The Masking of Cetacean Calls by Anthropogenic Noise

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Experiments with captive, trained beluga whales are presented during which the animals` detection thresholds of conspecific calls masked by anthropogenic noise were measured. Criteria for signal detection and signal recognition were deduced. Findings were incorporated in a software model that propagates anthropogenic noise through a location-specific ocean environment and predicts zones of bioacoustic impact o selected target species. Examples for icebreaker noise masking beluga and killer whale calls, whale-watching boats masking killer whale calls, and underwater acoustic research signals masking killer whale calls will be presented. The role of ambient noise in the masking by anthropogenic noise will be addressed. Data needs for a better understanding and modeling of masking in various species will be discussed. Last but not least, ``What is the biological significance of masking?`` will be asked.

Satellite-Monitored Radio-Tracking of Large Cetaceans

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Whales migrate between summer feeding areas and winter reproductive areas, but the location of many of those areas, the migratory routes between them, and their overlap with human activities has long remained unknown. ONR support has made it possible for the Oregon State University Marine Mammal Program to tag and track a variety of large, mostly endangered cetaceans, including: blue, fin, gray, humpback, right and sperm whales in the northern hemisphere, and humpback and right whales in the southern hemisphere. With just over 200 whales tagged, discoveries have included not only previously unknown range identification and habitat description, but also aspects of individual foraging strategies and social unit cohesion. These reveal strong correlations with oceanographic features as well as elements of how whales search for and find prey in varied environments. Tag technology has improved dramatically, with operational records of 10.5 months on blue whales, 8 months on humpbacks and 7+ months (ongoing) for sperm whales. The tags incorporate a long-dispersant (5–8 months) antibiotic and have remained attached to right whales for over two years, with no discernable changes in sightability, mortality or fecundity.

Revealing Pelagic Habitat Use: The Tagging of Pacific Pelagics Program

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Tagging of Pacific Pelagics (TOPP) is a pilot program of the Census of Marine Life that will lead to understanding of pelagic habitat use by marine vertebrates and large squid in the North Pacific. Taking a multi-species approach, the TOPP project will use a range of electronic tag technologies to put the distribution and behavior of pelagic organisms in the context of the oceanography of the North Pacific. Tag-bearing animals will be used as autonomous ocean profilers to enhance sparse oceanographic observations for vast ocean regions. These autonomous ocean samplers will provide unprecedented coverage of the water column structure of the North Pacific. The temporal and spatial data generated by this project will provide an “organism-eye” view of several interactive oceanic regimes in the North Pacific. Twenty target species, including tunas, sharks, pinnipeds, cetaceans, seabirds, and marine turtles will be

monitored with electronic tags. Animal-collected oceanic data will be assimilated into global ocean databases, complement traditional methodologies and is being used to help validate nearshore, regional, and basin scale ocean models. This multidisciplinary approach will allow a novel merger of biological and physical data to provide a new understanding of the relationship between the movements and behaviors of marine organisms and oceanographic processes in the eastern north Pacific.

DTAG: A Synchronous Sound and Orientation Recording Tag for Wild Marine Mammals

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The DTAG is a miniature archival tag designed for controlled exposure experiments (CEEs) on wild marine mammals. By recording sound and orientation synchronously, the tag can measure the received level of an exposure and verify the causality of any behavioral change of the tagged animal. The sampling rate and resolution of the orientation sensor are sufficient to track individual fluke strokes. The audio sampling rate is programmable and the tag memory of 2GBytes gives a continuous recording capacity of 400kHz-hours (e.g., 12.5 hours at 32 kHz sampling). The DTAG has been used since 1999 on 20+ experiments and 11 species including baleen whales, deep diving odontocetes, and manatees. Attachments of up to 20 hours have been obtained using suction cups. A new version of the tag, to be deployed in summer 2003, will add stereo hydrophones, loss-less audio compression, and EKG, and will be 60% of the current size. An integrated field protocol has been developed to combine DTAG data with ship-board visual and acoustic observations. This results in a 3-dimensional track of the whale from which heading changes towards, or away from, a sound source can be deduced. DTAG data has already provided new insights into the acoustic ecology of sperm whales and the responses to sound of right whales. Recently the field protocol has been extended to support simultaneous tagging of multiple animals. This technique opens the possibility of detecting changes in social interaction during a CEE.

Responses of DTAGes Sperm Whales to CEE

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In collaboration with Saclantcen and the Minerals Management Service, we have been using the Dtag to study responses of sperm whales to sounds of airgun arrays and a whale finding sonar. I present the design of our CEEs, where individual whales are tagged, we collect pre-exposure dives, exposure, and post exposure from the same individuals. We focus on responses where the biological significance of disturbance can be assessed: avoidance, changes in foraging, potential disruption of communication. Few such responses have been observed in initial experiments exposing animals to received levels on the order of 140dB.

A Miniature Acoustic Recording Tag and First Application to Northeast Pacific Blue Whales

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Perhaps the most promising technique to assess individual marine animals` response to sound is to place a sound-and-behavior recorder, or ``bioacoustic tag,`` directly on a free-ranging subject. However, in the eight years since the first bioacoustic tags were deployed, only a handful of investigators have attempted this approach. To enable wider use of bioacoustic-tag technology, a new instrument, the ``Bioacoustic Probe,`` has been developed. Design focused on ease of use, low power consumption, reliability, and miniaturization. Prototypes fulfilled these goals with a new computer and operating-system design, a new hydrophone-preamplifier design, polyurethane encapsulation, and infrared commanding via a Palm`s graphical-user interface. The prototypes weighed 340 g and measured 22 cm long by 3.8 cm in diameter without flotation, and measured sound, pressure, and temperature; revised units due in May 2003 are expected to occupy 25% less volume and to be capable of measuring 2D acceleration as well. In 2002 a simple passive attachment system for the tag was developed and applied with blue whales off the California coast, providing attachment times of a few hours and in one case over 25 hours. Recordings made during these tests included airgun pulses, vessel noise, and vocalizations. Further field applications are planned in 2003.

Feeding and Vocal Behavior of Blue Whales Determined Through Suction-Cup Attached Tags

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We deployed three instrument packages on blue whales off California and Mexico to examine their underwater behavior including vocalizations. Deployments primarily consisted of Crittercam (developed by National Geographic) and a dedicated acoustic tag (developed by Bill Burgess). We also collaborated with WHOI to deploy their dTag on blue and humpback whales. Deployments were conducted off California and in the Sea of Cortez. We deployed tags 43 times, 19 staying on for 0.25 to >15 h. We developed more effective approaches with an increased success rate including attachment of multiple instruments to the same animal. Insights into feeding behavior included: 1) blue whales feeding by conducting multiple upward lunges into prey fields, sometimes inverting, 2) blue whales diving deeper (300 m) than had previously been reported, 3) clear regional and diel patterns in diving behavior, 4) no apparent close spacing or coordination between pairs of whales. Deployments also provided insight into acoustical behavior. Most tagged whales were engaged in feeding and were not vocalizing,

nevertheless blue whales were recorded vocalizing with all three tag types. Along with gender and sightings histories, these provide new insights into the frequency and behavioral context of calling. Tags were also successfully deployed in the vicinity of a USGS airgun survey.

Use of Onboard Acoustic Dataloggers to Study Responses of Pinnipeds to Vessel Noise: Field Trials with Northern Fur Seals

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We field tested bioacoustic probes (BPs) on northern fur seals (*Callorhinus Ursinus*) in order to assess the usefulness of these instruments in addressing the potential for impact of interactions between free ranging otariid pinnipeds and fishing vessels. Our primary goals were to (1) deploy and retrieve the dataloggers with useful acoustic data, (2) correlate the acoustic data with seal behavior, and (3) assess whether these behaviors can be related to anthropogenic noise sources. During 2002, four BPs were deployed, all were recovered, and three recorded to capacity over multiple days, thus fulfilling goal 1. With respect to goal 2, we found the acoustic data to be exceptionally rich and able to provide a good index of the seal's behavior. Our results are less conclusive with respect to goal 3, relating the acoustic and movement data to anthropogenic noise disturbances. First, the number of interpretable ship encounters was low. Second, we found it possible to calculate change in movement direction from the relatively low resolution ARGOS data, but its reliability over short time periods is variable. Overall, mean bearing of movement combined with course deviation, distance covered in a specific direction and behavioral state assays, should be sufficient to test for ship encounter effects.

Advances in Density and Abundance Estimation for Cetaceans Using Geospatial Modeling and Passive Acoustics

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During 2001-2002, the U.S. Navy funded a number of projects at the Southwest Fisheries Science Center (SWFSC) to improve the estimation of marine mammal densities and thereby improve their environmental assessments. To identify and quantify spatial patterns in cetacean density in the eastern Pacific Ocean, we have built generalized additive models (GAMs) of encounter rate (number of sightings per km) and average school size based on 1986-96 survey data. The models were constructed using stepwise selection of predictor variables, including time-invariant geographic variables (latitude, longitude, offshore distance, ocean depth, slope of the ocean floor) and temporally dynamic oceanographic and biological variables (sea surface temperature, gradient in sea surface temperature, sea surface salinity, thermocline depth, thermocline strength, depth of the euphotic zone, and amount of primary production). We built separate models to describe the northern and southern regions of our study area for each of the following eleven species or species groups: blue whale

(Balaenoptera musculus), fin whale (B. physalus), sei and Bryde's whales (B. borealis and B. edeni, respectively), minke whale (B. acutorostrata), humpback whale (Megaptera novaeangliae), sperm whale (Physeter macrocephalus), dwarf and pygmy sperm whales (Kogia sima and K. breviceps, respectively), Baird's beaked whale (Berardius bairdii), Cuvier's beaked whale (Ziphius cavirostris), beaked whales of the genus Mesoplodon, and delphinids. The SWFSC conducted two additional cetacean surveys (along the U.S. west coast in 2001 and around Hawaii in 2002) for which the Navy funded the collection of oceanographic and other habitat variables (including acoustic backscatter) to facilitate future modeling of cetacean densities from these surveys. The Navy also has funded our development of a towed acoustic array and survey methods that were successful at detecting and localizing whistling dolphins at a range of up to approximately 10 km. During our survey of the Hawaiian Islands in 2002, several significant discoveries were made using acoustic methods, including the association of the ``boing`` sound with minke whales and the first known recordings of sei whale sounds in the North Pacific. The latter two discoveries will help define the previously unknown winter range of these two species.

Distributions and Densities of Marine Mammals and Their Role in Modeling Acoustic Effects

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Describing, modeling, and predicting acoustic effects on marine mammals depend on accurate inputs of various kinds. One required input is the distribution and density of marine mammals for a given area and time period. The quality of input is especially critical for endangered species and critical habitats. At times, acousticians may be requested to proceed with modeling in the absence of credible marine mammal data. This may produce unsatisfactory results for use in meeting environmental compliance and regulatory requirements. For any given period and area, it is unlikely that we will ever know the true population or density. Therefore, we are left to estimate it. Examples are provided of recent efforts to calculate marine mammal densities in proposed Navy East coast shallow water training ranges and opareas. How many marine mammals of each species occupy a several thousand square-nautical-mile area by season and depth strata? The effects of survey planning, sample size, data collection protocols and analyses on the resulting estimates are shown. Also shown are the effects of biological and sampling variability on current estimation methods that use line-transect methodologies. Options for sampling, including multi-platform and multi-sensor approaches, are provided. The inescapable conclusion is that increased interaction, collarboration, and understanding of methods and requirements between acousticians and survey biologists are not only desirable, but essential.

The Role of a Full Mission Ships Bridge Simulator Training to Measure Observer Performance

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The UK government has expressed a commitment to providing effective mitigation of disturbance for all cetaceans as protected species under National and International law. Methods of minimising disturbance from sources such as seismic or military activity rely on the acoustic and visual detection of marine mammals within an appropriate sensitivity zone. Although visual surveys by marine mammal observers are the main recommendation of the designated government agency, the Joint Nature Conservation Committee, to date there has been no validation of this approach or the factors, which affect observer efficiency. The aim of this feasibility study was to quantitatively investigate the role of training and experience on visual observer efficacy using a full Ship's Bridge Simulator to recreate accurate field conditions

aboard a research vessel. The innovative use of the simulator overcame the difficulties of testing efficacy in the field by providing targets of known timing, type, range, bearing and size, and allowing the manipulation of experimental variables.

The sample population (n = 13), selected on the criteria of marine mammal survey training and experience, had no other significant differences between the two groups in terms of gender, mean age , eyesight criteria, seasickness and simulator experience. The preliminary findings indicated that experienced observers detected more than twice the number of marine mammal targets than inexperienced observers and were significantly more accurate in terms of timing, position and description of target. Inexperienced observers detected eight times more incorrect targets than experienced observers. Overall, experienced observers were five times as efficient as inexperienced observers. These findings confirm that the simulator is an effective tool for assessment and indicate the important role that training and experience has on observer efficiency.

OBIS-SEAMAP: Mapping the Global Distribution of Marine Mammals

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A thorough understanding of the distribution of marine mammals is necessary for the mitigation of potentially harmful anthropogenic activities, such as the production of underwater sound. At the present time, however, data sets on marine mammal distribution are scattered across institutions in many countries, hindering attempts to access and synthesize this information. As part of the Ocean Biogeographic Information System (OBIS), we are compiling a global, geo-referenced database of the distribution of marine mammals, sea birds and sea turtles into a coherent and standardized format. These data sets include dedicated at-sea surveys, movements derived from telemetry and photo-identification, strandings, and counts at haul-out sites. To facilitate research applications of this global database, we are simultaneously developing a web-based system with data analysis and visualization tools. This publicly-available database will allow resource managers to display, query, subsample, and summarize information on marine mammal distributions in conjunction with environmental data. This dynamic global database will enhance our understanding of the biogeography and ecology of marine vertebrates. In particular, SEAMAP will support modeling efforts designed to mitigate anthropogenic impacts by predicting marine mammal distributions in time and space.

Correlation of AVHRR Sea Surface Temperature with the Presence of Loggerhead Sea Turtles

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The Mid-Atlantic serves as a host environment for a number of sea turtle species that encompasses their seasonal migration routes. Global evidence suggests that migration routes are strongly influenced by two factors: sea surface temperature and chlorophyll-concentrations. Data gathered from the Pacific Ocean presents compelling evidence of this relationship. In contrast, findings from studies conducted in the Atlantic have not yet confirmed the role of these factors.

Therefore this study established the correlation between sea turtle locations in the Mid-Atlantic Ocean in relation to sea surface temperature. Satellite sensor data including the NOAA AVHRR instrument were utilized for this study.

Cuvier`s Beaked Whale *(Ziphius cavirostris)* Habitat Use and Distribution in the Genoa Canyon, Mediterranean Sea

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Cuvier's beaked whales are a cosmopolitan species, yet very little is known about their ecology and distribution. The Genoa Canyon in the northwestern Ligurian Sea, is a known habitat of Cuvier's Beaked Whales. The NATO SACLANTCEN Sound, Ocean and Living MArine Resources (SOLMAR) project has successfully conducted five sea trials in the spring/summer time frame from 1999 to 2002 in the Ligurian Sea. During these cruises, visual sightings were made of this species along with concurrent temperature, chlorophyll-a, oxygen and turbidity measurements in the canyon region. The oceanographic conditions found in this canyon have been compared over this 4 year period to identify the driving forces affecting Cuvier's beaked whale habitat use as function of bathymetry and oceanographic features. For the data collected in 2002, multivariate statistic techniques (Multidimensional scaling techniques, Principal Component and Logistic Regression Analysis) have been applied to the data set in order to identify the driving forces affecting habitat use. This research is closely co-ordinated with ongoing research being performed by NUWC, U. of Aberdeen and SSC-SD for the development of a global map identifying known beaked whale distribution. The ultimate goal of this collective research is the development of predictive models to determine species presence.

Defining the Habitat of Beaked Whales in the Gulf of Mexico

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Beaked whales are found in all the world's oceanic waters from the equator to the edge of the ice. As compared to the other species of cetaceans, sighting data is relatively sparse, as beaked whales generally live off-shore and have long dive/short surfacing times making visual observations difficult. Beaked whale sighting and abundance will be used in combination with oceanographic feature information, such as bathymetry, slope, sea surface temperature, sea surface temperature fronts, and chlorophyll-a, to characterize statistically significant features of known beaked whale habitat and predict suitable habitat where survey data is not available. Data used in this analysis will be based on a geo-referenced database of global beaked whale records (both sightings and strandings), which is currently under development. This analysis will

be output to a statistical software package for the development of algorithms. The statistical algorithms will be used to predict areas of beaked whale occurrence, based on environmental parameters. Three initial regions have been chosen for habitat characterization: Gulf of Mexico, northeastern coast of the United States, and Mediterranean Sea. Preliminary findings from the Gulf of Mexico will be presented.

Insights Into the Determination of Beaked Whale Hot Spots Through the Development of a Global Database

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The first step in assessing or mitigating anthropogenic effects on a taxonomic group is to combine the best available information for the group with information about the potential impacts of the proposed activity. For beaked whales (family Ziphiidae; order Cetacea), this process is currently limited to identifying 'hotspots' where beaked whales may be particularly sensitive to disturbance from human activities. This determination involves two aspects: first, the construction of a series of criteria for defining an area as a 'hotspot' and secondly, the application of these criteria to currently available information to identify known beaked whale 'hotspots'. Six criteria were developed based on occurrence of individual species (including frequency of sightings, residency and migrational movements), the total range of a species or isolated population, the level of species diversity and areas where mass stranding events have occurred in the past. By applying these criteria to currently available information, an initial group of 'hotspots' are identified. This information can provide insight to planners to address concerns about the potential impacts of human activities on this species. As the global knowledge of beaked whales improves, additional 'hotspots' may be identified.

A Demonstration of the Use of GIS as an Aid in Mitigating Impacts When Planning Military Exercises

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Data were collected on the distributions of marine mammals, marine mammal watching areas, locations of seabird colonies and concentrations areas, locations used by rare threatened and endangered species, nature reserves, parks, fishing areas, sites used for aquaculture, ferry and shipping routes on the Atlantic Coast of Canada. These were entered into ARCINFO GIS and a program was written in MapObjects. Matrices included in the program guided the user to potential interactions between the planned navy activity and sensitive environmental aspects of the selected area at the planned time of the activity and the appropriate maps were displayed. A User's Guide with mitigation measures was included in the Help file. Mitigation measures in the help file were cross-referenced to very abbreviated reference to mitigation measures included in the GIS program. The project was included in an Environmental Assessment done for Maritime Forces Atlantic (Canada) as part of the recommended mitigation measures.

Comments on Ocean Noise "Budgets"

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One way to think about the relative contributions of various sources to the ocean noise field is in terms of a noise "budget". However, the issue that immediately arises is what to use as the "currency", i.e., the metric for measuring the contribution of a given source. In this presentation, the analytical basis for one approach to creating an ocean noise budget is developed. The development is based on the conservation of acoustic energy. The currency initially considered is the time-averaged pressure spectrum integrated over space, which is proportional to the total mechanical energy in the acoustic field. Integration over space permits the results to be independent of source/receiver range. Examples of noise budgets based on this currency for given sets of input parameters are presented. Extensions of the development to other currencies are discussed. A family of noise budgets based on various currencies probably is required for complete evaluation of the potential impact of manmade noise on the marine environment.

The Modeling and Simulation of Underwater Acoustic Energy Exposure Due to Surface Exercises

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Large amounts of acoustic energy may be released into the water column during live fire training exercises. This acoustic energy has the potential to harass or injure marine mammals. Accurately assessing the impact acoustic energy from multiple explosives may have on marine mammals requires modifications to existing acoustic models, as well as the development of exercise and marine mammal simulations. The exercise simulation takes known weapons characteristics (explosive warhead weight, hit/miss ratio, firing time lines, etc.) and predicts the acoustic energy that occurs within an exercise timeline. The biological is simulated by randomly placing a calculated density within the exercise area. As the exercise progresses using the exercise simulation, the animals swim throughout area. As each marine mammal moves through the exercise environment, it is exposed to varing intensities of acoustic energy. This acoustic energy is accumulated over the course of the exercise. Accumulating the energy over the duration of the exercise addresses the impact that exposure to multiple explosions over a period of time will have on marine mammals. This approach allows the Navy to realistically predict the impact a live fire training activity will have on the marine mammal population.

Acoustic Integration Model (AIM): Program Status Update

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The Acoustic Integration Model (AIM) was first designed as a tool to realistically model the ocean, acoustic propagation, and animal movement. Taken together, these provide the ability to predict the acoustic exposure of animals in any given scenario. As part of the ESME project, AIM has continued to be developed and updated. Recent upgrades include the ability to rerun projects with the same animals movements as in prior runs. This allows direct comparison of multiple runs, which is also useful for calculating the exposure from broadband sources. The model can now automatically extract environmental variables, such as bathymetry, sound velocity profile, and surface loss parameters once a location is specified. Furthermore, these can be augmented with user-supplied data. A default bottom loss curve has been implemented, and can be customized to each location by the user. The ability to read DBDB-V, and more detailed databases in the same format was recently implemented. Most significantly, the infrastructure of AIM has been modified to allow multiple sound sources to be operated simultaneously. Simulation of multiple ship exercises are now possible, as well as the design of projects to simulate the effects of masking noise.

Formal Risk Assessments: Sensitivities to Impact Criteria and Thresholds

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This paper offers some 'operations analysis' views on the risk assessment process. The motivation is simple: we want to know how changes in impact thresholds and metrics might change 'take counts.' It is usually worth doing at least a rough analysis on a case basis so that proper attention can be paid to the more sensitive relationships.

Some of the more well-known cases are discussed. These include: tactical sonars, explosives, seismic surveys, SURTASS-LFA, and NPAL. In the compliance documentation, each one of these has its own distinct set of criteria and thresholds, so that the sensitivities are different from one to another. In some cases, even the definition of the impact threshold can be very complicated, and the sensitivities not obvious.

As one example of our view, consider 'take' estimates for sonars when we compare an energy threshold against an intensity threshold. For some scenarios, the former yields the most takes, while for others, it's the latter. Besides an explanation of the result, we propose conditions under which simple sound field metrics can make sense.

Several research topics are offered, and potential transitions mentioned.