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Acoustic Monitoring for Killer Whales in the Bering Sea

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Executive Summary

The presence of killer whales in the Bering Sea was examined using data from High-Frequency Acoustic Recording Packages (HARPs) originally deployed for studies of North Pacific Right Whales. With support from ADFG, two HARPs were deployed at sites on the Bering Sea middle-shelf, in collaboration with the NOAA Pacific Marine Environmental Laboratory. The acoustic data provided by these instruments revealed information on killer whale presence based or recording their vocalizations. The presence of killer whale calls was evaluated from HARP data collected from April 24, 2005 to January 16, 2006 at PMEL mooring M2, and from September 24, 2005 to January 25, 2006 at PMEL mooring M4. A total of 267 days were examined from site M2, and from these 39 days (15 percent) were found to contain killer whale calls. Likewise, 123 days were examined from site M4, and 12 days (10 percent) were found to contain calls. Two peaks in call occurrence are evident at M2, one in late-June to early July, and the other extending from October to December. Further analysis of these data should provide a classification by ecotype (resident or transient), and potentially yield an estimate of killer whale relative abundance.

Background

Three ecotypes of killer whales, termed resident, transient, and offshore, have been described in the Northeast Pacific. These three forms refer to killer whales that can be distinguished based on genetics, acoustics, morphology and feeding ecology. Resident whales are found in coastal and inland waters and are known to select fish as their primary prey. Transient whales are seen in coastal water only occasionally, and are known to feed primarily on marine mammals. Offshore whales are seen only in outer waters, and initial data suggest that they feed primarily on fish.

Vocal communication is an essential element of the complex social structure of killer whales; distinct acoustic dialects have been documented for resident killer whales pods in the Northeast Pacific (Ford 1989, Ford 1991), with each dialect remaining stable over time. The other killer whale ecotypes, transients and offshore, also produce specific discrete calls that can be used for population identification. Other calls types, including clicks, whistles, and other variable calls are also heard from killer whales.

For Puget Sound, British Columbia and adjacent regions of Southeast Alaska a catalog of killer whale calls has been compiled which includes the discrete calls, organized by pod or clan, for each of southern and northern residents, offshore, and transient killer whales ecotypes (Ford 1987). Unfortunately the development of a catalog for Aleutian and Bering Sea killer whale calls is not as well developed.

In the past decade, passive acoustic techniques have become an increasingly powerful tool for assessing marine mammal populations. Acoustic monitoring has provided insight into cetacean presence and seasonality over long time periods and in remote regions (reviewed by Mellinger & Barlow 2003). Used as a method for monitoring marine mammals, underwater acoustic recordings have provided ecological, geographical, and behavioral information on a variety of species.

Objectives

The objective of this project was to monitor Bering Sea killer whales using High-frequency Acoustic Recording Packages (HARPs). This research was conducted as an ancillary project resulting from the deployment of HARPs on two oceanographic moorings deployed by the NOAA Pacific Marine Environmental Laboratory to monitor North Pacific right whales (Hildebrand & Munger 2007).

Technical Approach

With support from ADFG, we deployed HARPs at two NOAA-PMEL oceanographic moorings in the Bering Sea. The coordinates of these moorings are: M-2 lat 56º 51.60’ N lon 164º 03.60’ W depth 72 m; and M-4 lat 57º 51.18’ N lon 168º 52.20’ W depth 70 m. Figure 1 shows a map of the mooring locations and Table 1 lists details of the HARP instrument deployments, and the acoustic data that they recorded.

Site Name	Mooring Name	Begin Data Date	End Data Date	Sample Rate (kHz)	Total Data Storage Capacity	Hydophone Depth (m)
M-2	04BSP-2A	04/26/04	07/28/04	80	16x60Gb	67
M-2	04BSP-2B	09/28/04	12/05/04	32	16x80Gb	67
M-4	04BSP-4B	10/3/04	12/23/04	32	16x80Gb	69
M-2	05BSP-2A	04/23/05	09/23/05	40	16x80Gb	67
M-2	05BSP-2B	09/24/05	01/16/06	32	16x80Gb	67
M-4	05BSP-4B	09/25/05	01/25/06	32	16x80Gb	69

Table 1. HARPS deployments on NOAA Moorings M-2 and M-4 in the Bering Sea.

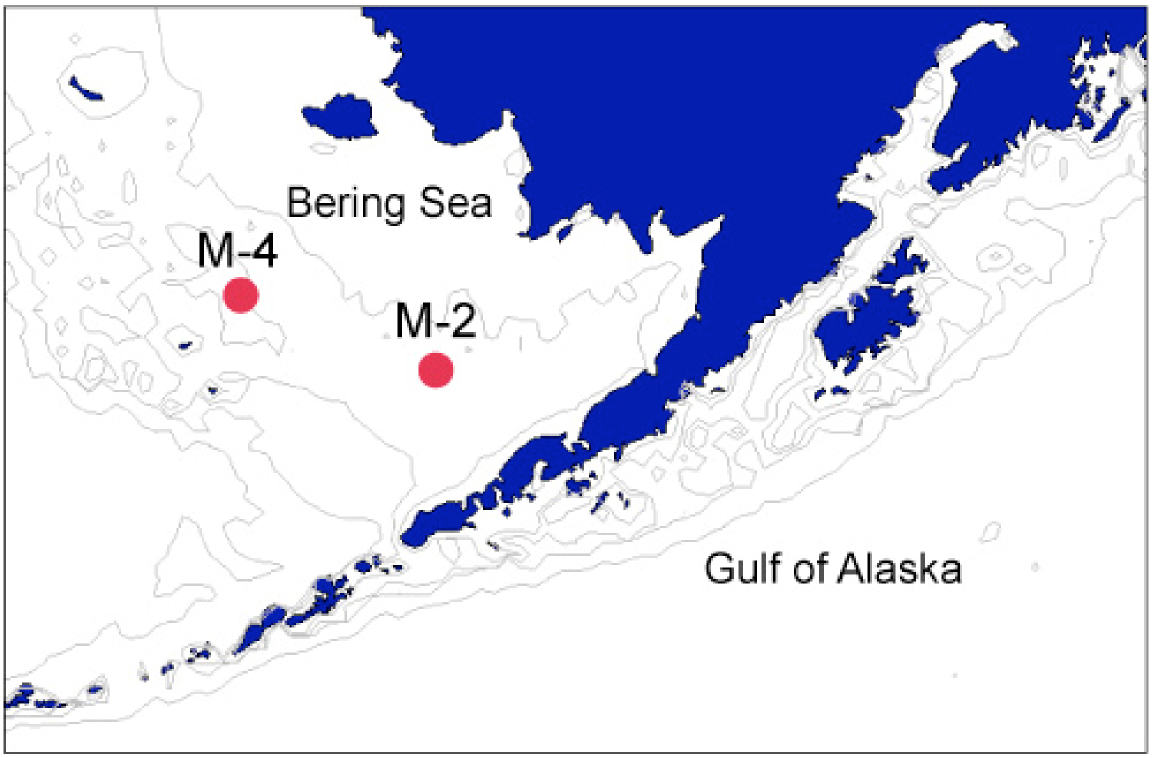

Figure 1. HARP deployment locations on NOAA Moorings M-2 and M-4 in the Southeast Bering Sea. The coordinates are: M-2 lat 56º 51.60' N lon 164º 03.60' W depth 72 m; and M-4 lat 57º 51.18' N lon 168º 52.20' W depth 70 m

The HARP instrumentation design is described in a companion report (Hildebrand and Munger 2007), as well as a recent publication (Wiggins & Hildebrand 2007).

The data analysis strategy for locating killer whale calls in broad-band large-volume recorded data involves the use of a spectral averaging algorithm in which the data are compressed and viewed as long duration spectrograms. Since each deployed HARP returns as much as 2 TB of acoustic data, it is not feasible to analyze these data in its continuous format. For initial data examination we used a means of file compression for data overview based on long-term spectral averages (LTSA). Instead of inspecting short duration spectrograms for individual calls, successive spectra were calculated and averaged together. These averaged-spectra were arranged sequentially to provide a time series of the spectra. For the short duration calls of killer whales we generally average 5 seconds of spectral data together. This spectral-averaging scheme produces a spectrogram of long time periods, essentially providing a map or table of contents to groups of events in the fine time scale data. Initial examination of data in LTSA has often resulted in the detection of 100% of the calling bouts for some species. Single calls or those with low signal-to-noise ratio may be missed in this format, requiring the use of an automatic detector for extraction of all calls in a calling bout. We have designed separate whistle and click detectors based on the presence of acoustic energy in specific frequency bands that we used to detect the clicks, whistles, and burst-pulse sounds produced by killer whales.

The acoustic data from each instrument was subjected to two processing steps. First the data were processed into long-term spectral averages for identification of killer whale calling bouts. The start and end time of each calling bout within the LTSA was logged. The data were also scanned with an automatic whistle and click detector, to identify any killer whales calls that might have been missed by scanning the LTSA alone. The detector provides the start and time of each click, whistle, and discrete call. Each detected call was then examined to determine 1) if the call was produced by a killer whale, 2) the type of calls present within the calling bout (i.e clicks, whistles, or discrete calls), and 3) the potential identity of discrete calls by acoustic clan or ecotype.

Discrete calls are classified to clan by listening to each call and comparing it to an acoustic catalog of reference sounds for each call type. Discrete pulsed calls can be used for measurement of call characteristics. Using Ford (1987) as a model, measurements of duration (ms), whistle component frequency (upper frequency component), and frequency intervals between sidebands (harmonics) (Hz) can be conducted, with the distance between sidebands reflecting the pulse repetition rate. Calls may be separated into segments using sudden shifts in pulse repetition rates or silent intervals (Yurk *et al.* 2002).

Assignment to clan is based on the similarity in structure of calls and the peak frequency difference and pulse repetition rate change (Harald Yurk, pers. Comm.). The best assignment by ecotype is revealed by the sharing of whole call types with repertoires of groups that have been determined by genetic analysis and photo-id. The number of call syllable classes used is lower than the number of different calls that killer whales produce, and the differences among ecotypes is substantial (e.g. residents and transients from the NE-Pacific only share 50% of the identified syllable classes).

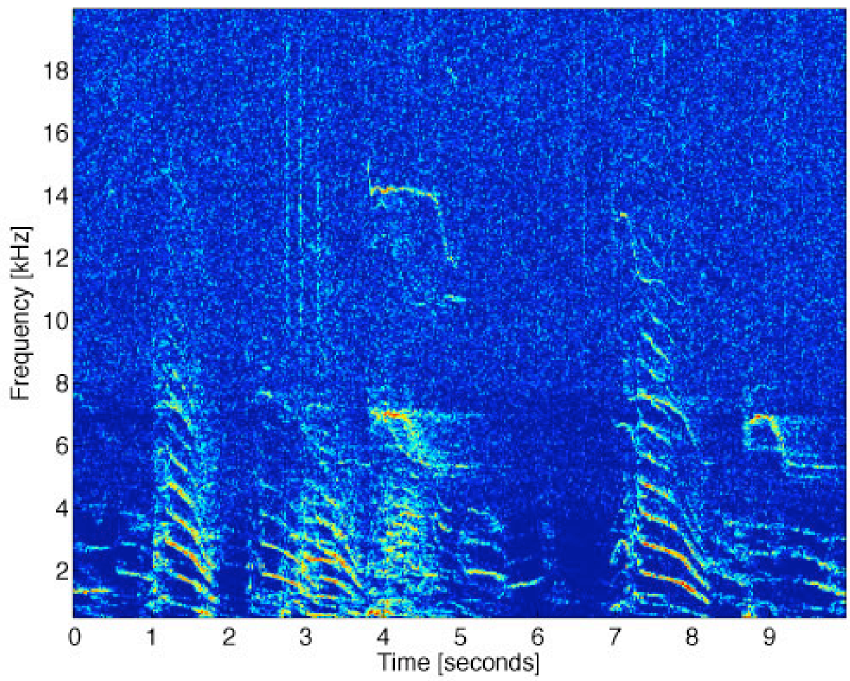

Figure 2. Spectrogram of killer whale calls recorded by the HARP at mooring M2 on July 31, 2005 at 03:21:05. A resident ecotype with clicks and discrete pulsed calls is suggested.

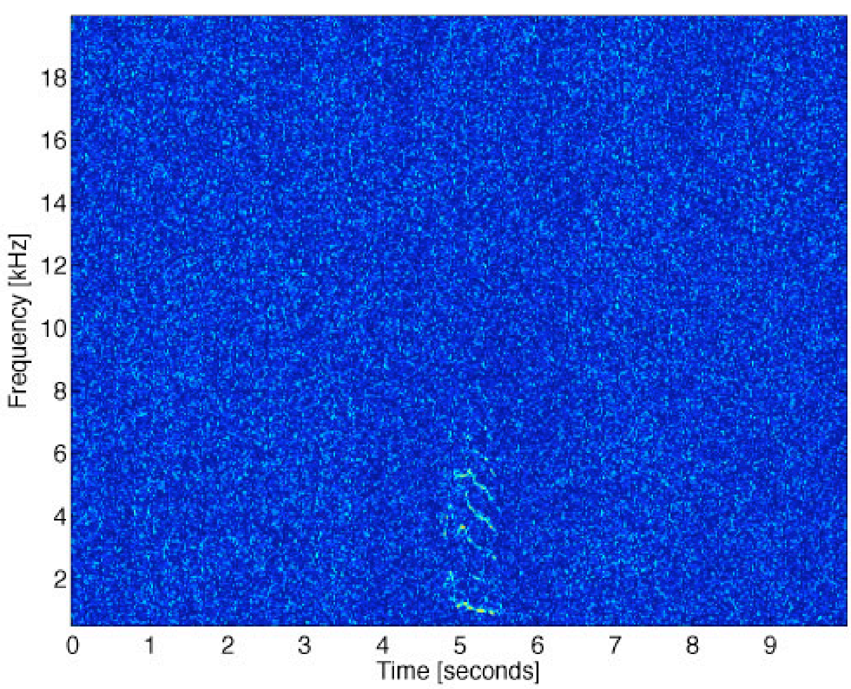

Figure 3. Spectrogram of killer whale calls recorded by the HARP at mooring M2 on June 20, 2005 at 02:22:10. A transient ecotype is suggested.

Results

The presence of killer whale calls was evaluated from HARP data collected from April 24, 2005 to January 16, 2006 at PMEL mooring M2, and from September 24, 2005 to January 25, 2006 at PMEL mooring M4. A total of 267 days (6408 hours) were examined from site M2, and from these 39 days (15 percent) were found to contain killer whale calls. Likewise, 123 days (2952 hours) were examined from site M4, and 12 days (10 percent) were found to contain calls. The Bering Sea HARP data provided high quality recordings of killer whales.

Examples of calls recorded at mooring M2 during June and July 2005 are shown in Figures 2 and 3. Figure 2 reveals both 10-20 kHz clicks and 1-9 kHz discrete calls produced during a highly vocal period, whereas Figure 3 shows a single call produced during a sparsely vocal period. The process of classifying the Bering Sea HARP killer whale calls to ecotype or clan is not yet complete, owing to the need for a more complete comparative catalog of calls. Example calls from the Bering Sea dataset have been given to Harald Yurk for study, and we hope to continue this collaboration as a means for call classification.

A few of the calling bouts have been provisionally identified to ecotype. Most notably, calls heard on 20 June, 2005 at mooring M2 were identified as transient call types (Figure 3). Further, calls heard on 1, 12, and 31 July, 2005 on mooring M2 were similar to those produced by South Alaskan residents (Figure 2). Some calling bouts are also thought to contain calls of offshore killer whales. Further analysis of all calling periods is ongoing.

Two seasonal peaks in call occurrence are evident at M2, one in late-June to early July, and the other extending from October to December (Figure 4a). Killer whale calls were detected in all months of recording effort at M2 with the exception of September. There were fewer days per month with killer whale calls at M4, though they were heard from October through December (Figure 4b).

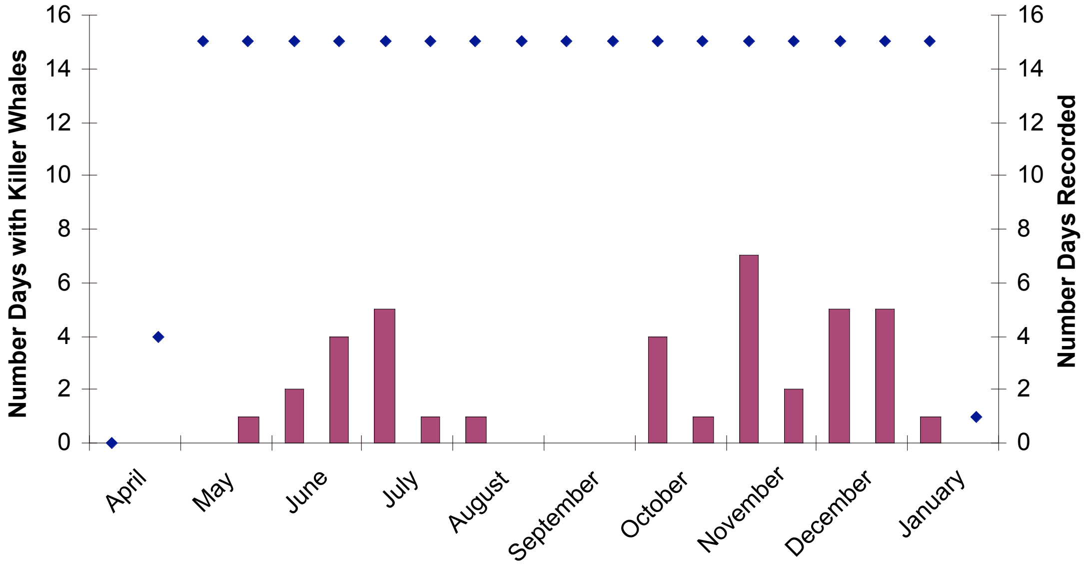

Figure 4a. Number of days with killer whale calls present at site M2, shown in bi-monthly bins. The number of recording days per bin is indicated by a blue diamond. Two peaks in seasonal presence are seen, in July and November.

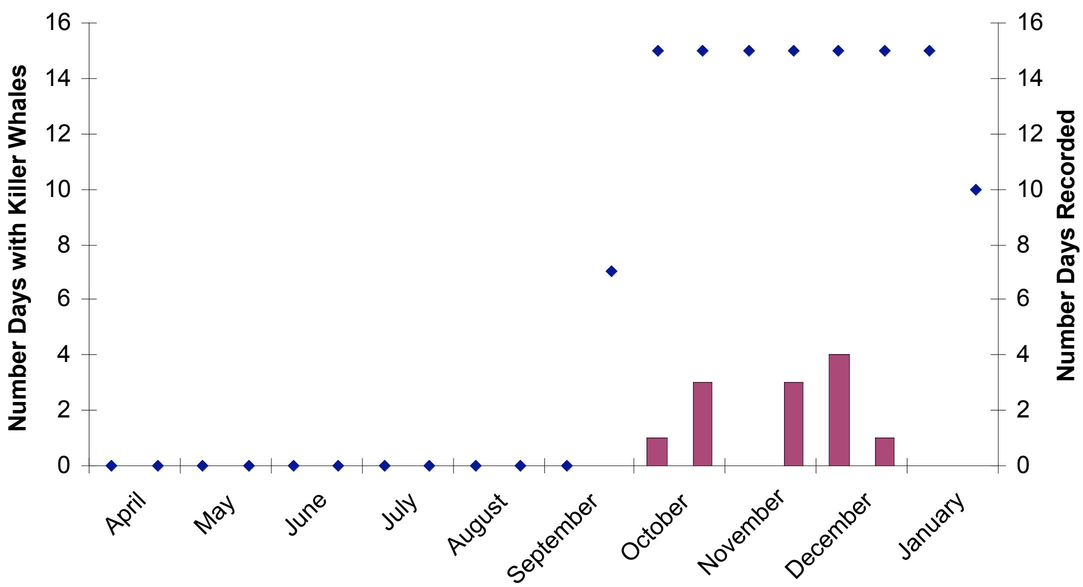

Figure 4b. Number of days with killer whale calls present at site M4, shown in bi-monthly bins. The number of recording days per bin is indicated by a blue diamond.

Discussion

The HARP data have revealed a high encounter rate for killer whales on the middle shelf of the Bering Sea. The two mooring sites (M2 and M4) yielded 15 percent and 10 percent daily occurrence of killer whale calls. Two seasonal peaks in occurrence were observed – one in the late spring and summer and the other in the late fall and winter. However, these data suggest that killer whales are present for most of the year at least at mooring site M2. Further analysis of these data should provide a classification by ecotype (resident or transient). In addition, better understanding of killer whale vocalization rates and acoustic propagation could also potentially yield an estimate of killer whale relative abundance.

Citations

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