within the scientific community as experts in ocean sound and cetacean or fish bioacoustics.

Expert scientist population.

All 272 authors of the 109 selected publications were researched for contact information for invitation to participate in the blind Internet Survey Questionnaire. University of Maryland Institutional Review Board (IRB) anonymity requirements demand full non-disclosure of individual identity of the population of authors being invited to participate in this survey aimed to measure how each scientist now interprets his/her data for sustainable policy recommendations. Search resources included publication document, professional society memberships, university rosters, conferences, symposiums, and public meeting attendance lists, permit applications, web pages, and Google. Of the original 272 authors, research revealed five scientists reported as deceased and contact information was not found for 36 individuals. E-mail was attempted for 231 scientists. "Undeliverable" emails were returned from 38 addresses. One hundred sixty scientists responded to initial request for information (Appendix D "Letters of Invitation") regarding their publications referenced for my dissertation related to ocean sound. After receiving the second letter describing the anonymity and confidentiality conditions of the project and the associated survey, 15 declined to participate, and 26 did not respond at all, so they were disqualified from receiving the electronic Internet survey link. Conditions for participation were accepted by 119 (74.4%) scientists[43] who were promptly emailed

43 The Central Limit Theorem states that when an infinite number of successive random samples are taken from a population, the distribution of sample means calculated for each sample will become approximately normally distributed with mean μ and

the link to the survey, representing authorship of 94 (86.2%) of the original 109 publications selected for meta-analysis. Publications which were unrepresented by authorship were dropped from the study. Ninety-four peer-reviewed articles published from 1990-2006 and 91 of their authors provided the data sets for this study.

Literature Analysis

Fifteen reported variables common to these publications were aligned, grouped, and coded in M.S. Excel, and cross-tabulated in SPSS, and are as follows (Appendix B): 1. Category (Captive, Fish, Free-Ranging, and Theoretical Models); 2. Journal (33 each); 3. Nation (20 each); 4. Primary Funding Source; 5. Represented Species Clustered by Functional Hearing Groups (NMFS[44] (Appendix H), and Benders et al. (Appendix I)); 6. Specific Research Topic; 7. Sample Size; 8. Geographic Location (of research); 9. Natural (initial) Behavior; 10. Primary Method of Observation/Data collection (for analysis); 11. Sound Source Level (rms/p-p); 12. Sound Received Level (rms/p-p); 13. Primary Sound Source Type; 14. Observed End Point, or Effect Behavior (the logit) based on short term (<48 hours) continuous observation, macro/microscopic examination of tissues, or, in few cases, model extrapolations; 15. Publication Date.

For the purpose of this dissertation, three specific variables from the publications are considered for analysis; sound source levels and sound received levels as the independent variables, and effect behaviors (End Point, disturbance, or

---

standard deviation $\sigma / \sqrt{N}$ ($\sim N(\mu, \sigma / \sqrt{N})$) as the sample size (N) becomes larger, irrespective of the shape of the population distribution. The larger the sample, the smaller the sampling error (Isaac, 1997).

44 Although Benders et al. is included for contrast, all analyses for this dissertation have been done according to the NMFS acoustic hearing groupings for cetaceans.

outcome behaviors) as reported by the authors. These variables were then compared to the authors' responses to Internet survey questions related to sound received levels to the species that they study; survey questions 14-16 (V16-18) addressing sustainability, *What lowest anthropogenic sound level range* [p-p] *(re 1 μPa) do you think will have an unreasonable adverse effect on the long-term survival, growth, and reproduction of the cetacean or fish species that you have studied* (each question for each of up to three top species studied); and question 19 (V21), addressing Level A harassment, *What "maximum standard" criterion for received anthropogenic sound levels* [p-p] *(RSL re 1 μPa) do you think should be included in sustainability legislation for all the species that you have studied in our oceans?*

All species listed in the publications and in the Internet survey were compiled and cetacean groups were arranged according to the NMFS acoustic groupings (Appendix H), and two additional groups were added for "other" animals, and fish, as listed in Appendix A along with reported sound spectra as currently known or speculated for each species, and their Red List[45] conservation status. Also listed is the alternative grouping scheme published by Benders et al., (2005), provided here for comparison, proposing 10 acoustic groups, placing *Tursiops* and *Lagenorhynchus* (Tt/La) together as one group, and creating a separate group for all beaked whales (Appendix I).

For the purpose of this study the observed "End Point (Effect) Behavior" is divided into five categories (Appendix B) based on observations reported in the

45 The International Union for the Conservation of Nature and Natural Resources is the world's most comprehensive inventory of the global conservation status of plant and animal species. The Red List catalogues and highlights taxa that are facing a higher risk of global extinction. www.iucnredlist.org.

publications, and qualitatively characterized in a manner that serves to minimize ambiguity and possible overlap in interpretation, where the ecological "risk" or impact to individuals or populations is considered. The five effect categories are; (by code number):

Category 141, "No apparent effect or unable to detect impact" indicates that the animals were not observed to change their routine or natural behaviors as they are currently understood in response to sounds. Most of the natural cetacean sound production studies resulted in this behavioral outcome.

Category 142, "Short– term altered behavior" includes slow or temporary/incidental orientation and/or vocalization/whistle and/or breathing rate changes, to which the observed animals seemed to quickly resume normal initial behaviors at the cessation of the acoustic stimulus.

Category 143, "Interruption in distribution and movement patterns, avoidance behavior" described by authors as "significant," "sudden," and/or "vigorous" responses by animals, or 50% avoidance or changes in behaviors, disruption of patterns such as feeding, socializing, traveling, reduced by-catch, and the like. Characterizing this end point behavior classification is animals not reported returning to pre-stimulus (normal initial) behaviors and/or distribution ranges during the observation period.

Category 144 represents "Reluctance or refusal behavior, stress or elevated catecholamine production; hair cell damage, startle behavior, flight/fleeing," represents end point behaviors described, or could be described as panic-like response, non-directional extreme speed, immediate break up of social units, neural-immune changes, etc.

Category 145, “Physical damage, acute trauma, stranded, and/or death” includes detonation studies, lesions, embolism, strandings, hemorrhage, etc., and is a self-explanatory measure of end point “behavior.”

Although arguments could be made, and in fact have been made in courts of law, that data which are characteristically placed in any category except Category 145 of this study should be viewed as having potentially greater or lesser impact than is represented here, I have based this risk characterization according to reported observable short term results and aligned them to the USEPA *Guidelines for Ecological Risk Assessment* (1998).

Anthropogenic Ocean Sound Survey

Questionnaire Construct

The Marine Mammal Commission’s Advisory Committee on Acoustic Impacts on Marine Mammals posted the outstanding questions which arose from the Workshop Outcomes on their website, dated 17 November 2005, and which were addressed in the Ocean Sound Internet survey questions designed for this dissertation. The MMC posting reads as follows:

> “The Marine Mammal Commission hosted the final meeting of its Advisory Committee on Acoustic Impacts on Marine Mammals on 20-21 September 2005 in Bethesda, Maryland. At the meeting, the Advisory Committee decided against a single, consensus-based report. Instead, each member was given the opportunity to submit a non-consensus statement to the Commission. Some members collaborated to produce multi-member statements. Each statement was limited to 30 pages. The compilation of these statements, along with a succinct summary of the Advisory Committee process, constituted the Advisory Committee’s report to the Commission (MMC, 2005). Outstanding questions faced by scientists for

which survey questions were constructed are:

- **Extent of the Problem**
    - How significant is the threat?
    - Relative importance of sound vs other threats
    - Impact on populations
    - Degree of scientific uncertainty and use of extrapolation
    - How to characterize acoustic energy – sound vs noise
- **Relationship between Stranding and Sound**
    - Level of relationship: cause/effect, correlated, associated
    - Number of relevant stranding or mortality events
    - Range of species involved: beaked whales, other?
    - Range of sound sources involved: sonar, airguns
    - Mechanisms of injury: auditory, behavioral, non-auditory
- **Effectiveness of Current Management / Mitigation**
    - What are best practices?
    - Cost effectiveness and practicality/practicability
    - Assignment of burden of proof: sound producers vs regulators
    - Precautionary approach –addressing the uncertainty
    - International or multi-lateral approach
- **Priorities and Conduct of Research**
    - What are priority research areas?
    - Relative importance of research and mitigation efforts
    - Diversification and distribution of research funding
    - Permitting and authorization for research
    - Animal Welfare aspects of research – CEE (Controlled Exposure Experiments), ABR (Auditory Brainstem Response)
    - Safeguards against bias in research"

Controversial topics and points of litigation and/or arguments in US courts of law were included in the Internet survey in an effort to establish a broader caucus within this expert scientific community in terms of representative statements either for or against current practices, specifically as related to the use of threshold shifts established for captive animals and their extrapolations to ocean ecosystems for the establishment of maximum standards for legislating anthropogenic ocean sound.

Demographic information and self-ranking opportunities were included in the Internet survey questionnaire (Appendix E).

Research Limitations and Assumptions

Limitations

Only English language publications were selected for this study.

No distinction has been made for animal behaviors which might have resulted from auditory vs. non-auditory impacts, but only that a given associated behavior was observed in response to either a sound source level or received level, if one is reported. For example, a "flight" or "stranding" event may have been prompted by either a sound induced pressure "trauma" to the head and/or ears, by sound induced tissue bubble nucleation, by sudden decompression, or by startle behavior. In any case the resulting observed outcome determined the impact characterization for this study. Further, published data related to observations of the duration times of sound exposure in the field ranges from seconds to minutes on single occasions, to multiple day segments of pulse or continuous exposure observed over several years. Sound sources represent single pulse/non- pulse, as well as multiple pulse/non-pulse exposures.

For the purposes of this assessment, no time variable was considered (in terms of a proposed "Behavioral Disturbance Criteria: 24-hour Rule)[46] as there are no baseline data established at the time of this writing that either supports or refutes that

46 See, Richardson, J.W., and P. Tyack, Noise Exposure Criteria: "Behavior Criteria" from the Noise Exposure Criteria Group Advisory Committee on Acoustic Impacts on Marine Mammals, Plenary Meeting Two April 28-30, 2004, Arlington VA. The authors recommend a "24 hour/one time only" exclusion in considering whether behavioral disturbance is significant. If a behavioral disruption resulting from noise exposure lasts greater than 24 hours and, for a given incident, occurs only once in an extended period (no firm definition for "extended period") the disturbance would not be considered biologically significant unless there is specific contrary evidence.

any anthropogenic sound induced distribution or movement pattern behavioral change (with the exception of stranding events, Category 145) may or may not be critical for growth, reproduction, and survival for the limited marine species observed thus far.

One confounding element in characterizing the effect behavior from each publication is related to behaviors as artifacts or collateral data. For instance, results of threshold shift studies reported results that qualified for Categories 141-144, depending on the features of the signals, where behaviors ranged from routine "go/no go" responses to "reluctance or refusal behavior,…" describes a "behavior" from which the observed animals seem to eventually recover and resume routine or natural initial behavior, however one must consider the inability of captive animals to escape their confines, or otherwise alter feeding, socializing, traveling, or other behaviors considered typical among free-ranging animals. These particular acoustic stimuli, therefore, may be assumed unlikely to threaten the survivability of individuals or populations based on current data and short term observations. There may currently be studies in progress which are yet unaccounted for in this study which may be related to these observations, however if the subjects are captive odontocetes the information may not be useful in characterizing effects on free ranging odontocetes because captive *Tursiops* and *Delphinapterus* were repeatedly tested for threshold shift and rewarded with fish after sound exposures so they may have experienced some habituation to the sound "stressor" (Finneran et al., 2002b).

Assumptions

This study makes three basic assumptions; firstly, the Internet survey requested scientists to answer from an "all things considered" perspective, therefore it is assumed that in terms of the hearing frequency distribution and habitat preferences, scientists responded based on normal distributions of variables as they understand them for the species that they study. Secondly, it is assumed that the scientists accounted for observed behavior alterations for the species they study when responding to the Internet survey questionnaire. A third basic assumption made here is the statistical independence of the decisions by the original panel which resulted in the 180 dB rms criterion. Assuming all 9 members of the original HESS panel independently estimated 180 dB rms as the standard criterion[47], then the standard deviation of the mean from the Internet survey results based on a sample of 102 criterion recommendation points, and is therefore reduced by a factor of $\sqrt{9/102} = .29$ with respect to the standard deviation of the mean estimate based on 9, thus improving the statistical confidence of criteria recommended by the Survey cohort over that of the HESS cohort.

Expert Scientist Participation

The final 94 publications represented by the authors participating in the Internet survey include scientists from 20 countries and research involving 27 species of cetaceans, 8 finfish, and one cephalopod over 10 major regions of virtually all oceans, including captive studies. Out of 267 living authors of the 109 selected publications, 160 authors (60%) were successfully contacted. One hundred nineteen accepted the survey (74.3% of those contacted). The Sociology Department at the University of Maryland registered 91 returns out of 119 electronic Internet surveys

47 There are likely several theories of cooperation which may have resulted in the 9-member HESS panel arriving at the current status quo, therefore this assumption is likely a false assumption; a scenario which could be likened to dropping 9 ping-pong balls and having them all land atop one another on a single point. This study assumes strict objectivity by this cohort of empiricists.

distributed (76.5% of the link distribution, or 56.8% of authors contacted) (Appendix B). Four people reported an "ERROR" message after the link was sent, after which the survey was "reset" to accept a second attempt for them to send the link. I don't know how many others might have gotten the ERROR message and did not report that to me, thus abandoning any further participation. A summary of the selection and return activity is illustrated in Table 2[48].

Table 2. Selection of peer-reviewed publications and expert scientists.

Process	N	
	Representative Authors	Representative Pubs
Titles reviewed		> 4000
Abstracts reviewed		428
Publications selected	272	109
Author contact attempted	231	
Authors responding	160	106
Survey accepted by authors	119	94
Surveys returned by authors	91	

Data preparation

Animal species are grouped into five data subsets; three subsets are based on the three NMFS Functional Hearing Groups for cetaceans (small odontocetes, medium/large odontocetes, and mysticetes), one subset representing finfish, and one subset representing "other" animals reported in the survey (unspecified cetaceans, non-cetacean marine mammals, turtles, and one cephalopod) (Appendix A). The independent variable, ocean sound levels, are grouped into seven discrete sets beginning with ≤100dB p-p and increasing by 20dB p-p increments through >200dB p-p. The dependent variables, effect behaviors, are arranged in five levels of behavioral response based on descriptions by the authors, and range from "no obvious

[48] Selection bias: English language publications only.

effect" through "physical damage; acute trauma; stranded and/or death." (Appendix B).

Kolmogorov-Smirnov two-sample test

The Kolmogorov-Smirnov two-sample test measures the differences in shape and locations of two distributions of data, based on the unsigned differences between the relative cumulative frequency distributions of the samples (Sokal & Rohlf, 1996). Comparison between observed and expected values leads to decisions whether the maximum difference between the two is significant, as follows

$$\mathrm{d} = \left| \frac{F_1}{n_1} - \frac{F_2}{n_2} \right| \quad (3)$$

The largest unsigned difference between samples, D, is multiplied by $n_1 n_2$, and compared to the critical value[49]. If $n_1 n_2$ D is smaller than its critical value, then the two samples are likely from populations with the same distribution characteristics. In this case study, this test was used to compare sound source level and sound received level data distributions within and between free-ranging and captive animal data sets.

Logistic Regression Analysis.

Logistic regression allows one to analyze the relationship between a categorical outcome and a set of explanatory variables (SAS Institute Inc., 2003) as an optimal means of estimating the probability of an event occurring, and is best suited where data sets are small. The logistic model is bounded between 0 and 1, and interpretation involves determining the functional relationship between the dependent

[49] critical values for Kolmogorov-Smirnov tests can be found in biometrics tables for statisticians.

and independent variables. For an arbitrary value of $\beta = (\beta_0, \beta_1)$ as the vector of parameters, and e = base of ln, the logistic regression model is described as

$$\pi(X) = \frac{e^{\beta_0 \beta_1 x}}{1 + e^{\beta_0 \beta_1 x}} \tag{4}$$

where $(\beta_0 + \beta_1 x)$ = the linear function of x, and β_1 is related to the slope (Hosmer & Lemeshow, 2000). Logistic regression can be applied when either one or both of the covariates in question are binary, but this study treats the dependent variable (logit) as dichotomous.

The probability that the event of interest will occur in response to a stimulus is termed the "odds ratio" described as the odds or relative risk which has the parameter equal to the ratio $\pi(1)/\pi(0)$. In this case study, the relative risk is defined as a measure of association between the presence or absence of anthropogenic ocean sound levels and the resulting behavior changes in cetacean and fish behaviors. The odds of the outcome (effect behavior) being observed among individuals in the presence of a specific anthropogenic sound level X=1, is defined as $\pi(1)/[1-\pi(1)]$, and odds of the outcome not observed among individuals in the presence of a specific anthropogenic ocean sound level, X=0, is defined as $\pi(0)/[1-\pi(0)]$. The odds ratio, denoted OR, is defined in the equation (from Hosmer & Lemeshow, 2000)

$$\text{OR} = \frac{\pi(1)/[1-\pi(1)]}{\pi(0)/[1-\pi(0)]}. \tag{5}$$

The odds ratio approximates how likely it is for the outcome to be present among those with the outcome variable (change in behavior) present (X=1) than with the outcome variable absent (X=0). In this algorithm, the odds ratio helps to numerically describe the relative risk association between anthropogenic sound levels and observed behavioral responses in cetaceans and fish. For example, if the OR = 10, then one would expect a 10 percent increase in observed animal effect behaviors in response to each incremental increase in anthropogenic ocean sound levels. If OR = 0.5, then the occurrence of an effect behavior is one half as likely to be observed among individuals exposed to each incremental increase (in this case study, by each 20 dB p-p increment) in specific sound levels . In summary, logistic regression compares observed values of the response value to predicted values obtained from models with and without the variable in question (Hosmer & Lemeshow, 2000).

Threshold Probability Estimation

From the set of threshold data points given in Tables 4 and 5, the estimate of the probabilities that the true effect threshold of cetaceans lies below given decibel levels are calculated by fitting a normal curve and computing the areas of appropriate regions. Assuming a normal distribution, the normal curve was fitted parametrically by computing the mean and variance of the data. The areas representing the desired probabilities were obtained using Error Function tables.

Chapter 4. Results

Publication data (Appendix C) and Internet survey data (Appendix E) were analyzed using SDA, SPSS, and SAS and the summary descriptive statistics are illustrated.

Publication Data

Tables 3-5 tabulate the publication independent variables of reported sound source levels p-p (SL) and reported sound received levels p-p (RL) against the dependent variable observed effect behaviors (Effect Categories 141-144) as described by the authors for both captive (10 publications, 25 animal observations) and free-ranging (35 publications, >2842 animal observations) animal populations (animal observations quantified in parentheses in Tables 3-5). The peer-reviewed publication data distribution for all species are plotted by observed behaviors, or "effects" as a result of marine sound levels which were reported as either received level (RL) and/or source level.(SL) (Behavior description categories are found in Chapter 3 and Appendix B).

Table 3. Captive animals' observed behaviors resulting from SL dB P-P n=10 publications representing 25 animal observations, which are in parentheses.

	Effect Categories				
SL dB pp	141	142	143	144	Total
<100					
101-120		1			1
121-140	1		2 (8)		3 (9)
141-160					
161-180				2 (5)	2 (5)
181-200				1	1
>200		1 (7)		2 (2)	3 (9)
Total	1	2 (8)	2 (8)	5 (8)	10 (25)

Table 4. Free-ranging observed behaviors resulting from SL dB P-P anthropogenic sound, n=17 publications representing > 1486 animals. * If animal counts were not reported, then this study assumes that there was at least one animal observed.						
	Effect Categories					
RL dB pp	141	142	143	144	145	Total
<100						
101-120			1 (501)			1 (501)
121-140			1			1
141-160			4 (633)	1		5 (634)
161-180			1			1
181-200				1 (101)		1 (101)
>200	2 (202)	3 (38)	2 (2)		1 (6)	8 (248)
Total	2 (202)	3 (38)	9 (1138)	2 (102)	1 (6)	17 (1486)

Table 5. Free-ranging observed behaviors resulting from RL dB P-P anthropogenic sound, n=18 publications representing > 1356 animals. See Fig. 3.					
	Effect Categories				
RL dB pp	141	142	143	144	Total
<100					
101-120		1 (501)	1		2 (502)
121-140		2 (102)	3 (503)		5 (605)
141-160	1	2 (17)	2 (22)	2 (7)	7 (47)
161-180		1 (101)			1 (101)
181-200	2 (102)	1			3 (103)
Total	3 (103)	6 (722)	6 (526)	2 (7)	18 (1358)

Figures 1-3 are graphic representations of data tables 3-5, and illustrate an apparent 20dB greater sensitivity of free-ranging animals than captive animals. These graphics assume that sound source level and sound received level of anthropogenic sound are virtually the same for captive animals.

Figure 1. Captive animals' observed behaviors resulting from SL dB P-P n=11 publications representing 25 animals. Data displayed in Table 3.

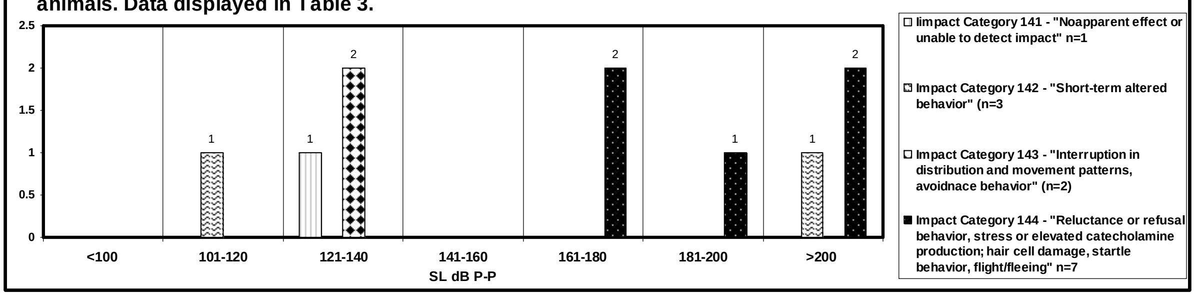


Figure 2. Free-ranging observed behaviors resulting from SL dB P-P anthropogenic sound, n=17 publications representing > 1486 animals. Data displayed in Table 4.

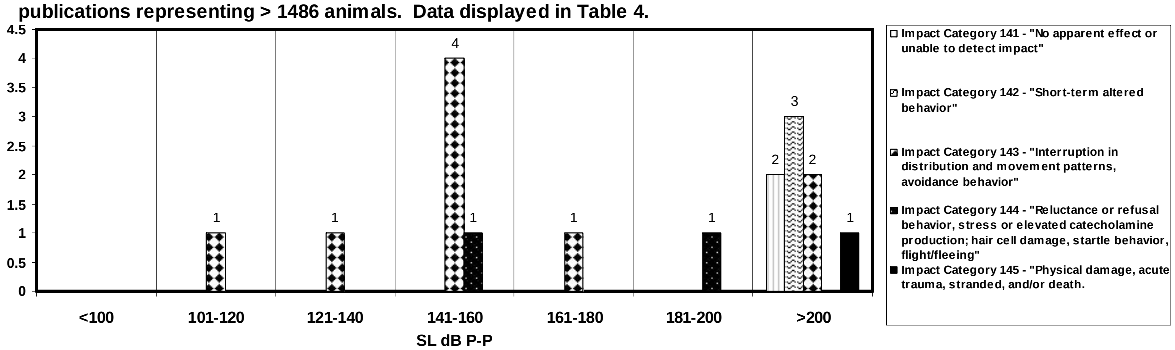
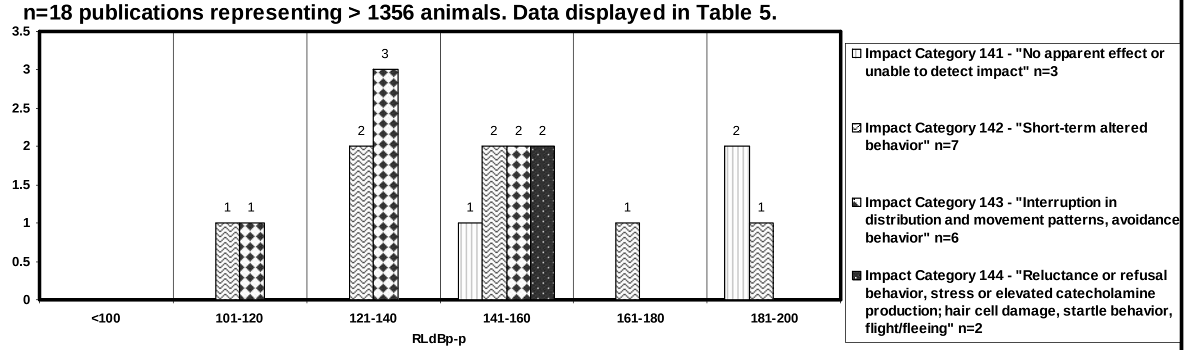


Figure 3. Free-ranging observed behaviors resulting from RL dB P-P anthropogenic sound, n=18 publications representing > 1356 animals. Data displayed in Table 5.



Behaviors for the category, "All Species" (Total) described in the literature as disturbance appears to become obvious beginning at 140 dB p-p (131 dB rms), with more than half the animals observed escalating to 'distress' at or below 180 dB p-p. Reported Received Levels result in behavior modifications observed at ten to twenty decibels lower than reported Source Level behavioral changes.

Although most of the literature data points come from free-ranging animals, captive animal (cetaceans and fish) data points skew to the other direction – possibly due to habituation following routine exposures to various acoustical simulations (NRC, 2003). But because of the highly controlled environment, captive animals, primarily bottlenose dolphins, white whales, and fish, provide precise measures of effects of sound on those individuals; however there has been wide speculation about how accurately those data can be applied to free-ranging animals as well as to other species. Assuming known source level and received level sound exposure to captive animals are virtually the same as the known received level experienced by all species represented, the data points depicted in Figures 1-3 suggest that there is a behavioral stimulus threshold difference of roughly 20 dB p-p between the two clusters of animals, with observed free-ranging animals responding with greater sensitivity to sound pressures, or changes in sound pressures.

The Kolmorogov-Smirnov two-sample test results

Tables 6-8 illustrate the Kolmorogov-Smirnov two-sample test of similarity between anthropogenic sound source levels (SL)[50] and received levels (RL) by free-ranging and captive animals to determine the distribution characteristics of those samples.

The Critical Value (Cr Val @ .05) from Table 6 between captive sound source levels (CSL) and free-ranging sound source levels (FRSL) is 89, which is greater than the test statistic D(n1n2) of 48.11, so we do not reject the null hypothesis that the two data samples for sound source level have been taken from populations with similar distribution characteristics.

Table 6. Two-Sample Kolmogorov-Smirnov tests of similarity between Captive animal Source Level data (CSL) and Free-Ranging animal Source Level data (FRSL).

	Sound Levels in dB pp	CSL	FRSL	F1/n1	F2/n2	d=F1/n1 - F2/n2		D(n1n2)	Cr Val @ .05
F is the freq at each sound level, n is the sample size	120	1	1	0.1	0.058	0.042			
	140	4	2	0.4	0.117	0.283	<- D = Largest unsigned difference.	48.11	89
	160	4	7	0.4	0.411	0.011			
	180	6	8	0.6	0.47	0.13			
	200	7	9	0.7	0.529	0.171			
	220	10	17	1	1	0			

[50] This data set arrangement assumes that source level (SL) and received level (RL) for captive animals is virtually the same.

The Critical Value from Table 7 comparing source level (SL) data against received level (RL) data is 133, smaller than the test statistic, 144, so we reject the null hypothesis that the two samples have been taken from populations with similar distribution characteristics.

Table 7. Two-Sample Kolmogorov-Smirnov tests of similarity between Source Levels and Received Levels on free-ranging animals only.

	Sound Levels in dB pp	FRSL	FRRL	F1/n1	F2/n2	d=F1/n1 - F2/n2		D(n1n2)	Cr Val @ .05
F is the freq at each sound level, n is the sample size	120	1	2	0.058	0.111	0.053			
	140	2	7	0.117	0.388	0.271			
	160	7	14	0.411	0.777	0.366			
	180	8	15	0.47	0.833	0.363			
	200	9	18	0.529	1	0.471	<- D = Largest unsigned difference.	144	133
	220	17	18	1	1	0			

Table 8 compares captive animal source level data (CSL) with free-ranging animal received level data (FRRL) resulting in a Critical Value of 92 against the test statistic of 67.86, therefore we do not reject the null hypothesis that the two populations have similar distribution characteristics.

Table 8. Two-Sample Kolmogorov-Smirnov tests of similarity between Captive Rource Level (CRL) data and Free-Ranging Received Level (FRRL) data.

	Sound Levels in dB pp	CRL	FRRL	F1/n1	F2/n2	d=F1/n1 - F2/n2		D(n1n2)	Cr Val @ .05
F is the freq at each sound level, n is the sample size	120	1	2	0.1	0.111	0.011			
	140	4	7	0.4	0.388	0.012			
	160	4	14	0.4	0.777	0.377	<- D = Largest unsigned difference.	67.86	92
	180	6	15	0.6	0.833	0.233			
	200	7	18	0.7	1	0.3			
	220	10	18	1	1	0			

The Internet Ocean Sound Survey Results.

The Survey was electronically distributed to 119 authors and co-authors of the 94 selected publications from Jan - May, 2006, and returned to the Sociology

Department of the University of Maryland under a 'veil of anonymity' from 91 of those authors. This return represents 74.4% of the distribution, which represents 86.2% of the original peer-reviewed publications selected for this study. Internet survey results include eight scientists disqualifying themselves from recommending criteria citing lack of expertise on cetacean or fish bioacoustics. The remaining 83 responses reveal a segregation of the population of empiricists into two clusters, one in which criteria are recommended (n=44) based on experimental work, and one in which criteria are not recommended (n=39) which corresponds to 39 publications with unknown sound level parameters, thus citing "not enough information to suggest criteria." Each qualifying cluster is analyzed separately, and then considered together for cohort analysis of risk characterization. The survey open-ended requests for scientists to describe their perceptions of 1) legislation of ocean sound, and 2) the survey itself, resulted in 155 comments from 70 participating authors (Appendix F[51]).

Sustainable Ocean Sound Levels.

Table 9 shows the author's responses to survey questions 14-16 addressing sustainability, combining responses on the first (top) three species reported. Table 10 weights the responses for species groups.

[51] Original 155 comments as posted in Table 34 are divided into the 177 segments found in Appendix F in an effort to facilitate the anonymity aspect of the study.

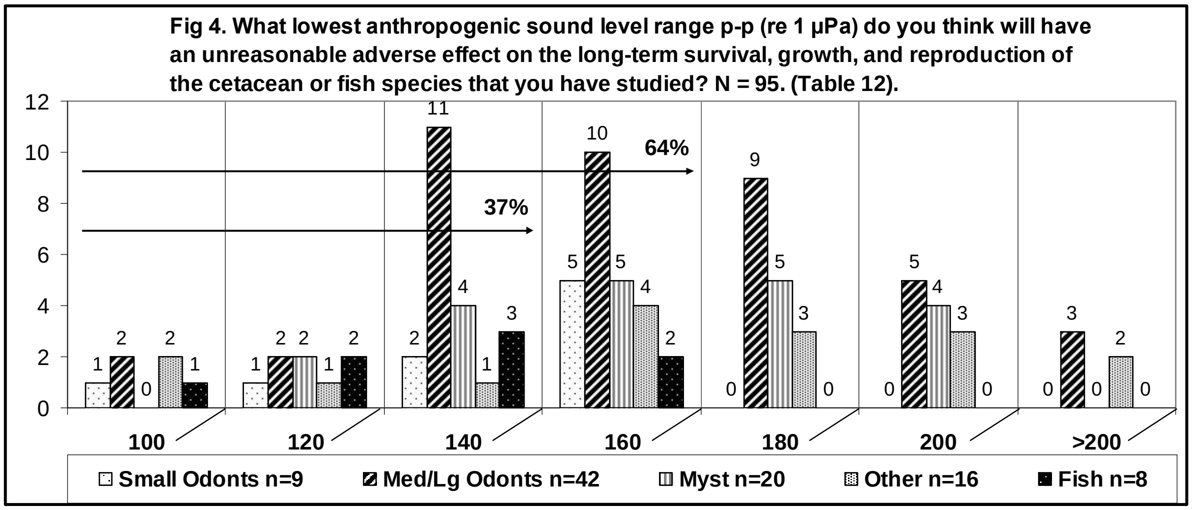
Table 9. Survey questions 14-16 on Sustainability: "What lowest anthropogenic sound level range p-p (re 1 μPa) do you think will have an unreasonable adverse effect on the long-term survival, growth, and reproduction of the cetacean or fish species that you have studied?" Responses compiled for top three species reported. Weighted statistics are found on Table 10.

dB p-p	Small Odonts n=9	Med/Lg Odonts n=42	Myst n=20	Other n=16	Fish n=8	Total n=95
100	1	2	0	2	1	6
120	1	2	2	1	2	8
140	2	11	4	1	3	21
160	5	10	5	4	2	26
180	0	9	5	3	0	17
200	0	5	4	3	0	12
>200 (210)	0	3	0	2	0	5
Weighted Mean dB P-P (Table 10)	144	163	165	166	135	160
Not enough Information	13	25	20	20	8	86

Table 10. Weighted data for "Sustainable" sound level.

	N	Minimum	Maximum	Mean	Std. Deviation
Small Odont	9	100	160	144.44	21.86
Med/Lg Odont	42	100	210	162.62	28.63
Mysticetes	20	120	200	165	25.85
Other	16	100	210	166.25	36.12
Fish	8	100	160	135	20.7
Total	95	100	210	159.68	29.41
Valid N (listwise)	8				

The weighted total of 160 dB p-p exceeds sustainability levels for two groups, small odontocetes (144 dB p-p) and fish (135 dB p-p), but is believed sustainable for medium and large odontocetes, mysticetes, and other unspecified marine biota.



Thirty-seven percent of expert scientists advise that 140 dB p-p and below is sustainable for their species, and 64% consider 160 dB p-p and below as sustainable (N=95).

"Maximum Standard" Anthropogenic Ocean Sound Recommended by Expert Scientists.

Fig. 5 illustrates the distribution of "Maximum Standard" criterion p-p recommendations made by expert scientists through the SDA Electronic Survey, as arranged groups based on the NMFS Acoustic Groupings (Appendix A). Fifty-three percent of the expert scientists responding recommended maximum standard exposure criteria based on current data for up to three species that they study in all oceans (N=102 cases of maximum criteria recommendations), of those, 51% suggest criteria on or below 140 dB p-p (131 dB rms), and 68.62% recommend no higher than 160 dB p-p ((~151 dB rms) as a standard criterion for sustainability of the species that they study in all oceans. There are no recommendations for maximum standard criteria which exceed 200 dB p-p as a general approach to sustainability.

Thirty-nine respondents believe there is not enough information to suggest a "maximum standard" ocean sound exposure criterion based on sound received level (RL) peak-peak pressure, with associated energy flux levels for the species that they study in all oceans. This Internet survey proportion is consistent with 39 out of the 94 selected publications which did not report specific sound level data which could be associated with the animals' observed behaviors, although they had reported that anthropogenic sound was present during animal behavior observations. These proportions are strong indicators that this cohort of empiricists is recommending criteria based on current empirical data, or lack thereof, as the source of their synthesis.

Tables 11 and 12 illustrate survey data from question 19 (V21) specific to the "maximum standard" anthropogenic ocean sound level p-p (re 1μPa) each scientist recommends for protective (sustainable) policy for the species that they study, grouped by the NMFS acoustic groupings.

Table 11. "Maximum Standard" criterion recommended for sustainability Internet survey results by NMFS Acoustic Groupings, RL dB P-P, N=102 (54%). Second cluster representing "Not enough information" N=88 (46%).

RL P-P	Small Odont n=12	Med/Lg Odont n=45	Myst n=19	Other n=20	Fish n=6	Total
<100	2	2	1	3	1	9
120	5	18	1	3	0	27
140	2	7	3	2	2	16
160	0	8	5	4	1	18
180	2	6	7	7	2	24
200	1	4	2	1	0	8
Total	12	45	19	20	6	102
Weighted Mean dB P-P (Table 12)	137	144	163	152	150	149
Not enough information	10	28	21	19	10	88

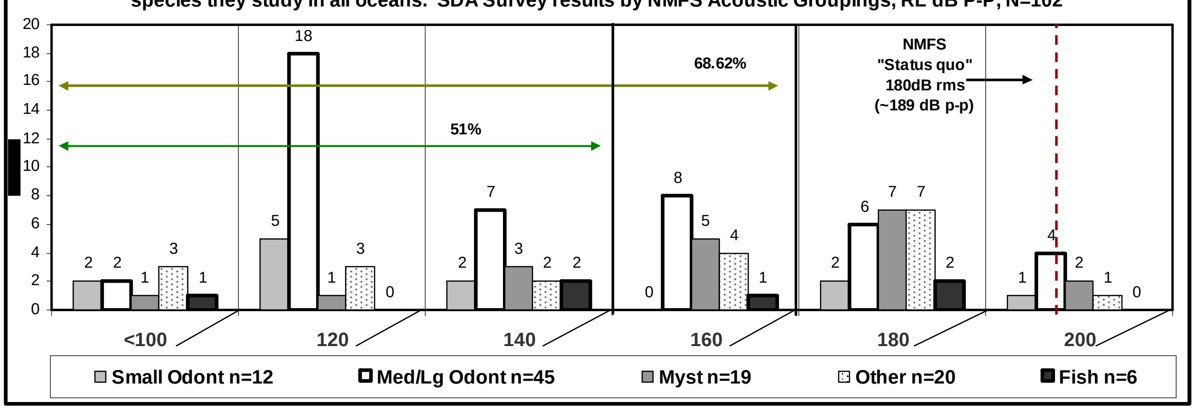
Table 12 lists the weighted values among responses, with a total mean criterion of 149 dB p-p. Although more conservative than the 160 dB p-p representing levels believed sustainable, this criterion also exceeds recommendations for two groups, small odontocetes (137 dB p-p), and medium and large odontocetes (144 dB p-p).

Table 12. Weighted data for "Maximum Standard" recommended criteria.

	N	Minimum	Maximum	Mean	Std. Deviation
Small Odont	12	100	200	136.66	32.84
Med/Lg Odont	45	100	200	144.44	28.88
Mysticetes	19	100	200	163.15	26.04
Other	20	100	200	152	32.05
Fish	6	100	180	150	30.33
Total	102	100	200	148.82	30.12
Valid N (listwise)	6				

Figure 5 represents raw data from table 11, where 51% of scientists with sufficient data to recommend criteria report 140 dB p-p as the appropriate maximum standard. Sixty-nine percent of respondents advocate 160 dB p-p or below as the appropriate maximum standard.

Fig 5. "Maximum Standard" criterion recommended by expert scientists for sustainability for the species they study in all oceans. SDA Survey results by NMFS Acoustic Groupings, RL dB P-P, N=102



Thirty-one percent recommended 180-200 dB pp as the upper limits of anthropogenic ocean sound for the sustainable management of the species that they study. There were no recommendations exceeding 200 dB p-p as an appropriate criterion for legislating anthropogenic ocean sound.

Combining Publication Variable Analysis with the Internet Survey Variable Analysis.

Logistic Regression Results

The LOGISTIC Procedure summary statistics for NMFS Acoustic Hearing Groups testing the global null hypothesis and calculating risk using logistic odds ratios across data mined from the peer-reviewed publications, the Internet survey questionnaire responses to "Sustainability" levels, and "Maximum Standard" criteria recommendations are listed below. Odds ratios indicate risk by calculating the expected percent increase in the incident of interest (behavioral response) per increase in the independent variable (anthropogenic ocean sound). Tests for significance include the Likelihood Ratio, Score, and Wald tests. Logistic curves for each data set illustrate the model fitting parameters.

Table 13 -15: The Logistic procedure for Small Odontocetes. Chi Square statistics indicate that the model is significant in three tests (Likelihood Ratio, Score, Wald). The logistic curves for each data set are illustrated below.

Table 13. Small Odontocete Publication data, n=4

Testing Global Null Hypothesis: BETA=0

Test	Chi-Square	DF	Pr > ChiSq
Likelihood Ratio	6.2754	1	0.0122
Score	4.1683	1	0.0412
Wald	1.9331	1	0.1644

Odds Ratio Estimates

Effect	Point Estimate	95% Wald Confidence Limits	
sound	1.117	0.956	1.306

Table 14. Small Odontocete "Sustainable" data, n=9

Testing Global Null Hypothesis: BETA=0

Test	Chi-Square	DF	Pr > ChiSq
Likelihood Ratio	17.7538	1	<.0001
Score	15.2100	1	<.0001
Wald	10.3328	1	0.0013

Odds Ratio Estimates

Effect	Point Estimate	95% Wald Confidence Limits	
sound	1.086	1.033	1.143

Table 15. Small Odontocete "Maximum Standard" data, n=12

Testing Global Null Hypothesis: BETA=0

Test	Chi-Square	DF	Pr > ChiSq
Likelihood Ratio	25.7529	1	<.0001
Score	20.9652	1	<.0001
Wald	12.4681	1	0.0004

Odds Ratio Estimates

Effect	Point Estimate	95% Wald Confidence Limits	
sound	1.056	1.025	1.089

Figures 6-8 are the logistic curves for Small Odontocete data.

Fig 6. Small Odontocete Publication data, n=4

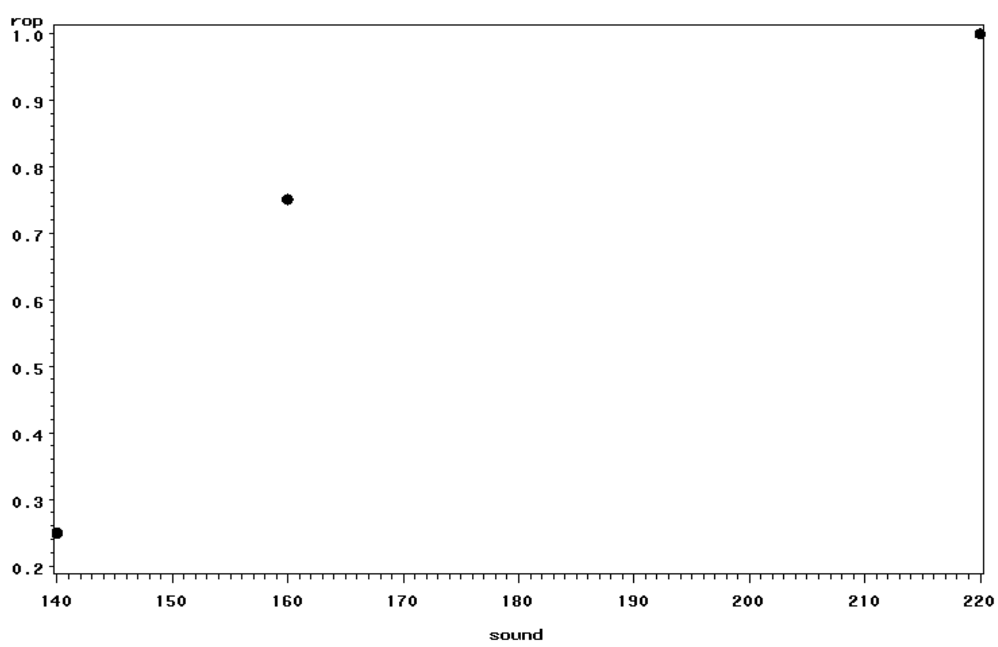


Fig 7. Small Odontocete Sustainable data, n=9

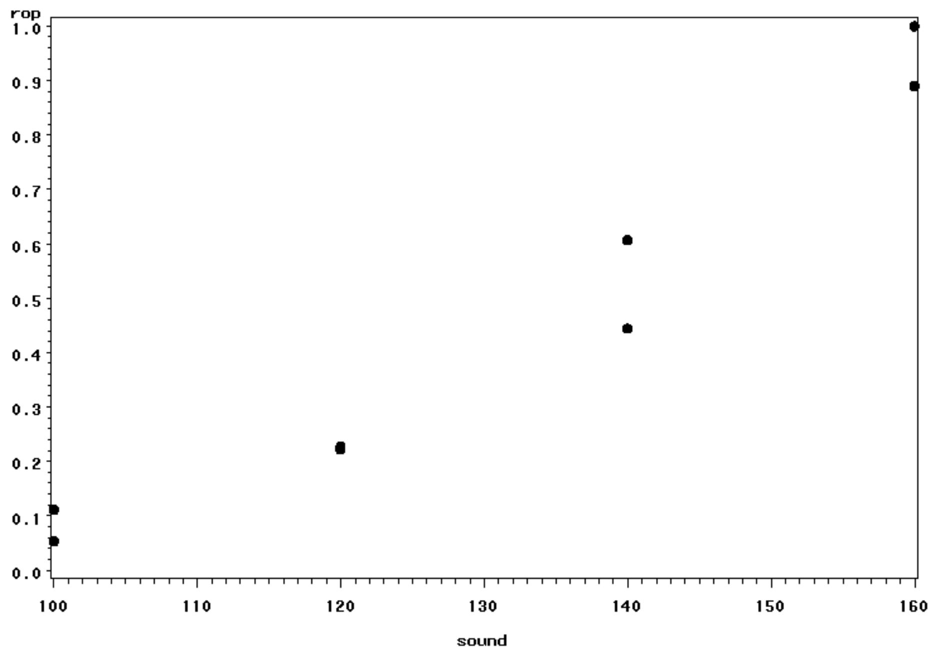
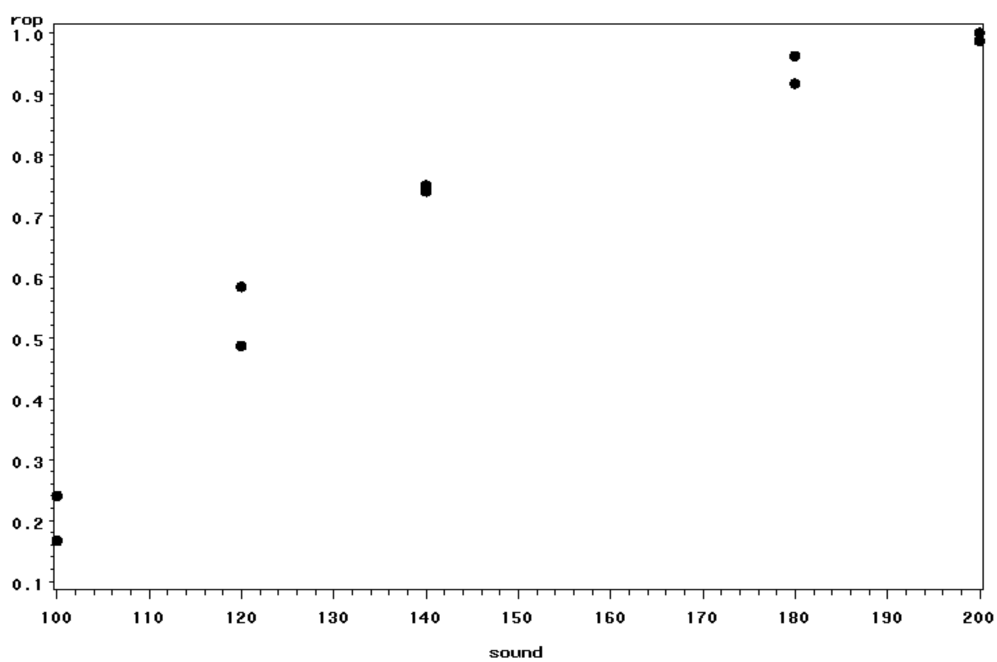
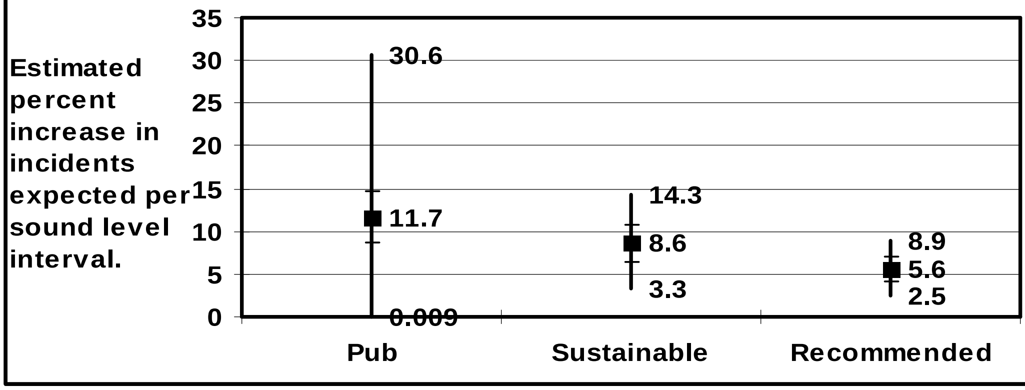


Fig 8.Small Odontocete Max Standard data, n=12.



Therefore, H_0, is rejected because it is not consistent with the data that $\beta_1 = 0$; concluding that anthropogenic ocean sound levels are significant predictors of effects on free-ranging small odontocetes.

Fig 9. Small Odontocetes: Effect Odds Ratios and 95% Confidence Limits



The risk to small odontocetes is illustrated in Fig. 9 as odds ratios, where point estimates and 95% confidence limits estimate the percent increase in incidents expected per ocean sound level increase.

Tables 16 – 18 depicts the Logistic procedure for Medium and Large Odontocetes. Chi Square statistics indicate that the model is significant in three tests (Likelihood Ratio, Score, Wald). The logistic curves for each data set are illustrated below.

Table 16. Medium and Large Odontocete publication data, n=11

Testing Global Null Hypothesis: BETA=0

Test	Chi-Square	DF	Pr > ChiSq
Likelihood Ratio	22.9105	1	<.0001
Score	19.7464	1	<.0001
Wald	14.7558	1	0.0001

Odds Ratio Estimates

Effect	Point Estimate	95% Wald Confidence Limits	
sound	1.039	1.019	1.059

Table 17. Medium and Large Odontocete "Sustainable" data, n=42

Testing Global Null Hypothesis: BETA=0

Test	Chi-Square	DF	Pr > ChiSq
Likelihood Ratio	185.8998	1	<.0001
Score	149.9348	1	<.0001
Wald	85.8446	1	<.0001

Odds Ratio Estimates

Effect	Point Estimate	95% Wald Confidence Limits	
sound	1.061	1.048	1.075

Table 18. Medium and Large Odontocete "Maximum Standard" data, n=45

Testing Global Null Hypothesis: BETA=0

Test	Chi-Square	DF	Pr > ChiSq
Likelihood Ratio	132.7486	1	<.0001
Score	111.3525	1	<.0001
Wald	72.7193	1	<.0001

Odds Ratio Estimates

Effect	Point Estimate	95% Wald Confidence Limits	
sound	1.060	1.046	1.074

Figures 10-12 are the logistic curves for Medium and Large Odontocete data

Fig 10. Med/Lg Odontocete Publication data.

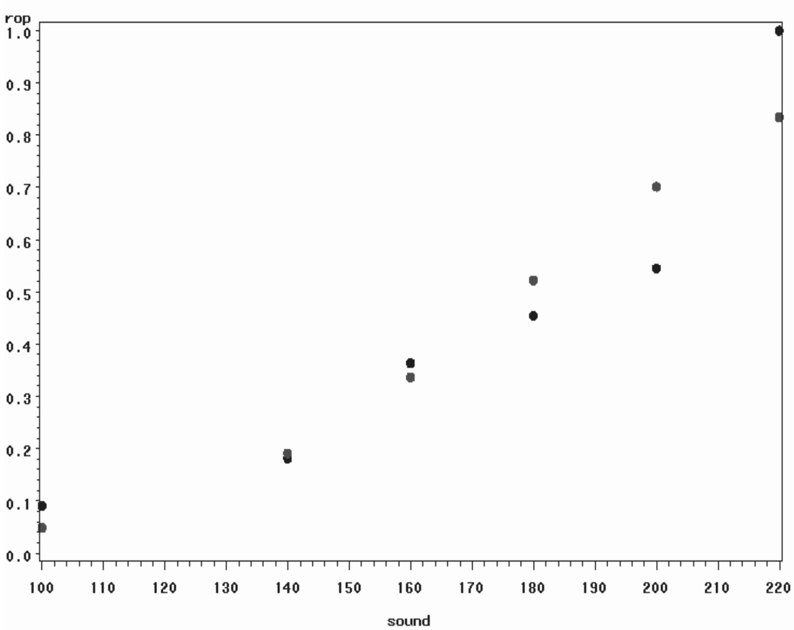


Fig 11. Med/Lg Odontocete Sustainable data.

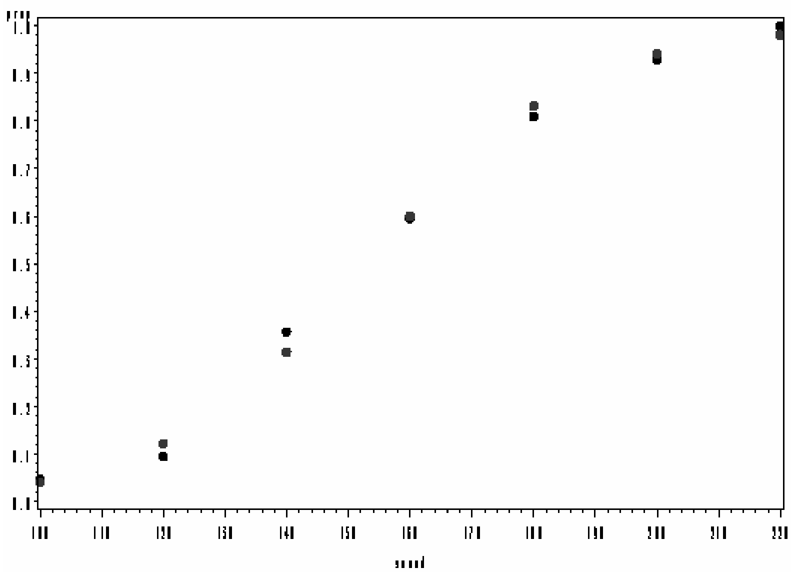
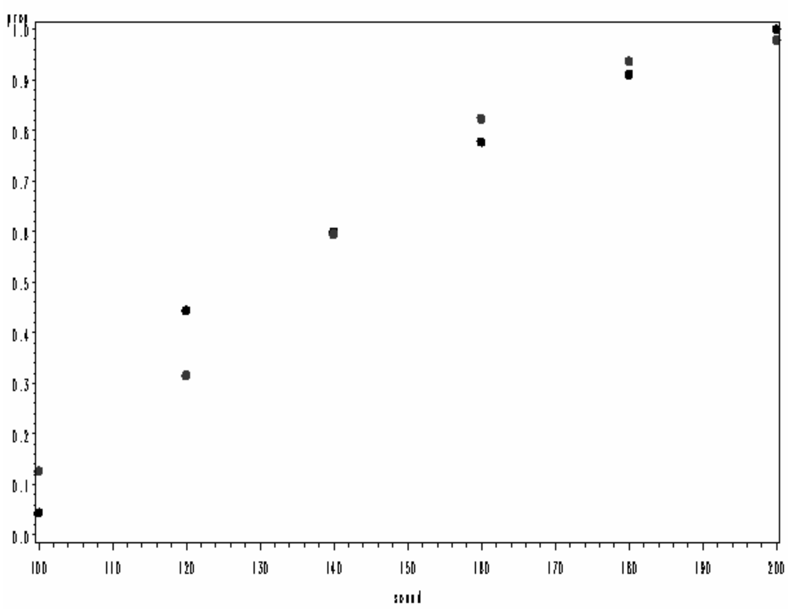
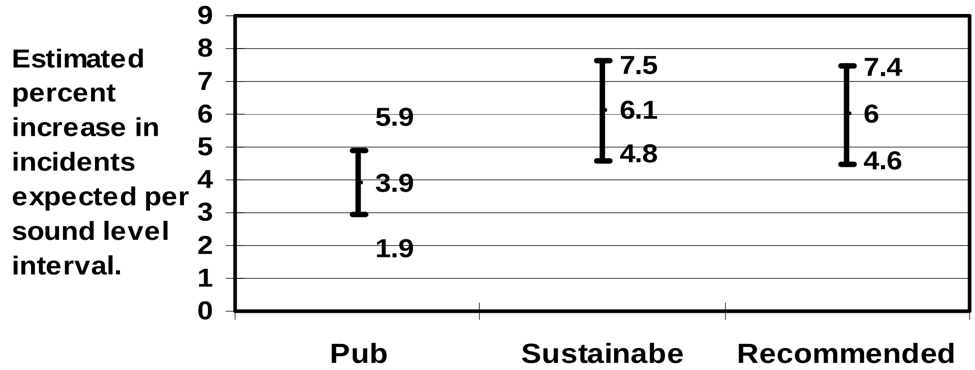


Fig 12. Med/Lg Odontocete Max Standard data



Therefore, H_0, is rejected because it is not consistent with the data that $\beta_1 = 0$; concluding that anthropogenic ocean sound levels are significant predictors of effects on free-ranging medium and large odontocetes.

Fig 13. Medium/Large Odontocetes: Effect Odds Ratios and 95% Confidence Limits



The risk to medium and large odontocetes is illustrated in Fig. 13 as odds ratios, where point estimates and 95% confidence limits estimate the percent increase in incidents expected per ocean sound level increase.

Tables 19-21: The Logistic procedure for Mysticetes. Chi Square statistics indicate that the model is significant in three tests (Likelihood Ratio, Score, Wald). The logistic curves for each data set are illustrated below.

Table 19. Mysticete publication data, n=7

Testing Global Null Hypothesis: BETA=0

Test	Chi-Square	DF	Pr > ChiSq
Likelihood Ratio	22.4751	1	<.0001
Score	19.3550	1	<.0001
Wald	13.7599	1	0.0002

Odds Ratio Estimates

Effect	Point Estimate	95% Wald Confidence Limits	
sound	1.047	1.022	1.073

Table 20. Mysticete “Sustainable” data, n=20

Testing Global Null Hypothesis: BETA=0

Test	Chi-Square	DF	Pr > ChiSq

Test	Chi-Square	DF	Pr > ChiSq
Likelihood Ratio	50.2603	1	<.0001
Score	42.7475	1	<.0001
Wald	28.6958	1	<.0001

Odds Ratio Estimates

Effect	Point Estimate	95% Wald Confidence Limits	
sound	1.069	1.043	1.096

Table 21. Mysticete “Maximum Standard” data, n=19

Testing Global Null Hypothesis: BETA=0

Test	Chi-Square	DF	Pr > ChiSq
Likelihood Ratio	73.3209	1	<.0001
Score	59.1111	1	<.0001
Wald	33.5539	1	<.0001

Odds Ratio Estimates

Effect	Point Estimate	95% Wald Confidence Limits	
sound	1.073	1.047	1.098

<u>Figures 14 – 16 are the logistic curves for Mysticetes data</u>

Fig 14. Mysticetes Publication data

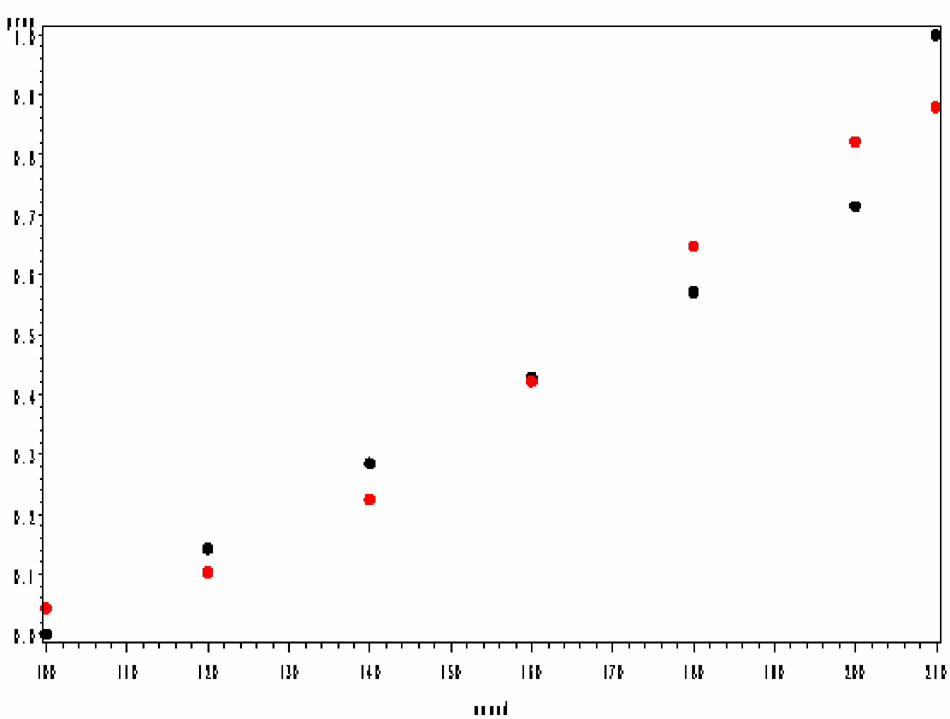


Fig 15. Mysticetes Sustainable data

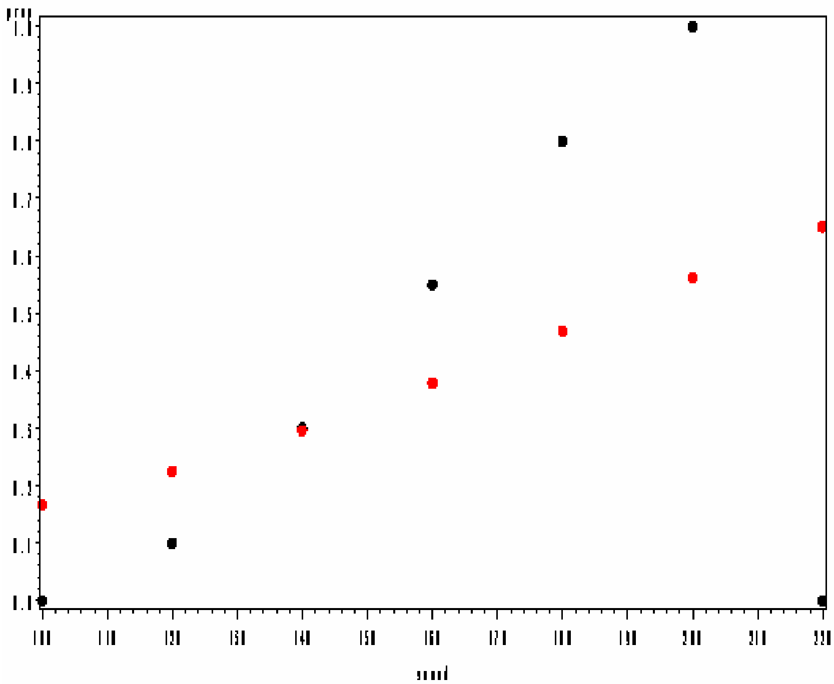
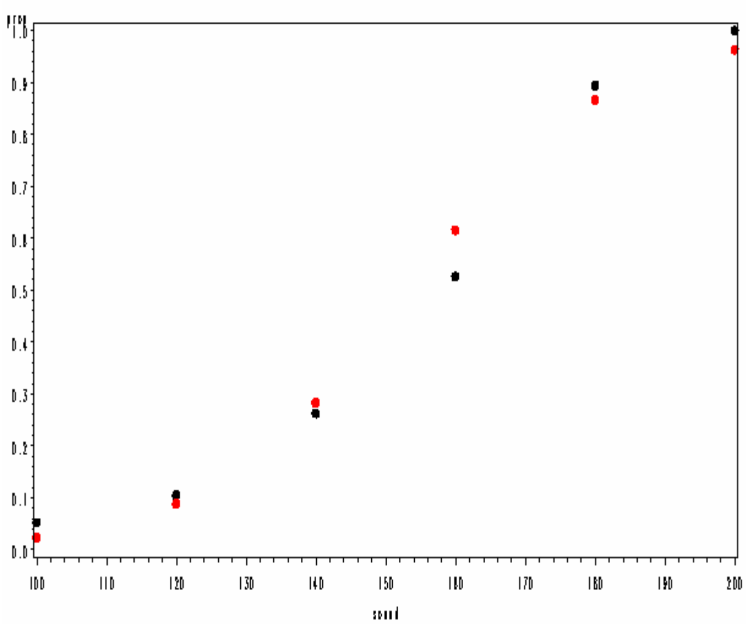
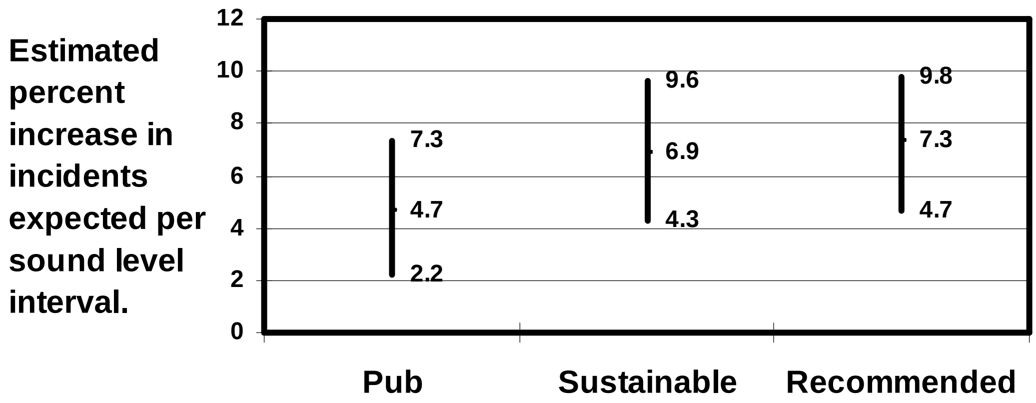


Fig 16. Mysticetes Maximum Standard data.



Therefore, H_0, is rejected because it is not consistent with the data that $\beta_1 = 0$; concluding that anthropogenic ocean sound levels are significant predictors of effects on free-ranging mysticetes.

Fig 17. Mysticetes: Effect Odds Ratios and 95% Confidence Limits



The risk to mysticetes is illustrated in Fig. 17 as odds ratios, where point estimates and 95% confidence limits estimate the percent increase in incidents expected per ocean sound level increase.

Tables 22-23: The Logistic procedure for Other (unspecified animals). Chi Square statistics indicate that the model is significant in three tests (Likelihood Ratio, Score, Wald). The logistic curves for each data set are illustrated below. Data for this category are available from the Internet survey only. “Sustainable levels” and “Maximum Criteria” are illustrated here.

Table 22. Other unspecified animal “Sustainable” data (for survey only), n=16

Testing Global Null Hypothesis: BETA=0

Test	Chi-Square	DF	Pr > ChiSq
Likelihood Ratio	52.4057	1	<.0001
Score	45.0664	1	<.0001
Wald	31.4702	1	<.0001

Odds Ratio Estimates

Effect	Point Estimate	95% Wald Confidence Limits	
sound	1.045	1.029	1.062

Table 23. Other unspecified animal “Maximum Standard” data, n=20

Testing Global Null Hypothesis: BETA=0

Test	Chi-Square	DF	Pr > ChiSq
Likelihood Ratio	55.4471	1	<.0001
Score	47.6587	1	<.0001
Wald	33.1992	1	<.0001

Odds Ratio Estimates

Effect	Point Estimate	95% Wald Confidence Limits	
sound	1.053	1.035	1.072

Figures 18 – 19 are the logistic curves for Other unspecified animals:

Fig 18. Other unspecified animal Sustainable data

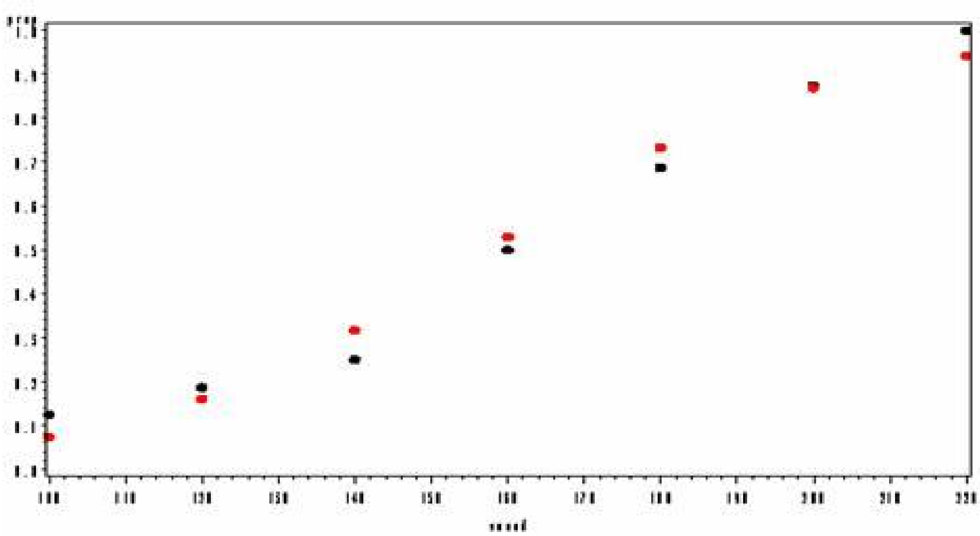
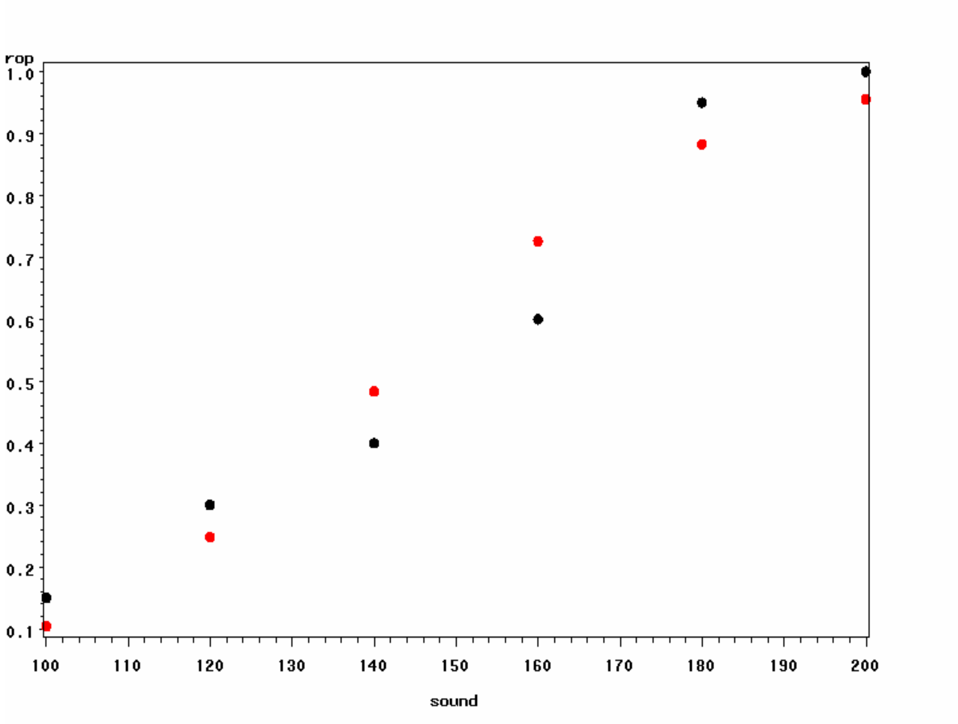
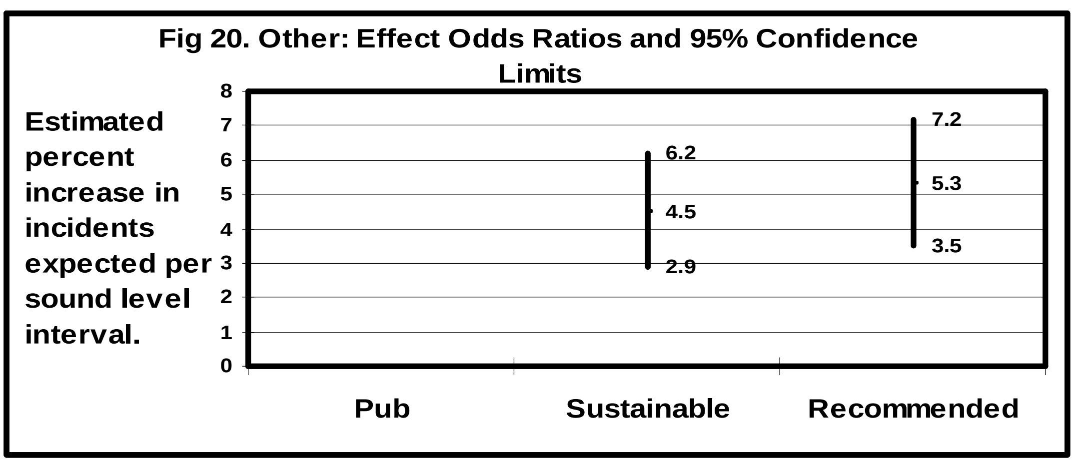


Fig19. Other unspecified animal Maximum Standard data



Therefore, H_0, is rejected because it is not consistent with the data that $\beta_1 = 0$; concluding that anthropogenic ocean sound levels are significant predictors of effects on other unspecified animals.



The risk to other unspecified animals is illustrated in Fig. 20 as odds ratios, where point estimates and 95% confidence limits estimate the percent increase in incidents expected per ocean sound level increase.

Tables 24 – 26: The Logistic procedure for Fish. Chi Square statistics indicate that the model is significant in three tests (Likelihood Ratio, Score, Wald). The logistic curves for each data set are illustrated below.

Table 24. Fish publication data, n=6

Testing Global Null Hypothesis: BETA=0

Test	Chi-Square	DF	Pr > ChiSq
Likelihood Ratio	10.7405	1	0.0010
Score	8.5018	1	0.0035
Wald	3.7821	1	0.0518

Odds Ratio Estimates

Effect	Point Estimate	95% Wald Confidence Limits	
sound	1.106	0.999	1.224

Table 25. Fish “Sustainable” data, n=7

Testing Global Null Hypothesis: BETA=0

Test	Chi-Square	DF	Pr > ChiSq
Likelihood Ratio	13.6138	1	0.0002
Score	11.6667	1	0.0006
Wald	7.9419	1	0.0048

Odds Ratio Estimates

Effect	Point Estimate	95% Wald Confidence Limits	
sound	1.086	1.025	1.150

Table 26. Fish “Maximum Standard” data, n=6

Testing Global Null Hypothesis: BETA=0

Test	Chi-Square	DF	Pr > ChiSq
Likelihood Ratio	9.5919	1	0.0020
Score	8.6400	1	0.0033
Wald	6.1713	1	0.0130

Odds Ratio Estimates

Effect	Point Estimate	95% Wald Confidence Limits	
sound	1.054	1.011	1.099

Figures 21-23 are the logistic curves for Fish data

Fig 21. Fish Publication data

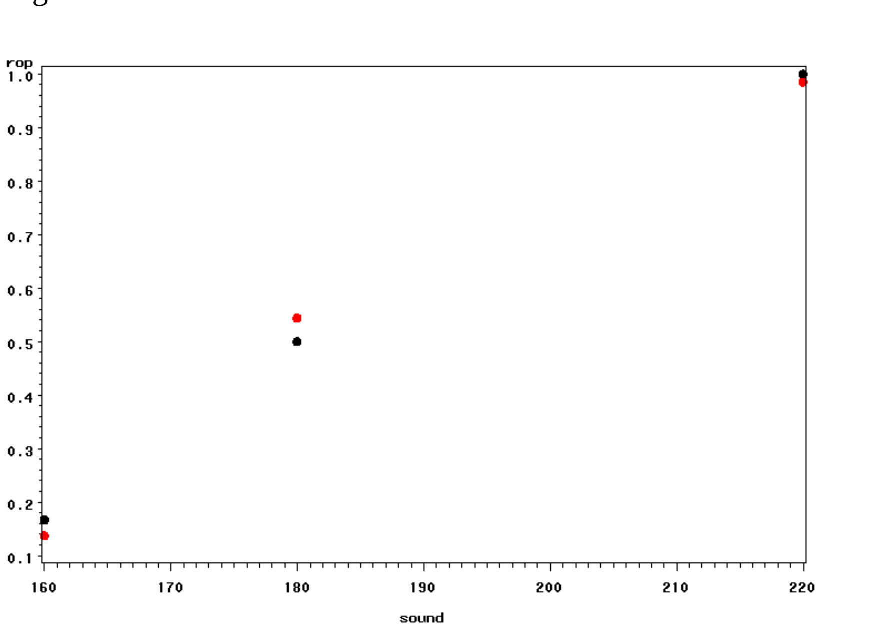


Fig 22. Fish Sustainable data

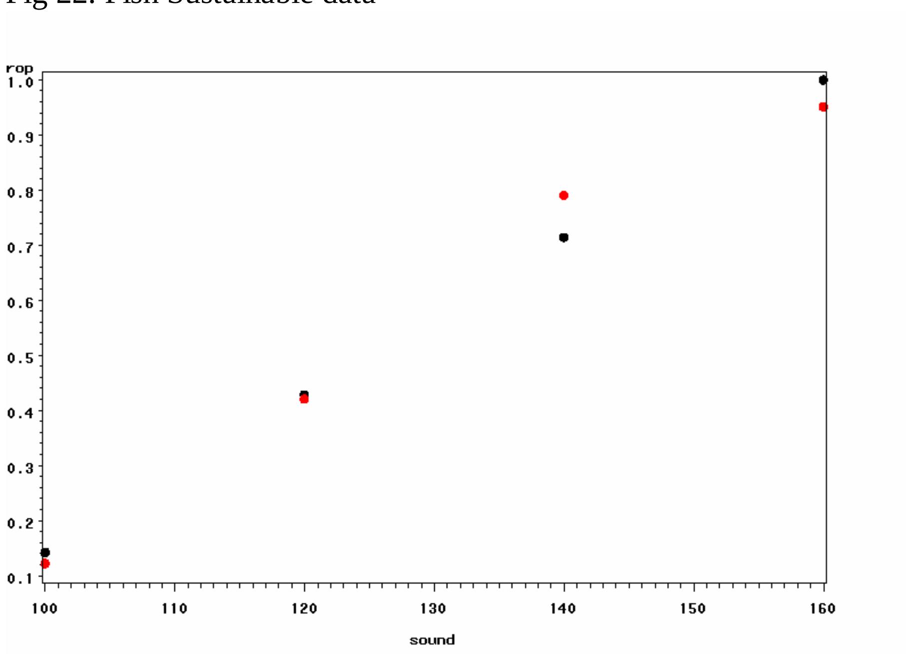
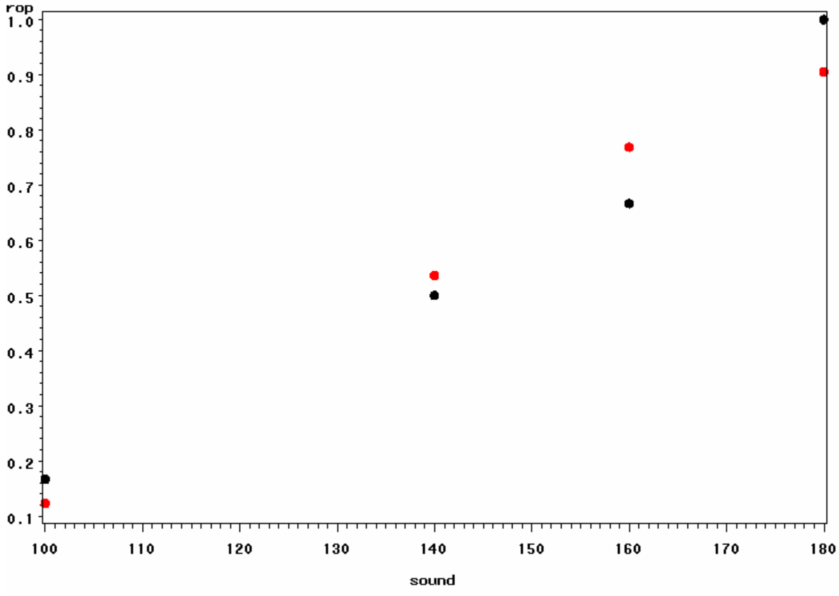
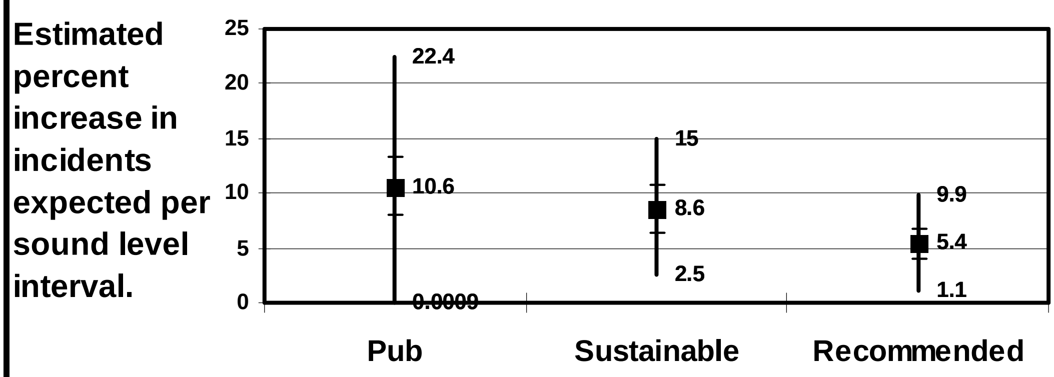


Fig 23. Fish Maximum Standard data



Therefore, H_0, is rejected because it is not consistent with the data that $\beta_1 = 0$; concluding that anthropogenic ocean sound levels are significant predictors of effects on fish.

Fig 24. Fish: Effect Odds Ratios and 95% Confidence Limits



The risk to fish is illustrated in Fig. 24 as odds ratios, where point estimates and 95% confidence limits estimate the percent increase in incidents expected per ocean sound level increase.

Tables 27 – 29: The Logistic procedure for All Species. Chi Square statistics indicate that the model is significant in three tests (Likelihood Ratio, Score, Wald). The logistic curves for each data set are illustrated below.

Table 27. All Species publication data, n=28

Testing Global Null Hypothesis: BETA=0

Test	Chi-Square	DF	Pr > ChiSq
Likelihood Ratio	87.4842	1	<.0001
Score	74.6968	1	<.0001
Wald	52.7809	1	<.0001

Odds Ratio Estimates

Effect	Point Estimate	95% Wald Confidence Limits	
sound	1.048	1.035	1.061

Table 28. All Species "Sustainable" data, n=87

Testing Global Null Hypothesis: BETA=0

Test	Chi-Square	DF	Pr > ChiSq
Likelihood Ratio	362.3786	1	<.0001
Score	296.2230	1	<.0001
Wald	177.5260	1	<.0001

Odds Ratio Estimates

Effect	Point Estimate	95% Wald Confidence Limits	
sound	1.058	1.049	1.066

Table 29. All Species "Maximum Standard" data, n=102

Testing Global Null Hypothesis: BETA=0

Test	Chi-Square	DF	Pr > ChiSq
Likelihood Ratio	294.8407	1	<.0001
Score	250.5125	1	<.0001
Wald	169.1099	1	<.0001

Odds Ratio Estimates

Effect	Point Estimate	95% Wald Confidence Limits	
sound	1.056	1.048	1.065

Figures 25 – 27 are the logistic curves for data on All Species

Fig 25. All Species Publication data

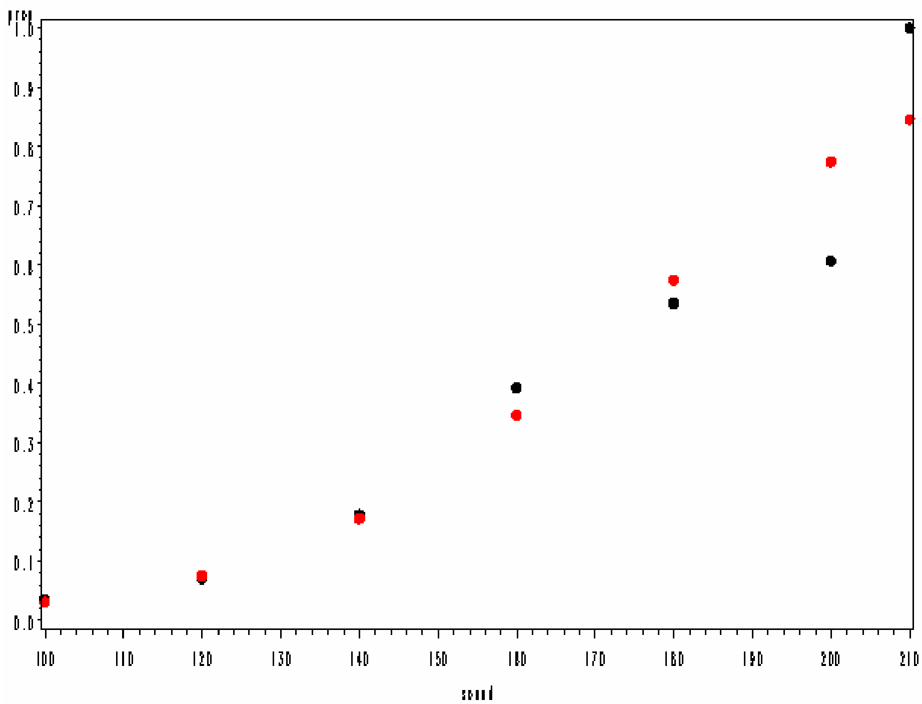


Fig 26. All Species Sustainable data

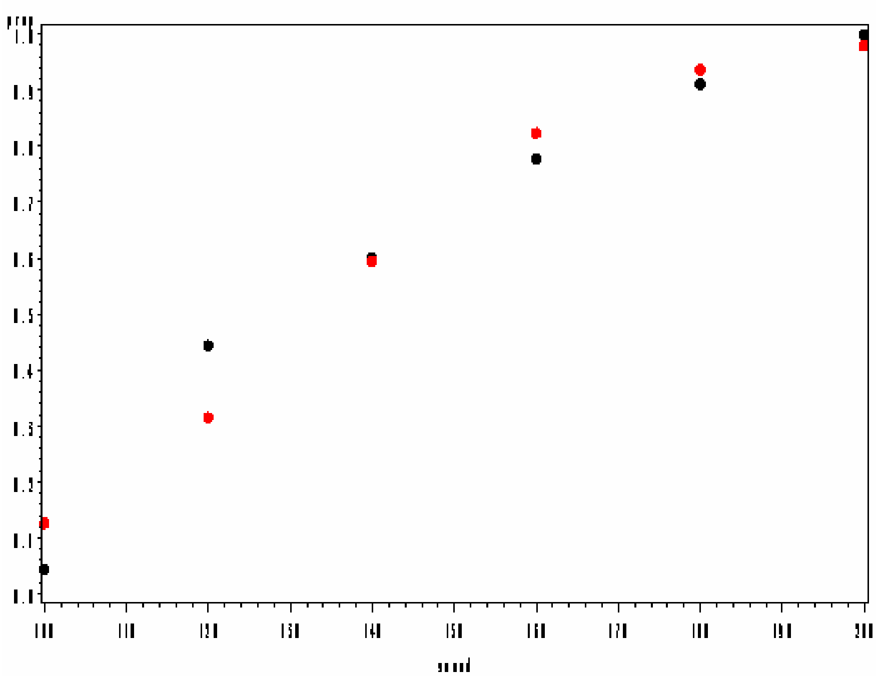
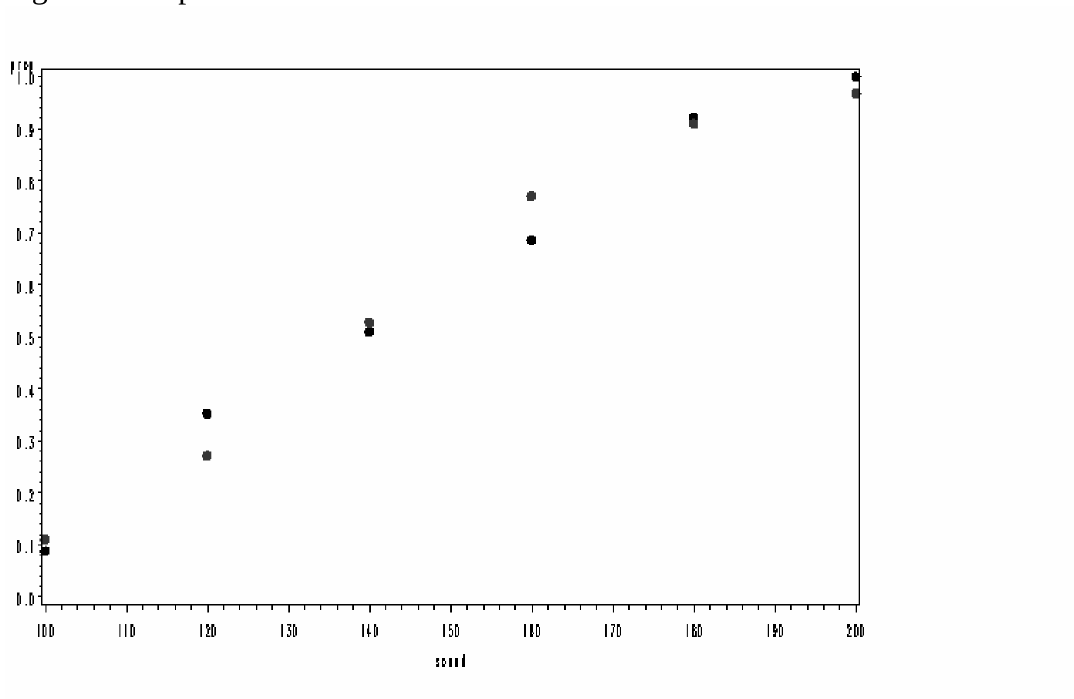
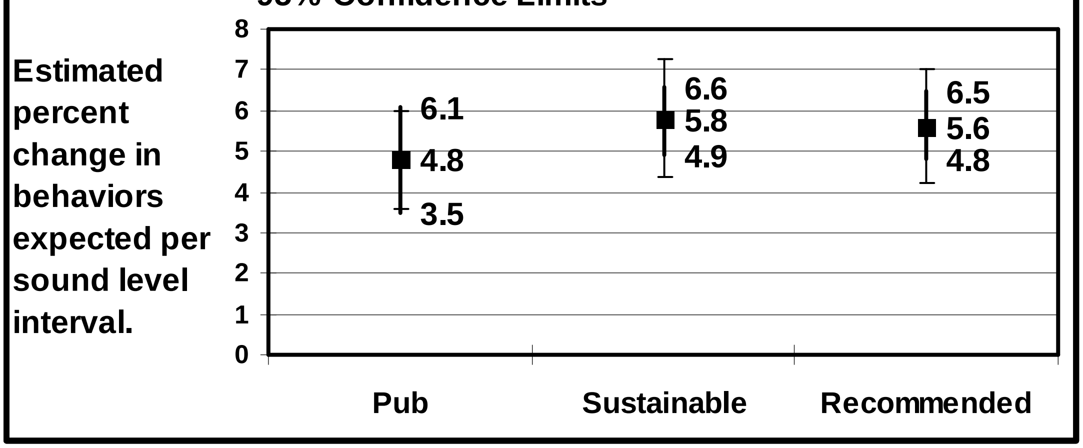


Fig 27. All Species Maximum Standard data



Therefore, H_0, is rejected because it is not consistent with the data that $\beta_1 = 0$; concluding that anthropogenic ocean sound levels are significant predictors of effects on all species.

Fig 28. All Species: Effect Odds Ratios and 95% Confidence Limits



The risk to all species is illustrated in Fig 28 as odds ratios, where point estimates and 95% confidence limits estimate the percent increase in incidents expected per ocean sound level increase.

Recommended Criteria

Survey results show that maximum standard criteria (MMPA Level A Acoustic Criterion) recommended by expert scientists begin at the observed onset of disturbance behaviors, and are as follows: Up to 120 dB p-p: 35%; up to 140 dB p-p: 51%; up to160 dB p-p: 69%; 161-200 dB p-p: 31%; >200 dB p-p: 0% (N=102). This recommended criteria distribution suggests a significant increase in concern by scientists, and assuming a 100 dB rms ambient ocean sound, represents more than a 50% shift downward from the 10-year "status quo" criterion of 180 dB rms. Weighted responses for species studied by these scientists were grouped into five functional hearing groups based on the NMFS acoustic groupings and are summarized in Table 30.

Table 30. Weighted maximum sound levels dB p-p @ 1 μPa by acoustic grouping (rough rms conversion included*).

	Small Odontocetes	Medium/Large Odontocetes	Mysticetes	Other unspecified	Fish	Total Weighted Mean
Possibly sustainable N=86	144.44	162.61	165	166.25	135	159.68
Maximum Standard Recommended N= 102	136.66	144.44	163.15	152	150	148.82
Weighted Mean of sustainable and maximum recommended	140.01	152.75	163.99	158.52	143.14	153.78
General equivilant decibel for weighted means in rms*	131.01*	143.75*	154.99*	149.52*	134.14*	144.78*

*Rms/p-p (root mean square/peak-peak) conversions are made based on sine wave structure, and are used here as a general guide, where, "the proper conversions of p-p vs. rms depends on the structure of the signal. For sine waves it is 9 dB. For noisy signals there are no simple rules. Take 9 dB as a guideline: rms + 9 dB = p-p; 140 dB p-p = roughly 131 dB rms; 180 dB rms = roughly 189 dB p-p" (W.Verboom, pers. comm. 2006).

"Not enough information to suggest criteria"

The second cluster of thirty-nine individuals responded that there is not enough information to suggest a maximum standard criterion. That datum corresponds to the publication data, where authors of 39 out of 94 publications did not report sound levels, but that anthropogenic sound was present when effect behaviors were observed. These data are consistent with scientists' survey comments asserting that specific sound level criteria cannot be determined without first defining specific parameters for which data are largely unavailable. Tables 31-33[52] summarize these parameters.

Table 31. Parametric qualifiers as described in scientists' commentary (Appendix F) deemed necessary to accurately determine sustainable anthropogenic ocean sound criteria.

	Sound Parameters Qualified					Biota Parameters Qualified	
	Sound Frequency/ Bandwidth/ Spectra	Duration	Intensity	Source Type	Direction	Habitat/ Ecology/ Life History	Cumulative Effects
Number of statements requiring parameter.	25	17	14	4	1	19	4

[52] Original 155 comments as posted in Table 32 are divided into the 177 segments found in Appendix F in an effort to facilitate the anonymity aspect of the study.

Table 32. Survey response indicating scientific expertise				
	Survey Comments		Survey Questions	
	Total Internet Survey Comments	Survey comments justifying non-response due to lack of expertise	"Not Knowledgable" [Q20 (V22)] compared to peers.	"No Reply" [Q19 (V21)] Max Standard sound criteria
Tally by Heading	155	8	8	8

Table 33. Survey response indicating inability to recommend criteria						
	Survey Comments		Survey Questions N=91			
	Qualifying expert comments from Survey.	Comments qualifying specific parameters necessary for criteria	"Not enough information" [Q14-16 (V16-18)] for Sustainability	"Not enough information" [Q19 (V21)] for Max Standard	"Not Confident" [Q21 (V23)] in criteria for species	"Not Confident" [Q22 (V24)] in criteria for oceans
Tally by Heading	147	44 (29.93%)	35 (38.46%)	39 (42.85%)	22 (24.2%)	26 (28.6%)

Mean survey questions indicating "no confidence" without qualified parameters totals 33.51%, compared to 29.93% survey comments justifying non-response to a discrete criterion range, and suggest that a grand mean of 31.5% of this cohort of empiricists, a) do not receive sufficient funding world-wide to collect the data necessary to do so; and/or b) view the survey options as too simplistic for specificity in recommending criteria. Empiricists qualify sound frequency, bandwidth, and spectra as primary physical parameters which must be clear; and animal habitat, ecology, and natural history as primary biotic parameters necessary to establish criteria, results which are similar to those indicated among MMC and NRC outcomes concerning uncertainty.

Chapter 5. Risk Characterization

The 94 peer-reviewed publications include 58 studies producing data resulting from the observations of 2844 free ranging animals (as compared to those generated from 25 captive animal observations, a factor of roughly 60) in the presence of anthropogenic ocean sound. Data indicate that substantial behavioral changes occur in these animals as a result of sound exposure, which is most noticeable beginning at approximately 140 dB p-p. Thirty-five publications reported effect behaviors among 1779 free-ranging animals which were observed to be associated with known levels of anthropogenic sound (Tables 4 and 5) and increasing effect behaviors. These data provide the basis for calculating a probability of effect thresholds of cetaceans to anthropogenic sound (Table 34). By contrast, based on the Internet survey response, Table 35 suggests the probability of the point above which scientists believe Level A impact is experienced by the species that they study.

Table 34. Probability of the point below which the true threshold of anthropogenic ocean sound lies for free-ranging cetaceans based on observations of 1779 animals.

Probability	Threshold dB p-p
0.139	120
0.405	140
0.729	160
0.945	180
0.989	200
0.999	220

Table 35. "Maximum Standard" - Probability of the sound level above which Level A harrassment is likely experienced by species studied, N=44 survey responses.

Probability	Sound Level dB p-p
0.340	120
0.500	140
0.659	160
0.909	180
1.000	200
1.000	220

Tables 34 and 35,[53] which represent both empirical data and expert scientific

[53] Table 34 probabilities are derived by fitting a Gaussian curve to data from the 1779 animals which were observed to respond with effect behaviors 143-145 to anthropogenic ocean sound levels beginning up to 120 dB p-p and progressing at 20 dB p-p intervals through 220 dB p-p. Threshold values were estimated by computing the mean (145.59 dB p-p), and standard deviation (21.55 dB p-p)

judgment, indicate that Level A impact likely occurs well below the status quo anthropogenic ocean sound level of 180dB rms. In terms of tactical management decisions, the current single-number single-species management approach seems to be losing momentum, while greater applications of ecosystem approaches and eclectic, integrated models are evolving. The data in Tables 34 and 35 appear at odds with the current NMFS definition for Level A harassment (180dB rms), and with the current goal of sustainability of cetacean species that have been studied in the world ocean.

Logistic regression results indicate that sound levels are strong predictors of effect behaviors. Small variances among the predicted effects suggest that increases in anthropogenic sound levels are consistent predictors of effect behaviors in cetaceans and fish, and Odds Ratios confirm that increasing levels of behavioral effects are linked to increasing anthropogenic sound levels, with an overall average for all species at 5.8% expected increase in effect behaviors observed among all species of cetaceans and fish at each sound level interval increase. Therefore, if 1138 free-ranging cetaceans alone are observed affected for example, at anthropogenic sound source level 141 - 160dB p-p (as reported in 6 publications, Table 4), the expected number of cetaceans which will likely be observed affected at 161 - 180dB p-p is estimated to be 1204; at 181 - 200 dB p-p estimates top 1274 animals observed affected; >200 dB p-p would be upwards of 1348 animals, and so forth. Barlow and Gisiner (2006) estimate that under good sighting conditions mitigation monitoring detects fewer that 2% of beaked whales if the animals are directly in the path of the

---

of observed responding animals. The area of the normal curve below the abscissa values of 120 - 180 dB rms were referenced in a table of error function values (Sokal and Rohlf, 1996). Table 35 probability for "Maximum Standard" anthropogenic ocean sound was similarly derived.

ship. If one assumes that the detection of all marine animals is similar to the detection estimates for beaked whales, then 1138 free-ranging animals observed affected at 141 – 160dB p-p (Table 4, Effect Category 143) would indicate that likely upwards of 56,900 animals were similarly affected among those 6 research/observation efforts alone.

Kolgomorov-Smirnov two-sample tests indicate that information gleaned from studies using animal source levels can not be confidently applied to defining how animals are likely to respond to received levels of anthropogenic sound. Given the numbers of individual animals observed responding to anthropogenic ocean sound (25 captive/ 2842 free-ranging), ecological risk to marine biota could range from comparatively small effects on greater populations, to potentially significant alteration of the ocean environment, the consequences of which remain uncertain and, based on the advise of this cohort of empiricists, warrants sustainable alternatives.

The outcome of the anthropogenic ocean sound Internet survey includes the successful engagement of expert scientists representing 20 countries, and more than 27 species of cetaceans and fish in virtually all oceans, their research findings, and their interpretation of their data as they relate to impacts from anthropogenic ocean sound. Fifty-three percent of the expert scientists responding translated their data for up to three species that they study in all oceans (N=102 cases of maximum criteria recommendations), of those, a majority (51%) recommend a “maximum standard” of 140 dB p-p or below as applicable to the MMPA Level A Criterion, above which this community of expert scientists characterize the risk to the species that they study as unlikely to be sustainable, a recommendation which is supported by their empirical data. This outcome indicates that the greater fraction of this expert community advises that adaptive management of cetaceans and fish must be advanced within a precautionary framework; one which negates the ecological risk of anthropogenic ocean sound levels to the species, or acoustical hearing groups of species, that they study. These expert scientists have converged on criteria which lie well below the status quo of 180 dB rms.

Thirty-nine peer-reviewed publications did not report source levels or received levels of anthropogenic ocean sound associated with effect behaviors, corresponding to 39 expert scientists that responded, "not enough information to recommend criteria" in the Internet survey. Responses to Internet survey questions and comments indicate a mean of 31.5% of scientists stating that they have not yet achieved a sufficient understanding of the dynamics of ocean sound as it relates to the animals' biology to recommend legislative criteria. These areas of greatest uncertainty represent data deficiencies which are consistent with those highlighted in the MMC and NRC outcomes and reports, pointing to the need to improve global funding distributions to underwrite a suite of projects which must be undertaken world-wide and internationally to explicitly define critical habitats and life histories of species of cetaceans (and other biota), along with sound frequency and duration parameters for the advancement of our understanding of the effects of anthropogenic ocean sound on marine ecosystems.

On the Fraction of Non-Participation

Ernst Mayr advocated a necessity of an enculturation of the expert scientific community to maintain an esotericism that resists pressures to blend with disciplines considered distal to empirical goals (Mayr, 2003, pers. comm.). It is not the position of the pure scientist to engage the political arena. This point of view is possibly shared by the fraction of scientists not responding to or declining to participate in the Internet survey aimed to facilitate the science/policy interface. However, neither should the singular elements (data) of empirical discovery and synthesis be hidden or sequestered from policy-making processes. Although scientists generally vary in their willingness and ability to approximate or simplify their results in order to communicate them readily to politicians, Malnes (2006) speculates that scientists may occasionally tailor their opinion to their interests with a view to procuring funds or securing positions. Wallace (2003) published results indicating that, *inter alia*, social and organizational factors, "… strongly, and in some cases predominately" influenced the decision-making behavior of marine mammal recovery program participants over the time interval from 1996 - 1999.

Although observations as characterized by Wallace were less apparent to me at the end of this study than at it's beginning, it is important to recognize that the Internet survey population is not without those scientists reporting that they felt pressure, in some cases from "employers," to sequester information, limit discussion related to data, or not to participate fully in this study (Appendix F). This population of empiricists also expressed concerns about a communication network which suffers from lack of transparency and/or lack of confidence among and between the expert community of scientists, stakeholders, and policymakers. Internet survey anonymous "comments" and personal communications indicate possible biases; some scientists reported perceived pressures by funding agencies related to research methods, proprietary ownership of research data sets, publication editing, and selectivity of data sets and/or interpretation of data in terms of research results, and are reported as having used future funding potential and/or future employment at reputable universities as a leverage for cooperation from researchers. Although there are scientific organizations which are ostensibly in place to facilitate information transfer among and between scientists and policy makers, a troubling proportion of this population of experts convey that they are working in environments that are unsupportive of open communication.

While these sentiments seem to reflect the outcome reported by Wallace, the Internet survey results indicate that only 7.7% of the scientists believe it is very likely or extremely likely that a precautionary approach to legislating ocean sound would limit their research in some way (a statistic which may be an artifact of the exemption permit bureaucracy[54]), indicating that the vast majority of scientists engaging this project are un-intimidated by the prospect of protective policy or bureaucratic procedural changes. Nevertheless, a significant proportion of this community elected to provide comments about their data and their perceptions of the current academic environment, transparency, and dissemination of their best judgment which is supported by their data. In fact, overall participation in this study could be viewed as an indicator that the larger fraction of the Internet survey population, at least anonymously, view cooperative efforts and precaution with greater value than traditional autonomous strategies.

---

54 Once the NMFS exemption permit application process is complete, the parties are allegedly allowed to exercise any sound as a consequence of their given activities. Therefore, one could presume the value of risk aversion strategies advocated by scientists as null.

Discussion

The Characterization of Ocean Sound Survey questionnaire was constructed with an aim to determine if an anthropogenic ocean sound decibel level recommended by expert scientists worldwide would be different from the U.S. NMFS status quo Level A Criterion of 180 dB rms, all other variables being equal. The result of this effort has produced a measure of that variance to be significant, with more than half the recommended criteria at 140dB p-p or below. The response to the Internet survey along with the shift of this magnitude suggests that the broader scientific community is willing to engage alternative avenues for information exchange and the science is providing the basis for tactical world ocean management decisions and governance.

However, results also provides evidence of problems which are consistent with those hindering the MMC and NRC efforts to achieve general consensus among stakeholders, and coupled with the comments provided in Appendix E by respondents, points to the need to go beyond specifying a single decibel reference level, thus confirming that the status quo criterion of 180dB rms remains unsatisfactory.

Seventy-six percent of the population of expert scientists accepting the Internet Survey engaged this effort for the purpose of recommending maximum standard criteria for anthropogenic ocean sound for the sustainable management of the species that they study based on the best available science. Raw data are coded in SDA for statistical analysis by anyone with internet access, and are posted in

Appendix E of this dissertation. The strong response[55] to the Internet survey realized through this dissertation effort establishes that this cohort of empirical scientists accepted a social survey instrument for measuring their judgment and to make recommendations to policy makers, potentially marking an evolution[56] of scientific expertise toward a willingness to engage alternative strategies toward caucus and consensus when scientific certainty is limited.

From a social science perspective, the distribution of those willing or not willing to generalize recommendations from 20 dB bins (disputed among some respondents as too broad a spread) could be linked to the complexity of problem sets. However, problems such as this one presents opportunities to approach solutions from two directions; one from the strictest empirical approach; the other by way of demonstrated steps toward an eclectic (or ecosystem) approach which are seemingly taken by those who have elected to generalize, based on their expertise, criteria for guiding policy toward sustainability. Those responses indicate the potential for success in the use of future caucusing instruments to include a focus on more discrete parameters which are typically demanded by empiricists, to include, in this case, frequency levels (and durations and habitats as they are understood) in addition to decibel levels, which can then be grouped within a precautionary framework according to acoustic hearing groups using NMFS (Appendix H), Benders et al.

55 Participation rate was exceptionally high compared to average survey response rates of 17% for telephone solicitations, and 34% for email solicitations.

56 In his postscript to the third edition of The Structure of Scientific Revolutions, Thomas Kuhn (1969), used the expression "disciplinary matrix" instead of the term "paradigm shift” to refer to a set of concepts, values, techniques, and methodologies in which cases of conflicting scientific data are punctuated by intellectual crisis, followed by a convergence of mindset which is fundamentally changed in the way events are perceived.

(Appendix I), or any other species grouping schemes deemed appropriate by the scientific community.

From a statistical perspective, the Kolmogorov-Smirnov two-sample test indicates that data sets are similar between captive animal and free-ranging animal clusters, but different between the two free-ranging source level and received level sound clusters. This is an interesting statistic as it has been assumed that sound source level parameters based on observations of captive animals can be successfully applied, at least to some degree, to free-ranging animals, an assumption which is supported by this test result. As anthropogenic sound source levels were among the first data points measured in relation to cetacean behavior, it is logical that source level parameters would serve as an initial baseline on which criteria could be established and then further explored. As sound level data distribution differs between source level and received level of sound among free-ranging animal data sets, information associated with either one may not accurately predict a response to the other. This distinction seems apparent among this cohort of expert scientists, and is measured in the survey as well as iterated in Appendix F, Survey Comments by Question Number.

Risks to ecological sustainability of any species are best estimated from studies within the critical habitats and communities of those species (USEPA, 1992a). Field surveys usually represent exposures and effects (including secondary effects) better than estimates generated from laboratory studies or theoretical models (USEPA, 1992a). Field data are more important for assessments of multiple stressors or where site-specific factors significantly influence exposure and are also often useful for analyses of larger geographic scales and higher levels of biological organization. However, because conditions are not controlled in field studies, variability may be higher and it may be more difficult to detect differences, which is clearly the case for anthropogenic ocean sound.

Extrapolations based on professional judgment are frequently required when managers wish to use field data obtained from one geographic area, such as inshore or continental shelf species like bottlenose dolphins, and apply them to different species of concern, such as deep marine canyon or open ocean basin dwellers like the beaked and sperm whales. Although statistical confidences found among the publication data and conclusions used for this study are acceptable, twenty-two out of ninety-one scientists report that they are not confident in the sound level criteria they have suggested in the Internet survey for averting detrimental effects on mortality, growth, and reproduction of the species that they have studied in our oceans. However, fifty-eight scientists expressed some level of confidence in the criteria they have recommended.

Factors altering exposure in the field are among the most important factors limiting extrapolations from laboratory test results, but indirect effects on exposed organisms due to predation, competition, or other biotic or abiotic factors, or cumulative and/or long-term effects not evaluated in the laboratory are believed to be critical to the scientists surveyed. Seventy-eight percent of Internet survey respondents report that they are not confident that habitats characterized as important to the long term survival of the species that they study have been sufficiently identified in establishing safe anthropogenic ocean sound levels (Appendix E).

Variations in behavioral responses to known sound levels between laboratory tests and field situations contribute to the overall uncertainty of the extrapolation, with a mere 2.2% of scientists accepting that threshold shift criteria established through captive studies are appropriate for the sustainable management of open ocean anthropogenic sound (Appendix E).

From a Socio-Governance Perspective

Social Construct

The Internet survey distribution of anonymous responses from the wider community of expert scientists shifted down from 180 dB rms as the ten-year upper limit "status quo" criterion for anthropogenic ocean sound, with 51% recommending 140 dB pp and below, a point representing a >50% shift toward an assumed ambient of 100 dB rms in limits and thresholds viewed as acceptable among responding expert scientists. From a social construct perspective, this "general approach" recommendation by roughly half of expert scientists providing criteria guidance represents a more than 50% shift over ten years from the status quo upper limit of 180 dB rms as determined by the original HESS panel downwards toward 100 dB rms[57], demonstrating that these scientists now fall clearly on the side of caution where uncertainty prevails. Given the turbulence underlying the status quo constructs and

---

57 This pattern models social equilibrium states described by mapping the states of the population onto points in the diagram below when N% of the population shifts onto the point of the line N% of the way to the leftmost point, toward a state of greater stability.

100dBrms <---------------<---------------140dBrms <-------------------------> 180dB rms

Defect Cooperate

Fifty-one percent of the expert scientist population converged on the point more than 50% back along the continuum from 180dB rms to 140 dB p-p constituting paradigm shift (Kuhn, 1996).

criteria outcomes, this statistic may indicate a progression towards a new convergence of mindset, from which the evolution, or “frame shift” in normative behavior evolves (Ostrom, 1990; FrameWorks Institute, 2006). Another feature arising from a social science perspective seems rooted in the evolution vs paradigm dynamic where scientific data deficiencies, variances, confusion, conflict, crisis, and then convergence occur, and are measured here over a relatively brief period of time (10 years). Paradigm is characterized by random convergence points as described by Kuhn (1996), equally likely to be "worse" or "better" than the preceding state. Evolution, however, favors adaptation (as in adaptive management), and is sometimes marked by sudden turns of events, otherwise described as punctuated equilibrium, with the resulting convergence occurring at a point, or state, providing greater stability.

Environmental problem structures necessarily includes variants such as incentives, capacities, and norms (Mitchell, 2006), but most central to the issue of managing the impacts of ocean sound on marine biota is uncertainty, the result of gaps throughout the informational environment. In the recent *Festschrift* to Professor Dr. Philos. Arild Underdal, (*Global Environemental Politics (August 2006)*), Ronald B. Mitchell addresses the importance of problem structure in terms of priorities for effective (sustainable) environmental policy, and seems to describe a political obstreperousness in his observation that, “…greater scientific uncertainty about an environmental problem leads states to be more reluctant to alter their behaviors but prompts them to make scientific components more central to any institutions they may establish.” (Mitchell, 2006). Hovi and Sprinz, (2006) agree that the advantage rests with the status quo, regardless of what creative alternatives may offer, which appears to be the scenario in the case of the NMFS status quo of 180 dB rms. However, the magnitude of this particular “shift” in recommendations from expert scientists over a 10-year span could represent a turning point as demonstrated in the adaptive management behavior among this particular cohort of blended (empirical and eclectic) thinkers.

On Governance

The usual response to theoretical and empirical uncertainty in international environmental regime building such as regulating anthropogenic ocean sound is to create a mechanism for scientists from participating countries to assess the state of knowledge, recommend appropriate research programs, and synthesize what is known and unknown concerning the issues being dealt with (Miles, 2006), the process exercised by the MMC advisory committee. But the MMC Scientific Advisory Committee Caucus Statement recommended no numbers, a position implying scientific ambiguity, a circumstance likely to strengthen the stance of other stakeholders in support of an economically and politically maintained status quo. For communities of stakeholders perceived hesitation within a community of experts (in this case, scientists) generally results in a greater weighting of “external” interests, such as those important to the political and/or economical sectors in the development of protective policy. Already temporary threshold shift criteria status quo of 180dB rms, which 61.5% of survey respondents believe is not a reasonable criterion on which to base global safe received underwater sound levels, is being adopted as sound threshold criteria for exploratory activities in regions of the Antarctic (Kremser et al., 2005). In theory, this type of “first move” scenario further underwrites the societal adoption of criteria which is at great variance from the recommended criteria reflected in the survey responses from this expert community, an indicator that the relevance of expert scientific judgment has limited value in global environmental and natural resource management regimes, unless for selective data mining (Sarewitz, 2004) in the justification for advancing exploitation. These, it appears, have advanced under the assumption that the impact from humans on the natural world, like the science, is no greater than the sum of its parts.

Historically decision rules such as those of the International Whaling Commission require a simple majority among the members voting; similarly, amendments to Appendices I and II of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) requires a two-thirds majority of Parties present and voting (Hovi and Sprinz, 2006). In the United Nations Convention on the Law of the Sea (UNCLOS) III, the scientific expert community was given no real scope for having an impact, with outcomes serving economic and political interests (Miles, 2006).

But that does not imply that all scientists are silent in matters of policy making with some clusters aggregating into positions of making joint decisions based on problem resolution and assimilation, and then presenting that decision with the intent of guiding policy. However, there are few directional steps or other organizational templates available to guide the scientists to the policy making bodies for the purposes of planning for sustainability. Further, there are substantial impediments to the science effecting policy (Mihursky, 1999), not the least of which is insufficient data, but also poor communication (transparency issues), lack of political interest among empirical scientists, and lack of funds for research necessary to understand how management can improve. Moreover, priorities in agenda setting contribute to impediments such as a lack of coordination, territorial sovereignty, legal and jurisdictional issues, and military use and restrictions. But impediments to successful outcomes are becoming clearer and therefore manageable, in part by way of recent shifts toward effecting transparency in 'expert judgment', both within the scientific community and among stakeholder groups.

But in environmental regulation there tends to be less uncertainty relative to physical effects and much greater levels of uncertainty relative to chemical, biological, and social effects, in that order (Brooks, 1977 cited in Miles, 2006). The Internet survey results addressing these aspects appeared skewed with more than 70% reporting that compared to other impacts to the species that they study anthropogenic ocean sound is very important or extremely important, and 75% are very concerned or extremely concerned that behavioral effects[58] of anthropogenic ocean sound can be as serious as direct physical/physiological effects on the species that they study. Given that commercial fishery operations, based on management resulting in fish stocks having dropped at least 90% below pre-exploitation levels (Pauly et al., 1998; Myers and Worm 2003; Downs, Rocke, and Barsoom 1996; and Miles et al., 2002, as cited

58 On the topic of "50% behavioral avoidance:" Several years ago I read an article on "dolphin sleep behavior" where captive *Lagenorhynchus* (among other small odontocetes) would posture in pairs, each with the "inside" eye open so as to view its partner along with the open space beyond its partner. It was speculated that one advantage of doing so (along with rare cases of bilateral eye closure in odontocetes) could be to remain invulnerable to predators while "blind" on the opposite (sleeping) side, where the eye is closed. If this supposition is true, then it seems conceivable to me that, from an evolutionary perspective, a 50% or greater vulnerability (in terms of behavioral avoidance) would be unacceptable to at least one of those two individuals (Lily, 1964; Goley, 1999; Lyamin et al. 2004).

in Mitchell, 2006) results in thousands of cetacean (and many tons of fish bycatch) deaths each year as compared to the relatively few deaths known to be a consequence of anthropogenic ocean sound[59] (Cohen, 2003), the scientists' concerns about behavioral impacts appears to be linked to two outstanding concerns; uncertainty of the science, and an emphasis that cumulative, long-term effects must be considered critically when stakes include ecological tipping point exacerbation (even if only for the species that they study), neither of which is mutually exclusive.

Weaknesses of the Study.

From the empirical perspective as expressed by many of those responding, the questionnaire fell short of adequately representing the spectra of sound characteristics such as frequency and duration. This characterizes how these empiricists perceive or construct schemata representing the hierarchy of relevant parameters (in terms of priorities) necessary to summarize what their data could mean in terms of effect. Alternately, based on the "all things considered" clause attached to the letter accompanying the survey, responses to the survey by empiricists suggests a distribution of scientists who are willing, if not best suited, to convey qualitative assessments for the purpose of guiding policy, thus potentially qualifying the anonymous survey model as an adequate instrument for the conveyance of scientific data interpretation.

From a policy makers perspective the graphics and tables are "too complicated" and should be distilled into a more reader-friendly, easily understood format such as a single criterion or a single criterion for groups of biota. This

59 Notwithstanding a potential relationship between increasing anthropogenic sound and decreasing stocks of fish.

difficulty characterizes how the political mind processes and prioritizes information, and although this dissertation does not focus on legislators, the record indicates that if policy makers need a number they will likely find someone who is willing to provide that number[60].

As a framework for creating blind international collaboration among the authorities of this discipline, this project's greatest potential shortfall is yet to be measured, but could be echoed from the voice of Dean Swanson, NMFS Division Chief of International Fisheries, "If you are not basing living marine resource management on scientific advice as the core of decision making, you are going to do the wrong thing." (Email comm., September 5, 2006).

Closing Thoughts

The original motivation for this study was to explore trends in how an international community of expert scientists summarize and interpret data for the purpose of guiding policy makers and other legislative bodies toward achieving adaptive management for natural resource sustainability. The scientists participating in this case study demonstrated an adaptive management strategy promoting knowledge management, open data base access, and reducing uncertainty through research coordination and collaboration, and at least to some extent, exercised relatively unrestricted academic freedom.

60 During the 2003 MMPA re-authorization hearings (DOD exemption hearing) the Ocean Sub-Committee chaired by Rep. Richard Pombo asked the panel of marine mammal scientists what maximum standard anthropogenic ocean sound criterion should be considered. There was no reply from the participating empiricists, however representatives of the U.S. DOD were quick to respond that the status quo, at a minimum, was appropriate. That criterion was accepted and defended as credible (Truett, personal observation).

The evolution of the ocean sound criteria development reflects a leadership role emerging within this scientific community which demonstrates the primacy of pre-eminent solution alternatives. But until integrated scientific design, international collaborative field research funding, curricular expansion, and innovative technology can provide a greater understanding of the impacts of anthropogenic sound in the ocean, the greater international expert scientific judgment falls predominantly on the side of precaution.

There is one question that, in retrospect, I should have asked which might have revealed a stronger indication of the direction the science/policy interface is moving; what is the intergenerational distribution among the population of scientists participating in this study and recommending these criteria? What form might we expect that distribution to take? Proposals to equip generations of brilliant young scientists to possess the leadership skills necessary to carry the evolution of global environmental collaboration and management forward to ecological success and sustainability may yet emphasize equitable funding distribution, transparency among databases, and curricular integration. The infrastructure for open collaboration is apparent, but how will a model for the open sharing of raw data and its interpretation evolve? Will a model be delegated, or collaborated? How will it link to strategies advancing sustainable policy goals? In that light, the data bases for this study are opening even beyond the raw data found in the appendices of this dissertation; by way of the Internet link to the survey results, coded in SDA from the Sociology Department of the University of Maryland, as promised to the scientists accepting the survey. It will be most interesting to follow how policy might respond to an emergence, perhaps in a Bayesian[61] sense, of scientific transparency and collaboration.

The baiji are now gone by our own hand, and with their passing I am compelled to consider how our own eventuality will follow in their wake. If global biodiversity is necessary for human prosperity then how will the next generations of scientists characterize the relics of decisions that we bequeath to them? From a realist perspective, whales are apex predators and competitors for ever-dwindling kettles of fish. In a world of rapid human population growth and competitive natural resource exploitation and degradation, there seems declining justification for supporting any species that have little economic value beyond the potential for becoming a source of protein for human consumption (notwithstanding the relative toxicity of their meat). In the end, this may be our best reason to advance collaborative protective policy where transparency underwrites accuracy and a rapid evolution of "Best Available Science" models sustainability.

The chess-board is the world;
the pieces are the phenomena of the universe;
the rules of the game are what we call the laws of Nature.
The player on the other side is hidden from us.
We know that his play is always fair, just, and patient.
But also we know, to our cost, that he never overlooks a mistake,
or makes the smallest allowance for ignorance.

T.H. Huxley 1825-1895,
Lay Sermons: A Liberal Education

61 In cognitive science, Bayesian reasoner is the technically precise codeword that is used to mean rational mind. Bayes' Theorem describes what makes something "evidence" and how much evidence it is. Bayesian theory also suggests that Bayes' theorem can be used as a rule to infer or update perspectives in light of new information. Bayes' Theorem binds reasoning into the physical universe. (Bayes, T., 1763).

Appendix A. Species reported in 94 selected publications and 91 Internet survey responses coded to Acoustic Groupings by NMFS (Southall, 2006), and Benders, et al. (2005). Numeric 'Code' corresponds to: column A: Species listed by relative size, and column B: Acoustic Grouping. NMFS 3/5 indicates 5 acoustic groups, three of which include cetaceans (coded 513, small odontocetes; 512, med/lg odontocetes; and 511, mysticetes). Benders, et al (2005) proposed 10 acoustic groups, 5 of which include cetaceans and are represented here (coded 521, 523-526). This case study necissarily created three additional groups (+3) to accouont for fish (group 535), unspecified cetaceans and other marine mammals (group 536), and physiological studies (537).

Species	Acoustic Groupings				Estimated General frequency ranges (kHz)[1]	Estimated Vocalization/ Phonation frequency ranges (kHz)[1][2]	Estimated Echolocation frequency ranges (kHz)[1][[2]	Estimated Vocalization source levels in dB re 1μPa rms [1][3] (tonal/whistle)	Estimated Echolocation source levels in dB re 1μPa rms [1][3] (impulse/ clicks)	Conservation Status[4][1]
	NMFS 3/5 +3 Code		Benders 5/10 +3 Code							
Name	A	B	A	B						
Vaquita (*Phocoena sinus*)	1	513	1	524	?-120		2+130			Critically Endangered
Hector's dolphin (*Cephalorhynchus hectori*)	2	513	2	524			130		160	Endangered
Finless porpoise (*Neophocaena phocaenoides*)	3	513	3	524	?-120					Data deficient
White-beaked dolphin (*Lagenorhynchus albirostris*)	4	513	4	526	?-120	3-17			180; (194-219 p-p)	Not listed
Tucuxi dolphin (*Sotalia fluviatilis*)	5	513	5	524		4-26	80-100		190	Data deficient
Harbor porpoise (*Phocoena phocoena*)	6	513	6	524	0.5-120	0.5-2	2+130	140	170	Vulnerable
Dusky dolphin (*Lagenorhynchus obscures*)	7	513	7	524	0.5-30	3-30k				Data deficient
Spotted dolphin (*Stenella frontalis*)	8	512	8	524	0.5-140	1.0-20 7.0-14	30-130		210	Lower Risk
Common dolphin (*Delphinus delphis*)	9	512	9	524	0.5-140	0.5-20	30-130		170	Common
White-sided dolphin (*Lagenorhynchus acutus*)	10	512	10	524	0.3-140	12-24; 9.0-30	60-130		175	Not listed
Bottlenose dolphin (*Tursiops truncatus*)	11	512	11	526	0.2-160	0.8-30	3.5-130	170	210	Data deficient
Risso's dolphin (*Grampus griseus*)	12	512	12	524	2-110 0.1-110	2.5-12	3.5-5; 6-65		175	Data deficient
White whale (*Delphinapterus leucas*)	13	512	13	524	0.2-120	0.260-50	40-120	206-225	210	Vulnerable
Pilot whale (LF/SF)	14	512	14	524	0.5-60	0.1-8; 0.5-20, 1-50	1-18; 3-06k; 30-60, 100	180	170	Not listed; Common
Narwhal (*Monodon monoceros*)	15	512	15	524	0.5-40	0.3-10	0.3-100	218	208	Data deficient
False killer (*Pseudorca crassidens*)	16	512	16	524	1-115	7-50; 4.0-10	2+10-130		210-220	Not listed
Beaked whale (~16 species)	17	512	17	525		20-40	7-20+			Data Deficient
N bottlenose whale (*Hyperoodon ampullatus*)	18	512	18	523		20-60; 3-16	8.0-06			Lower Risk
Killer whale (*Orcinus orca*)	19	512	19	523	0.5-25	1.2-25; 0.5-18	6.0-06; 12.0-35	160	180	Lower Risk
Sperm whale (*Physeter catodon*)	20	512	20	523	0.1-35	0.1-30	2.0-35		180-213	Vulnerable

Appendix A continued on next page

Species	Acoustic Groupings									
	NMFS 3/5 +3 Code		Benders 5/10 +3 Code		Estimated General frequency ranges	Estimated Vocalization/ Phonation frequency ranges	Estimated Echolocation frequency ranges	Estimated Vocalization source levels in dB re 1μPa rms [1][3]	Estimated Echolocation source levels in dB re 1μPa rms	
Name	A	B	A	B	(kHz)[1]	(kHz)[1][2]	(kHz)[1][[2]	(tonal/whistle)	[1][3] (impulse/ clicks)	Conservation Status[4][1]
Humpback whale (*Megaptera novaeangliae*)	21	511	21	521	0.03-8	0.03-8; 0.3-4	0.012-4	180		Vulnerable
N Pacific Gray whale (*Eschrichtius robustus*)	22	511	22	521	0.02-3	0.02-3; 0.2-2.5	0.02-4; 0.3-1	185		Critically Endangered
Bowhead whale (*Balaena mysticetus*)	23	511	23	521	0.02-5	0.02-5; 0.03-5	0.02-1	145-165; 189	185	Regionally –Lower Risk to Critically Endangered
N/S Right Whale (*Balaena glacialis / australis*)	24	511	24	521	0.05-1	0.30-5; 0.16-5	0.05-0.5	145-165	180	Endangered
Fin whale (*Balaenoptera physalus*)	25	511	25	521	0.01-2.5	0.014-.75; 0.01-5	0.02-0.07	165-185; 180		Endangered
Blue whale (*Balaenoptera musculus*)	26	511	26	521	0.01-0.4	0.01-0.4 0.08-.039	0.01-0.4; 0.015-0.25	165-185; 188=max		Endangered
small odontocetes	27	513	27	524	0.5-120	0.5-30; 0.5-120	2+130	<140; 170-225	<190; <220	
medium odontocetes		512		524	0.1-160	.1-120	.3-130	160-225 ?	170-220	
large odontocete	28	512	28	523	0.1-160	.1-120	3-130	160-225?	170-220	
mysticetes (clicking)	29	511	29	521	0.01-8	0.01-5	0.01-4	<190	<186	
mysticetes (non-clicking)		511		521	0.01-3	0.01-1		<190		
unspecified cetaceans	30	536	30	536						
Other marine mammals and turtles	31	536	31	536						
fish [5][6][7]	32	535	32	535	0.1-2.0			129-135; 147		Most commercial species overfished
Physiological studies		537		537						

[1] Compiled from Au, W.W.L., Clark, Christopher, and Verboom, Wim, Email comm. 2006; and from Ketten, D. (2000). Cetacean Ears. In: Au, W.W.L., Popper; A.N., Fay, R.R. (eds) Hearing by Whales and Dolphins. Springer Handbook of Auditory Research; .

[2] National Research Council (NRC). (2000). Marine Mammals and Low-Frequency Sound. Washington, D.C. National Academy Press.

[3]. Be aware that published dB levels are not all calculated in a consistent manner and the recording systems were rarely calibrated, so the listed values will be inconsistent. Furthermore, extremes are interesting but not all that informative. For example, the entry of a right whale producing a 186 dB sound is highly suspect. Even if true, it represents an extreme. The norm ±1 s.d. is probably closer to 155 ± 10 dB re 1 μPa. Same with blue whales; 188 dB range estimate between the whale and the hydrophone. We rarely detect and estimate a singing blue whale at 188 dB re 1 μPa^2/Hz. Notice difference between a reference of 1 μPa^2/Hz vs 1 μPa. The former is a spectrum level for a single Hz – usually done with narrowband sound such as a blue whale tonal at 19-21 Hz versus a sound that sweeps through a range of frequencies – such as a right whale glissando from 80 – 350 Hz. Christopher Clark, Cornell University. Email Comm, June, 2006.

[4] IUCN 2006. Red List of Threatened Species. <www.iucnredlist.org>. Downloaded on 16 May 2006.

[5] Captive (fathead minnow, tilapia, cod, haddock, American shad, goldfish, pink snapper, silver bream, trevally (cephalopod)

[6] Platt, C. and Popper, A.N. (1981) "Fine structure and function of the ear" In *Hearing and Sound Communication in Fishes* (W.N. Tavolga, A.N. Popper, and R.R. Fay, editors), Springer-Verlag, Berlin, pp. 3–36

[7] Joseph J. Luczkovich, pers. comm., Nov 2006.

Appendix B. Publication Variables by Numeric Code.

1. Category

11 – Captive, n=13

12 – Fish, n=7

13 – Free Ranging, n=58

14 – Theoretical Modeling & Extrapolations, n=16

2. Journal

21 – J. Acoust. Soc. Am., n=28

22 – Marine Mammal Science, n=12

23 – Fisheries journals, n=6

24 – Other, n=48

Animal Conservation, Antarctic Science, ARLO, Bahamas Journal of Science, Bioacoustics, Biological Conservation, Canadian Journal of Fisheries and Aquatic Science, Canadian Field Naturalist, Caribbean Journal of Fisheries and Aquatic Science, Comparative Biochemistry and Physiology, Conservation Biology, Elsevier International Congress Series, Fisheries Science, Hearing Research, IEEE J. Oceanic Engr., J. Cetacean Res. Management, J. Comp. Psych, J. of Experimental Biology, J. Zool. Lond., J.Theor. Biol, J of Animal Ecology, J. of Aquatic Ecosystem Stress and Recovery, Marine Environmental Research, Marine Technology Society Journal, Memoirs of the Queensland Museum, Nature, Naturwissenschaften, Royal Society B, Science, Vet Pathology, Zoo Biology.

Publication dates:

1990-1999, n=15	2003, n=10
2000, n=10	2004, n=17
2001, n=13	2005, n=7
2002, n=21	2006, n=1

3. Nation (PI)

31 – USA, n=55 32 – USA + Other, n=13 33 – Other, n=26

Countries represented in survey: Australia, Bahamas, Brazil, Canada, Denmark, Germany, Greece, Italy, Japan, Mexico, Netherlands, Newfoundland, New Zealand, Norway, Russia, Singapore, Spain, Sweden, UK, US.

4. Primary Funding source

41 – Office of Naval Research, n=26

42 - Petrol industry/Mineral Management Service, n=9

43 – Governmental orgs. (NOAA, NMFS, Depts. of the Environment, etc.), n=26

44 – University/Science (Projects undertaken under the auspices of academic institutions), n=27

45 – Non Governmental organizations, n=4

46 – NR/NA, n=2

5. Acoustic Groupings of Represented Species (with codes in Appendix A).

NMFS = 511, 512, 513

Benders et al. = 521, 523-526

Other marine mammals / turtles = 535

Fish = 536

6. Topic

61 – Threshold Shift (TTS/MTTS) captive only, n=11

62 – Vocal/acoustical/whistle/call behaviors, n=33

63 – Movement/orientation/distribution/abundance/ incl. breathing behaviors, n=29

64 – Physical impacts/stress (gas bubble/bone/cellular/ears; catecholamines), n=21

7. Sample Size

71 – 1-2, n=14

72 – 3-5, n=6

73 – 6-10, n=7

74 – 11-20, n=7

75 – 21-50, n=8

76 – 51–100, n=3

77 – 101-200, n=5

78 – 201-500, n=3

79 - >500, n=6

710 – NR or # of “calls” etc., n=35

8. Location

81 – North West Pacific, n=2

82 – North East Pacific, n=18

83 – North West Atlantic, n=10

84 – North East Atlantic, n=12

85 – Hawaii, n=14

86 – Mediterranean, n=1

87 – Caribbean/South Atlantic, n=2

88 – Arctic/Antarctic, n=10

89 – Australia, n=7

810 – Tank/Lab, n=11

811 – NR (or International), n=8

9. “Behavior”

91 – Threshold Shift (TTS, MTTS), n=4

92 – Vocal/acoustic, n=25

93 – Movement/orientation/distribution/abundance, n=23

94 – Physiological responses, n=24

95 – 92+93, n=15

96 – 93+94, n=3

10. Primary method of observation (for analysis)

101 – Visual, n=16

102 – Acoustical, n=16

103 – Visual and acoustical (and tracking devices), n=33

104 – Physiological (TTS, blood tests, necropsies, etc.), n=21

105 – Simulations/models, n=8

11. Source level rms

111 - <100dB, n=2

112 - 101 - 120dB, n=1

113 - 121 - 140dB, n=8

114 - 141-160dB, n=6

115 - 161 - 180dB, n=7

116 - 181 - 200dB, n=10

117 - > 200dB, n=18

118 – NR - None Reported, n=42

21. Source level p-p

211 - <100dB, n=1

212 - 101 - 120dB, n=2

213 - 121 - 140dB, n=4

214 - 141-160dB, n=8

215 - 161 - 180dB, n=7

216 - 181 - 200dB, n=7

217 - > 200dB, n=23

218 – NR - None Reported, n=42

12. Received level rms

121 - <100dB, n=1

122 - 101 - 120dB, n=6

123 - 121 - 140dB, n=9

124 - 141-160dB, n=11

125 - 161 - 180dB, n=7

126 - 181 - 200dB, n=2

127 - > 200dB, n=5

128 – NR - None Reported, n=54

22. Received level p-p

221 - <100dB, n=1

222 - 101 - 120dB, n=2

223 - 121 - 140dB, n=10

224 - 141-160dB, n=12

225 - 161 - 180dB, n=6

226 - 181 - 200dB, n=5

227 - > 200dB, n=4

228 – NR - None Reported, n=54

13. Primary Source Type

131 –Sounds naturally generated by animals, n=25.

132 - Boat motors, n=8.

133 – Aircraft, n=2.

134 – Sound Navigation and Ranging (SONAR), n=9.

135 – Acoustic Thermometry of Ocean Climate (ATOC), n=5.

136 – Acoustic Harassment Devices (AHD), n=6.

137 – Seismic watergun/drill ship, n=12.

138 – Digital/analog laboratory generated tones and harmonics, etc., n=18.

139 – Non-specific or None Reported, n=9.

14. Observed Behaviors (based on short-term observations)

141 –No obvious effects, n=24.

142 - Short– term altered behavior; slow or temporary/incidental orientation and/or vocalization changes, n=18.

143 – Interruption in distribution and movement patterns; avoidance behavior, n=18.

144 - Reluctance or refusal behavior; stress or elevated catecholamine production; startle behavior, flight/fleeing, n=22.

145 - Physical damage; acute trauma; stranded and/or death, n=8.

146 – None Reported, n=4.

"End Point Behavior" Risk Characterization

Category 141, "No obvious effects" include studies reporting no apparent effect or unable to detect impact, and indicates that the animals were not observed to change their routine or natural behaviors as they are currently understood in response to sounds. Most of the natural cetacean sound production studies resulted in this behavioral outcome.

Category 142, "Short– term altered behavior; slow or temporary/incidental orientation and/or vocalization changes" also includes whistle and/or breathing rate changes to which the observed animals are described to resume normal initial behaviors within a short time after the cessation of the acoustic stimulus.

Category 143, "Interruption in distribution and movement patterns; avoidance behavior" described by authors as "significant," "sudden," and/or "vigorous" responses by animals, or 50% avoidance or changes in behaviors, disruption of patterns such as feeding, socializing, traveling, reduced by-catch, and the like. Characterizing this end point behavior classification are animals observed not returning to pre-stimulus (normal initial) behaviors and/or distribution ranges.

Category 144 represents, “Reluctance or refusal behavior; stress or elevated catecholamine production; startle behavior; flight/fleeing,” represents end point behaviors described, or could be described as panic-like response, non-directional extreme speed, immediate break up of social units, neural-immune changes, hair cell damage, etc.

Category 145, “Physical damage; acute trauma; stranded and/or death” includes detonation studies, lesions, embolism, hemorrhage, strandings, etc., and is a self-explanatory measure of end point “behavior.”

Although arguments could be made, and in fact have been made in courts of law, that data which are characteristically placed in any category except category # 5 of this study should be viewed as having potentially greater or lesser impact than is represented here, I have based this risk characterization according to the reported observable short term results and aligned them to the USEPA *Guidelines for Ecological Risk Assessment.*

Appendix C. Published research content variables coded and listed by publicaton date. NMFS and Benders Acoustic groupings organized in Appendix A. Code Key listed in Appendix B.

Date	Research Category	Journal	Sponsoring Nation	Major (first) Funder	Acoustic Grouping NMFS	Acoustic Grouping Benders	Topic	Sample Size	Research Location	Natural (initial) Behavior	Observation Method	Max SL rms	Max SL pp	Max RL rms	Max RL pp	Sound Source Type	End Point Behavior
1990	11	24	31	42	512	524	64	72	82	96	104	114	215	123	224	137	141
1990	13	24	32	43	511	521	63	74	88	95	101	115	215	122	223	137	143
1994	13	21	31	44	511	521	63	78	88	95	103	117	217	128	228	134	143
1996	12	23	33	43	535	535	63	710	88	93	103	117	217	122	223	137	144
1997	11	21	31	41	512	524	63	71	85	93	101	118	218	124	224	135	142
1997	13	21	33	45	512	524	63	79	84	94	102	118	218	128	228	135	144
1997	13	24	31	44	513	524	63	75	83	93	101	113	214	128	228	136	143
1998	11	23	33	43	513	524	63	71	81	93	101	118	218	128	228	138	143
1998	13	24	33	44	512	523	62	77	89	92	103	118	218	128	228	131	141
1998	14	24	32	42	513	524	64	79	810	94	104	118	218	128	228	136	143
1998	14	24	31	43	511	521	62	710	85	92	102	116	216	126	226	131	141
1999	13	22	33	43	512	524	62	74	83	92	103	118	218	128	228	132	142
1999	13	22	33	45	512	524	62	75	86	92	102	118	218	128	228	134	143
1999	13	24	33	43	537	537	62	72	810	92	102	118	218	128	228	131	141
1999	14	21	31	44	511	521	62	710	811	92	105	118	218	128	228	131	141
2000	11	21	31	41	512	524	61	73	82	95	101	117	217	127	227	138	142
2000	13	21	31	41	511	521	62	77	85	93	103	116	217	122	223	135	142
2000	13	21	31	41	511	521	63	710	82	93	101	118	218	124	224	138	143
2000	13	21	33	44	512	523	63	72	88	95	103	117	217	125	226	137	141
2000	13	21	33	44	512	523	62	710	88	92	102	117	217	128	228	131	141
2000	13	22	31	44	511	521	62	710	85	92	103	118	218	122	223	131	143
2000	13	24	31	41	511	521	62	73	811	92	103	118	218	124	224	134	142
2000	13	24	31	44	511	521	63	710	85	93	103	113	213	123	223	132	143
2000	14	21	33	43	512	524	63	710	83	95	105	117	217	128	228	132	144
2000	14	24	31	43	537	537	64	710	811	94	105	118	218	128	228	139	144
2001	11	24	31	45	512	526	64	71	83	94	103	111	211	121	221	138	144
2001	12	24	31	44	535	535	61	73	810	94	104	114	214	124	224	138	144
2001	13	21	33	41	511	521	62	77	89	92	103	115	215	124	224	131	141
2001	13	21	31	43	511	521	63	77	82	95	103	116	216	126	226	131	141
2001	13	22	31	44	512	526	63	75	83	93	101	118	218	128	228	132	142
2001	13	24	31	41	511	521	63	710	82	93	103	118	218	125	226	134	141
2001	13	24	33	42	511	521	63	710	89	93	103	114	214	123	222	136	143
2001	13	24	32	43	513	526	63	71	84	93	103	113	214	128	228	136	143
2001	13	24	32	45	512	525	64	710	87	94	101	117	217	128	228	134	145
2001	14	21	31	41	536	536	61	710	811	94	104	118	218	128	228	139	144
2001	14	24	31	41	537	537	64	710	811	94	104	118	218	127	228	134	144

Appendix C continued on next page

Date	Research Category	Journal	Sponsoring Nation	Major (first) Funder	Acoustic Grouping NMFS	Acoustic Grouping Benders	Topic	Sample Size	Research Location	Natural (initial) Behavior	Observation Method	Max SL rms	Max SL pp	Max RL rms	Max RL pp	Sound Source Type	End Point Behavior
2001	14	24	31	44	511	521	62	710	85	92	102	116	216	128	228	131	141
2001	14	24	31	44	511	521	62	710	85	92	102	116	216	128	228	131	142
2002	11	21	31	41	512	524	61	73	810	91	103	113	213	123	223	138	144
2002	11	21	31	41	512	524	61	71	82	95	103	117	217	127	227	137	143
2002	11	24	31	41	512	526	61	71	85	93	103	112	212	125	225	138	142
2002	12	24	32	42	535	535	64	74	89	96	104	118	218	125	225	137	144
2002	11	21	31	41	512	524	61	71	82	91	103	113	214	123	224	138	144
2002	13	21	31	42	512	523	62	72	84	92	102	118	218	128	228	131	141
2002	13	21	32	44	513	526	62	710	88	92	103	117	217	128	228	131	141
2002	13	22	31	41	511	521	62	71	82	92	102	116	216	128	228	131	141
2002	13	22	31	41	511	521	63	79	85	93	103	116	217	122	223	135	143
2002	13	22	32	42	511	521	63	79	88	93	101	118	218	122	222	133	142
2002	13	22	33	43	513	524	63	710	83	93	101	116	217	128	228	131	143
2002	13	24	31	41	537	537	64	75	810	94	104	118	218	128	228	134	145
2002	13	24	31	43	513	526	63	710	81	93	102	118	218	124	224	132	141
2002	13	24	31	43	511	521	63	710	82	93	101	118	218	123	223	133	142
2002	13	24	33	43	512	523	64	710	84	94	101	118	218	128	228	131	142
2002	13	24	33	44	512	523	62	78	82	95	103	113	214	124	224	131	141
2002	13	24	33	44	512	523	62	710	83	92	102	118	218	128	228	131	141
2002	13	24	33	44	512	523	62	710	89	92	103	118	218	128	228	131	141
2002	14	22	33	43	512	523	62	710	82	95	103	115	215	128	228	132	142
2002	14	23	32	41	512	523	62	71	85	94	103	114	214	128	228	138	141
2002	14	24	31	44	536	536	62	710	810	92	105	118	218	128	228	139	146
2003	11	21	31	41	512	526	61	71	85	91	104	115	216	125	226	138	144
2003	12	21	32	42	535	535	64	76	89	94	104	117	217	128	228	137	144
2003	12	23	31	43	535	535	63	76	810	93	101	116	217	128	228	138	144
2003	13	21	31	41	511	521	62	77	85	95	103	117	217	124	225	136	142
2003	13	21	31	41	512	524	62	710	87	92	102	117	217	127	227	131	142
2003	13	21	33	44	512	523	62	710	88	92	102	117	217	128	228	131	141
2003	13	22	31	43	512	524	63	75	82	93	101	114	214	124	224	136	143
2003	13	24	31	43	511	521	62	75	84	92	103	118	218	128	228	131	141
2003	13	24	33	43	511	521	64	75	88	94	104	118	218	128	228	137	145
2003	13	24	33	44	512	525	64	73	84	94	104	118	218	128	228	134	145

Appendix C continued on next page

Date	Research Category	Journal	Sponsoring Nation	Major (first) Funder	Acoustic Grouping NMFS	Acoustic Grouping Benders	Topic	Sample Size	Research Location	Natural (initial) Behavior	Observation Method	Max SL rms	Max SL pp	Max RL rms	Max RL pp	Sound Source Type	End Point Behavior
2004	11	22	31	41	512	526	61	71	85	91	104	114	215	124	225	138	144
2004	11	23	31	41	512	524	64	71	82	94	104	117	217	127	227	138	144
2004	12	24	31	44	535	535	61	710	810	94	104	115	215	125	225	138	144
2004	12	24	31	44	535	535	64	75	810	94	104	115	215	125	225	138	144
2004	13	21	31	41	511	521	63	79	85	93	101	116	217	128	228	135	141
2004	13	21	31	41	512	523	62	72	82	93	102	117	217	128	228	131	141
2004	13	21	31	41	511	521	62	78	84	92	105	117	217	128	228	137	142
2004	13	21	31	42	512	523	62	710	84	92	102	118	218	128	228	131	141
2004	13	21	31	42	511	521	62	79	82	95	103	111	212	128	228	137	143
2004	13	22	31	44	512	526	62	74	83	92	103	118	218	123	224	132	142
2004	13	24	31	43	511	521	62	73	83	93	103	115	216	124	224	138	144
2004	13	24	31	43	536	536	64	72	89	94	104	118	218	128	228	139	144
2004	13	24	32	44	512	523	63	74	82	92	102	118	218	128	228	132	142
2004	13	24	33	44	536	536	63	710	811	95	103	118	218	128	228	131	143
2004	13	24	31	44	512	523	64	74	810	94	101	118	218	128	228	139	145
2004	13	24	33	44	532	532	64	76	84	94	104	118	218	128	228	139	145
2004	14	24	31	46	536	536	63	710	811	95	105	118	218	128	228	139	146
2005	13	24	31	41	512	524	61	71	83	94	103	113	213	123	223	138	141
2005	11	24	33	43	513	524	63	71	84	93	103	113	213	123	223	138	143
2005	13	24	33	43	512	525	64	73	84	94	104	118	218	128	228	139	143
2005	13	24	32	43	512	525	64	74	84	94	104	118	218	128	228	137	145
2005	14	23	32	43	537	537	64	710	810	94	104	118	218	128	228	138	145
2005	14	24	32	44	536	536	62	710	82	95	105	118	218	128	228	139	146
2005	14	24	33	46	512	525	63	710	88	95	105	117	217	128	228	137	142
2006	13	24	33	43	512	525	64	710	811	96	104	117	217	128	228	134	146

Appendix D. Letters of Invitation (to participate in Internet Survey) :

1. Dear Dr. ,

   I need to speak with you regarding one of your publications for my dissertation at the University of Maryland. Could you please send me a phone number and time when you can be available to speak with me? It is important to me, and I would be very appreciative of your time.

   I know that you are very busy, but I hope that I hear from you soon.

   Very truly yours,

   Amanda Truett
   Doctoral Candidate
   University of Maryland

2. Dear Dr. ,

   I have recently gotten the “okay” from my committee to communicate with you via email so long as you will agree not to circulate information related to my study to anyone else.

   My project focuses on the science/policy interface, is specific to ocean policy, and spans three different departments at the University of Maryland: Sociology, Government and Political Science, and Environmental Science. My case study is on ocean sound. I am looking at Characterization Analysis using the, “Professional Judgment Line of Evidence Approach” (USEPA 1998), more specifically for this part of the study, “expert opinion.” You are one of those “expert” scientists whose opinion is of interest for this study.

   I have reviewed a number of publication databases from which I have researched 109 peer-reviewed scientific publications related to ocean sound and cetaceans or fish which are authored or co-authored by 272 scientists from 20 countries around the world. The publications come from 37 scientific journals which include studies on 24 specific cetacean species, and 4 “general” categories of cetaceans and fish. They include studies on wild (free-ranging), captive, stranded cetaceans (and fish), and model extrapolations. They cover 11 independent variables (such as aircraft sound, ATOC/NPAL/low freq. sounds, pure tone, natural sounds, sonar, pingers, etc.) and 12 dependent variables (such as acoustic effects, behavior/response, bycatch, habituation, stress, thresholds, etc.).

   Because of the anonymity required by the University's IRB (Institutional Review Board) any emails or questions that I have for you about your study must not be shared with any others outside of that closed community of 272 scientists (which must remain anonymous to you, as well).

Will you agree to that condition?

Further, the IRB anonymity requirements also dictate that I am not at liberty to disclose anything that we might discuss, email, or convey to anyone in a way that might disclose who you are.

Also, if you agree to participate then I will elaborate further on my project and share my final spreadsheet (anonymous) data with you and the others who agree to "speak" with me. So far I have gotten a 92% positive response rate. Please, will you participate? It is most important that I get the participation of as many of the 272 scientists as possible for validity.

Please advise,

Amanda

3. THANK YOU!! I will send you my questions in the form of an electronic survey under a separate email, subject line reading: **Characterization of ocean sound survey**. It is the Professional Judgment aspect, or "Expert Opinion" perspective. Please understand that you should view the questions as a general approach to uncertainty, and answer as if a U.S. Congressperson were asking these questions. If there are questions that you are uncomfortable answering, you need not do so, but please state why in the last section which is an open-ended question, or comment area. Again, these are not intended to be the detailed questions, or specific numbers, that a scientist would likely prefer, but it is a broad-brush generalization (all things considered) of how a scientist might respond to a policy maker about the species that they are the experts on.

   If you have any questions about this project, please do not hesitate to contact me. Thank you again.

   Very truly yours, Amanda

4. Dear Dr. ,

   Thank you for agreeing to participate in my Characterization Analysis of Anthropogenic Ocean Sound Internet survey. Below is the link for the Professional Judgment aspect of this study – a short 24-question electronic survey. Please respond to the link as soon as possible. After you click the "submit" button, the survey will enter directly into the University of Maryland Sociology Department computer where your contact information (email address) will be removed for anonymity.

When the survey data collection is complete, I will be happy to share the results with you. If you have any questions about the survey or this study, please do not hesitate to contact me. Again, all correspondences are confidential.

(Link deliverable under separate cover)

Very truly yours,

Amanda Truett
University of Maryland
College Park

Appendix E

Anthropogenic Ocean Sound Survey Questionnaire
(Confidential; please do not distribute)

The following questions are designed to help describe what you think regarding impacts to cetaceans or fish from exposure to received anthropogenic ocean sound **at RSL re 1 µPa Peak-Peak, with associated energy flux levels.** There is an increasing value of survey results regarding governmental policy decision-making in sensitive issues, and this short questionnaire may serve to facilitate gathering the broader perspectives of as many marine scientists familiar with ocean sound as possible.

Although in some cases the answer may not be obvious, please respond as accurately as you can. Your professional, **yet anonymous**, opinions will be considered when sketching a "Professional Judgment" (USEPA, 1998) line of evidence approach to uncertainty for ecological risk characterization of ocean sound, and will supplement a dissertation effort on ocean policy.

Q1. Which species do you primarily study (list up to three)? **(All species submitted are listed in Appendix A**). 1a.(V1) ____________. 1b.(V2) _____________. c..(V3)____________.

Q2 (V4) **Since January 2000, how many times have you been directly contacted by governmental policy decision-making bodies about your professional knowledge/opinions regarding anthropogenic ocean sound?**

Percent	N	Value	Label
1.1	1	**0**	no reply
38.5	35	**1**	never
29.7	27	**2**	1-3 times
9.9	9	**3**	4-7 times
4.4	4	**4**	8-11 times
5.5	5	**5**	12-20 times
11.0	10	**6**	Greater than 20 times
100.0	**91**		**Total**

Q3 (V5) **Since January 2000, how many times have you offered your professional knowledge/opinions regarding anthropogenic ocean sound directly to governmental policy decision-making bodies?**

Percent	N	Value	Label
0.0	0	**0**	no reply
33.0	30	**1**	never
31.9	29	**2**	1-3 times
17.6	16	**3**	4-7 times
1.1	1	**4**	8-11 times
4.4	4	**5**	12-20 times
12.1	11	**6**	Greater than 20 times
100.0	**91**		**Total**

Q4 (V6) **How important do you think the issue of impacts from anthropogenic ocean sound is relative to other anthropogenic impacts to the species that you study and their habitats?**

Percent	N	Value	Label
1.1	1	**0**	no reply
25.3	23	**1**	extremely important
45.1	41	**2**	very important
26.4	24	**3**	somewhat important
2.2	2	**4**	not important
100.0	**91**		**Total**

Q5 (V7) **How concerned are you about the potential acute effects of anthropogenic ocean sound on the species that you study?**

Percent	N	Value	Label
1.1	1	**0**	no reply
18.7	17	**1**	extremely concerned
35.2	32	**2**	very concerned
39.6	36	**3**	somewhat concerned
5.5	5	**4**	not concerned
100.0	**91**		**Total**

Q6 (V8)	How concerned are you about the potential chronic effects of anthropogenic ocean sound on the species that you study?		
Percent	**N**	**Value**	**Label**
1.1	1	**0**	no reply
29.7	27	**1**	extremely concerned
41.8	38	**2**	very concerned
23.1	21	**3**	somewhat concerned
4.4	4	**4**	not concerned
100.0	**91**		**Total**

Q7 (V9)	How concerned are you that behavioral effects of anthropogenic ocean sound can be as serious as direct physical/physiological effects on the species that you study?		
Percent	**N**	**Value**	**Label**
1.1	1	**0**	no reply
30.8	28	**1**	extremely concerned
44.0	40	**2**	very concerned
22.0	20	**3**	somewhat concerned
2.2	2	**4**	not concerned
100.0	**91**		**Total**

Q8 (V10)	How confident are you that habitats characterized as important to the long term survival of the species that you study have been sufficiently identified in establishing safe anthropogenic ocean sound levels?		
Percent	**N**	**Value**	**Label**
1.1	1	**0**	no reply
0.0	0	**1**	completely confident
8.8	8	**2**	very confident
12.1	11	**3**	somewhat confident
78.0	71	**4**	not confident
100.0	**91**		**Total**

Q9 (V11)	As a general approach, how reasonable do you believe it is to base global safe received underwater sound levels on the Temporary Threshold Shift (TTS) onset established for 8 individual captive bottlenose dolphins and 2 individual captive beluga whales?		
Percent	**N**	**Value**	**Label**
3.3	3	**0**	no reply
2.2	2	**1**	extremely reasonable
6.6	6	**2**	very reasonable
26.4	24	**3**	somewhat reasonable
61.5	56	**4**	not reasonable
100.0	**91**		**Total**

Q11 (V13) As a general approach, how reasonable do you believe it is to manage "biologically significant impacts" of anthropogenic ocean sound using time/seasonal/area closures?

Percent	N	Value	Label
1.1	1	**0**	no reply
15.4	14	**1**	Extremely reasonable
28.6	26	**2**	Very reasonable
48.4	44	**3**	Somewhat reasonable
6.6	6	**4**	not reasonable
100.0	**91**		**Total**

Q12 (V14 How important do you believe it is to consider cumulative effects of ocean sound (including ambient sound) in establishing safe anthropogenic sound criteria legislation for all species?

Percent	N	Value	Label
2.2	2	**0**	no reply
31.9	29	**1**	extremely important
50.5	46	**2**	very important
12.1	11	**3**	somewhat important
3.3	3	**4**	not important
100.0	**91**		**Total**

Q10 V12) As a general approach, how reasonable do you believe it is to base safe sound exposure criteria on an observable 50% behavioral avoidance in the species that you have studied?

Percent	N	Value	Label
5.5	5	**0**	no reply
2.2	2	**1**	extremely reasonable
13.2	12	**2**	very reasonable
49.5	45	**3**	somewhat reasonable
29.7	27	**4**	not reasonable
100.0	**91**		**Total**

Q13 (V15) As a general approach, how reasonable do you believe it is to base safe sound exposure criteria on whether the sound is short duration (about one second or less impulse, or "ping") or long duration (longer than one second, or "continuous")?

Percent	N	Value	Label
7.7	7	**0**	no reply
18.7	17	**1**	extremely reasonable
35.2	32	**2**	very reasonable
25.3	23	**3**	somewhat reasonable
13.2	12	**4**	not reasonable
100.0	**91**		**Total**

Q14 (V16)	What lowest anthropogenic sound level range (re 1 µPa) do you think will have an unreasonable adverse effect on the long-term survival, growth, and reproduction of the cetacean or fish species that you have studied (listed in 1a-c above)? Species 1a.

Percent	N	Value	Label
14.3	13	**0**	no reply
3.3	3	**1**	less than 100dB
5.5	5	**2**	101 - 120dB
8.8	8	**3**	121 - 140dB
14.3	13	**4**	141 - 160dB
8.8	8	**5**	161 - 180dB
4.4	4	**6**	181 - 200dB
2.2	2	**7**	Greater than 200dB
38.5	35	**8**	Not enough information to suggest a range
100.0	**91**		**Total**

Q15 V17	What lowest anthropogenic sound level range (re 1 µPa) do you think will have an unreasonable adverse effect on the long-term survival, growth, and reproduction of the cetacean or fish species that you have studied (listed in 1a-c above)? Species 1b.

Percent	N	Value	Label
34.1	31	**0**	no reply
2.2	2	**1**	less than 100dB
3.3	3	**2**	101 - 120dB
7.7	7	**3**	121 - 140dB
8.8	8	**4**	141 - 160dB
4.4	4	**5**	161 - 180dB
5.5	5	**6**	181 - 200dB
1.1	1	**7**	Greater than 200dB
33.0	30	**8**	Not enough information to suggest a range
100.0	**91**		**Total**

Q16 V18	**What lowest anthropogenic sound level range (re 1 µPa) do you think will have an unreasonable adverse effect on the long-term survival, growth, and reproduction of the cetacean or fish species that you have studied (listed in 1a-c above)? Species 1c.**

Percent	N	Value	Label
52.7	48	**0**	no reply
1.1	1	**1**	less than 100dB
0.0	0	**2**	101 - 120dB
6.6	6	**3**	121 - 140dB
5.5	5	**4**	141 - 160dB
5.5	5	**5**	161 - 180dB
3.3	3	**6**	181 - 200dB
2.2	2	**7**	Greater than 200dB
23.1	21	**8**	Not enough information to suggest a range
100.0	**91**		**Total**

Q17 V19	**From your perspective as a scientist, what would you consider a "precautionary approach to management" maximum limit for short duration (ping) anthropogenic sound levels (re 1 µPa) which should be included in sustainability legislation for our oceans?**

Percent	N	Value	Label
11.0	10	**0**	no reply
6.6	6	**1**	Less than 100dB
5.5	5	**2**	120 dB
9.9	9	**3**	140 dB
13.2	12	**4**	160 dB
7.7	7	**5**	180 dB
4.4	4	**6**	200 dB
4.4	4	**7**	Greater than 200 dB
37.4	34	**8**	Not enough information to suggest a range
100.0	**91**		**Total**

Q18 V20	**From your perspective as a scientist, what would you consider a "precautionary approach to management" maximum limit for long duration (continuous) anthropogenic sound levels (re 1 µPa) which should be included in sustainability legislation for our oceans**

Percent	N	Value	Label
8.8	8	**0**	no reply
13.2	12	**1**	Less than 100dB
11.0	10	**2**	120 dB
15.4	14	**3**	140 dB
7.7	7	**4**	160 dB
4.4	4	**5**	180 dB
1.1	1	**6**	200 dB
0.0	0	**7**	Greater than 200 dB
38.5	35	**8**	Not enough information to suggest a range
100.0	**91**		**Total**

Q19 V21	**What "maximum standard" criterion for received anthropogenic sound levels (RSL re 1 µPa) do you think should be included in sustainability legislation for all the species that you have studied in our oceans?**

Percent	N	Value	Label
8.8	8	**0**	no reply
4.4	4	**1**	Less than 100dB
12.1	11	**2**	120 dB
7.7	7	**3**	140 dB
7.7	7	**4**	160 dB
12.1	11	**5**	180 dB
4.4	4	**6**	200 dB
0.0	0	**7**	Greater than 200 dB
42.9	39	**8**	Not enough information to suggest a range
100.0	**91**		**Total**

Q20 V22 **Compared to your peers, how would you describe your own professional knowledge about impacts of anthropogenic ocean sound on the species that you have studied or on their habitats?**

Percent	N	Value	Label
0.0	0	**0**	no reply
17.6	16	**1**	extremely knowledgeable
33.0	30	**2**	very knowledgeable
40.7	37	**3**	somewhat knowledgeable
8.8	8	**4**	not knowledgeable
100.0	**91**		**Total**

Q21 V23 **How confident are you in the sound level criteria that you have suggested in this survey for a goal of ecological sustainability for the species that you have studied in our oceans?**

Percent	N	Value	Label
12.1	**11**	**0**	**no reply**
5.5	**5**	**1**	**extremely confident**
18.7	**17**	**2**	**very confident**
39.6	**36**	**3**	**somewhat confident**
24.2	**22**	**4**	**not confident**
100.0	**91**		**Total**

Q22 V24 **How confident are you in the sound level criteria that you have suggested in this survey for a goal of ecological sustainability in our oceans?**

Percent	N	Value	Label
12.1	11	**0**	no reply
2.2	2	**1**	extremely confident
19.8	18	**2**	very confident
37.4	34	**3**	somewhat confident
28.6	26	**4**	not confident
100.0	**91**		**Total**

Q23 V25	What do you think is the likelihood that a precautionary approach to legislating ocean sound would limit your research in some way?

Percent	N	Value	Label
1.1	1	**0**	no reply
2.2	2	**1**	extremely likely
5.5	5	**2**	very likely
26.4	24	**3**	somewhat likely
64.8	59	**4**	not likely
100.0	**91**		**Total**

Q24 V26	Over the past 24 months have you changed your views on the criteria for legislating anthropogenic ocean sound that should be used in relation to the species that you study?

Percent	N	Value	Label
1.1	1	**0**	no reply
19.8	18	**1**	yes
79.1	72	**2**	no
100.0	**91**		**Total**

The following open-ended questions are listed with answers in Appendix F.

If so, in what way and what would you suggest are the best ideas for impact criteria now?
____.

1. What other comments or opinions would you like to offer regarding,

   a. the characterization of risk of anthropogenic ocean sound, or

   b. this survey?____.

2. Additional comments or suggested alternatives for legislating anthropogenic ocean sound:____.

Appendix F. Survey Comments by question number. In the interest of anonymity, the survey comments are edited to remove obvious identifying markers only.

Over the past 24 months have you changed your views o the impact criteria for legislating anthropogenic ocean sound that should be used in relation to the species that you have studied? Yes = 19.8%; No = 79.1%; No reply = 1.1%]

If so, in what way and what would you suggest are the best ideas for impact criteria now?

[Answers grouped by stated emphasis on physics, habitat/ecology/behavior, legislation/management, and 'other' response]

Physics (frequency, duration, direction of signal, intensity, energy, etc.):

1. It is not the sound level alone which determines the impact on the animal. The animal's total received energy flux in combination with a maximum sound level for short signals seem to describe the correlation to an impact better. Also the frequency as well as the direction of the signal (horizontally or vertically emitted) have to be taken into account.

2. Some further development in knowledge over last 24 months rather than change of views. Criteria should avoid TTS (depends on sound level, duration, frequency) or allow only minimal very occasional TTS, to be sure of avoiding hearing damage (this would also avoid physical/physiological damage). Determine long term biological effects from noise exposure and use these as criteria rather than evidence of behavioral reactions to noise.

3. Must consider intensity of sound, duration, frequency, variation, total energy exposure, as well as species affected, their physiological condition, experience, reproductive condition, population status, habitat availability, and cumulative factors affecting their status. In short, understanding the effects of anthropogenic sound on marine mammals is a lot more complex than previously suggested.

4. db criteria should be in energy flux density. That takes care of the need to specify duration.

5. In the last year or so I have begun to appreciate its important to specify whether pulsed sounds are being measured P-P (which I now consider the most relevant) or RMS.

6. The only justifiable approach, in my experience, would be to assess on a case-by-case basis based on the type of sound, frequency involved, species involved, etc.

Habitat/Ecology/Behavior:

7. (The species I study) hears a lot better than anyone realized. My best idea for criteria for this species depends entirely on gaining more information about this species and its habitat around areas of proposed anthropogenic noise sources.

8. Evidence that mortality of beaked whales is likely the result of a behavioral-mediated response to mid-frequency sonar has elevated my view of the importance of behavioral response and the very limited utility of TTS measurements.

9. The management process is flawed if it is limited to direct damage. Behavioral changes could be induced by lower sound levels - we do not know enough about the fright response of many species to the onset of anthropogenic sound.

10. We need better information on what sound levels are associated with TTS and PTS, and what sound levels are associated with inappropriate (i.e., dangerous) behavioral responses. Given the spectrum of organisms under consideration, we also need to identify a subset of species that can be studied, which will provide adequate information for making broad inferences regarding the impact of anthropogenic noise. Finally, bathymetry and bottom surface characteristics need to be included in the criteria. We also need to incorporate uncertainty.

11. Flexible and based on research and habitat and ecology of different species.

12. (Controlled studies have been done) to determine the discomfort threshold levels of (some species). Under quiet conditions, the animals avoided areas with SPL's of around 100-105 dB re 1 uPa. (Studies) have also been conducted on the reaction of fish to sound. The 10 species on which data has been collected showed a wide range in reactivity. Sea bass were very responsive, and should be used as the example species for further studies.

13. Evidence has emerged that beaked whale deaths associated with high-intensity underwater sounds are most likely behaviorally mediated, and thus they may be impacted by much lower SPLs than previously thought.

14. Establishing criteria must be based not only on the intensity of the sound but also the characteristics of the signal. Level/intensity are important, but an animal's response threshold to one type of signal could be significantly lower than to a less meaningful one.

Legislation/management:

15. I suggest setting standards through scientific professional societies.

16. Sound is clearly damaging to the animals and legislation is appropriate to preserve their health and wellbeing.

17. The beaked whale problem would seem to require legislative action.

Expertise:

18. It is clear that we do not have enough information from enough species to offer intelligent or useful legislative guidelines.

Other:

19. I now believe that cetaceans can safely experience short duration pulses of 200dB receive levels with no permanent harm. I now believe that the limits for behavioral reaction (for some sounds and some species) is so low (~120dB) as to preclude virtually any anthropogenic sound if that receive level is judged as a precautionary limit.

20. Fund more studies.

21. Difficult to say, we have a long way to go in our understanding of how sound, which sounds and under what circumstances sound affects beaked whales in particular.

22. Unfortunately, this field is highly technical. Most of the questions you have asked suggest a naive approach that was rejected a long time ago by the agencies who publish damage risk criteria for humans. A spit-ball single-number cannot possibly benefit any of the species I have worked on. Dose-response models must be developed based on a sound grasp of the psychophysics of noise effects, which means resources must be allocated to collect the appropriate data. Preliminary models must be developed by practicing scientists who are familiar with the technical issues. At that point, they may be used by policy makers, but the models themselves must be scientifically-grounded, just as they are for humans.

<u>23. What other comments or opinions would you like to offer regarding,</u>

(A) the characterization of risk of anthropogenic ocean sound. (Answers grouped by emphasis on physics, habitat/ecology/behavior, and 'other')

Physics:

23. Use of a maximum sound level as criterion is appealing to everyone but is far too simplistic. Criteria should also depend on duration of sound (not just ""short"" or ""long"") acoustic characteristics (e.g. frequency range, temporal nature), species and sensitivity of individuals and activity (e.g. mothers with calves, feeding, breeding). Should be based on long term biological effects not behavioral reactions.

24. Unlike other pollutants, sound is ephemeral rather than persistent. It can be controlled, and overdoses (while they can be lethal) dissipate rapidly. Repeated exposures above precautionary levels increase risk; repeated exposures at or below precautionary levels may result in habituation. Furthermore, behavioral responses are contextual. The point estimates provided for ""precautionary approach"" are for maximum precaution, and apply to perfect world, not world as it exists with anthropogenic sound today.

25. While I offered responses to your questions concerning sound levels, in reality it's very important to consider both the level and the frequency of the sound, and to put it in the context of the hearing sensitivity of your species at that frequency. High frequency sounds tend to attenuate more rapidly, and even very loud source levels may not be a concern if they are near or above the hearing threshold. For example, 210dB sonic transmitters were attached (to the species I study), but because they transmitted at 70kHz, and (the species I study) are insensitive to such high frequencies, they did not affect the behavior of the tagged animals. On the other hand, AHDs have been prohibited because they were generating source levels of 195+ dB, but at frequencies of 10kHz, to which seals and porpoise are much more sensitive. Very low frequency sounds tend to travel much greater distances, and therefore are of greater concern. Unfortunately, it's hard to study these low frequency sounds (and the large whales that are probably most sensitive to them) in captivity, so we know much less about their impacts.

26. I think that you can use "professional knowledge" in addition to what little data do exist to characterize risk of anthropogenic ocean sound, but it would have to be with a much more detailed survey which include species specific questions and would break sound out more into frequencies, sound levels, and durations.

27. I think that it's a mistake to talk about SPL (dB) limits without talking about: a) frequencies involved; b) species involved; c) type of sound, whether plosive, pulsed, etc. and d) duration There's no ""one size fits all"" limit for all occasions.

28. At this point in time attempting to legislate limits on sound in the ocean is not a reasonable thing to do. Sound exposure is much more than dB. It depends on situation, duration, type of sound, animal species and much more. The sky

is not falling, sound is not killing off populations of animals, more research is needed, but attempting to pass legislation at this point limiting sound for shipping companies, fishermen, oil producers, and the military would likely end up in failure. Legislation is NOT the current answer.

29. On a theoretical basis, we can expect anthropogenic noise to have the same kinds of effects on wildlife that it does on humans after exposure to the right combination of level, frequency, and duration. We have also seen that some unexpected effects could potentially occur (we still don't know why beaked whale strandings occur after exposure to mid-frequency sonar, for example). However, the word "characterization" implies a level of knowledge that we don't yet have and can't get without scientific data. The "precautionary principle" is great as a goal (and even more useful to advocates as a rhetorical artifice) but can have counter-productive and counter-intuitive effects on our ability to balance human and animal needs. Complete gridlock in needed research permits might be one example; another might be functional absence of regulation because published regulations can't be justified (for example, potentially-damaging noise is produced by fish-finding sonars, which are currently unregulated, ubiquitous, and not on the advocacy radar). The world has 6.5+ billion people. They're going to continue to make a lot of noise. The only thing we can do is learn how much noise is too much in what circumstances and correct accordingly.

30. Characterization of the risk of anthropogenic sound should be inclusive: research, shipping, oil and gas exploration/production, military, commercial, and recreational. The duration of the sounds must also be taken into account.

31. Two critical items stand out with regard to anthropogenic noise in the ocean: 1- the most consistent noise comes from merchant shipping and not military, ecotourism or scientific sources yet we do not routinely include them as part of the overall issue. 2- People fail to realize that adverse (essentially occupational) exposure to noise is the direct result of three factors- intensity of the noise, the frequency that it encompasses relative to the dynamic range of the affected species, and the duration of exposure. ALL THREE of these MUST be considered in the analysis of effects to the species with no exclusion. One cannot be traded for another nor given more weight then another.

32. Fish and mammals are affected quite differently by anthropogenic sound: while fish (this holds especially true for the species I did work on) easily die from stress if suddenly confronted with noises (signals) above 160 dB SPL this is not likely to happen to marine mammals like cetaceans. However marine mammals, as humans, are unable to repair damaged haircells, rendering any damage as permanent. Considering that they depend to a much higher degree on hearing capability than humans do, one can generalize: short, high impact(>180 dB) signals will kill fish and deafen mammals, weaker

(140-160dB) long duration signals will scare away bony fish and kill (on the long run) marine mammals.

33. There is a great deal of confusion regarding the presentation of sound levels that have been used in the past and that are part of the questions above. The basis for sound level measurement need to be clearly identified and the levels that are quoted need to be more clearly specified. How are the sound levels referenced above measures (peak to peak, peak, RMS, SEL)? The sound levels given in dB are relative and the reference level and measurement methods need to be stated precisely in legislation so that the potential exposures are properly evaluated.

34. Effects of anthropogenic sound depends on frequency, band width, species, sound propagation, acclimation, habitat, life history and many other factors. Criteria including specific sound pressure level should be established for each case based on scientific assessment.

35. It is very difficult to suggest exact dB values for different impacts, since hearing is frequency dependent and each species has a different audiogram. The application of 'single-dB sound level criteria' is therefore very preliminary at best.

36. Q 14-17 are not fully correct and therefore difficult to answer. A sound level is a dB-value + reference level + bandwidth and eventually also a duration and reference distance (in case of source level). If one is absent, an accurate comment/effect is not possible. In Q14 I assumed an overall (broadband) 'weighted' level. Our study for fish is not yet ready. For Q15 you must separate duration in less or more than hearing integration time (take 1 s).

Habitat/ecology/behavior:

37. The increased anthropogenic sound level in the ocean might lead to diseases which in the long run reduce or even kill whole populations.

38. Need long-term monitoring over representative sample of marine mammal habitat to assess trends in sound levels over time. Also need to relate sound levels to other related factors (e.g., coastal development, commercial shipping, military activities, oil and gas operations) to determine how they are related. Also need to consider the applicability of zoning of the continental shelf areas. Need experimental assessment of sound effects (controlled exposure experiments).

39. It will vary among individuals based on their degree of sociality, age, sex, and whether they are feeding, breeding or traveling.

40. To use TTS as a limit to sound levels is wrong in my opinion. Avoidance behavior and masking of ecologically important sounds should determine the maximum levels.

41. Very little is known on the full impacts and consequences of noise pollution for cetaceans, particularly the long term effects. Adverse impacts may occur in a number of diverse ways and much greater information is needed to assess and predict impacts on marine mammal populations.

42. Species that are most likely influenced by anthropogenic sound are also those that are most difficult to monitor/study (i.e., beaked whales), and so little is known about these species that large scale population declines may have occurred in the last 30 years due to anthropogenic sounds, and such declines would have been completely undetected.

43. I believe that habitat loss due to avoidance behavior of chronic noise is a real possibility. Also, seasonal area closure may not work in some places because migratory behavior may change over time, as will our knowledge about species behavior (i.e., cruises in British Columbia waters this winter identified a fin whale cow/calf pair near 54N in Feb. Quite different from our typical assumptions about this species).

44. Permanent ocean installations producing anthropogenic sound in areas of species habitat should be limited to source levels below 180 dB energy flux density. Such installations should not be allowed in National Ocean Sanctuaries or in areas of critical habitat for the species.

45. That research designed to assess the risk of noise not be directly funded by noise producers as this can lead to perceptions of bias and conflict-of-interest. That risk not only include cumulative noise exposure (from several sources of noise) but cumulative impacts in general from by-catch, chemical pollution, global warming, etc. on whales. Risk assessment for noise impacts must consider the great amount of unknowns in this area and be extremely precautionary.

46. Behavioral changes are probably the best criteria, but these are complicated by habituation.

47. We are quite far from knowing enough, particularly about long-term and behavioral impacts, to make informed judgments yet about acceptable levels of sound in the ocean. I know that NOAA is trying to set such levels, and I realize why they have to, but they need to allow for flexibility, indeed great flexibility, in adjusting their levels in light of future research.

48. I think the behavioral aspects, both proximate and cumulative, are quite underestimated. Cetaceans are both passive listeners and active vocalizers.

They use many subtle cues, both in reception of sound, and production of sound, that are understudied and underappreciated. I believe an extreme precautionary approach is the only way to approach this problem. In addition, many areas need baseline profiles, including seasonal and yearly sampling.

49. I think it is very important to characterize the main risk factors that anthropogenic sound might cause. High dB might damage at different levels the marine ecosystem. We know that many marine animals communicate through sounds which are very important in their behavior, and these would interrupt or alter different marine ecological processes.

50. Humans are not particularly good at calculating the long term, more subtle costs to our own species associated with various non point, chronic, polluting sources in our own environment--thus, it makes sense that we are having a hard time characterizing the possible negative impacts of chronic, increasing, levels of noise on marine mammals over generations. This is not easy, especially when modeled to incorporate possible cumulative or interactive impacts, and we will be adjusting/adapting our management techniques for decades to come. That said, we can make considerable progress more quickly at the cultural aspects of this debate, which centers around how we manage ocean resources to take into account multiple stakeholder groups, and the average US citizen's understanding of the state of the ocean environment, including its beloved marine mammals.

51. We need more research on biological (especially behavioral) effects. Too much effort at the moment is dedicated to better understanding source characteristics and propagation. Areas that are already relatively well known. The opposition of many NGOs to controlled exposure experiments has greatly hampered progress to an understanding of behavioral effects, and is delaying the search for possible solutions. “Precautionary” (by some definitions) government policies could limit this type of research. At the moment it’s a lack of political will and funding that’s the issue.

52. Impacts of noise is extremely species specific - proper risk assessments need to be applied on a case to case basis and a full regiment of impacts (behavioral, physiological and physical) need to be investigated.

53. Risk varies by species, both with respect to exposure (habitat use, critical habitat and behavior - e.g. deep vs shallow divers), and physiology. It is therefore difficult to devise effective strategies that are the same in all areas. For example, the best data about killer whales is from regional near-shore populations impacted by the tourist industry. Here long-term affects on their behavior (especially ability to coordinate behavior) and prey are likely most important. Elsewhere this species may be impacted by intense sounds as are e.g. Ziphiids, Grampus, etc. More data are needed before specific ranges of

permitted sound intensity levels can be established, and these should reflect the needs associated with particular species in regional jurisdictions.

54. The usual way of assessing the impact of anthropogenic sound on cetaceans is to make sounds, of no biological interest to the species under study, at increasing sound levels. If no change in behavior is seen, the usual conclusion is that the species is unaffected by that sound level. The analogous experiment with humans would be to repeatedly drive a fire truck down the street with siren going, then count how many residents sell their homes and move away. The fact the most residents would not sell out and move away, doesn't mean they aren't impacted by the sound. Similarly, when cetaceans do not react to sounds that are not interesting to them, one should not conclude that they are not impacted by the sound. Due to shipping, background noise levels in the ocean are now much higher than levels under which most cetaceans evolved. We know from studies of humans that unnatural levels of noise have negative effects on health. Therefore it can be expected that unnatural levels of noise will have negative effects on fitness and survival of cetaceans. Noise regulations need to pay attention to the fact that cetaceans are already barraged by unnatural levels of noise. The fact that we have come to regard such noise as ""background"" does not make it less significant.

55. Regarding legislation of ocean sound levels, it is important to include industrial sources such as shipping, drilling and surveying, and also private ships, especially pleasure boats and personal watercraft, as these sources vastly outnumber any research efforts, which seem well regulated by the NMFS permitting process. Also, it seems sensible to identify and designate areas of the ocean as critical habitats, and regulate anthropogenic sound in these locations more conservatively (strictly). Regarding level selection, it is important to legislate SPL at the sources, rather than at the receivers, as this seems to be the only practical way to enforce any limits (ie. by inspections). In the cases where sound output amplitude can be varied, it would be sensible to require a ramp up period so that animals can move clear of any potential harm before levels become dangerous.

56. Generally, it is my opinion that masking i.e. the generally increased noise levels in the oceans is the bigger problem. Animals using sound for communication or foraging have to be ever closer, this could disrupt reproductivity and foraging. Only rarely will pinging, unless extremely loud, have any impact.

Expertise:

57. Because of my current lack of knowledge, it is extremely difficult to specify exposure limits. Hence, a highly precautionary approach is required.

Other:

58. I cannot unravel myself from my employer enough to respond to your survey questions in an unbiased manner.

59. The confidentiality requirement for this survey all sounds very mysterious to me. I prefer not to participate, thank you.

60. I'm afraid I can't be trustworthy with the confidentiality requirement right now for your survey. Good luck.

61. The primary funding agent for my research apparently uses only part of the data because they only ask for part of the data from our research. They are not interested in other information, and they own the results.

62. I am appalled at the profound ignorance of acoustics displayed by most of the vocal opponents of sound in the ocean. I think many of the suggested measures are flawed, but the best possible at our current state of knowledge. I also believe that shipping noise is a far greater threat for continuous exposure than episodic scientific or seismic uses of sound.

63. This is an incredibly hard issue to tackle given our limited or absent knowledge of almost all marine mammal species. I'm not sure what I'd do if I were a policy maker faced with making these laws without much hard data on which to base my opinion.

64. Why is the list limited to cetaceans and fish?

65. Sound is only one of several, adverse anthropogenic factors. It is important to deal with sound in this perspective. Another perspective to keep in mind: Whales, themselves, do produce transient sounds with 230 dB + source levels. What about 'maximum limits' that outlaw the whales own signals?

66. It must include baseline data where possible and have sufficient statistical power to overcome the logistical difficulties of studying marine mammals. Long term studies of specific populations are essential.

67. Observing animal reactions to sound exposure is no way to characterize risk. There are too many confounding variables. Observing damage or injury to animals from sound exposure is meaningful.

68. I could not tell if questions 15 and 16 were asking for maximum received or source levels making it hard to answer. I answered as if these were referring to maximum allowable received levels.

69. Read the four documents produced by the National Research Council and the summary produced from the Marine Mammal Commission's Committee

Caucus of Researchers. There are reasonable people, without axes to grind, stating that research is needed but that the problem may not be as severe as some are contending. Don't jump into large restrictive and costly legislative fix when the extent of the problem remains very undefined.

70. This is an extremely complex issue and potential solutions should be taken with caution.

71. This field needs work on the basic medical impacts of sound on animals in the field. Needs work on how sound would impact gas chemistry in diving animals. Needs comparative work across many species.

72. I believe that the only proven risks are military sonar and airguns. The next most serious potential risk (still unproven) is masking of baleen whale calls by low-frequency ship noise. These topics should be addressed as a highest priority for research.

73. Considering the research that has been done to date, I think the current criteria are the "best" that can be expected until more research suggests otherwise. Yes, these criteria are based on very few studies, but I also understand that until more data is available this is the best that can be done.

74. Too little is known about the influence of anthropogenic noise on cetacean hearing. TTS investigations are not numerous and are NOT a good model for PTS, which is of the greatest concern. Experimental PTS investigation is not allowed by ethic reasons. Therefore, to-date knowledge of noise impact on cetacean hearing is not sufficient.

75. The public view has been distorted by unfounded and inflated statements by poorly informed or biased individuals and organizations. This has resulted in unnecessary official meetings, review panels, and lawsuits. The time and money would have been far better spent in organized presentation of the facts and properly moderated meetings as well as funding useful research. It is appropriate that all should have their say but it is detrimental to solving the problem to give equal weight to any and all opinions. Expertise should be recognized and attended.

76. We need to develop a policy on how much risk our society or the world community is wiling to accept regarding potential adverse impacts of anthropogenic sound on living marine organisms. We also need to establish immediately a relatively large number of stations across the world's oceans, where instruments are deployed to allow long-term monitoring of trends in anthropogenic noise. In some cases, retrofitting existing buoys is all that is needed. These data are needed to allow for inferences about impacts as anthropogenic noise increases into the future.

77. Your question 7 is critically important, and this distinction was perhaps the most important item to come out of the NMFS conference on biological impacts on beaked whales conference in Baltimore in 2004.

78. Noise pollution tends to be assessed on its potential to cause a TTS or PTS, however as acoustic communication is often important in so many functions which contribute to the health of populations, then masking potential, which can occur at much lower received levels than needed to cause a TTS, should also be considered more frequently than it is.

---

b. this survey? (Answers grouped by emphasis on physics, "simplicity" of survey, lack of expertise, and 'other')

Physics:

79. For question #14, i don't believe that you can set a limit on sound level for all species as hearing range varies among cetaceans and fish. The acceptable sound level would also depend on the source's frequency bandwidth.

80. The questions regarding acceptable levels for short and long pings need to be specific regarding frequency in order to answer these specifically. For example, 200 dB at 200 kHz may be acceptable, while 200 dB at 200 Hz clearly would not be.

81. In this survey ""short duration"" must be defined. I answered as if ping duration were 100 milliseconds or less for short duration pings. Also the interval for repeated pings should be specified. I rate ocean pollution from chemical effluent, shipping, and garbage dumping by all ships including cruise lines as more important problems than anthropogenic sound. Still, anthropogenic sound is important.

82. You need to be able to specify the frequency band, and bandwidth or spectral characteristics to say which spl could cause harm Q 15, 16: this needs to be species-specific AND frequency-specific Q 17: I don't support one safe level for all marine life. Again, levels must be species-specific and as such frequency and time dependent. If one wanted to take it further, safe levels that avoid a behavioral response could also be location-specific, seasonal and be linked to the current animal behavior. Physiologically safe levels should at least be species, frequency and time specific.

"Simplicity of survey":

83. The questions are quite o.k. but sometimes need an explanation - for example question 9: TTS can be (exactly) measured but the results certainly will be different for species and individuals. Behavioral effects are more difficult to measure. When using TTS-data you have to be very careful if you want to generalize them. From my point of view the physically based criteria are - for the time being - the best. Great danger arises from military. Permanent survey of the ocean by powerful active sonars at low frequencies and using the natural stratification (noise channel) will be dangerous for marine species. How to deal with shipping?

84. The sound ranges given are very broad. I think 10 dB bins might be more reasonable. It would have been good to have a question asking how confident respondents were in their understanding of acoustics and sound propagation in the ocean.

85. Many answers required are too simplistic and not what I would give as responsible scientific advice. Question #7 - not clear that there are physical/physiological effects, at least there is no scientific evidence of these (apart from explosions). ##9 TTS basis also includes other knowledge of mammal hearing that is not stated. #13-17 are almost meaningless since actual duration is as important as level. In my answer 'Not enough information' means not enough information in the question rather than not enough scientific information. 'Short' or 'long' is as useless as describing levels as high or low. Actual duration should be stated. #15-17 answers assume short is seconds but long is too vague so not enough information in the question to answer #16. Also assumes the level is actual exposure at the animal, thus involves source character and distance of animal from source and is NOT source level. Too much dependence on sound level alone (see 23 a). Energy flux is more appropriate in some cases as opposed to mean square levels given here. Peak to peak would only be useful for explosive shock waves.

86. It seems a bit overly-simplistic but it is a wonderful start to tackling this issue

87. Question 13 is too ambiguous, possibly misleading, it depends on if the animal's response is behavioral or physiological Question #14 is poorly written - I have listed species other than fish & cetaceans Some questions seem to be geared to direct physiological damage and not the damage that could be caused by a sound that could modify behavior, which could cause damage!

88. Answers on Q14-17 are species dependent. I took the most sensitive group to answer your questions. Q9: TTS can be used as guideline, but legislation should be based on TTS levels minus a species dependent margin.

89. Re: Question 14. Not able to answer this question. The impacts of noise are likely to be context specific - both with regard to the animals' behavior and the acoustic properties of the location. The precise nature of the noise may also be important. What might seem to be a relatively low noise source could be important if exposure occurs in the wrong time/wrong place.

90. The questions about levels suffer from the same problem as Congress: they are looking for a single number and that is a red herring (with or without hearing impairment). It is not level alone that is the useful criterion. Species hearing capacities PLUS received level PLUS durations, etc must all be considered. To accede to the demand for a level is to provide misleading information.

91. I can not answer many of the questions (13 to 20) in a meaningful way. Also, different species require different ticks, not allowed by this form. A frame for explanations of why a given question is impossible might generate more answers.

92. It is very difficult to respond to such a complicated and poorly understood field through such a simple questionnaire survey as this one. Sound levels are not adequately described – e.g. is it rms or peak to peak. However, given the uncertainty involved I would have answered in the same way - we don't know enough to set these thresholds for the species being considered.

93. Well assembled, though some of the key issues (eg. question #14) lack enough information in the question to make a reasoned response. This is unfortunate because they are key issues, though i must admit that assessing long term effects such as growth and reproduction is a very difficult prospect.

94. This survey was next to impossible to fill out for various reasons. First, I work on multiple species, some of which I am less concerned about noise than I am for others. Also, the question ""As a general approach, how reasonable do you believe it is to base global safe received underwater sound levels on the Temporary Threshold Shift (TTS) onset established for 8 individual captive bottlenose dolphins and 2 individual captive beluga whales, and Permanent Threshold Shifts (PTS) based on model extrapolations including data on terrestrial mammals?"" is difficult to answer. I don't believe using TTS is a good metric for ""safe"" sound, but I do think it is reasonable to extrapolate PTS from terrestrial animals in the absence of other data. I also did not answer questions 14-20 because there is not enough information -- the safe dB level would depend on frequency, which is not part of the question."

95. Question 14 is so non-specific as to be nearly meaningless. Over what duration is the sound present? Once or many times or continuously? How much of the population is exposed? What frequency? Does the sound itself bear any similarity to biologically significant sounds? Question 9 appears very slanted. If you are referring to the proposed sound levels from NOAA, I think they included species other than bottlenose dolphins and belugas -- e.g.,

false killer whales. Also, in questions 15-17, I assumed you were talking about received levels.

96. Question #9 is unreasonable because there is more information available than you posit. #11 ""Time/seasonal/area closures"" is only one approach. A combination of considerations is a reasonable approach to managing ""Biologically significant impacts"". At the top of the survey you refer to RSL in dB re 1 uPa (peak-peak. Why peak-peak and not root-mean-square? You never mention peak-peak again but most reports of sound exposure characterize continuous sounds as rms, and most respondents are going to be thinking rms answering 14 - 17.

97. Due to the options of the multiple choice and the choice of phrasing in some questions it appears the design of this survey is skewed and looking for support for only the negative impact of sound. For example question 4, reads how important is sound relative to other anthropogenic impacts. I would respond 'not as important' because there are other impacts that I believe are more important at this time. However, this response is not an option and the closest response is 'not important' which is essentially a different answer.

98. The questionnaire falls into the same trap as which most other people fall into with this topic. 1) is units, you cannot state a dB value and expect a reasonable answer without the units (dB is not a unit but a ratio) and different unit systems apply best to different effect scenarios, consequently I refuse to give numbers to these questions; 2) One cannot apply the risk same criteria to all scenarios, there will be some areas / times / animal behaviors or habits where anthropogenic sound may have profound impacts for a species and other times/ places where the same anthropogenic sound will have hardly any impact.

99. Interpretation will also depend on level of expertise of the person being surveyed. Analysis should stratify based on question 18. Also, because questions were phrased in terms of ""species you work on" and I work on all marine mammals, my answers had to be on that basis. However, had the questions been more specific (concerns about risk to beaked whales) then my answers would have changed (generally more concerned).

Lack of expertise:

100. I am not an expert in and do not conduct research in the effects of anthropogenic sound in the oceans.

101. Leaving blank all those questions I cannot answer due to my own lack of knowledge or if the question refers to a previous question that I did not answer. For example #17 I did not choose answer E because the info may be out there, but I certainly do not know it. Perhaps there should be an option to

opt out of the question. It would be less ambiguous to you than leaving it blank. #19 I left blank because I couldn't answer a previous question.

Other:

102. Very well thought out questions, look forward to seeing the final thesis.

103. It would be good to know how this information will be used.

104. I am happy to see this kind of work undertaken. It will be necessary to impose international legislation in the area.

105. Question 19-20 are very similar; the added modifier of ""species"" in number 20 was a little confusing.

106. The issue of national defense and the trade offs between protecting marine organisms from anthropogenic noise needs to be addressed. Some type of balance is necessary. In addition, funding is woefully inadequate for monitoring and research. The survey should include questions about what it would cost to adequately monitor and to conduct the necessary research on anthropogenic noise.

107. Most avoidance studies have been done under quiet conditions. It would be good to test the effects of anthropogenic sounds under various noise conditions (sea states). Per area in the world an average sea state should be used when setting a maximum allowable level for an anthropogenic acoustic activity. More studies on masking should be carried out.

108. I responded assuming dB re 1 micropascal (rms) because this has been the understood in past.

109. Question 14 - the suggested levels apply to intermittent sounds (short duration)

110. It would be helpful to clarify of questions 16 & 17 refer to SOURCE levels. That is how I interpreted them.

111. A good idea

112. This survey is well worded, and the details of the questions show that the author has fully grasped a great deal of the controversies.

113. Many of the questions come across as having been written by someone with little knowledge of acoustics or anthropogenic noise impacts and a particular political stance. This is why I have not answered a number of them.

114. Interesting and possibly a useful tool.

115. I don't believe you asked about cumulative impacts from human activities and how this can interact (synergistically) with the impacts from noise, causing even greater risks for marine life. You should have asked which funding agencies/bodies respondents received research grants from, as this can greatly influence results. It was unclear whether the noise standards that were asked about were for marine areas in general or especially sensitive areas.

116. Question 9 seemed loaded.

117. The questions could be interpreted as leading the respondent to more "negative" responses. (Question 9 in particular but I don't know how else to have framed it.)

118. Too Restrictive - The only allowed answers are about legislative remedy. That is not the only way to approach problems.

119. This field: Needs work on the basic medical impacts of sound on animals in the field. Needs work on how sound would impact gas chemistry in diving animals Needs comparative work across many species.

120. Difficult.

121. I would follow the recommendations of ""Report of a Workshop to Understand the Impacts of Anthropogenic Sound on Beaked Whales"" by Cox et al.

<u>24. Additional comments or suggested alternatives for legislating anthropogenic ocean sound:</u> (Answers grouped by emphasis on physics, habitat/ecology/behavior, lack of expertise, and 'other')

Physics:

122. I think determining 'noise budgets' will be important, e.g. determining time budget of the received levels individuals are exposed too, very helpful for determining chronic exposure. Also more effort in using evoked potentials on wild specimens in incidents such as live stranding to obtain more audiograms from different environments.

123. Audiograms are U-shaped curves, indicating that animals have different hearing sensitivities for different frequencies. However, in all the answers the scientists gave to the questions above, the spectrum of the anthropogenic noise was not stated. Therefore the answers have (unfortunately)a limited value. Good luck with the analysis of this questionnaire!

124. Three additional criteria need to be considered. For pulsed sounds the rise time (how rapidly the sound increases) is critical for evaluating potential injury. Very intense sounds with slow rise times have less potential for injury than lower sounds with rapid rise times. A second criteria is the frequency or time between exposures. There is some recovery in hearing systems between exposure to intense sounds with time, but if the pulses are relatively close together the hearing system does not have time to return to normal, and a second pulse may cause physical damage that would not occur if the pulses were more widely spaced. Third, total energy that the animal is exposed to is important when considering potential injury. As noted above this also depends on interval between pulses, but an animal exposed to multiple pulses at a given sound level may suffer hearing damage that an animal exposed to one or a few pulses at the same or slightly higher level would not suffer damage from.

125. You need to consider both the level and the frequency in the context of the hearing sensitivity and propagation distances at various frequencies.

126. Q13: Need more info. Is the short sound repeated often and for a long period of time? Is the long sound never repeated? Q14-17: Too difficult for me to determine -sounds affect different species quite differently. Marine mammal auditory capabilities differ by species.

127. Extensive research in dose-effect relationships should provide division in hearing sensitivity groups for marine mammal species; frequency dependent criteria for each group, including correction for duty cycle (duration/interval time; separate criteria for pulsed pure tones (e.g. sonars) and broadband sounds (shipping, wind turbines, etc.)

128. There's no other way to establish criteria. The existing guidelines used by NOAA are nonsense because they do not include either frequency range or integration time.

129. My reaction to the next series of questions is that you're looking for a 'one-number' answer to a question that really should be addressed with a dose-response model. Time, frequency, and level are all important components of dosage criteria for ANY of the species I have worked with. I think it's irresponsible to give a single number answer.

130. This question has no answer without knowing more about the noise (especially duration) and in most contexts the level must be expressed in Pa-squared-seconds.

Habitat/ecology/behavior:

131. Some behavior responses to sound will be inevitable, just as some level of fishery mortality and some level of ship strikes is inevitable. The trick will be finding the level of behavioral modification that does not affect population sustainability. For this we need better monitoring, both of marine mammal population (to detect population-level effects) and of anthropogenic sound.

132. Long term effect of anthropogenic sound should be studied in many species from behavioral/physiological/reproductive point of view. We have little knowledge on this.

133. Evaluate the behavioral responses to sound - do not limit species response by measurable physical or physiological damage to the organism - the current methods to measure these lesions may be inadequate - there is considerable bias towards the observable effects on too few specimens.

134. Behavior and physiology cannot be separated - they are like the faces of Janus, two manifestations of an internal process that is triggered by external stimuli. Noise is likely to affect both simultaneously and inseparably. I've done my best to answer this and the next question the way you mean it.....

135. You cannot determine what levels marine mammals are adapted to unless you know what natural sounds they are exposed to. In particular, the sounds they make themselves are going to represent a very high proportion of the dosage received in many species, especially schooling odontocetes. Some investigators have even suggested that marine mammals compete with each other by trying to damage each other's hearing.

Lack of expertise:

136. Unanswered questions reflect my lack of expertise in acoustics specifically and therefore current knowledge of experimental/empirical results on acoustic effects.

137. I believe that I am not an appropriate candidate to participate in this survey. I have in no way participated in research regarding the impacts or assessment of ocean sound. For this reason I have left many of the questions unanswered.

138. My knowledge of underwater sound is not sufficient to lend insight to legislation.

139. I have not answered question 9 as I am not familiar with ""Temporary Threshold Shift (TTS) onset established for 8 individual captive bottlenose dolphins and 2 individual captive beluga whales, and Permanent Threshold Shifts (PTS) based on model extrapolations including data on terrestrial mammals.

Other:

140. You can't keep this anonymity – emails can be subpoenaed and computers confiscated. They can find out who sent this survey in.

141. Need to start at the precautionary end until more data are available on the effects of anthropogenic sound in the ocean. Research on existing noise sources should be conducted before adding new noise sources. Once this research has been carried out, there will be better information on what sorts of noise to avoid.

142. Thank you for putting together this interesting and timely survey. I look forward to its results.

143. Legislation should be formulated with the best available information not derived from the demands of the loudest and most insistent voices. Those who foster accusations of doom, collusion, and falsification of data should be forced to prove their charges and if they fail in providing proof, lose their equal access and place in public forums. At the moment there is no penalty for providing misinformation. Consequently we continue on this non-productive and divisive treadmill.

144. I have confidence in NMFS current criteria and applaud them for trying to account for different species, realizing that there is a diversity of inhabitants in the ocean that may require different criteria.

145. We will need to experiment on small scales with methods for balancing multiple use and accounting for cumulative impacts in regulations. These case studies will prepare responsible agencies, legislators and voters for the kinds of decisions we will need to make on larger scales re: regulation of sound within the U.S. EEZ and the U.S. position in international forums.

146. More research is critical at this stage, but the field is hampered because the majority of funding for even basic research is sourced directly from the polluters themselves, raising conflict of interest concerns.

147. In my humble knowledge, it is more than proved that in areas where beaked whales are and sonar activities are developed, many of them die within 12 hours of exposure.

148. The Navy should stop burying their head in the sand about this issue and support relevant research.

149. Regardless of the current research to-date and aside of our ability to do the math and understand the physics of sound we still do not know and may never

completely understand what a fully aquatic animal (whale, dolphin, etc.) ACTUALLY HEAR with their ear. We cannot and should not ascribe the qualities and function of a human ear that is not designed nor equipped to function in water, to a fully aquatic ear. We routinely make this error.

150. Give more humans the opportunity to listen underwater. Require the Chief of Naval Operations, the Commander in Chief, and all CEO's of activities producing anthropogenic sound to have speakers in their homes and offices that faithfully reproduce the frequencies and received levels (corrected for in air) of their activities in real-time, from hydrophones placed at the mitigation distance (eg. 1000 meters from source).

151. Research should be funded to test hearing and conduct physiological and pathological examinations on beached and stranded marine mammals. Such research should take priority over attempts to refloat or rehabilitate stranded animals.

152. Use incentives/disincentives for noise-producers to reward them for decreasing their noise output or increase the legislative burden if they do not. Noise producers should be encouraged to fund quieting technologies or find alternatives less risky to marine life. Marine Protected Areas should be established to safeguard important areas and these areas should be protected from even moderate noise, i.e. there should be differing noise standards depending on the sensitivity of the area.

153. This survey manifests considerable bias against the direction being taken in regulating sound exposure limits. There is no consideration for the exposure limits that have been in use since ~1995 and the value and importance of updating those limits with the newer information available, no matter that it is not complete (and it will NEVER be complete--everyone always wants more data). We can gainfully use what we have.

154. Visit the history of dealing with anthropogenic sound. This issue started in the early 50's with the development of Jet aircraft.

155. I believe that our level of ignorance about the impact of anthropogenic sound in the ocean is great enough right now that the community should be putting significant effort into allocating resources to get the basic answers that are needed. The research should also be planned by people with appropriate expertise and not the concern-du-jour. We know that noise can impact humans and laboratory animals in the following ways: 1) hearing damage, 2) interference with communication, 3) masking of biologically-important sounds, 4) clinical/stress/immune responses, 5) interference with cognitive function, and 6) effects on social interactions. We also have limited evidence that there may be other, even unexpected, physical and functional effects in the aquatic environment. Any of these effects can have population-level

consequences under the right circumstances. However, you can't guess or politic a characterization of ""too much noise"" - you have to get competent people to collect the needed information. It would be best if the money were coming from a variety of sources. The approach that is being taken with wildlife at present would never pass muster in human clinical research, where independent, investigator-initiated, appropriately-replicated, and adequately-sampled data are considered essential. Legislation must be based on the results of appropriate research that is focused on biologically-meaningful effects.

156. That simple behavioral alterations (e.g. avoiding a sound source) is not sufficient to suggest damage or potential damage from a sound source.

157. For sonars such as LFA, we could look at suppression of whales song (passive acoustic recordings)at ocean basin scales as these sonars are audible across the entire ocean basin when the sonar is located near the edge of a continental shelf (as it commonly is at present). These need not be controlled experiments in the sense that the scientists control the LFA sound source. Such studies could develop behavioral response measures at various levels and eventually measure habituation.

158. If sound is to be regulated, which I believe is appropriate, then there must be some enforcement language and mechanisms included in the legislation.

159. Needs to be adaptive, both in terms of thresholds and in terms of spatial designations.

160. Noise can be divided into deliberate and some might say 'necessary' or 'useful' noise such as seismic survey, sonars, etc. Other noise such as ships engines is accidental and also quite easily dealt with if only there were legislation, it's just that ship owners don't currently try. For 'useful' noise, make researchers produce better justifications of levels worked at and always try to work at the lowest possible level to achieve research aim.

161. I think that opinions from researchers specializing in this area might be much more helpful. I’m glad to collaborate and I have a marine ecology background and I work with (area of specialization removed). Anyway, legislation for anthropogenic ocean sound must be considered in all terms.

162. Rather than just a simple temporal/spatial closed area management, it maybe advantageous to also use a dynamic modeling approach that can produce a nowcast or a forecast of the likelihood of occurrence of individual species or groups of species within a specific area of operation combined with real-time mitigation. This would reduce the likelihood of unforeseen negative impacts occurring in areas outside known important areas that have been closed.

163. For better understanding of the degree of noise impact on cetacean hearing, an extensive program of hearing investigation in stranded cetaceans may be helpful.

164. When the tourist industry is a major contributor to the impact, it may be more effective to limit the number of boats (e.g. through licensing), than to designate boat-free areas or restrict the duration of the exposure.

165. In general, legislation is written at a fairly high level. Subsequently, the regulatory agency or agencies responsible for implementation then address the details through draft implementation regulation, public comments, and final implementation. This allows for a reasonably transparent process through NEPA, APA, and other environmental statutes. It generally doesn't work for Congress to write legislation that is unnecessarily prescriptive. However, the process described above takes time and money. To many people, the traditional approach will lead to unacceptable delays and loss of environmental quality.

166. Be conservative. Avoid wishful thinking.

167. More field and laboratory research is needed!!!!

168. Needs to address all sources of sound, not just military or oil and gas. Others include commercial shipping, fishing, recreation.

169. Use of sound level as the criteria is problematic because it is only one aspect that needs to be considered and because people confuse exposure level (level received by the animal) with sound source level (an artificial value used in models to estimate received level). Typically exposure level at 100 m from a source would be 40 dB less than source level. Better to frame legislation in terms of distances for particular types of source and species, and for particular sensitivities (e.g. cows with calves, feeding resting, breeding) with appropriate management and mitigation measures. Adequate compliance with and policing of legislation is much simpler and more achievable with this approach. The criteria should be based on best scientific knowledge which is usually out of step with most of the information freely available on these issues, so education may also be required (but difficult to achieve because of strong activism).

170. No matter how you look at it, marine organisms are unlikely to evolve fast enough to adapt to the impacts from the rapidly increasing noise in the oceans. There is no solution and collapse is probable.

171. I've filled out your questionnaire. A few comments that didn't fit in a box: Generally: Be aware that the metrics you have chosen are not standard measures and are part of the controversy in this field. No one agrees about

which metrics should be reported and how. I have assumed that you are referring to received peak-to-peak sound pressure level (why peak-to-peak? integration time? these issues make a big difference) and sound exposure level (which people tend to refer to as energy - measured in Pa-squared-s).

172. I tend to use a comparative approach to noise issues. Therefore, the species I am studying tend to change from project to project. I have listed the only marine mammal species that I am working on actively in studies of noise exposure this year (also, just for the record, anyone who sees the species list and a couple of the other answers will know exactly who provided a given set of comments).

173. In my opinion, this question is inflammatory and politically-motivated. I won't answer it as written. I'm happy to answer the two implicit questions. 1) Am I happy with the sample size of animals that have been tested in TTS experiments? No, but small sizes are typical in marine mammal studies. The work is very expensive and the organization you have targeted with this question is the only one that is putting any money into the problem right now. If you want better sample sizes, someone must authorize the needed expenditures and contract a number of laboratories to collect data. 2) Am I happy about using TTS as a criterion for injury? Depends on the particular type of exposure. It is reasonable for acute, single exposures such as ship shock trials; it is insufficient for some types of intermittent noise (e.g., mid-frequency sonar, fish-finding sonar, seismic survey impulses, pingers) and for any kind of chronic exposure.

174. A better answer to 11 is "sometimes reasonable and sometimes not reasonable; it depends on the type of exposure".

175. The question has no answer without knowing what species or taxonomic grouping is being discussed. Also "short" needs some interpretation.

176. Right now, research in the area of anthropogenic effects of noise is not being funded the way it should be. There should be multiple independent funding sources along the lines of NIH or NSF balanced by private research interests. They should be allocating enough money and the appropriate expertise to manage the work that needs to be done. ONR provides a small amount of money of this kind, but the Navy has fairly specific research goals that don't cover many of the important questions, especially about long-term exposure. Human noise exposure criteria would be ineffective without knowledge of long-term effects. At present, much of our research is being driven by whatever controversy-du-jour the NGOs come up with, with little focus on the basic scientific questions that need to be answered before population-level concerns can be addressed. Somehow, everyone expects that policy-makers will be able to invent effective management guidelines on the basis of spotty and uncoordinated information. They don't want to invest

substantial resources, and they don't want to "bother" any animals. I'd say that the outcome of the recent Marine Mammal Commission effort is a tribute to the unworkability of this approach.

177. To put some perspective on the issue, I can tell you what the research environment in noise is like from the perspective of a scientist in a non-profit research organization. Only 3% of the charitable donations made in this country target environmental research as a whole, and only a small fraction of that is spent on applied research. If we did biomedical research the way we do whole-animal environmental impact research, we still wouldn't know whether cigarettes cause cancer. The most important thing you can do right now is to help people understand that the precautionary approach advocated by most of the environmental community cannot possibly cope with the establishment of effective noise exposure criteria in the face of pressure from 6.5+ billion people.

Appendix G – Logistic Regression Analyses (SAS) arranged by Acoustic Groupings: a. Publication data analysis; b. Survey "Sustainable" data analysis, and; c. "Maximum Standard" data analysis.

G.1. Small Odontocete

a. Publication logistic regression analysis

The SAS System

Obs	sound	no	cumul	n
1	140	1	1	4
2	160	2	3	4
3	220	1	4	4

The LOGISTIC Procedure

Model Information

Data Set	WORK.SOUND
Response Variable (Events)	cumul
Response Variable (Trials)	n
Model	binary logit
Optimization Technique	Fisher's scoring

Number of Observations Read	3
Number of Observations Used	3
Sum of Frequencies Read	12
Sum of Frequencies Used	12

Response Profile

Ordered Value	Binary Outcome	Total Frequency
1	Event	8
2	Nonevent	4

Model Convergence Status

Convergence criterion (GCONV=1E-8) satisfied.

Model Fit Statistics

Criterion	Intercept Only	Intercept and Covariates
AIC	17.276	13.001
SC	17.761	13.971
-2 Log L	15.276	9.001

Testing Global Null Hypothesis: BETA=0

Test	Chi-Square	DF	Pr > ChiSq
Likelihood Ratio	6.2754	1	0.0122
Score	4.1683	1	0.0412
Wald	1.9331	1	0.1644

The LOGISTIC Procedure

Analysis of Maximum Likelihood Estimates

Parameter	DF	Estimate	Standard Error	Wald Chi-Square	Pr > ChiSq
Intercept	1	-16.5991	11.9734	1.9219	0.1656
sound	1	0.1107	0.0796	1.9331	0.1644

Odds Ratio Estimates

Effect	Point Estimate	95% Wald Confidence Limits	
sound	1.117	0.956	1.306

Association of Predicted Probabilities and Observed Responses

Percent Concordant	78.1	Somers' D	0.750
Percent Discordant	3.1	Gamma	0.923
Percent Tied	18.8	Tau-a	0.364
Pairs	32	c	0.875

Obs	prop	pred
1	0.25	0.24871
2	0.75	0.75173
3	1.00	0.99957

b. "Sustainable" logistic regression analysis.

The SAS System

Obs	sound	no	cumul	n
1	100	1	1	9
2	120	1	2	9
3	140	2	4	9
4	160	5	9	9

The LOGISTIC Procedure

Model Information

Data Set	WORK.SOUND
Response Variable (Events)	cumul
Response Variable (Trials)	n
Model	binary logit
Optimization Technique	Fisher's scoring

Number of Observations Read	4
Number of Observations Used	4
Sum of Frequencies Read	36
Sum of Frequencies Used	36

Response Profile

Ordered Value	Binary Outcome	Total Frequency
1	Event	16
2	Nonevent	20

Model Convergence Status

Convergence criterion (GCONV=1E-8) satisfied.

Model Fit Statistics

Criterion	Intercept Only	Intercept and Covariates
AIC	51.461	35.707
SC	53.045	38.874
-2 Log L	49.461	31.707

Testing Global Null Hypothesis: BETA=0

Test	Chi-Square	DF	Pr > ChiSq
Likelihood Ratio	17.7538	1	<.0001
Score	15.2100	1	<.0001
Wald	10.3328	1	0.0013

The LOGISTIC Procedure

Analysis of Maximum Likelihood Estimates

Parameter	DF	Estimate	Standard Error	Wald Chi-Square	Pr > ChiSq
Intercept	1	-11.1540	3.4700	10.3326	0.0013
sound	1	0.0828	0.0258	10.3328	0.0013

Odds Ratio Estimates

Effect	Point Estimate	95% Wald Confidence Limits	
sound	1.086	1.033	1.143

Association of Predicted Probabilities and Observed Responses

Percent Concordant	80.0	Somers' D	0.731
Percent Discordant	6.9	Gamma	0.842
Percent Tied	13.1	Tau-a	0.371
Pairs	320	c	0.866

Obs	prop	pred
1	0.11111	0.05332
2	0.22222	0.22771
3	0.44444	0.60687
4	1.00000	0.88989

c. “Max Standard” logistic regression analysis.

The SAS System

Obs	sound	no	cumul	n
1	100	2	2	12
2	120	5	7	12
3	140	2	9	12
4	180	2	11	12
5	200	1	12	12

The LOGISTIC Procedure

Model Information

Data Set	WORK.SOUND
Response Variable (Events)	cumul
Response Variable (Trials)	n
Model	binary logit
Optimization Technique	Fisher's scoring

Number of Observations Read	5
Number of Observations Used	5
Sum of Frequencies Read	60
Sum of Frequencies Used	60

Response Profile

Ordered Value	Binary Outcome	Total Frequency
1	Event	41
2	Nonevent	19

Model Convergence Status

Convergence criterion (GCONV=1E-8) satisfied.

Model Fit Statistics

Criterion	Intercept Only	Intercept and Covariates
AIC	76.920	53.167
SC	79.014	57.356
-2 Log L	74.920	49.167

Testing Global Null Hypothesis: BETA=0

Test	Chi-Square	DF	Pr > ChiSq
Likelihood Ratio	25.7529	1	<.0001
Score	20.9652	1	<.0001
Wald	12.4681	1	0.0004

Analysis of Maximum Likelihood Estimates

Parameter	DF	Estimate	Standard Error	Wald Chi-Square	Pr > ChiSq
Intercept	1	-6.6277	1.9721	11.2938	0.0008
sound	1	0.0548	0.0155	12.4681	0.0004

Odds Ratio Estimates

Effect	Point Estimate	95% Wald Confidence Limits	
sound	1.056	1.025	1.089

Association of Predicted Probabilities and Observed Responses

Percent Concordant	81.0	Somers' D	0.739
Percent Discordant	7.1	Gamma	0.840
Percent Tied	11.9	Tau-a	0.325

Pairs	779	c	0.870

Obs	prop	pred
1	0.16667	0.24087
2	0.58333	0.48700
3	0.75000	0.73961
4	0.91667	0.96216
5	1.00000	0.98703

G.2. Medium and Large Odontocetes

a. Publication logistic regression analysis.

The SAS System

Obs	sound	no	cumul	n
1	100	1	1	11
2	140	1	2	11
3	160	2	4	11
4	180	1	5	11
5	200	1	6	11
6	220	5	11	11

The LOGISTIC Procedure

Model Information

Data Set	WORK.SOUND
Response Variable (Events)	cumul
Response Variable (Trials)	n
Model	binary logit
Optimization Technique	Fisher's scoring

Number of Observations Read	6
Number of Observations Used	6
Sum of Frequencies Read	66
Sum of Frequencies Used	66

Response Profile

Ordered Value	Binary Outcome	Total Frequency
1	Event	29
2	Nonevent	37

Model Convergence Status

Convergence criterion (GCONV=1E-8) satisfied.

Model Fit Statistics

Criterion	Intercept Only	Intercept and Covariates
AIC	92.523	71.613
SC	94.713	75.992
-2 Log L	90.523	67.613

Testing Global Null Hypothesis: BETA=0

Test	Chi-Square	DF	Pr > ChiSq
Likelihood Ratio	22.9105	1	<.0001
Score	19.7464	1	<.0001
Wald	14.7558	1	0.0001

The LOGISTIC Procedure

Analysis of Maximum Likelihood Estimates

Parameter	DF	Estimate	Standard Error	Wald Chi-Square	Pr > ChiSq
Intercept	1	-6.7912	1.7710	14.7043	0.0001
sound	1	0.0382	0.00995	14.7558	0.0001

Odds Ratio Estimates

Effect	Point Estimate	95% Wald Confidence Limits	
sound	1.039	1.019	1.059

Association of Predicted Probabilities and Observed Responses

Percent Concordant	76.9	Somers' D	0.646
Percent Discordant	12.3	Gamma	0.724
Percent Tied	10.8	Tau-a	0.323
Pairs	1073	c	0.823

Obs	prop	pred
1	0.09091	0.04887
2	0.18182	0.19163
3	0.36364	0.33740
4	0.45455	0.52240
5	0.54545	0.70144
6	1.00000	0.83462

b. "Sustainable" logistic regression analysis

The SAS System

Obs	sound	no	cumul	n
1	100	2	2	42
2	120	2	4	42
3	140	11	15	42
4	160	10	25	42
5	180	9	34	42
6	200	5	39	42
7	220	3	42	42

The LOGISTIC Procedure

Model Information

Data Set	WORK.SOUND
Response Variable (Events)	cumul
Response Variable (Trials)	n
Model	binary logit
Optimization Technique	Fisher's scoring

Number of Observations Read	7
Number of Observations Used	7
Sum of Frequencies Read	294
Sum of Frequencies Used	294

Response Profile

Ordered	Binary	Total

Value	Outcome	Frequency
1	Event	161
2	Nonevent	133

Model Convergence Status

Convergence criterion (GCONV=1E-8) satisfied.

Model Fit Statistics

Criterion	Intercept Only	Intercept and Covariates
AIC	406.900	223.000
SC	410.583	230.367
-2 Log L	404.900	219.000

Testing Global Null Hypothesis: BETA=0

Test	Chi-Square	DF	Pr > ChiSq
Likelihood Ratio	185.8998	1	<.0001
Score	149.9348	1	<.0001
Wald	85.8446	1	<.0001

The LOGISTIC Procedure

Analysis of Maximum Likelihood Estimates

Parameter	DF	Estimate	Standard Error	Wald Chi-Square	Pr > ChiSq
Intercept	1	-9.0890	1.0013	82.3911	<.0001
sound	1	0.0594	0.00641	85.8446	<.0001

Odds Ratio Estimates

Effect	Point Estimate	95% Wald Confidence Limits	
sound	1.061	1.048	1.075

Association of Predicted Probabilities and Observed Responses

Percent Concordant	87.6	Somers' D	0.820
Percent Discordant	5.6	Gamma	0.879
Percent Tied	6.8	Tau-a	0.408
Pairs	21413	c	0.910

Obs	prop	pred
1	0.04762	0.04096
2	0.09524	0.12279
3	0.35714	0.31450
4	0.59524	0.60060
5	0.80952	0.83133
6	0.92857	0.94171
7	1.00000	0.98146

c. "Maximum Standard" logistic regression analysis

The SAS System

Obs	sound	no	cumul	n
1	100	2	2	45
2	120	18	20	45
3	140	7	27	45
4	160	8	35	45
5	180	6	41	45
6	200	4	45	45

The LOGISTIC Procedure

Model Information

Data Set	WORK.SOUNDMED
Response Variable (Events)	cumul
Response Variable (Trials)	n
Model	binary logit
Optimization Technique	Fisher's scoring

Number of Observations Read	6
Number of Observations Used	6
Sum of Frequencies Read	270
Sum of Frequencies Used	270

Response Profile

Ordered Value	Binary Outcome	Total Frequency
1	Event	170
2	Nonevent	100

Model Convergence Status

Convergence criterion (GCONV=1E-8) satisfied.

Model Fit Statistics

Criterion	Intercept Only	Intercept and Covariates
AIC	357.942	227.194
SC	361.541	234.391
-2 Log L	355.942	223.194

Testing Global Null Hypothesis: BETA=0

Test	Chi-Square	DF	Pr > ChiSq
Likelihood Ratio	132.7486	1	<.0001
Score	111.3525	1	<.0001
Wald	72.7193	1	<.0001

The LOGISTIC Procedure

Analysis of Maximum Likelihood Estimates

Parameter	DF	Estimate	Standard Error	Wald Chi-Square	Pr > ChiSq
Intercept	1	-7.7186	0.9458	66.6061	<.0001

sound	1	0.0579	0.00679	72.7193	<.0001

Odds Ratio Estimates

Effect	Point Estimate	95% Wald Confidence Limits	
sound	1.060	1.046	1.074

Association of Predicted Probabilities and Observed Responses

Percent Concordant	83.2	Somers' D	0.757
Percent Discordant	7.5	Gamma	0.835
Percent Tied	9.3	Tau-a	0.354
Pairs	17000	c	0.879

Obs	prop	pred
1	0.04444	0.12670
2	0.44444	0.31586
3	0.60000	0.59502
4	0.77778	0.82381
5	0.91111	0.93703
6	1.00000	0.97932

G.3. Mysticetes

a. Publication logistic regression analysis

The SAS System

Obs	sound	no	cumul	n
1	100	0	0	7
2	120	1	1	7
3	140	1	2	7
4	160	1	3	7
5	180	1	4	7
6	200	1	5	7
7	210	2	7	7

The LOGISTIC Procedure

Model Information

Data Set	WORK.PUBLG
Response Variable (Events)	cumul
Response Variable (Trials)	n
Model	binary logit
Optimization Technique	Fisher's scoring

Number of Observations Read	7
Number of Observations Used	7
Sum of Frequencies Read	49
Sum of Frequencies Used	49

Response Profile

Ordered Value	Binary Outcome	Total Frequency
1	Event	22
2	Nonevent	27

Model Convergence Status

Convergence criterion (GCONV=1E-8) satisfied.

Model Fit Statistics

Criterion	Intercept Only	Intercept and Covariates
AIC	69.417	48.942
SC	71.309	52.726
-2 Log L	67.417	44.942

Testing Global Null Hypothesis: BETA=0

Test	Chi-Square	DF	Pr > ChiSq
Likelihood Ratio	22.4751	1	<.0001
Score	19.3550	1	<.0001
Wald	13.7599	1	0.0002

The LOGISTIC Procedure

Analysis of Maximum Likelihood Estimates

Parameter	DF	Estimate	Standard Error	Wald Chi-Square	Pr > ChiSq
Intercept	1	-7.6982	2.0958	13.4924	0.0002
sound	1	0.0461	0.0124	13.7599	0.0002

Odds Ratio Estimates

Effect	Point Estimate	95% Wald Confidence Limits	
sound	1.047	1.022	1.073

Association of Predicted Probabilities and Observed Responses

Percent Concordant	82.3	Somers' D	0.731
Percent Discordant	9.3	Gamma	0.798
Percent Tied	8.4	Tau-a	0.369
Pairs	594	c	0.865

Obs	prop	pred
1	0.00000	0.04377
2	0.14286	0.10329
3	0.28571	0.22473
4	0.42857	0.42178
5	0.57143	0.64734
6	0.71429	0.82204
7	1.00000	0.87991

b. “Sustainable” logistic regression analysis

The SAS System

Obs	sound	no	cumul	n
1	120	2	2	20
2	140	4	6	20
3	160	5	11	20
4	180	5	16	20
5	200	4	20	20

The LOGISTIC Procedure

Model Information

Data Set	WORK.SOUND
Response Variable (Events)	cumul
Response Variable (Trials)	n
Model	binary logit
Optimization Technique	Fisher's scoring

Number of Observations Read	5
Number of Observations Used	5
Sum of Frequencies Read	100
Sum of Frequencies Used	100

Response Profile

Ordered Value	Binary Outcome	Total Frequency

1	Event	55
2	Nonevent	45

Model Convergence Status

Convergence criterion (GCONV=1E-8) satisfied.

Model Fit Statistics

Criterion	Intercept Only	Intercept and Covariates
AIC	139.628	91.367
SC	142.233	96.578
-2 Log L	137.628	87.367

Testing Global Null Hypothesis: BETA=0

Test	Chi-Square	DF	Pr > ChiSq
Likelihood Ratio	50.2603	1	<.0001
Score	42.7475	1	<.0001
Wald	28.6958	1	<.0001

The LOGISTIC Procedure

Analysis of Maximum Likelihood Estimates

Parameter	DF	Estimate	Standard Error	Wald Chi-Square	Pr > ChiSq
Intercept	1	-10.3360	1.9634	27.7130	<.0001
sound	1	0.0668	0.0125	28.6958	<.0001

Odds Ratio Estimates

Effect	Point Estimate	95% Wald Confidence Limits	
sound	1.069	1.043	1.096

Association of Predicted Probabilities and Observed Responses

Percent Concordant	81.5	Somers' D	0.743
Percent Discordant	7.1	Gamma	0.839
Percent Tied	11.4	Tau-a	0.372
Pairs	2475	c	0.872

Obs	prop	pred
1	0.10	0.08981
2	0.30	0.27305
3	0.55	0.58842
4	0.80	0.84477
5	1.00	0.95395

c. “Maximum Standard” logistic regression analysis

The SAS System

Obs	sound	no	cumul	n

1	100	1	1	19
2	120	1	2	19
3	140	3	5	19
4	160	5	10	19
5	180	7	17	19
6	200	2	19	19

The LOGISTIC Procedure

Model Information

Data Set	WORK.SOUNDLG
Response Variable (Events)	cumul
Response Variable (Trials)	n
Model	binary logit
Optimization Technique	Fisher's scoring

Number of Observations Read	6
Number of Observations Used	6
Sum of Frequencies Read	114
Sum of Frequencies Used	114

Response Profile

Ordered Value	Binary Outcome	Total Frequency
1	Event	54
2	Nonevent	60

Model Convergence Status

Convergence criterion (GCONV=1E-8) satisfied.

Model Fit Statistics

Criterion	Intercept Only	Intercept and Covariates
AIC	159.722	88.401
SC	162.458	93.873
-2 Log L	157.722	84.401

Testing Global Null Hypothesis: BETA=0

Test	Chi-Square	DF	Pr > ChiSq
Likelihood Ratio	73.3209	1	<.0001
Score	59.1111	1	<.0001
Wald	33.5539	1	<.0001

The LOGISTIC Procedure

Analysis of Maximum Likelihood Estimates

Parameter	DF	Estimate	Standard Error	Wald Chi-Square	Pr > ChiSq
Intercept	1	-10.7370	1.8693	32.9939	<.0001
sound	1	0.0701	0.0121	33.5539	<.0001

Odds Ratio Estimates

Effect	Point Estimate	95% Wald Confidence Limits	
sound	1.073	1.047	1.098

Association of Predicted Probabilities and Observed Responses

Percent Concordant	87.3	Somers' D	0.821
Percent Discordant	5.2	Gamma	0.888
Percent Tied	7.6	Tau-a	0.413
Pairs	3240	c	0.910

Obs	prop	pred
1	0.05263	0.02341
2	0.10526	0.08872
3	0.26316	0.28330
4	0.52632	0.61612
5	0.89474	0.86697
6	1.00000	0.96358

G.4. Other unspecified cetaceans, marine animals: data for this category is available from the Internet survey only. "Sustainable levels" and "Maximum Criteria" are illustrated here.

b. "Sustainable" logistic regression analysis

The SAS System

Obs	sound	no	cumul	n
1	100	2	2	16
2	120	1	3	16
3	140	1	4	16
4	160	4	8	16
5	180	3	11	16
6	200	3	14	16
7	220	2	16	16

The LOGISTIC Procedure

Model Information

Data Set	WORK.SOUND
Response Variable (Events)	cumul
Response Variable (Trials)	n
Model	binary logit
Optimization Technique	Fisher's scoring

Number of Observations Read	7
Number of Observations Used	7
Sum of Frequencies Read	112
Sum of Frequencies Used	112

Response Profile

Ordered Value	Binary Outcome	Total Frequency
1	Event	58
2	Nonevent	54

Model Convergence Status

Convergence criterion (GCONV=1E-8) satisfied.

Model Fit Statistics

Criterion	Intercept Only	Intercept and Covariates
AIC	157.122	106.716
SC	159.841	112.153
-2 Log L	155.122	102.716

Testing Global Null Hypothesis: BETA=0

Test	Chi-Square	DF	Pr > ChiSq
Likelihood Ratio	52.4057	1	<.0001
Score	45.0664	1	<.0001
Wald	31.4702	1	<.0001

The LOGISTIC Procedure

Analysis of Maximum Likelihood Estimates

Parameter	DF	Estimate	Standard Error	Wald Chi-Square	Pr > ChiSq
Intercept	1	-6.9724	1.2729	30.0058	<.0001
sound	1	0.0443	0.00790	31.4702	<.0001

Odds Ratio Estimates

Effect	Point Estimate	95% Wald Confidence Limits	
sound	1.045	1.029	1.062

Association of Predicted Probabilities and Observed Responses

Percent Concordant	82.1	Somers' D	0.725
Percent Discordant	9.5	Gamma	0.792
Percent Tied	8.4	Tau-a	0.366
Pairs	3132	c	0.863

Obs	prop	pred
1	0.1250	0.07316
2	0.1875	0.16079
3	0.2500	0.31741
4	0.5000	0.53020
5	0.6875	0.73256
6	0.8750	0.86925
7	1.0000	0.94164

c. “Maximum Standard” logistic regression analysis

The SAS System

Obs	sound	no	cumul	n
1	100	3	3	20
2	120	3	6	20
3	140	2	8	20
4	160	4	12	20
5	180	7	19	20
6	200	1	20	20

The LOGISTIC Procedure

Model Information

Data Set	WORK.SOUND
Response Variable (Events)	cumul
Response Variable (Trials)	n
Model	binary logit
Optimization Technique	Fisher's scoring

Number of Observations Read	6
Number of Observations Used	6
Sum of Frequencies Read	120
Sum of Frequencies Used	120

Response Profile

Ordered Value	Binary Outcome	Total Frequency
1	Event	68
2	Nonevent	52

Model Convergence Status

Convergence criterion (GCONV=1E-8) satisfied.

Model Fit Statistics

Criterion	Intercept Only	Intercept and Covariates
AIC	166.216	112.769
SC	169.003	118.344
-2 Log L	164.216	108.769

Testing Global Null Hypothesis: BETA=0

Test	Chi-Square	DF	Pr > ChiSq
Likelihood Ratio	55.4471	1	<.0001
Score	47.6587	1	<.0001
Wald	33.1992	1	<.0001

The LOGISTIC Procedure

Analysis of Maximum Likelihood Estimates

Parameter	DF	Estimate	Standard Error	Wald Chi-Square	Pr > ChiSq
Intercept	1	-7.3587	1.3207	31.0447	<.0001
sound	1	0.0521	0.00904	33.1992	<.0001

Odds Ratio Estimates

Effect	Point Estimate	95% Wald Confidence Limits	
sound	1.053	1.035	1.072

Association of Predicted Probabilities and Observed Responses

Percent Concordant	81.3	Somers' D	0.724
Percent Discordant	8.9	Gamma	0.803
Percent Tied	9.8	Tau-a	0.359
Pairs	3536	c	0.862

Obs	prop	pred
1	0.15	0.10435
2	0.30	0.24823
3	0.40	0.48344
4	0.60	0.72621
5	0.95	0.88260
6	1.00	0.95517

G.5. Fish

a. Publication logistic regression analysis

```
                         The SAS System

              Obs    sound    no    cumul    n

               1      160      1      1      6
               2      180      2      3      6
               3      220      3      6      6


                    The LOGISTIC Procedure

                      Model Information

        Data Set                      WORK.SOUND
        Response Variable (Events)    cumul
        Response Variable (Trials)    n
        Model                         binary logit
        Optimization Technique        Fisher's scoring


            Number of Observations Read           3
            Number of Observations Used           3
            Sum of Frequencies Read              18
            Sum of Frequencies Used              18


                       Response Profile

              Ordered     Binary           Total
                Value     Outcome      Frequency

                    1     Event               10
                    2     Nonevent             8


                  Model Convergence Status

        Convergence criterion (GCONV=1E-8) satisfied.


                    Model Fit Statistics

                                          Intercept
                              Intercept         and
            Criterion              Only  Covariates

            AIC                  26.731      17.990
            SC                   27.621      19.771
            -2 Log L             24.731      13.990


            Testing Global Null Hypothesis: BETA=0

    Test                 Chi-Square       DF     Pr > ChiSq

    Likelihood Ratio        10.7405        1         0.0010
    Score                    8.5018        1         0.0035
    Wald                     3.7821        1         0.0518


                    The LOGISTIC Procedure

           Analysis of Maximum Likelihood Estimates
```

Parameter	DF	Estimate	Standard Error	Wald Chi-Square	Pr > ChiSq
Intercept	1	-17.9548	9.1039	3.8896	0.0486
sound	1	0.1007	0.0518	3.7821	0.0518

Odds Ratio Estimates

Effect	Point Estimate	95% Wald Confidence Limits	
sound	1.106	0.999	1.224

Association of Predicted Probabilities and Observed Responses

Percent Concordant	78.8	Somers' D	0.750
Percent Discordant	3.8	Gamma	0.909
Percent Tied	17.5	Tau-a	0.392
Pairs	80	c	0.875

Obs	prop	pred
1	0.16667	0.13730
2	0.50000	0.54406
3	1.00000	0.98531

b. "Sustainable" logistic regression analysis

The SAS System

Obs	sound	no	cumul	n
1	100	1	1	7
2	120	2	3	7
3	140	2	5	7
4	160	2	7	7

The LOGISTIC Procedure

Model Information

Data Set	WORK.SOUND
Response Variable (Events)	cumul
Response Variable (Trials)	n
Model	binary logit
Optimization Technique	Fisher's scoring

Number of Observations Read	4
Number of Observations Used	4
Sum of Frequencies Read	28
Sum of Frequencies Used	28

Response Profile

Ordered Value	Binary Outcome	Total Frequency
1	Event	16
2	Nonevent	12

Model Convergence Status

Convergence criterion (GCONV=1E-8) satisfied.

Model Fit Statistics

Criterion	Intercept Only	Intercept and Covariates
AIC	40.243	28.629
SC	41.575	31.293
-2 Log L	38.243	24.629

Testing Global Null Hypothesis: BETA=0

Test	Chi-Square	DF	Pr > ChiSq
Likelihood Ratio	13.6138	1	0.0002
Score	11.6667	1	0.0006
Wald	7.9419	1	0.0048

The LOGISTIC Procedure

Analysis of Maximum Likelihood Estimates

Parameter	DF	Estimate	Standard Error	Wald Chi-Square	Pr > ChiSq
Intercept	1	-10.2138	3.7014	7.6145	0.0058
sound	1	0.0825	0.0293	7.9419	0.0048

Odds Ratio Estimates

Effect	Point Estimate	95% Wald Confidence Limits	
sound	1.086	1.025	1.150

Association of Predicted Probabilities and Observed Responses

Percent Concordant	79.2	Somers' D	0.729
Percent Discordant	6.3	Gamma	0.854
Percent Tied	14.6	Tau-a	0.370
Pairs	192	c	0.865

Obs	prop	pred
1	0.14286	0.12255
2	0.42857	0.42080
3	0.71429	0.79077
4	1.00000	0.95160

c. “Maximum Sustainable” logistic regression analysis

The SAS System

Obs	sound	no	cumul	n
1	100	1	1	6
2	140	2	3	6
3	160	1	4	6
4	180	2	6	6

The SAS System

The LOGISTIC Procedure

Model Information

Data Set	WORK.SOUND
Response Variable (Events)	cumul
Response Variable (Trials)	n
Model	binary logit
Optimization Technique	Fisher's scoring

Number of Observations Read	4
Number of Observations Used	4
Sum of Frequencies Read	24
Sum of Frequencies Used	24

Response Profile

Ordered Value	Binary Outcome	Total Frequency
1	Event	14
2	Nonevent	10

Model Convergence Status

Convergence criterion (GCONV=1E-8) satisfied.

Model Fit Statistics

Criterion	Intercept Only	Intercept and Covariates
AIC	34.601	27.009
SC	35.779	29.366
-2 Log L	32.601	23.009

Testing Global Null Hypothesis: BETA=0

Test	Chi-Square	DF	Pr > ChiSq
Likelihood Ratio	9.5919	1	0.0020
Score	8.6400	1	0.0033
Wald	6.1713	1	0.0130

The SAS System

The LOGISTIC Procedure

Analysis of Maximum Likelihood Estimates

Parameter	DF	Estimate	Standard Error	Wald Chi-Square	Pr > ChiSq
Intercept	1	-7.2419	3.1090	5.4256	0.0198
sound	1	0.0528	0.0212	6.1713	0.0130

Odds Ratio Estimates

Effect	Point Estimate	95% Wald Confidence Limits

sound	1.054	1.011	1.099

Association of Predicted Probabilities and Observed Responses

Percent Concordant	76.4	Somers' D	0.686
Percent Discordant	7.9	Gamma	0.814
Percent Tied	15.7	Tau-a	0.348
Pairs	140	c	0.843

The SAS System

Obs	prop	pred
1	0.16667	0.12294
2	0.50000	0.53641
3	0.66667	0.76876
4	1.00000	0.90523

G.6. Total (All Species)

a. Publication logistic regression analysis

The SAS System

Obs	sound	no	cumul	n
1	100	1	1	28
2	120	1	2	28
3	140	3	5	28
4	160	6	11	28
5	180	4	15	28
6	200	2	17	28
7	210	11	28	28

The LOGISTIC Procedure

Model Information

Data Set	WORK.PUBTOTAL
Response Variable (Events)	cumul
Response Variable (Trials)	n
Model	binary logit
Optimization Technique	Fisher's scoring

Number of Observations Read	7
Number of Observations Used	7
Sum of Frequencies Read	196
Sum of Frequencies Used	196

Response Profile

Ordered Value	Binary Outcome	Total Frequency
1	Event	79
2	Nonevent	117

Model Convergence Status

Convergence criterion (GCONV=1E-8) satisfied.

Model Fit Statistics

Criterion	Intercept Only	Intercept and Covariates
AIC	266.299	180.815
SC	269.578	187.372
-2 Log L	264.299	176.815

Testing Global Null Hypothesis: BETA=0

Test	Chi-Square	DF	Pr > ChiSq
Likelihood Ratio	87.4842	1	<.0001
Score	74.6968	1	<.0001
Wald	52.7809	1	<.0001

The LOGISTIC Procedure

Analysis of Maximum Likelihood Estimates

Parameter	DF	Estimate	Standard Error	Wald Chi-Square	Pr > ChiSq
Intercept	1	-8.1085	1.1137	53.0082	<.0001
sound	1	0.0467	0.00643	52.7809	<.0001

Odds Ratio Estimates

Effect	Point Estimate	95% Wald Confidence Limits	
sound	1.048	1.035	1.061

Association of Predicted Probabilities and Observed Responses

Percent Concordant	82.5	Somers' D	0.733
Percent Discordant	9.2	Gamma	0.799
Percent Tied	8.3	Tau-a	0.355
Pairs	9243	c	0.867

Obs	prop	pred
1	0.03571	0.03117
2	0.07143	0.07570
3	0.17857	0.17253
4	0.39286	0.34673
5	0.53571	0.57468
6	0.60714	0.77475
7	1.00000	0.84587

b. "Sustainable" logistic regression analysis for

The SAS System

Obs	sound	no	cumul	n
1	100	6	6	87
2	120	8	14	87
3	140	13	27	87
4	160	26	53	87
5	180	17	70	87
6	200	12	82	87
7	220	5	87	87

The LOGISTIC Procedure

Model Information

Data Set	WORK.SOUNDQ16-18abctotal
Response Variable (Events)	cumul
Response Variable (Trials)	n
Model	binary logit
Optimization Technique	Fisher's scoring

Number of Observations Read	7
Number of Observations Used	7
Sum of Frequencies Read	609
Sum of Frequencies Used	609

Response Profile

Ordered	Binary	Total

Value	Outcome	Frequency
1	Event	339
2	Nonevent	270

Model Convergence Status

Convergence criterion (GCONV=1E-8) satisfied.

Model Fit Statistics

Criterion	Intercept Only	Intercept and Covariates
AIC	838.419	478.040
SC	842.831	486.864
-2 Log L	836.419	474.040

Testing Global Null Hypothesis: BETA=0

Test	Chi-Square	DF	Pr > ChiSq
Likelihood Ratio	362.3786	1	<.0001
Score	296.2230	1	<.0001
Wald	177.5260	1	<.0001

The LOGISTIC Procedure

Analysis of Maximum Likelihood Estimates

Parameter	DF	Estimate	Standard Error	Wald Chi-Square	Pr > ChiSq
Intercept	1	-8.4890	0.6529	169.0727	<.0001
sound	1	0.0559	0.00420	177.5260	<.0001

Odds Ratio Estimates

Effect	Point Estimate	95% Wald Confidence Limits	
sound	1.058	1.049	1.066

Association of Predicted Probabilities and Observed Responses

Percent Concordant	86.5	Somers' D	0.802
Percent Discordant	6.3	Gamma	0.864
Percent Tied	7.1	Tau-a	0.397
Pairs	91530	c	0.901

c. "Maximum Standard" logistic regression analysis

The SAS System

Obs	sound	no	cumul	n
1	100	9	9	102
2	120	27	36	102
3	140	16	52	102
4	160	18	70	102
5	180	24	94	102
6	200	8	102	102

The LOGISTIC Procedure

Model Information

Data Set	WORK.SOUNDtotal
Response Variable (Events)	cumul
Response Variable (Trials)	n
Model	binary logit
Optimization Technique	Fisher's scoring

Number of Observations Read	6
Number of Observations Used	6
Sum of Frequencies Read	612
Sum of Frequencies Used	612

Response Profile

Ordered Value	Binary Outcome	Total Frequency
1	Event	363
2	Nonevent	249

Model Convergence Status

Convergence criterion (GCONV=1E-8) satisfied.

Model Fit Statistics

Criterion	Intercept Only	Intercept and Covariates
AIC	829.052	536.212
SC	833.469	545.045
-2 Log L	827.052	532.212

Testing Global Null Hypothesis: BETA=0

Test	Chi-Square	DF	Pr > ChiSq
Likelihood Ratio	294.8407	1	<.0001
Score	250.5125	1	<.0001
Wald	169.1099	1	<.0001

The LOGISTIC Procedure

Analysis of Maximum Likelihood Estimates

Parameter	DF	Estimate	Standard Error	Wald Chi-Square	Pr > ChiSq
Intercept	1	-7.5726	0.6048	156.7870	<.0001
sound	1	0.0549	0.00422	169.1099	<.0001

Odds Ratio Estimates

Effect	Point Estimate	95% Wald Confidence Limits	
sound	1.056	1.048	1.065

Association of Predicted Probabilities and Observed Responses

Percent Concordant	82.2	Somers' D	0.741
Percent Discordant	8.1	Gamma	0.821
Percent Tied	9.7	Tau-a	0.358
Pairs	90387	c	0.871

Obs	prop	pred
1	0.08824	0.11076
2	0.35294	0.27189
3	0.50980	0.52820
4	0.68627	0.77045
5	0.92157	0.90960
6	1.00000	0.96791

Appendix H: NMFS proposed exposure criteria management guidelines.

NMFS will be proposing to replace the current Level A and Level B harassment thresholds with guidelines based on exposure characteristics that are derived from empirical data and are tailored to particular marine mammal species groups and ocean sound types. Each marine mammal functional hearing group has somewhat different hearing capabilities, and frequency-specific thresholds are being developed based on what is known about these differences. Based on current noise exposure guidelines, marine mammals would be divided into five functional hearing groups;

1) low frequency cetaceans (all mysticetes, i.e., baleen whales);
2) mid-frequency cetaceans (all odontocetes i.e., dolphins and porpoises not included in the low or high frequency groups);
3) high-frequency cetaceans (harbor and Dall's porpoise, river dolphins);
4) pinnipeds under water (seals, fur seals and sea lions);
5) and pinnipeds out of water.

The criteria would also categorize all anthropogenic sounds into four different types: single pulses (brief sounds with a fast rise time); single non-pulses (all other sounds); multiple pulses in a series; and multiple non-pulses in a series:

Sound Type	**Characteristics (at source)**	**Selected Examples**
Single Pulse	Single sound: short duration, fast rise time.	Single explosion, single airgun, watergun, or sparker pulse, single ping of certain sonars/depth sounders
Single Non-Pulse	Single sound: long duration, slow rise time	Single vessel pass, drilling event, aircraft overflight, single ping of certain sonars
Multiple Pulse	Multiple sounds: each short duration, fast rise time	Airguns, some sonar/depth sounder systems, waterguns, sparkers, pile driving, serial explosions
Multiple Non-Pulse	Multiple sounds: each long duration, slow rise time	Multiple vessel/aircraft passes, certain sonar systems, tomography sources

Source: Dr. Brandon Southall, NMFS, 2004.

Each of the five functional hearing groups would then be paired against the four sound types resulting in a matrix of values. These values would represent the noise-exposure criteria that NMFS would use, at least in part, to guide determinations of when an anthropogenic sound results in an acoustic ‘‘take’’ by harassment under the MMPA or ESA for each of the different marine mammal hearing groups. All threshold values would be expressed in terms of either a sound pressure level value that the animal receives, or as a measure of exposure that incorporates both sound pressures and time as a dimension where it is appropriate.

There are several alternatives which are being considered for determining the acoustic threshold at which both **Level A** and **Level B** harassment takes might occur:
1) maintaining the status quo (the no action alternative);
2) using a precautionary approach and very conservative interpretations of data on marine mammals based on considering human noise exposures relative to ambient noise conditions;
3) defining a **Level A** harassment take as that exposure which results in a temporary shift in hearing sensitivity (TTS) and a **Level B** harassment take as that exposure estimated to result in a 50 percent behavioral avoidance for each species or group of species;
4) defining **Level A** harassment take as that exposure which results in a Permanent Threshold Shift (PTS) minus 6 decibels (dB) and defining a **Level B** harassment take as a level 6 dB below that exposure estimated to causes TTS;
5) defining a **Level A** harassment take as noise exposure consistent with estimated PTS onset and a **level B** harassment take as TTS onset; and
6) defining a **Level A** harassment take as occurring at the PTS onset plus 6 dB and **level B** harassment take as 6 dB below the estimated point of PTS onset (see following table).

NMFS TABLE 1: ACOUSTIC CRITERION FOR EACH OF THE PROPOSED ALTERNATIVES

Alternative	Level A Criterion	Level B Criterion
I (Status Quo)	180 dB rms re: 1μPa	160 dB rms re: 1μPa (impulse) 120 dB rms re: 1μPa (continuous).
II	Highest average	lowest possible natural ambient.
III	TTS Onset	50% Behavioral Avoidance.
IV	PTS Onset minus 6dB	TTS Onset minus 6dB.
V	PTS Onset	TTS Onset.
VI	PTS Onset plus 6dB	PTS Onset minus 6dB.

Alternative I: A no action alternative would perpetuate the use of the existing thresholds for Level A harassment (sound pressure level of 180 dB rms re: 1µPa) (hereafter dB SPL), and Level B harassment (160 dB SPL for impulse noise and 120 dB SPL for continuous sound) that have been used for the past six years. The advantages of this alternative are that the public is familiar with this approach, and safety zones can easily be calculated from standard sound propagation models. A disadvantage is that this considers only the sound pressure level of an exposure but not its other attributes, such as duration, frequency, or repetition rate, all of which are critical for assessing impacts on marine mammals. For example, a sound of 181 dB SPL lasting for two seconds would be identified as a Level A harassment take, but a potentially more harmful sound of 179 dB SPL lasting two days is currently considered a Level B harassment take. It also assumes a consistent relationship between rms (root-mean-square) and peak pressure values for impulse sounds, which is known to be inaccurate under certain (many) conditions.

Alternative II: A second alternative is based on very conservative behavioral response data for marine mammals. Under this alternative takes would occur at the SPL at which the most sensitive species first begin to show a behavioral response. Level A harassment would occur if the received noise from a human source exceeded the highest average ambient noise level in the area of operation. Level B harassment would occur if the received noise from a human source exceeded the lowest possible ambient noise condition. Criteria based largely on behavioral responses to noise just above ambient level would be extremely conservative. Under this alternative, a behavioral response may, and behavioral avoidance would, constitute Level B harassment.

Alternative III: A third alternative would define a Level A harassment take as occurring at that level of exposure which results in a temporary loss of hearing sensitivity (TTS) but which is fully recoverable. This approach is also conservative because scientific experts in this field do not consider TTS to result in harm or injury because no irreversible cell damage is involved. A Level B harassment take would be defined as that level of noise exposure known or estimated to result in 50 percent behavioral avoidance of a sound source for each species or animal group. There are a small number of these types of empirical data available for certain conditions, but some of the level B criteria constructed in this manner would require extrapolations and assumptions, particularly in the above context of how biological significance is defined. Generally this alternative would be less conservative than the previous alternative.

Alternative IV: A fourth alternative would determine that a Level A harassment take occurs at that level of noise exposure which results in a permanent loss of hearing sensitivity (PTS) due to non-recoverable cell damage, minus some ‘‘safety’’ factor. This alternative would be more conservative than federal workplace standards for humans which permit exposures that result in some degree of PTS over a lifetime for some individuals. A doubling of absolute sound pressure magnitude (in µPa) represents a 6 dB increase in SPL. A proposed ‘‘safety’’ factor to ensure that exposures do not result in permanent injury is to set the Level A harassment criteria 6 dB below that noise exposure estimated to cause PTS onset for each animal group. The proposed Level B harassment take criteria for alternative 4 are those exposures resulting in TTS onset minus a ‘‘safety’’ factor of 6 dB.

Alternative V: A fifth alternative defines a Level A harassment take as noise exposures estimated to result in PTS onset and Level B harassment take as noise exposures consistent with TTS onset for each animal group. This alternative would allow Level A harassment criteria levels that are higher than either TTS (Alternative III) or PTS minus some safety factor (Alternative IV); Level A harassment criteria would be based on those exposures that are believed to result in irreversible tissue damage. The Level B harassment criteria under Alternative V would set the take threshold slightly higher than Alternative IV but considerably below those in Alternative 6.

Alternative VI: A sixth alternative defines a Level A harassment take based on estimated PTS onset (as in Alternatives 4 and 5), but requires a higher probability of exposed animals experiencing a meaningful change in hearing sensitivity above merely the onset of tissue injury, such as 6 dB of PTS. Under Alternative VI, Level B harassment take would be defined as exposures estimated as 6 dB below those required to cause PTS onset. This alternative would result in noise threshold levels that are greater than any of the other proposed alternatives.

A number of assumptions will be made in developing the acoustic matrix of threshold levels. For example, in most cells within the matrix, the criteria assume that all species in a functional hearing group have the same threshold apply to all species in the group. In reality, some species are so different from others in their functional hearing group that separate threshold criteria are appropriate for them. Further, there are no direct data on the effects of many kinds of sounds on many species of marine mammals. For now, therefore, it is necessary to extrapolate making reasonably conservative criteria from existing data to cover cases of missing data.

An example of an extrapolation is the use of data from dolphins or beluga whales for other cetaceans. Most data on the effects of noise on marine mammals come from mid-frequency dolphins, especially bottlenose dolphins and beluga whales. The results of studies on these species are applied directly to low- and high-frequency cetaceans (for which data are sparse or non existent) without adjustment. This substitution is likely conservative for low frequency cetaceans because the mid-frequency cetacean ear is almost certainly more sensitive. The substitution is also likely satisfactory for high-frequency cetaceans. In the absence of data for marine mammals, in some cases, data from terrestrial mammals are used in determining exposure criteria.

The noise exposure criteria are based on research available for all species of marine mammals, plus some data from terrestrial mammals and humans. Using data from one species of mammals to set criteria for another species is acceptable for injury because the anatomy of the inner ear of all mammals is extremely similar. As an example, certain human hearing standards are based in part on extrapolations from the effects of noise on the chinchilla ear. Table 2 provides an example of noise exposure criteria that would result under each of the proposed alternatives for gray whales. Gray whales were selected as an example because some data on behavioral reactions exist and are used (in Alternative III), but setting criteria based on TTS or PTS rely on extrapolations from other cetacean species (Alternatives III-VI). The use of direct information combined with reasonable extrapolation is representative of how such criteria would be established under any of the alternatives.

NMFS TABLE 2: EXAMPLE OF NOISE EXPOSURE CRITERIA FOR GRAY WHALES FOR EACH OF THE PROPOSED ALTERNATIVES

Alternative	Level A Criterion	Level B Criterion
I	180 dBrms re: 1µPa	160 dBrms re: 1µPa (impulse) 120 dBrms re: 1µPa (continuous).
II	Both criteria variable	depending on environment.
III	195 dB re: 1µPa2(s)	160 dBrms re: 1µPa.
IV	209 dB re: 1µPa2(s)	189 dB re: 1µPa2(s).
V	215 dB re: 1µPa2(s)	195 dB re: 1µPa2(s).
VI	221 dB re: 1µPa2(s)	209 dB re: 1µPa2(s).

Alternative I indicates the status quo criteria already in place.

Alternative II criteria are established based on ambient noise conditions experienced by animals in the area of operation. Since these conditions may be dominated by either natural or human noise and are quite variable depending on many spatial and temporal factors, the criteria for determining both Level A and Level B harassment are variable depending on the operational environment.

Alternative III, the **Level A** criterion is set at noise exposures estimated to cause TTS [195 dB re: 1µPa2(s). This is the estimated point of TTS onset for cetaceans based on Finneran et al. (2002)].

Alternative III, **Level B** criteria are based on behavioral avoidance data for migrating gray whales (Malme et al., 1983; 1984). These are, in fact, the same data upon which the status quo (Alternative I) **Level B** data are based. An additional extrapolation is made in **Alternative IV** to estimate PTS. The level of noise exposure required to induce PTS in marine mammals is unknown, but may be estimated using the TTS onset data and extrapolations based on terrestrial mammals. Using the slope of the function relating increases in noise exposure and TTS, and using a relatively conservative estimate of PTS as 40 dB of TTS, it is estimated that an additional 20 dB of noise exposure is required above TTS onset to induce PTS. Thus, for **Alternative IV**, the **Level A** harassment criterion is estimated TTS onset (195 dB re: 1µPa2(s)) plus 20 dB to equal PTS onset (215 dB re: 1µPa2(s)) minus 6 dB, or 209 dB re: 1µPa2(s). The **Level B** harassment criterion for Alternative IV is estimated TTS onset (195 dB re: 1µPa2(s)) minus 6 dB, or 189 dB re: 1µPa2(s).

For **Alternative V**, the **Level A** harassment criterion is the estimated PTS onset (215 dB re: 1µPa2(s) as described above) and the **Level B** harassment criterion is estimated TTS onset (195 dB re: 1µPa2(s)).

In **Alternative VI**, the **Level A** harassment criterion is 6 dB above estimated PTS onset (or 221 dB re: 1µPa2(s)) while the **Level B** harassment criterion is 6 dB below estimated PTS onset (or, 209 dB re: 1µPa2(s)).

Appendix I. Benders et al., (2005). Model for the 'Identification & Registration of Marine Animals' (IRMA):

> *"For the application of Risk Mitigation Measures it is important to know how sensitive a marine mammal is to anthropogenic sound. Currently this sensitivity is mostly estimated, based on two factors. The first is the biological family of the mammal. The second is the sounds produced by the mammal. It is obvious to assume that acoustic sensitivity is directly related to their vocalisations. Some of these sensitivity curves have been validated [*]. The sensitivity has lead to a subdivision of marine mammals into ten groups. The following groups are identified:*
>
> *1a. Mysticeti (baleen whales), use only sounds below 250 Hz called moans; they are not known to use clicks.*
>
> *1b. Mysticeti (baleen whales), use sounds below 1 kHz and clicks.*
>
> *2a. Large Odontoceti and possibly the smallest Mysticeti, use high level clicks and sounds below 20 kHz.*
>
> *2b. Most (offshore) Ondontoceti, mostly use clicks between 40-80 kHz.*
>
> *2c. Ziphioidea (beaked whales), use clicks around 7 kHz and above 20 kHz.*
>
> *2d. (Smaller) inshore and riverine Odontoceti, use clicks above 80 kHz.*
>
> *3. Sirenia, use sounds below 20 kHz.*
>
> *4a. Phocidae (hair seals)*
>
> *4b. Otarioidea (eared seals)*
>
> *4c. Odobenidae (walrus)*
>
> *Each of these groups has its own frequency dependent sensitivity curve. This curve is used in the risk mitigation measure calculation of SAKAMATA.* **[*]**
>
> **Verboom, W.C, & Kastelein, R.A.**, Some examples of marine mammal 'discomfort thresholds' in relation to man-made noise, UDT Europe 2005, Amsterdam, The Netherlands, June 2005.

This division allows a comparison of how scientists translated their data in terms of management strategies which are more specific to each species or species group. Codes for both Survey Result graphics are correlated to Appendix A Groups.

Bibliography

Anderson, P., "Did Navy Tests Kill Porpoises?" CBSNEWS.com, 23 July 2003, from,
http://www.cbsnews.com/stories/ 2003/07/23/tech/main564700.shtml (accessed 11 July 2005).

Andre, M., (2002). University of Las Palmas de Gran Canaria. In: Socolovshy, J. "Investigation points to NATO exercise in mass whale beaching in the Canary Islands" Associated Press, October 9th, 2002.

Andresen, S. (1989). Science and politics in the international management of whales. *Marine Policy* 13(2):99-117.

Andresen, S., Skodvin, T., Underdal, A., Wettestad, J. Science and Politics in International Environmental Regimes, Between Integrity and Involvement (2000). Manchester University Press, Manchester and New York.

Andrewartha, HG, & Birch, LC. (1984). The ecological web: More on the distribution and abundance of animals. Chicago, IL: University of Chicago Press.

ANSI, (American National Standard Preferred Reference Quantities for Acoustical Levels), S1.8-1969.

ATOC <http://atoc.ucsd.edu/Climate_page.html>

Au, W.W.L. **(**2000**)**. Hearing in whales and dolphins: An overview. In: Au, W.W.L., Popper, A.N., & Fay, R.J., (eds) *Hearing by whales and dolphins*. New York, NY. Springer-Verlag.

Au, W. W. L., Ford, J. K. B., Horne, J. K., & Newman-Allman, K. A. (2004). Echolocation signals of free-ranging killer whales (*Orcinus orca*) and modeling of foraging for Chinook salmon (*Oncorhynchus tshawytscha*), *J. Acoust. Soc. Am.*, 56, 1280-1290.

Au, W. W. L., Frankel, A., Helweg, D. A., and Cato, D. H. (2001). "Against the humpback whale sonar hypothesis," *IEEE J. Oceanic Engr.*, 26, 295-300.

Au, W.W. L., Nachtigall, P.E., & Pawloski J.L. (1997). Acoustic effects of the ATOC signal (75 Hz, 195 dB) on dolphins and whales. *J. Acoust. Soc. Am.*, 101(5) 2973-2977.

Babson, J., "Dolphins Beaching Closely Followed Sub's Exercises" Miami Herald , March 5, 2005, Page 1A.

Baker, C.S., Herman, L.M., Bays, B.G., & Stifel, W.F. (1982). The impact of vessel traffic on the behavior of humpback whales in Southeast Alaska. (*Megaptera novaeangliae*). Natl. Mar. Fish. Ser. Contract No. 81-ABC-00114. University of Hawaii, Kewalo Basin Marine Mammal Laboratory, Honolulu, 39p.

Balcomb, K. C., & Claridge, D. E. (2001). A mass stranding of cetaceans caused by naval sonar in the Bahamas. *Bahamas Journal of Science,* 5:2-12.

Barlow, J., and Gisiner, R. (2006). Mitigating, monitoring and assessing the effects of anthropogenic sound on beaked whales. *J. Cetacean Res. Manage.* 7(3):239-249.

Barnett, V. (1991). *Sample survey principles & methods.* London: Edward Arnold.

Bayes, Thomas (1763): "An essay towards solving a problem in the doctrine of chances." *Philosophical Transactions of the Royal Society.* **53**:370-418.

Beamish, P.C. (1970). Biological sonar of diving mammals: An analytical model. In: Proceedings of the 7th Annual Conference on Biological Sonar and Diving Mammals. Stanford Research Inst., Stanford. p. 1-3.

Bekoff, M. (Ed.). (2005). *Encyclopedia of animal behavior.* (Vols. 1-3, pp.1274). SanDiego, CA: Greenwood.

Bel'Kovich, V.M. (1970). Some new ideas on the capabilities of the echolocation apparatus of dolphins. *Ekologiya* 1(6):89-93.

Benders, F.P.A, van der Zwan, T., Verboom, W.C. (2005). Identification & Registration of Marine Animals (IRMA). TNO Defense, Security and Safety, P.O. Box 96864, 2509 JG The Hague, The Netherlands.

Boesch D. F. (1999). The role of science in ocean governance. *Ecological Economics* 31:189-198.

Borgese, E.M., ed. (1972). Pacem in Maribus. Dodd, Mead & Co.

Bowles, A.E., Smultea, M., Wursig B., DeMaster, D.P. & Palka D. (1994). Relative abundance and behavior of marine mammals exposed to transmissions from the Heard Island Feasibility Test. *J. Acoust. Soc. Am.,* 96:2469-2484.

Bradbury, J.W. & Vehrencamp, S.L. (1998). *Principles of animal communication*. Sunderland, MA: Sinauer.

Brookfield, S.D. (1995). *Becoming a critically reflective teacher*. Jossey-Bass Publishers.

Brooks, H. (1977). Potentials and Limitations of Societal Response to Long-Term Environmental Threats. In *Global Chemical Cycles and Their Alteration by Man*, edited by Werner Strumm. Berlin: Dahlem Konferenzen.

Brooks, R.J. (1979). Lemming behavior: A possible parallel to strandings? In Geraci, J.B., & St. Aubin, D.J. (Eds.). *Biology of marine mammals: Insights through strandings*. (114-128). (Final report to U.S. Marine Mammal Commission in fulfillment of contract MM7AC020. NTIS PB-293 890).

Buck, E. H., Calvert, K. (2005). Active Military Sonar and Marine Mammals: Events and References. Congressional Research Service Report for Congress, Library of Congress, Washington, D.C.

Buckstaff, K.C. (2004). Effects of watercraft noise on the acoustic behavior of bottlenose dolphins, *Tursiops truncates,* in Sarasota Bay, Florida. *Marine Mammal Science*. 20(4).

Busnel, R. (ed) (1963). Acoustic behavior of animals. New York. Elsevier Publ. 933p.

Caldwell, M.C., & Caldwell, D.K. (1965). Individualized whistle contours in bottlenosed dolphins (*Tursiops truncatus*). *Nature* (London) 207, 434-435.

Cape Cod Times, February 28, 2005, p. A5

Castellini, M. A., Rivera, P.M. Rivera, & Casellini, J. M. Castellini. (2002). Biochemical aspects of pressure tolerance in marine mammals. *Comparative Biochemistry and Physiology*, 133(part A): 893-899.

Chapman, M.F., & Ellis, D.D., (1998). The Elusive Decibel: Thoughts on Sonars and Marine Mammals. *Canadian Acoustics/Acoustique Canadienne*, 26(2) 29-31.

Charif, R.A., Mellinger, D.K., Dunsmore, K.J., Fristrup, K.M., & Clark, C.W. (2002). Estimated source levels of Fin whale (*Balaenoptera physalus*) vocalizations: adjustments for surface interference. *Marine Mammal Science*, 18(1):81-98.

Clark, C. (2006). Cornell University. Email Communication.

Cohen, B.S. (2003). Testimony before the Senate Committee on Environment and Public Works, April 2, 2003.

Congressional Research Service archives (CRS) (2005).

Cook, R.M., Goossens, L.H.J. (2004). Expert judgment elicitation for risk assessments of critical infrastructures. *Journal of Risk Research* 7 (6), 643-656.

Croll, D. A., Clark, C. W., Calambokidis, J., Ellison, W. T., & Tersy, B. R. (2001). Effect of anthropogenic low-frequency noise on the foraging ecology of Balaenoptera Whales. *Animal Conservation*, 4: 13-27.

Dalton, R. (2003). Push to protect whales leaves seafloor research high and dry. *Nature*, 425, 549.

Dept. of Defense, Authorization Bill, H.R. 1835, 2003

Dept. of Defense, Federal Register 02-18592 (July 22, 2002).

Dept. of the Navy. (1999). FOEIS, (EIS Technical Report 1).

Dept. of the Navy. (2001). FOEIS for SURTASS LFA, (Final Overseas Environmental Impact Statement and Environmental Impact Statement for Surveillance Towed Array Sensor System Low Frequency Active Sonar). Dept. of the Navy, Chief of Naval Operations).

Dept. of the Navy, (2004). From http://www.cpf.navy.mil/archive/first_release.htm.

Downs, G.W., Rocke, D.M., Barsoon, P.N. (1996). Is the Good News About Compliance Good News About Cooperation? *International Organization* 50(3):379-406.

Eaton, R. (1979). Speculations on strndings as "burial", suicide and interspecies communication. *Carnivore,* 2(3):24.

Environmental Consequences of Underwater Sound (ECOUS) Symposium (2003).

Elsner, R., Hornbein, T.F., & Wright, J. (1964). Blood flow distribution in diving mammals. Federation Proceedings 32:111.

Elster, J. (1983). *Sour Grapes*. Cambridge: Cambridge University Press.

Endangered Species Act of 1973, Public Law 93-205, (16 U.S.C. 1531-1544). Endangered Species Act of 1973 to limit designation as critical habitat of areas owned or controlled by the Department of Defense, and for other purposes. House Resource Committee; House Armed Services, H.R.1835. April 29, 2003.

Engås, A., and Løkkeborg, S. (2002). Effects of seismic shooting and vessel-generated noise on fish behaviour and catch rates. *Bioacoustics*, 12:313-315.

Engås, A., and Løkkeborg, S., Ona, E., & Soldal, A.V. (1996). Effects of seismic shooting on local abundance and catch rates of cod (*Gadus morhua*) and haddock (*Melanogrammus aeglefinus*). *Canadian Journal of Fisheries and Aquatic Sciences* 53:2238-2249.

Erbe, C. (2002). Underwater noise of whale-watching boats and potential effects on killer whales (*Orcinus orca*), based on an acoustic impact model. *Marine Mammal Science*, 18(2):394-418.

Erbe, C., Farmer, D.M. (2000). Zones of impact around icebreakers affecting beluga whales in the Beaufort Sea. *J. Acoust. Soc. Am*., 108(3):1332-1340.

Fed. Reg. 70 1872 (January 11, 2005).

Feyerabend, P. (2000). *Against Method*, Third Edition. Verso, London/New York.

Feynman, R.P. (1962). *The Feynman Lectures on Physics, Caltech*. (Vol. 12). Feynman on Sound. Perseus Publishing *(audiotape)*.

Feynman, R.P., Leighton, R.B., & Sands, M.. (1966). *The Feynman Lectures on Physics*. (Vols. I-III). California Institute of Technology & Addison Wesley.

Fichtelius, K.E. (1968). How to communicate with dolphins. *Zoologiskrevy* 30(1):10-12.

Finneran, J.J., Carder, D.A., & Ridgway, S.H. (2002a). Low-frequency acoustic pressure, velocity, and intensity thresholds in a bottlenose dolphin (*Tursiops truncatus*) and white whale (*Delphinapterus leucas*). *J. Acoust. Soc. Am*., 111(1): 447-456.

Finneran, J.J., Schlundt, C.E., Dear, R., Carder, D.A., & Ridgway, S.H. (2002b). Temporary shift in masked hearing thresholds in odontocetes after exposure to single underwater impulses from a seismic watergun. *J. Acoust. Soc. Am*., 111(6):2929-2940.

Fischer, J., Hammerschmidt, K. & Todt, D. (1995). Factors affecting acoustic variation in Barbary-macaque (*Macaca sylvanus*) disturbance calls. *Ethology*, 101:51-66.

Fistrup, K.M., Hatch, L.T., & Clark, C.W. (2003). Variation in humpback whale (*Megaptera novaeangliae*) song length in relation to low-frequency sound broadcasts *J. Acoust. Soc. Am*., 113(6): 3411-3424.

Fletcher, W.J. (2005). The application of qualitative risk assessment methodology to prioritize issues for fisheries management. *ICES Journal of Marine Science*, 62:1576-1587.

Framework for Ecological Risk Assessment. U.S. Environmental Protection Agency, Risk Assessment Forum, Washington, DC, USEPA/630/R-92/001, 1992.

FrameWorks Institute, 2006. http://www.frameworksinstitute.org/strategicanalysis/index.shtml.

Frankel, A.S. (1994). Acoustic and visual tracking reveals distribution, song variability and social roles of humpback whales in Hawaiian waters. Ph.D. Dissertation, University of Hawaii, Honolulu, HI.

Frankel, A.S., and Clark, C.W. (2000). Behavioral responses of humpback whales (*Megaptera novaeangliae*) to full-scale ATOC signals. *J. Acoust. Soc. Am*., 108(4).

Frankel, A.S. & Clark, C.W. (2002). ATOC and other factors affecting the distribution and abundance of humpback whales (*Megaptera novaeangliae*) off the north shore of Kauai. *Marine Mammal Science*, 18(3):644-662.

Frantzis, A. (1998). Does acoustic testing strand whales? *Nature*, 392: 20-29.

Frantzis A., Goold J.C., Skarsoulis, E.K., Tariydajusm M.I & Kandia, V., **(**2002)**.** Clicks from Cuvier's beaked whales, *Ziphius cavirostris. J. Acoust. Soc. Am. 112(1):* 34-37.

Fraser, F.C. (1936). Recent strandings of the false killer whale, *Pseudorda crassidens*. *Scottish Naturalist,* 220:105-114.

Frazer, L.N., & Mercado III, E. (2000). A Sonar Model for Humpback Whale Song. *IEEE Journal of Oceanic Engineering*, 25(1):160-182.

Garrison, T. (2005). Oceanography, an invitation to marine science. (5th ed.). Pacific Grove, CA. Brookscole.

Gentry, R. pers. com., (2006). Senior Scientist, NMFS, Silver Spring, MD.

Geraci, J.R. (1989). Clinical investigation of the 1987-1988 mass mortality of bottlenose dolphins along the U.S. central and south Atlantic coast. (*Tursiops truncatus*). Final report to National Marine Fisheries Service, U.S. Navy (Office of Naval Research) and Marine Mammal Commission. 63pp.

Geraci, J.R. & St. Aubin, D.J. (1979). Stress and disease in the marine environment: Insights through strandings. In: J.B. Geraci & D.J. St. Aubin, (Eds.). *Biology of Marine Mammals: Insights Through Strandings*. (pp. 114-128). (Final report to U.S. Marine Mammal Commission in fulfillment of contract MM7AC020. NTIS PB-293 890).

Gilmore, R. M. (1959). On the mass stranding of Sperm whales. *Pacific Naturalist,* 1(9):9-16.

Glass, G.V., McGraw, B., & Smith, M.S. (1981). Meta-analysis in social research. Beverly Hills, CA: Sage.

Goley, P. G. (1999) Behavioral aspects of sleep in Pacific white-sided dolphins *(Lagenorhynchus obliquidens,* Gill 1866). *Mar. Mamm. Sci.* 15, 1054-1064.

Goold, J.C., Whitehead, H. & Reid, R.J. (2002). North Atlantic Sperm Whale, *Physeter macrocephalus*, strandings on the coastlines of the British Isles and Eastern Canada. *Canadian Field-Naturalist*, 116(3):371-388.

Greenpeace (2005) from http://www.greenpeace.org/international/campaigns/save-our-seas-2/save-the-whales

Gregr, E.J., & Trites, A.W. (2001). Predictions of critical habitat for five whale species in the waters of coastal British Columbia. *Canadian Journal of Fisheries and Aquatic Science*, 58:1265-1285.

Guidelines for Ecological Risk Assessment. U.S. Environmental Protection Agency, Risk Assessment Forum, Washington, DC, USEPA/630/R095/002F, 1998.

Haas, P.M. (1990). Saving the Mediterranean: The Politics of International Environmental Cooperation (New York: Columbia University Press).

Haas, P.M. (1992a). Introduction: Epistemic Communities and International Policy Coordination. *International Organization*, 46: 1-37.

http://www.epa.gov/sustainability/index.htm

http://www.surtass-lfa-eis.com/docs/180dBCriteria.pdf

http://www.surtass-lfa-eis.com/EIA/

http://www.websurveyor.com/pdf/webvsmail.pdf.

Hamazaki, T. (2002). Spatiotemporal prediction models of cetacean habitats in the mid-western North Atlantic Ocean (from Cape Hatteras, North Carolina, U.S.A. to Nova Scotia, Canada). *Marine Mammal Science*, 18(4):920-939.

Harwood, J. (2000). Risk assessment and decision analysis in conservation. Biological Conservation, 95:219-226.

Hastie, G.D., Wilson, B., Tufft, L. H., & Thompson, P. M. (2003). Bottlenose dolphins increase breathing synchrony in response to boat traffic. *Marine Mammal Science*, 19(1): 74-84.

Hastings, M. (2003). International conference on acoustic communications by animals, introduction to acoustics and communication short course, University of Maryland, College Park. “Production of Sound” and “Transmission of Sound.” Office of Naval Research, Arlington, Virginia.

Hedges, L.V., and Olkin, I. (1985). *Statistical methods for meta-analysis*. Academic Press, Orlando, FL.

Hill, S.H. (1978). A guide to the effects of underwater shock waves on Arctic marine mammals and fish. Pacific Marine Science Report 78-26. Institute of Ocean Sciences, Patricia Bay, Sidney, B.C. 50p.

Hobday, A.J., A. Smith, H. Webb, R. Daley, S. Wayte, C. Bulman, J. Dowdney, A. Williams, M. Sporcic, J. Dambacher, M. Fuller, T. Walker (2007). Ecological Risk Assessment for the Effects off Fishing: Methodology Report R04/1072 for the Australian Fisheries Management Authority, Canberra.

Hofman, R. J. (2003). Scientific Program Director (retired), Marine Mammal Commission. Pers. Comm.

Hohn, A.A, Rotstein, D.S., Harms, C.A. and Southall, B.L. (2006). Report on marine mammal unusual mortality event UMESE0505Sp: Multi-species mass stranding of pilot whales (*Globicephala macrorhynchus*), minke whale (*Balaenoptera acutorostrata*), and dwarf sperm whales (*Kogia sima*) in North Carolina on 15-16 January 2005. NOAA Technical Memorandum NMFS-SEFSC-537. Southeast Fisheries Science Center, Beaufort, North Carolina. Available from: http://www.sefsc.noaa.gov/PDFdocs/Report_on_UMESE0501sp.pdf

Holling, C.S. (1986). Resilience of ecosystems; local surprise and global change. In W.C. Clark and R.E. Munn, (Eds.). *Sustainable development of the biosphere* (pp. 292-317). Cambridge: Cambridge University Press.

Hooker, S.K., & Whitehead, H., 2002. Click characteristics of northern bottlenose whales (*Hyperoodon ampullatus*). *Marine Mammal Science* 18: 69-80.

Houde, E. (1999). Chesapeake Biological Lab, Solomons Island, MD. Pers. Comm.

Houser, D.S., Howard, R., & Ridgway, S. (2001). Can diving-induced tissue nitrogen supersaturation increase the chance of acoustically driven bubble growth in marine mammals? *Journal of Theoretical Biology*, 213(2):183-195.

Hosmer, D.W., Lemeshow, S. (2000). *Applied Logistic Regression, Second Edition*. John Wiley & Sons, Inc., New York.

Hovi, J. and Sprinz, D. F. (2006). The Limits of the Law of the Least Ambitious Program. *Global Environmental Politics*, 6(3): 28-42.

Huxley, T.H. (1868). *Lay Sermons: A Liberal Education*. London: MacMillan and Co. London R. Clay, Sons, and Taylor, Printers, Bread Street Hill.

Ichihara, T. (1959). Formation mechanism of ear plug in baleen whales in relation to glove-finger. *Scientific Reports of the Whales Research Institute*.

Iida, Y. Tsutsui, K. Ishii, R. Yamada, Y. (1991). Natural-Convection Heat Transfer in a Field of Ultrasonic Waves and Sound Pressure. *Journal of Chemical Engineering of Japan* 24(6):794-796.

IPCC (2007). Summary for Policymakers. In: *Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change* [Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M.Tignor and H.L. Miller (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

Isaac, S., & Michael, W.B. (1997). *Handbook in research and evaluation*. (3rd ed.). San Diego, California: EdITS.

Jepson, P.D., Arbelo, M., Deaville, R., Patterson, I.A.P, Castro, P., Bakers, J.R., Degollada, et al. (2003). Gas-bubble lesions in stranded cetaceans. *Nature*, 425, 575.

Johnson, C.S. (1966). Auditory thresholds of the bottlenosed porpoise (*Tursiops truncatus*, Montagu). U.S. Naval Ordance Test Station (NOTA) TP4178, 22p.

Kastelein, R.A., Verboom,W.C., Muijsers,M., Jennings, N.V., & van der Heul, S. van der Heul. (2005). The influence of acoustic emissions for underwater data transmission on the behaviour of harbour porpoises (*Phocoena phocoena*) in a floating pen. *Marine Environmental Research*, 59: 287-307.

Kaufman, M., " Whales' Plight Revives Sonar Theory Navy Denies Role In Near-Stranding" Washington Post , Sunday, July 11, 2004; Page A01.

Kaufman, M., "Whale Stranding in N.C. Followed Navy Sonar Use Military Says Connection to Death of 37 Animals Is 'Unlikely'" Washington Post, Friday, January 28, 2005; Page A03

Kellogg, W.N. & Kohler, R. (1952). Reactions of the porpoise to ultrasonic frequencies. *Science* 116(3010):250-252.

Kellogg, W.N., Kohler, R., Morris, H.N. (1953). Porpoise sounds as sonar signals. *Science* 117(3036):239-243.

Ketten, D. (2000). Cetacean Ears. In: Au, W.L., Popper; A.N., Fay, R.R. (eds) *Hearing by Whales and Dolphins*. Springer Handbook of Auditory Research.

Kirschunk, J.L. Dizon, A.E., & Westphal, J.A. (1986). Evidence from strandings for geomagnetic sensitivity in cetaceans. *Journal of Experimental Biology* 120(1):1-24.

Klinowska, M. (1986). The cetacean magnetic sense – evidence from strandings. In: *Research on Dolphins*. Bryden, M. M., & Harrison, R.J., (eds.). Oxford Univ. Press, Oxford, England. p.401-432.

Knudsen, V.O., Alford, R.S., & Emling, J.W. (1948). Underwater Ambient Noise. 7 *Journal of Marine Research* 3:410-429.

Kremser, U., Klemm, P., Kotz, W-D. (2005). Estimating the risk of temporary acoustic threshold shift, caused by hydroacoustic devices, in whales in the Southern Ocean. *Antarctic Science* 17(1):3-10.

Krogh, A., (1965). Osmotic regulation in aquatic mammals. New York, NY. Dover Publications, Inc. 242pgs.

Kuhn, T.S. (1996). *The Structure of Scientific Revolutions,* 3rd ed., Chicago: University of Chicago Press

Laird, N.M.; Mosteller, R. (1990) Some statistical methods for combining experimental results. *Int. J. Technol. Asses. Health Care* 6: 5-30.

Lethery, Steve (2006). Pers. Comm., Former Chief of the Protected Resources Permits Division. NOAA.

Lien, J., Guigne, J., Chopin, F. (1989). Development of acoustic protection for fixed fishing gear to minimize incidental catches of marine mammals. Report from Fisheries Innovation Industrial Support Program, St. John's, Newfoundland. 24pgs.

Lesage, V., Barrette, C., Kingsley, M.C.S., & Sjare, B. (1999). The effect of vessel noise on the vocal behavior of belugas in the St. Lawrence River Estuary, Canada. *Marine Mammal Science,* Vol. 15, No. 1, pp. 65-84.

Lilly, J.C. (1961). *Man and dolphin: Adventures on a new scientific frontier*. Garden City, NY. Doubleday & Co.

Lilly, J. C. (1964) Animals in aquatic environments: Adaptation of mammals to the ocean. In: D. B. Dill (ed.). *Handbook of Physiology - Environment,* pp. 741-747. American Physiology Society: Washington, D.C.

Lipton, J; Galbraith,H., Burger,J., Wartenberg, D. (1993). A paradigm for ecological risk assessment. *Environmental Management,* 17:1-5.

Lucas, Z. N. & Hooker, S.K. (2000). Cetacean strandings on Sable Island, Nova Scotia, 1970-1998. *Canadian Field-Naturalist*, 114(1):45-61.

Luczkovich, Joseph (2006). Biology Department, East Carolina University. Pers. comm..

Lyamin, O.I., Mukhametov, L.M., Siegel, J.M. (2004). Relationship between sleep and eye state in cetaceans and pinnipeds. *Archives Italiennes de Biologie*, 142:557-568.

Mackay, R. S., Lettvin, J.Y., Gruberg, E.R., Rose, R.M., Plotkin, G., Ridgway, S.H., & Howard, R. (1982). Dolphins and the bends. *Science* (Washington D.C.) 216(4546):650-651.

Maier, R. (1968). Effects of stress upon social distance in dolphins. *Perceptual and Motor Skills* 27(3):862.

Malnes, R. (2006). Imperfect Science. *Global Environemental Politics*, 6(3): 58-71.

Mann, J. (1999). Behavioral sampling methods for cetaceans: a review and critique. *Marine Mammal Science*, 15(1):102-122.

Marine Mammal Commission (2003). Notice of intent to charter the Advisory Committee on Anthropogenic Sound and Marine Mammals and request for comments and nominations. [DOCID: fr21oc03-98].

Marine Mammal Commission (2005). Report of the Advisory Committee on Acoustic Impacts on Marine Mammals.

Marine Mammal Commission (2006). Advisory Committee on Acoustic Impacts on Marine Mammals Report to the Marine Mammal Commission, 1 February http://mmc.gov/sound.html

Marine Mammal Protection Act of 1972, Public Law 92-522, (16 U.S.C. 1361 et seq.)

Mayr, Ernst (2003). Pers. Comm. Alexander Agassiz Professor of Zoology Emeritus, Harvard University.

Mazzuca, L., Atkinson, S., Keating, B., & Nitta, E. (1999). Cetacean mass strandings in the Hawaiian Archipelago, 1957-1998. *Aquatic Mammals,* 25(2):105-114.

McCarthy, E. (2004). *International Regulation of Underwater Sound: Establishing Rules and Standards to Address Ocean Noise Pollution*. 2004. Boston/Dordrecht/New York/London. Kluwer Academic Publishers.

McCauley, R.D., Fewtrell, J., & Popper, A.N. (2003). High intensity anthropogenic sound damages fish ears. *J. Acoust. Soc. Am.*, 113(1) 638-642.

McCauley, R.D., Fewtrell, J., Duncan, A.J., & Adhitya, A. (2002). Behavioural, physiological and pathological responses of fishes to air gun noise. *Bioacoustics*, 12(2/3):318-321.

McCauley, R.D., Fewtrell, J., Duncan, A.J., Jenner, C., Jenner, M.N., Penrose, J.D., et al. (2000). Marine seismic surveys: Analysis and propagation of air-gun signals; and effects of exposure on humpback whales, sea turtles, fishes and squid. Australian Petroleum Production Association, Canberra, Australia, 198pp.

McClure, R., "Tests on Marine Mammals to Look for Sonar Link to Injuries," *Seattle Post-Intelligencer*, 12 July 2003, http://www.seattlepi.nwsource.com/local/30609_sonar12.html (accessed 11 July 2005).

McDonald, M.A., Calambokidis, J., Teranishi, A.M., & Hildebrand, J.A. (2001). Acoustic behavior of individual blue whales off California. *J. Acoust. Soc.Am.*, 109:1728-1735.

Meador, J.P., Varanasi, U., Robisch, A., & Chan, S-L. (1993). Toxic metals in pilot whales (*Globicephala melaena*) from strandings in 1986 and 1990 on Cape Cod, Massachusetts. *Canadian Journal of Fisheries and Aquatic Sciences*, 50(12):2698-2706.

Mercado III, E., Frazer. L.N. (1999). Environmental constraints on sound transmission by humpback whales. *J. Acoust. Soc. Am.*, 106(5), 3004-3016.

Mercado III, E., Frazer. L.N. (2001). Humpback Whale Song or Humpback Whale Sonar? A Reply to Au et al. *IEEE Journal of Oceanic Engineering*, 26(3): 406-415.

Miles, E.L., Underdal, A., Andresen, S., Wettestad, J., Skjaerseth, J.B., Carlin, E.M., eds. (2002). *Environmental Regime Effectiveness: Confronting Theory with Evidence*. Cambridge, MA:MIT Press.

Miles, E.L. (2006). Negotiating a New Design for a World Ocean Regime. *Global Environmental Politics*, 6(3): 43-57.

Mitchell, R.B. (2006). Problem Structure, Institutional Design, and the Relative Effectiveness of International Environemntal Agrements. *Global Environemntal Politics*, 6(3): 72-89.

Mohl, B., Wahlberg, M., Madsen, P.T., Miller, L.A., & Surlykke, A. (2000). Sperm whale clicks: Directionality and source level revisited. *J. Acoust. Soc. Am.*, 107:638-648.

Monteiro-Neto, Avila, F.J.C., Alves-Jr, T.T. Araujo, D.S., Furtado-Neto, A.A. Lein, J. (2004). Behavioral responses of *Sotalia fluviatilis* (Cetacea, Delphinidae) to acoustic pingers, Fortaleza, Brazil. *Marine Mammal Science,* 20(1) 145-160.

Moore, M.J., Early, G.A., (2004). Cumulative Sperm Whale Bone Damage and the Bends. *Science*: 306, 2215.

Mulroy, M.J. (1991). Munk's Experiment. *Science*, 253(5016):119.

Munk, W., Baggeroer, A. (1994). The Heard Island papers: A contribution to global acoustics. *J. Acoust. Soc. Am.,* 96(4).

Myrberg, A.A. (1978). Ocean noise and the behavior of marine animals: relationships and implications. In Fletcher, J.L. & Busnel, R.G. (eds). *Effects of Noise on Wildlife*. London. Academic Press. P 168-208.

Nachtigall, P.E., Lemonds, D.W., & Roitblatt, H.L. (2000a). Psychoacoustic studies of whale and dolphin hearing. Pages 330-364. In: Au, W.W.L., Popper, A.N., & Fay, R.J, (eds) *Hearing by whales and dolphins*. New York, NY. Springer-Verlag,

Nachtigall, P.E., Pawloski, J.L., & Au, W.W.L. (2003). Temporary threshold shifts and recovery following noise exposure in the Atlantic bottlenose dolphin (*Tursiops truncatus*). *J. Acoust. Soc. Am.,* 113(6).

Nachtigall, P.E., Supin, S.Y., Pawloski, J., & Au, W.L. (2004). Temporary threshold shifts after noise exposure in the bottlenose dolphin (*Tursiops truncates*) measured using evoked auditory potentials. *Marine Mammal Science,* 20(4) 673-687.

Nagel, E.L., Morgane, P.J., McFarland, W.L., & Gallliano, R.E. (1968). Rete mirable of dolphin: Its pressure-damping effect on cerebral circulation. (*Tursiops truncatus*). *Science* (Washington D.C.) 161(3844):898-899.

National Marine Fisheries Service (2000). Small takes of marine mammals incidental to specified activities; marine seismic reflection data collection in southern California/Notice of receipt of application. Fed. Regist**.** 65(60, 28 Mar.):16374-16379.

National Marine Fisheries Service (2005). Environmental Impact Statement for National Acoustic Guidelines on Marine Mammals Scoping Report. Compiled by Battelle, May 2005 Under ARO Contract Number 04040 Delivery Order 0377.

National Marine Fisheries Service (2006). Ecology of the Northeast Continental Shelf; Toward an Ecosystem Approach to Fisheries Management. Northeast Fisheries Science Center and Northeast Regional Office.

National Oceanic and Atmospheric Administration (2001). National Marine Fisheries Service, Secretary of the Navy. Joint Interim Report Bahamas Marine Mammal Stranding Event of 15-16 March 2000.

National Oceanic and Atmospheric Administration (2004). From http://www.nwr.noaa.gov/mammals/cetaceans/necropsypage.htm.

National Oceanic and Atmospheric Administration (2005). Endangered Fish and Wildlife; Notice of Intent to Prepare an Environmental Impact Statement. 70 Fed. Reg. 1871.

National Research Council (NRC). (2000). *Marine Mammals and Low-Frequency Sound*. Washington, D.C. National Academy Press.

National Research Council (NRC). (2003). *Ocean Noise and Marine Mammals*. Washington, D.C. National Academy Press.

National Research Council (NRC). (2005). *Marine Mammal Populations and Ocean Noise, Determining when Noise Causes Biologically Significant Effects*. Washington, D.C. National Academy Press.

Natural Resources Defense Council v. Evans, F. Supp 2d. 1003 (N.D. Cal., Opinion and Order Granting Plaintiffs' Motion for a Preliminary Injunction, 31 October 2002).

Natural Resources Defense Council (2005). www.nrdc.org

Natural Resources Defense Council (2006). www.nrdc.org

Nishiwaki, M. (1957). Age characteristics of the ear plugs of whales. *Scientific Reports of the Whales Research Institute.*

Nowacek, D.P., Johnson, M.P., & Tyack, P.L. (2004). North Atlantic right whales (*Eubalaena glacialis*) ignore ships but respond to alerting stimuli. *Proceedings of the Royal Society of London Series B Biological Sciences*, 271(1536):227-231. 2004.

Nowacek, S.M., Wells, R.S., & Solow, A.R. (2001). Short-term effects of boat traffic on bottlenose dolphins, *Tursiops truncates*, in Sarasota Bay, Florida. *Marine Mammal Science,* 17:673-688.

Nummela, S., Thewissen, J.G.M., Bajpai, S., Hussain, S.T., Kumar, K. (2004). Eocene evolution of whale hearing. *Nature*, 430:776-778.

Odell, D.K. (1987). The mystery of marine mammal strandings: Researchers are investigating a wide variety of possible causes ranging from mysticism to magnetism. *Cetus,* 7(2):2-6.

Office of Naval Research, Alexandria Virginia. Index of Research Funding, from http://www.onr.navy.mil/sci%5Ftech/personnel/341/docs/index.pdf

Ogawa, T. & Aarifuku,S. (1948). On the acoustic system in the cetacean brains. Sci Rep. Whales Res. Inst. 2: 1-20. Illus. P. 14-20.

Olsen, D.R., Elsner, R. Hale, F.C. & Kenney, D.W. (1969). "Blow" of the pilot whale. (*Globicephala*). *Science* (Washington D.C.) 163(3870):953-955.

Omnibus Appropriations Act (Public Law 108-7) 2003.

Orr, R.L.; Cohen, S.D.; Griffin, R.L. (1993) Generic non-indigenous pest risk assessment process. Beltsville, MD: USDA Animal and Plant Health Inspection Service.

Osenberg, C.W., Sarnelle, O., Cooper, S.C. (1997). Effect Size in Ecological Experiments: The Application of Biological Models in Meta-Analysis. *The American Naturalist* 150(6):798-812.

Ostrom, E. (1990). *Governing the Commons, The Evolution of Institutions for Collective Action*. Cambridge University Press.

Patenaude, J.J., Richardson, W.J., Smultea, M.A., Koski, W.R., Miller, G.W., Wursig, B., et al. (2002). Aircraft sound and disturbance to bowhead and beluga whales during spring migration in the Alaskan Beaufort Sea. *Marine Mammal Science*, 18(2):309-335.

Pauley, D., Christensen, V., Dalsgaard, J., Froese, R., Torres, F., Jr. (1998). Fishing Down Marine Food Webs. *Science* 279:860-863.

Payne, R. & Webb, D. (1971). Orientation by Means of Long Range Acoustic Signaling in Baleen Whales. Annals of the New York Academy of Sciences: 111.

Payne, R.S., & McVay, S. (1971). Songs of humpback whales: Humpbacks emit sounds in long, predictable patterns ranging over frequencies audible to humans. *Science* (Washington D.C.) 173(3997):585-597.

Perrin, W.F. & Hunter, J.R. (1972). Escape behavior of the Hawaiian spinner porpoise (Stenella cf *S. longirostris*). *Fishery Bulletin* 70(1):49-60.

Peterman, R.M. (1990). The importance of reporting statistical power: the forest decline and acidic deposition example. *Ecology* 71: 2024-2027.

Petitti, D.B. (1994) Meta-analysis, decision analysis and cost-effectiveness analysis: methods for quantitative synthesis in medicine. *Monographs in epidemiology and biostatistics*, v. 24. New York, NY: Oxford University Press.

Pickard, G.L., & Emery, W.J. (1996). *Descriptive Physical Oceanography,* 5th ed. Linacre House, Jordan Hill, Oxford OX2 8DP. Butterworth-Heinemann.

Principles of Underwater Sounds, Nat. Def. Res. Comm. Div. 6 Sum. Tech. Rep. 7, pp. 175-199 (1946), In: Urick, R.J. (1983). *Principles of Underwater Sound*, 3rd ed. New York, McGraw-Hill.

Purves, P.E. (1955). The wax plug in the external auditory meatus of the Mysticeti. *Discovery Reports* 27:293-302.

Rasmussen, M.H., Miller, L.A. and Au, W.W.L. (2002). Source levels of clicks from free-ranging white-beaked dolphins (*Lagenorhynchus albirostris* Gray 1846) recorded in Icelandic waters. *J. Acoust. Soc. Am.*, 111(2): 1122-1125.

Reaka-Kudla, M., Wilson, D.E., & Wilson, E.O., eds. (1997). *Biodiversity II, Understanding and Protecting Our Biological Resources*. Washington, D.C. Joseph Henry Press.

Reauthorization of the Marine Mammal Protection Act of 1972, and for other purposes. House Resource Committee, H.R.2693, July 10, 2003.

Rendell, L., & Gordon, J.C.D. (1999). Vocal response of long-finned pilot whales (*Globicephala melas*) to military sonar in the Ligurian Sea. *Marine Mammal Science,* 15:198-204.

Rendell, L.E., Matthews, J.N., Gill, A., Gordon, J.C.D., & Macdonald, D.W. (1999). Quantitative analysis of tonal calls from five odontocete species, examining interspecific and intraspecific variation. *J. Zool. Lond.,* 249, 403-410.

Rendell, L.E., Whitehead, H. (2003). Vocal clans in sperm whales (*Physeter macrocephalus*). *Proceedings of The Royal Society of London. Series B. Biological Sciences*, 270(1512):225-231.

Richardson, W.J., Wursig, B., & Greene, C.R., Jr. (1990). Reactions of bowhead whales, *Balaena mysticetus*, to drilling and dredging noise in the Canadian Beaufort Sea. *Marine Environmental Research,* 29(2):135-160.

Richardson, W.J., Greene, C.R., Malme, C.I., & Thomson, D.H. (1995). *Marine Mammals and Noise*. San Diego, CA. Academic Press.

Ridgway, S.H. (1979). Brain abscesses, flukes and strandings. In: Geraci, J.B., & St. Aubin, D.J. (eds.). *Biology of Marine Mammals: Insights Through Strandings*. p.83-

84 (Abstract only). Final report to U.S. Marine Mammal Commission in fulfillment of contract MM7AC020. NTIS PB-293 890. 1979.

Ridgway, S.H. (2000). The Auditory Central Nervous System of Dolphins. In: Au, W.W.L., Popper, A.N., & Fay, R.J., (eds) *Hearing by whales and dolphins*. New York, NY. Springer-Verlag,

Ridgway, S.H., & Johnston, D.G. (1966). Blood oxygen and ecology of porpoises of three genera. *Science* (Washington, D.C.) 151(3709):456-458.

Ross, D. (1993). On Ocean Underwater Ambient Noise. *Institute of Acoustics Bulletin*: 5-8.

Rundus, S.A., & Hart, L.A. (2002). Overview: Animal Acoustic Communication and the Rose of the Physical Environment. *Journal of Comparative Psychology,* Vol. 116(2).

Saprykin, V.A., Kovtunenko, S.V., Bekker, I.V., Dmitrieva, E.S., Korolev, V.I. (1975). Invariance of the perceptive properties of the dolphin auditory analyzer in differentiation of tone-pulse signals. (*Tursiops truncatus*). *Doklady Akademii Nauk SSSR Seriya Biologiya* 221(4):999-1000.

Sarewitz, D. (2004). How science makes environmental controversies worse. *Environmental Science & Policy* 7, 385-403.

SAS Institute Inc. *The Analyst Application, Second Edition.* Cary, NC 2003

Scheifele, P.M. J. (1997). Potential impacts of low-frequency anthropogenic noise on the hearing of subarctic beluga whales in the Saint Lawrence estuary. *J. Acoust. Soc. Am.,* 101, 3164.

Schevill, W.E. (1964). Underwater sounds of cetaceans. In: Tavolga, N. (ed) *Marine Bio-acoustics.* Oxford. Pergamon Press. p. 307-316.

Schevill, W.E., & Watkins, W.A. (1971). Pulsed sounds of the porpoise *Lagenorhynchus australis. Breviora* 366:1-10.

Schimpff, R.D., & N.R. Hall. (1979). Neuropathology in relation to strandings. Captive and single stranded cetaceans. In: Geraci, J.B., & St. Aubin, D.J. (eds.). *Biology of Marine Mammals: Insights Through Strandings*. p.234-235 (Abstract only). Final report to U.S. Marine Mammal Commission in fulfillment of contract MM7AC020. NTIS PB-293 890. 1979.

Schlundt, C.E., Finneran, J.J., Carder, D.A., & Ridgway, S.H. (2000). Temporary shift in masked hearing thresholds of bottlenose dolphins, *Torsions truncatus,* and white whales, *Delphinapterus leucas,* after exposure to intense tones. *J. Acoust. Soc. Am.,* 107, 3496.

Scholik, A.R., Yan, H.Y. (2001). Effects of underwater noise on auditory sensitivity of a cyprinid fish. *Hearing Research*, 152(1-2):17-24.

Simberloff, D.; Alexander, M. (1994) Issue paper on biological stressors. In: Ecological risk assessment issue papers. Washington, DC: Risk Assessment Forum, U.S. Environmental Protection Agency; pp. 6-1 to 6-59. USEPA/630/R-94/009.

Simmonds, M.P., & Lopez-Jurado, L.F., (1991). Whales and the military. *Nature,* 351; pg 448.

Skjaerseth, J.G., Stokke, O. S., Wettestad, J. (2006). Loft Law, Hard Law, and Effective Inplementation of International Environmental Norms. *Global Environmental Politics,* 6(3): 104-120.

Skodvin, T. and Andresen, S. (2006). Leadership Revisited. *Global Environmental Politics,* 6(3): 13-27.

Smith, E.P.; Shugart, H.H. (1994). Issue paper on uncertainty in ecological risk assessment. In: Ecological risk assessment issue papers. Washington, DC: Risk Assessment Forum, U.S. Environmental Protection Agency; pp. 8-1 to 8-53. USEPA/630/R-94/009.

Smith, M.E., Kane, A.S., & Popper, A.N. (2004). Noise-induced stress response and hearing loss in goldfish (*Carassius auratus*). *The Journal of Experimental Biology,* 207:427-435.

Smith, M.E., Kane, A.S., & Popper, A.N. (2004). Acoustical stress and hearing sensitivity in fisher: does the linear threshold shift hypothesis hold water? *The Journal of Experimental Biology,* 207:3591-3602.

Smithsonian Institution, (2005). Museum of Natural History, Washington, DC.

Society of Marine Mammalogy Conference (2003-2005).

Sokal, R.R., & Rohlf, F.J. (1996). *Introduction to Biostatistics, Second Edition*. New York. W.H. Freeman and Company,

Southall, B. (2004). “Noise Exposure Criteria” Advisory Committee on Acoustic Impacts on Marine Mammals, Plenary Meeting Two, April 28-30, 2004, Arlington, VA.

Southall, B.L., Braun, R., Gulland, F.M.D., Heard, A.D., Baird, R.W., Wilkin, S.M. and Rowles, T.K. 2006. Hawaiian melon-headed whale (*Peponocephala electra*) mass stranding event of July 3-4, 2004. NOAA Technical Memorandum NMFS-OPR-31, Office of Protected Resources, NOAA, Silver Spring, Maryland, http://www.nmfs.gov/pr/health/mmume/event2004jul.htm)

Stein, J.E., Tilsbury, K.L., Meador, J.P., Gorzelany, J., Worthy, G.A.J., & Krahn, M.M. (2003). Ecotoxicological investigations of bottlenose dolphin (*Tursiops truncatus*) strandings: Accumulation of persistent organic chemicals and metals. In: Vos, J.G., Bossart, G.D., Fournier, M., O'Shea, T.J. (eds.) *Toxicology of Marine Mammals*. p.458-488. New York. 643pgs. Taylor & Francis Publishing Group.

Strauss, M.B. (1969). Mammalian adaptations to diving. U.S. Naval Submarine Medical Center Report No. 562. 31pgs.

Swanson, Dean, (2006). E-mail Comm. NMFS Division Chief of International Fisheries. Email comm.

Swartz, S.L., & Hofman, R.J. (1991). Marine Mammal and Habitat Monitoring: Requirements, Principles, Needs, and Approaches. Marine Mammal Commission. NTIS PB91-215046.

Thewissen, J.G.M. (1998). *The Emergence of Whales*. New York: Plenum Press.

Thewissen, J.G.M., Williams, E.M., Roe, L.J., & Hussain, S.T. (2001). Skeletons of terrestrial cetaceans and the relationship of whales to artiodactyls. *Nature*, 413:277-281.

Thomas, J.A., Kastelein, R.A., & Awbrey, F.T. (1990). Behavior and blood catecholamines of captive belugas during playbacks of noise from an oil drilling platform. *Zoo Biology*, 9(5):393-402.

Thomsen, F., Franck, D., & Ford, J.K.B. (2002). On the communicative significance of whistles in wild killer whales (*Orcinus orca*). *Die Naturwissenschaften*, 89(9):404-407.

Tyack, P. (1983). Differential response of humpback whales (*Megaptera novaeangliae*) to playback of song or social sounds. *Behavioral Ecology and Sociobiology* 13:49-55.

United Nations Convention on the Law of the Seas. Third UN Conference on the Law of the Sea, Report of the Secretary-General, GAOR A/38/570 (18 Nov. 1983).

Underdal, A. (2000). Science and politics: the anatomy of an uneasy partnership. *In* Andresen et al., *Science and Politics in International Environmental Regimes, Between Integrity and Involvement*. Manchester University Press.

Underdal, A. and Young, O.R. (eds). *Regime Consequences, Methodological Challenges and Research Strategies*. Kluwer Academic Publishers, 2004, Netherlands.

Underdal, A. (ed.), *The Politics of International Environmental Management*, 1-11. Kluwer Academic Publishers, 1998, Netherlands.

Urick, R.J. (1983). *Principles of Underwater Sound*, 3rd ed. New York, McGraw-Hill.

USC, 2005. Digital library, ftp://nhmftp.nhm.org/

U.S. Commission on Ocean Policy, September 20, 2004. An Ocean Blueprint for the 21st Century: Final Report of the U.S. Commission on Ocean Policy, Chapter 3, Setting the Nation's Sights, from http://oceancommission.gov/documents/full_color_rpt/000_ocean_full_report.pdf.

U.S. Environmental Protection Agency. (1992a). Framework for ecological risk assessment. Washington, DC: Risk Assessment Forum, U.S. Environmental Protection Agency. 10 USEPA/630/R-92/001.

U.S. Environmental Protection Agency. (1998). Guidelines for ecological risk assessment. (Risk Assessment Forum), 63 Fed. Reg. 26846-26924.

U.S. Environmental Protection Agency, Total Maximum Daily Load. (2005) from http://www.USEPA.gov/owow/tmdl/intro.html

Van Bree, P.J.H., & Kristensen, I. (1974). On the intriguing stranding of four Cuvier beaded whales, *Ziphius cavirostris* G. Curier, 1823, on the Lesser Antillean Island of Bonaire. *Bijdragen tot de Dierkund*, 44(2):253-238.

Vanselow, K.H., & Ricklefs, K. (2005). Are solar activity and sperm whale *Physeter macrocephalus* strandings around the North Sea related? *Journal of Sea Research,* 53(4): 319-327.

Vedder, T. "This Is Another Smoking Gun," KOMO TV, 8 August 2003, http://www.komotv.com/news/printstory.asp?id=26542 (accessed 11 July, 2005).

Victor, D. G. (2006). Toward Effective International Cooperation on Climate Change: Numbers, Interests and Institutions. *Global Environmental Politics,* 6(3): 90-103.

Vidal, O. *et al.* (1999). Vaquita. In Ridgeway, S.H., & Harrison, R. (eds) *Handbook of Marine Mammals, Volume 6: The Second Book of Dolphins and Porpoises*. San Diego. Academic Press.

Wallace, R. L. (2003). Social Influences on Conservation: Lessons from U.S. Recovery Programs for Marine Mammals. *Conservation Biology* 17(1):104-115.

Wartzok, D., & Ketten, D.R. (1999). Marine Mammal Sensory Systems. Pp. 117-175 In *Biology of Marine Mammals,* Renolds III, J.E., & Rommel, S. eds. Washington, D.C., Smithsonian Institution Press.

Washington Post, 16 July 2002, http://www.commondreams. org/headlines02/0716-06.htm (accessed 12 July 2005).

Watkins, W.A. (1986). Whale reactions to human activities in Cape Cod [Massachusetts, USA] waters. *Marine Mammal Science* 2(4):251-262.

Watkins, W. A., Moore, K. E. & Tyack, P. (1985). Sperm whale acoustic behavior in the southeast Caribbean. *Cetology* 49: 1-15.

Watkins, W.A., Schevill, W.E. (1975). Sperm whales (*Physeter catodon*) react to pingers. *Deep Sea Research* 22(3):123-129 +1pl.

Watkins, W. A., Tyack, P., Moore, K. E., & Bird, J. E. (1987). The 20-Hz signals of finback whales (*Balaenoptera physalus*). *J. Acoust. Soc. Am.,* 82: 1901-1912.

Webster's Ninth New Collegiate Dictionary. (1983). Springfield, Massachusetts, U.S.A. Merriam-Webster Inc., Publishers.

Weiss, K.R. "Sonar Approved Despite Possible Risks to Whales," *Honolulu Advertiser,* 16 July 2002.

Wenz, G.M. (1962). Acoustic Ambient Noise in the Ocean: Spectra and Sources. *J. Acoust. Soc. Am.,* 34.

Wilson, D., Ruff, S. (1999). *The Smithsonian Book of North American Mammals*. Washington: Smithsonian Institution Press.

Wood, F.G. (1973). *Marine mammals and man. The Navy's porpoises and sea lion.* Washington-New York. Robert B. Luce, Inc. 264p.

Wright, A. (2005). Lunar cycles and sperm whales (*Physeter macrocephalus*) strandings on the North Atlantic coastlines of the British Isles and eastern Canada. *Marine Mammal Science,* 21(1):145-149

Wursig, B., Greene, C.R. (2002). Underwater sounds near a fuel receiving facility in western Hong Kong: relevance to dolphins. *Marine Environmental Research,* 54(2):129-145.

Young, O.R., and Zurn, M. (2006). The International Regimes Database: Designing and Using a Sophisticated Tool for Institutional Analysis. *Global Environmental Politics*, 6(3): 121-143.

Zacharias, M.A. & Gregr, E.J. (2005). Sensitivity and Vulnerability in Marine Environments: an Approach to Identifying Vulnerable Marine Areas. *Conservation Biology*, 19(1):86-97.