REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302, and to the Office of Management and Budget, Paperwork Reduction Project (0704-0188), Washington, DC 20503.
PLEASE DO NOT RETURN YOUR FORM TO THE ABOVE ADDRESS.

1. REPORT DATE *(DD-MM-YYYY)*	2. REPORT TYPE	3. DATES COVERED
20-05-2004	Final Report	1 Dec. 2001 - 31 Dec. 2002

4. TITLE AND SUBTITLE

Analysis of Sperm whale Acoustic Signals in the Gulf of Mexico and the Mediterranean

5a. CONTRACT NUMBER

5b. GRANT NUMBER

N00014-02-1-0448

5c. PROGRAM ELEMENT NUMBER

6. AUTHOR(S)

Aaron Thode

5d. PROJECT NUMBER

5e. TASK NUMBER

5f. WORK UNIT NUMBER

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)

MPL/ SIO/ UCSD
9500 Gilman Dr
La Jolla CA 92093-0238

8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)

Office of Naval Research
800 N. Quincy St.
Arlington VA 22217-5000

10. SPONSOR/MONITOR'S ACRONYM(S)

11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT

Distribution Unlimited

13. SUPPLEMENTARY NOTES

14. ABSTRACT

Self-explanatory

20040526 051

15. SUBJECT TERMS

sperm whale, ocean acoustics, marine mammal mitigation

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT	b. ABSTRACT	c. THIS PAGE			Aaron Thode
Unclass.	Unclass.	Unclass.	UL	3	19b. TELEPHONE NUMBER *(Include area code)* 858-822-4864

Standard Form 298 (Rev. 8/98)
Prescribed by ANSI Std. Z39.18

Best Available Copy

FINAL REPORT

GRANT #: N00014-02-1-0448 (see also N00014-02-1-0187)

PRINCIPAL INVESTIGATOR: Aaron M Thode

INSTITUTION: Marine Physical Laboratory, Scripps Institution
of Oceanography

GRANT TITLE: Analysis of Sperm Whale Acoustic Signals in the
Gulf of Mexico and the Mediterranean

AWARD PERIOD: 1 December 2001 - 31 December 2002

OBJECTIVE: To design, develop, and simulate an automated
procedure for passively tracking sperm whales in three-
dimensions, using natural vocalizations recorded on two
towed arrays, deployed either alone or in conjunction with
dive tags. The algorithms would permit automated tracking
of multiple animals over complete dive cycles, producing
statistically significant sample sizes for evaluation of
controlled-exposure studies. When used in conjunction with
a dive tag, the algorithm would permit better resolution
tracking of animals detected on both the tag in array,
effectively increasing the number of animals tracked by the
tag.

APPROACH: Previous work by the PI had shown that 3D tracking
of sperm whales is possible using a single towed array,
using multi-path reflections from the ocean surface and
bottom. However, the resulting algorithm was difficult to
automate and required substantial effort by a human,
yielding only one 3D trajectory per ten hours of work. In
addition, the bottom returns were detected only
sporadically, during times when the animals were in their
initial descent to presumed foraging depth. During feeding
and/or social behavior the bottom returns are usually
absent.

To overcome these difficulties, a new algorithm was been
developed, using two spatially-separated towed arrays
deployed from a single vessel to record both the direct and
surface reflections of sounds. The automated detection and
classification of direct and surface paths is considerably
simpler than that required for bottom returns, but requires
information about the array depths to be effective. The
results would have lower depth resolution than those
obtained using bottom returns, but could be computed
automatically, reducing the processing time to an estimated
15 minutes per trajectory. Thus the technique is designed
to produce large numbers of low-resolution tracks, as
opposed to a single high-resolution track generated by an

tagged animal. The technique will also only work on acoustically active animals.

If one of the animals present has an acoustic tag, the algorithm can be extended to time-sync the tag with the array record, effectively creating a large-aperture array. This approach would provide much more precise localizations of all vocalizing animals, at the cost of requiring a tagged animal to be present.

ACCOMPLISHMENTS: The localization algorithms were written and tested in simulation in 2002. The automated data extraction algorithms were written using both MATLAB and the software package Ishmael (written by David Mellinger of Oregon State University under ONR support). The algorithms were successfully tested on field data in 2002 and 2003 under ONR N00014-02-1-0187, and additional support from the Minerals Management Service (MMS). A peer-reviewed publication has resulted from this work, and MMS and the North Pacific Research Board (NPRB) are currently funding research that exploits this technique.

CONCLUSIONS: The use of surface-reflected multipath to track sperm whales in range in depth has been found to be a robust technique that can be used with either a towed horizontal array or a bottom-mounted vertical array. The technique was found to be easily automated, using standard signal-processing software found in the public domain.

SIGNIFICANCE:
The demonstration of the technique is expected to yield 1-3 trajectories per half-hour of recording time, if a group of animals is being followed. Over the course of a night (7 hours) one might reasonably expect to obtain at least 25 tracks, a credible sample size for studying variables such as dive descent time, maximum depth obtained, and the depth at which "creak" sounds begin. The success of this algorithm would provide an inexpensive and rapid way of collecting statistically significant numbers of animal track for future environmental impact studies conducted by the division and other interested parties. Some of these predictions are being tested in the Gulf of Mexico in 2004, as part of the Sperm Whale Seismic Study (SWSS).

The algorithm used here is also being use to examine how sperm whales remove fish from longline fishing gear in the Gulf of Alaska, to gain insight into possible means of reducing the depredation without harming the animals.

AWARD INFORMATION: Work presented here lead to contracts with MMS and the North Pacific Research Board (North Pacific F0412) to apply the results of this research to sperm whale behavioral studies.

RELEVENT PUBLICATIONS AND ABSTRACTS:

1. Thode, A., Millinger, D.K., Martinez, A. (2002) Passive three-dimensional tracking of sperm whales using two towed arrays during the 2001 SWAMP cruise. Abstract presented at Dec 2002, Acous. Soc. Am. 144th conference proceedings, Cancun, Mexico.

2. Thode, A (2004) Tracking sperm whale (Physeter macrocephalus) dive profiles using a towed passive acoustic array. J. Acous. Soc. Am., in press.