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Monitoring Cetaceans in the North Pacific

by

Kathleen M. Stafford

April 2009

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Two projects were undertaken in order to monitor cetaceans in the North Pacific. The first was designed to obtain passive acoustic data from the U.S. Navy's Northern Edge Range. Three instruments were deployed in April 2008 to monitor both high (up to 25 kHz) and low (up to 1 kHz) frequencies for odontocetes and mysticetes, respectively. Unfortunately, these instruments did not record any data. The second project was to analyse retrospective data obtained by analysts at the Whidbey Island NAVFAC for broad regions of the North Pacific. Long-term (1996-2002) trends of blue and fin whale vocalizations were found to have strong seasonal and geographic differences. Furthermore, the number of fin whale call events detected increased significantly over time throughout the North Pacific. Onset and continuation of fin whale calling seemed to be primarily driven by day length, while blue whale calling behavior was influenced by combinations of sea surface temperature, surface chlorophyll *a* concentration, and day length.

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Monitoring Cetaceans in the North Pacific

Kathleen M. Stafford
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Abstract

Two projects were undertaken in order to monitor cetaceans in the North Pacific. The first was designed to obtain passive acoustic data from the US Navy's Northern Edge Range. Three instruments were deployed in April 2008 to monitor both high (up to 25 kHz) and low (up to 1 kHz) frequencies for odontocetes and mysticetes, respectively. Unfortunately, these instruments did not record any data. The second project was to analyse retrospective data obtained by analysts at the Whidbey Island NAVFAC for broad regions of the North Pacific. Long-term (1996-2002) trends of blue and fin whale vocalizations were found to have strong seasonal and geographic differences. Furthermore, the number of fin whale call events detected increased significantly over time throughout the North Pacific. Onset and continuation of fin whale calling seemed to be primarily driven by day length, while blue whale calling behavior was influenced by combinations of sea surface temperature, surface chlorophyll *a* concentration, and day length. Two manuscripts for peer-reviewed publications have been prepared for these data.

Acoustic recorder development and deployment report

Figure 1. Orfin acoustic data logger

In 2007, in collaboration with Dr. Chris Jones of APL/UW, we developed a processing system using a Blackfin processor, Orfin (Orca Blackfin). This bio-acoustic recorder design used a new processor with improved signal processing capabilities, more device interfaces, and large solid-state data storage (no moving disks). The system was designed both to allow flexible programming for new processing and detection applications and to be low-cost. Large amounts of high-bandwidth acoustic data can be recorded.

Processor:	Analog Devices Blackfin BF537E
Sensor:	Reson TC4040, TC 4037, or other
Max Frequency:	100 kHz
Storage capacity:	128 GB using 2-32 GB USB sticks
Battery capacity:	120 Ah D-Cell Alkaline
Device Interfaces:	Ethernet 100bT, USB 2.0, RS-232

In April 2008, three instruments (Figure 1) using this processor were deployed in the Gulf of Alaska to monitor a part of the Northern Edge Range before, during, and after the 2008 exercise in this area to examine the presence of vocal large whales. Two of the instruments recorded at high sample rates (65 kHz, low pass at 25 kHz) and low duty cycles (1 min. on, 14 min. off), while one instrument recorded at a low sample rate (4 kHz, low pass at 1 kHz) and high duty cycle (10 min. on, 5 min. off). The high frequency instruments were designed to record odontocetes such as beaked whales, while the low-frequency instrument was programmed to record the low-frequency sounds of baleen whales. Just prior to the deployment of these instruments, the active acoustic part of the exercise was scrapped. Nevertheless, the instruments were deployed as planned in order to obtain data in this region for comparison with future exercises (tentatively planned for 2010).

Table 1. Locations and sample rates of deployed hydrophone packages

Inst. Number	Latitude (North)	Longitude (West)	Depth (Fa.)	Sample Rate (kHz)	Low Pass (kHz)	On/off duty cycle (minutes)
1	59° 01.634	148° 00.203	77	65	25	1/14
2	58° 20.884	148° 45.082	72	65	25	1/14
3	59° 02.883	149° 00.626	88	4	1	10/5

Instrument 1 was deployed on 21 April 2008 at 2009 local (ADT), and instruments 2 and 3 were deployed on 22 April 2008 at 0145 and 0836 local. The two high frequency instruments (1 and 2) were deployed along the shelf break to monitor for odontocetes, while the third, low-frequency instrument was deployed on the shelf to monitor for baleen whales (Figure 2).

Balaenopterid cetaceans were seen, despite very little visual effort, in the vicinity of all three deployments. These included 2 fin whales, 1 humpback whale, 2 minke whales, and 2 unidentified baleen whales.

All three instruments were successfully recovered on 10 and 11 June 2008. Unfortunately, a last-minute software kernel change by the engineer in charge of programming the instruments caused a catastrophic failure such that no data were recorded on any of the three instruments. This was an extremely disappointing development, as the instruments had worked well with a prior kernel both on the bench and during in-water tests. However, we still feel that this area will benefit from passive acoustic monitoring with these instruments. Because we were able to determine the cause, which can be fixed, of the recording failure, the time and effort put into the development of the Blackfin for recording acoustic data were not in vain.

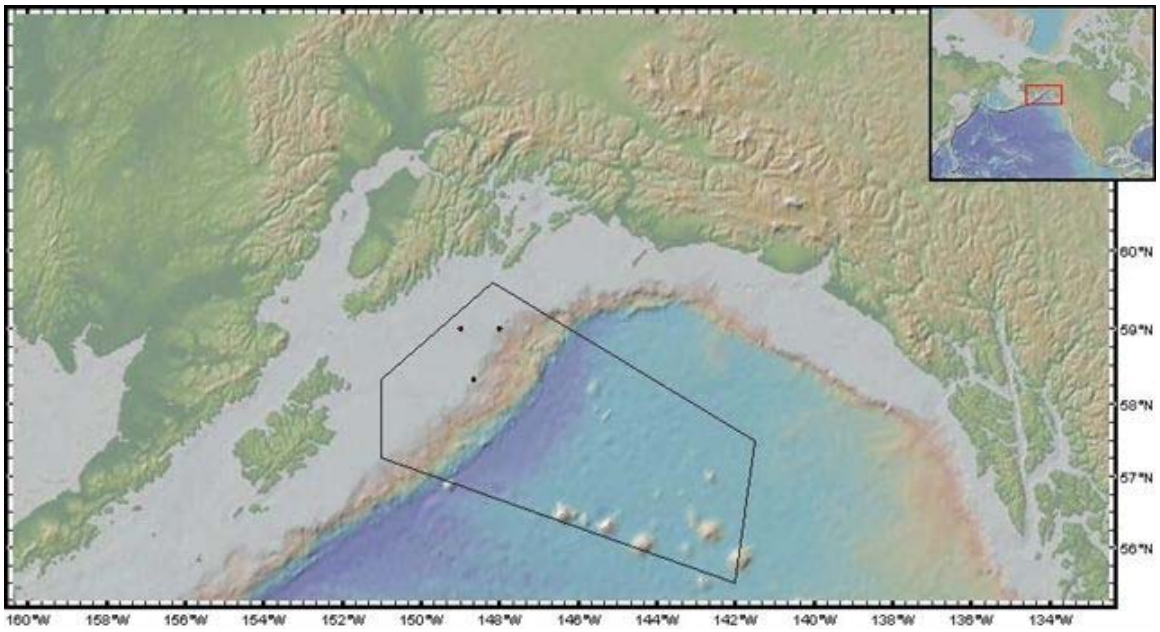

Figure 2. Location of three Orfin acoustic data loggers (dots) with the rough boundaries of the Northern Edge Range (solid line).

Revisting SOSUS and the Watkins data

Over the past decade, the Navy (CNO[N45] and ONR) in cooperation with the National Oceanic and Atmospheric Administration (NOAA) has increasingly relied on acoustic detection and tracking methods for marine mammal monitoring and mitigation. The reliance on acoustic tools is due in part to the development of the necessary hardware and software, and in part to the capability of acoustics to (1) detect animals underwater, (2) work at night and in poor weather, and (3) record the relevant signals, post-processing them if necessary. In the North Pacific, much of what we know about large whale seasonal occurrence comes from "dual use" of SOSUS arrays (Nishimura and Conlon 1994; Moore *et al.* 1998; Watkins *et al.* 2000; Stafford *et al.* 2001). Since these papers were published, an additional 5-year record from SOSUS has been archived. Benefit from a retrospective analysis is useful because this unique dataset provides long-term baseline data, including seasonal records that can be used with remotely-sensed environmental variables to compare with current and future datasets.

In 2007, a collaborative project with Ms. Mary Ann Daher of the Woods Hole Oceanographic Institution was initiated to revisit detections of large whales in the North Pacific collected by analysts at the Whidbey Island Naval Facility under the direction of the late Dr. Bill Watkins. Two papers resulting from this analysis are currently in preparation: the first is an analysis of long-term trends of blue and fin whales in the North Pacific, and the second is a correlation of these data with oceanographic variables such as sea surface temperature and chlorophyll *a* concentrations. Abstracts and titles for both of these papers are below.

Submitted to Marine Ecology Progress Series 1/09:

Long-term records of blue and fin whale calls in the North Pacific Ocean: Seasonal and geographic variation 1996-2002. Mary Ann Daher, Kathleen M. Stafford, Joseph E. George, David Rodriguez, and Kimberly Amaral

Abstract

The seasonality and geographic variation of blue and fin whale calls were examined using acoustic recordings made in the deep, offshore waters of the North Pacific Ocean. From 1996 to 2002, two blue whale call types, the northeastern blue whale call (NEP) and the northwestern blue whale call (NWP), and fin whale calls were recorded at the Naval Ocean Processing Facility on Whidbey Island, Washington, using the U.S. Navy Sound Surveillance System (SOSUS) systems. Arrays were selected to provide representative data for four defined regions offshore to the continental shelf edge, designated as Northwest (NW), Northcentral (NC), Northeast (NE) and Southeast (SE). Two arrays were used for each region. All three call types showed distinct seasonal and geographic variation over the entire data set. Generally, the numbers of fin whale calling events detected increased significantly when regressed on both year and date for all but two arrays, NE2 and SE3. NEP blue whale calling events only increased significantly at one site, NE3, and NWP blue whale events did so at four sites but only regressed on date, not year. For all call types and all arrays, there were significant differences amongst monthly means. Blue whale calls dominated the record in the western Pacific, NW, while fin whale events were more abundant in the remaining three regions NC, NE and SE.

To be submitted to Marine Ecology Progress Series or Deep-Sea Research I:

Long-term records of blue and fin whales in the North Pacific Ocean: broad-scale oceanographic correlates. Kathleen M. Stafford, Sue E. Moore, Mary Ann Daher, Joseph E. George, David Rodriguez, and Kimberly Amaral

Abstract

Blue and fin whale calls from acoustic recordings made from four regions in the deep, offshore waters of the North Pacific Ocean were compared with satellite-derived oceanographic data to determine the relationship among whale calling behavior, sea surface temperature (SST), surface chlorophyll *a* (chl *a*) concentration and mixed layer depth (MLD) in order to provide a predictive model of whale call occurrence. Both the acoustic and oceanographic data were obtained over broad spatial (30° of longitude by 15° of latitude) and temporal (monthly values) scales. Both blue and fin whale calls were statistically significantly correlated with SST and chl *a*, but not with MLD. In general, blue whale call peaks were tightly correlated with SST maxima but lagged behind chl *a* by 3 months. Fin whales, on the other hand, increased as SST was decreasing and showed a greater lag with chl *a* than blue whales. These general patterns did vary by location. This variability is expected as the four regions studied encompass very different oceanographic regimes from the sub-tropical to the sub-arctic.

Peer-reviewed publications relevant to CNO (N45) from 9/1/07-8/30/08

Moore, S.E., K.M. Stafford, D.K. Mellinger, and C.W. Clark. *In review*. Insights into large whale ecology from broad-scale passive acoustic sampling. *Marine Ecology Progress Series*.

Moore, S.E., B.M. Howe, K.M. Stafford, and M.L. Boyd. 2008. Including whale call detection in standard ocean measurements: application of acoustic seagliders. *Marine Technical Society Journal* **41**: 49-53.

Mellinger, D.K., K.M. Stafford, S.E. Moore, R.P. Dziak, and H. Matsumoto. 2007. An overview of fixed passive acoustic observation methods for cetaceans. *Oceanography* **20(4)**: 36-45.

Stafford, K.M., D.K. Mellinger, S.E. Moore, and C.G. Fox. 2007. Seasonal variability and detection range modeling of baleen whale calls in the Gulf of Alaska, 1999-2002. *Journal of the Acoustical Society of America* **122**: 3378-3391.

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