FINAL REPORT

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GRANT TITLE: Assessment tool development for marine mammal critical habitats

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OBJECTIVE: The objective is to develop a mapping system to visualize the distribution and movement of marine mammals by time of year and location so that animal movement and distribution can be easily compared to bathymetry and a variety of oceanographic features. The mapping system will be integrated with the Global Information System for the Distribution of Marine Mammals that is being developed by the National Marine Mammal Laboratory (NMML). The mapping system will provide the Navy with the capability to rapidly assess potential impacts on marine wildlife, and allow it to plan operational activities accordingly. Naval operations can take place at times and locations that would otherwise be prohibited because of ambiguous, protected-species use definitions. Our ultimate goal is to develop statistical methods that are appropriate for analysis of habitat use and to develop models that predict marine mammal presence.

Our primary objective is to develop a mapping toolkit. Modules built into this toolkit will be based on the following objectives:
1. Develop software for rapid visualization of animal tracking data on a variety of projections, spatial scales and backgrounds, including bathymetric data sets.
2. Develop techniques for processing data from animal-borne instruments and to construct profiles of local ocean conditions and marine mammal behavior.
3. Develop techniques to acquire remotely sensed satellite data, such as PODAAC (NASA's JPL Physical Oceanography Data Archiving and Access Center), and to time slice it for comparison to animal position or movement data.
4. Develop techniques to join the data listed above along common points in time, or common locations at differing times.
5. Develop a toolkit module to analyze animal position relative to sea surface temperature (SST) and SST discontinuities.
6. Develop a frontal analysis toolkit module that plots animal position data relative to the Navy's "Fronts and Eddies" Report, and marks acute angles in the fronts. As these data are no longer available to the public, this module would be currently for Navy use only.
7. Develop a residence time grid analysis toolkit module. This module adds a representation of time to plotted animal tracks. A grid is superimposed on the study area and the amount of time an animal spent in each grid cell is represented by shading. This analysis is useful for the study of habitat selection during foraging, in

that it provides an easy visual way to distinguish areas of slow transit, which may be preferred areas.

8. Explore the use of these techniques in marine mammal data archives that are being developed by SPAWAR Systems Center and NMFS.
9. Develop statistical methods that appropriate for analysis habitat use and models that predict marine mammal presence.

APPROACH: The approach will be to build tools to assess marine mammal distribution and critical habitats. The tools will be tested by analyzing data from other projects that support improved satellite data and animal-borne instruments. The tools can be used to quantitatively assess marine mammal behavior and distribution to reduce conflicts with naval operations. The techniques to fuse and analyze the data must be developed. Development will proceed in six main areas:

1. Techniques to rapidly visualize animal distribution and behavior will be refined.
2. Time-slicing techniques will be extended to other remotely sensed oceanographic data and other data from Earth Observing Systems (EOS) as they become available.
3. New generation animal-borne recorders that are being developed will provide better quality data on local ocean environment and diving behavior of marine mammals. Data from northern elephant seals will be used to develop techniques to process these measurements. The techniques can be used to link the increasing body of data on marine mammal behavior with distribution data and ocean features.
4. Joining techniques will be extended to quantify relationships between new and existing data on animal behavior, animal distribution, and oceanographic features
5. Statistical methods appropriate for observations where many of the usual statistical assumptions are violated will be developed to test hypotheses about the relationships between animal behavior, animal distribution, and oceanographic data and to quantitatively assess critical habitats.
6. The use of these techniques in national and global marine data archives being developed by SPAWAR Systems Center, San Diego, and NMFS/NMML will be investigated.

ACCOMPLISHMENTS: The current version of the mapping system allows rapid visualization of animal positional and movement data over bathymetric and oceanographic data sets. We have completed the beta testing of the first toolkit and all developed modules. This software program allows rapid visualization of animal tracking and distribution data on a variety of projections, spatial scales and backgrounds. This software is designed to work on any PC under a variety of OS and to facilitate production of high quality graphics previously requiring use of high-powered work stations. The Bigseal Kit was revised to work with Windows NT because at present that platform is widely used by the Navy. The Installation Procedure was greatly simplified and now allows incremental upgrading of the Bigseal Kit. An online installer was created to simplify distribution and installation of new modules.
http://bigseal.ucsc.edu/kit/setup.exe.

Techniques for processing data from animal-borne instruments and remote -sensing platforms to construct profiles of local ocean conditions and marine mammal behavior were developed. We have developed software to use animal-acquired data to describe sub-surface oceanographic structure and identify frontal systems. This is a key step towards the project goal of developing predictive tools for the relationship of marine mammal distributions to available real-time oceanographic data and allowed incorporation of animal acquired temperature data into the NODC database. The current toolkit version accesses oceanographic data sets for comparison to marine mammal distribution and movement data using three base modules.

1. The SST (Sea Surface Temperature) Module was beta-tested, modified and fully integrated into the toolkit. The module was used to develop the system for output of statistical data from maps for use in habitat analysis and modeling and allows visual and quantitative comparisons of marine mammal presence and movements to sea surface temperature and thermal discontinuities. This module can be modified to utilize additional remote sensing data streams.
2. The Frontal Analysis module renders a map animal position relative to a visualization of the Navy's "Fronts and Eddies" Report, and marks acute angles in the fronts. As of the date of this report, May 2002, the "Fronts and Eddies" report is no longer available to the public online. This module is retained as an appendix to the Bigseal Kit in case these reports become available again, or for the internal use of the Navy.
3. The Residence Time Grid Analysis Module adds a representation of time to plotted animal tracks. A grid is superimposed on the study area and the amount of time an animal spent in each grid cell is represented by shading. This analysis is useful for the study of habitat selection during animal movement in that it provides an easy visual way to distinguish areas of slow transit, which may be preferred areas. The SST Module and the Residence Time Grid Analysis Module can both output tables suitable for use in statistical analysis.

The mapping system will ultimately be integrated with the LMRIS system being developed by ONR and the Global Information System for the distribution of marine mammals that is being developed by the National Marine Mammal Laboratory. We have distributed the toolkit to numerous potential users working on Navy sponsored marine mammal research and are beginning the process of interfacing with LMRIS.

CONCLUSIONS: Numerous techniques for processing data from animal-borne instruments and remote-sensing platforms to construct profiles of local ocean conditions and marine mammal behavior were developed. These techniques were integrated into a user-friendly toolkit. These techniques were utilized in a number of submitted journal articles and conference presentations and allowed integration of animal-acquired oceanographic data into the NODC oceanographic database. These features represent important strides forward in defining features of ocean habitat critical to marine mammals and increasing the Navy's ability to predict the presence of marine mammals.

SIGNIFICANCE: These accomplishments were important steps in the development of a quantitative system for assessing marine mammal critical habitats. Tools to quantitatively

assess marine mammal critical habitats and to integrate data on marine mammal distribution, abundance, and behavior with available bathymetric data and oceanographic data will increase the Navy's ability to rapidly assess operational effects on protected species and to predict the presence of marine mammals in the marine environment.

This task supports the Navy Environmental Quality Research, Development, Test, and Evaluation Strategic Plan (CNO, N045) under requirement 2.II.1.h, "Assess Effect of Acoustic Emissions on Marine Mammals and Endangered Species." It also supports the Science and Technology Requirements Guidance (CNO, N091) under requirement 13.1.a, "Determine the effects of acoustic and other emissions on marine mammals and threatened and endangered species." This task will provide techniques that could be useful to and integrated with the marine mammal national and global distribution archives that are being developed by SPAWAR and NMFS/NMML. These techniques will also be useful in integrating and analyzing acoustic and behavioral data from the acoustic recording tag that is being developed in other Navy sponsored studies.

PUBLICATIONS

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4. Le Boeuf, B.J., D.E. Crocker, J. Grayson, J. Gedamke, S.B. Blackwell, P.M. Webb, and D.P. Costa. 2000. Surface breathing rate and heart rate in free-ranging elephant seals. Journal of Experimental Biology.203: 3265-3274.

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