

MARINE MAMMAL SCIENCE, 15(4):1351–1357 (October 1999)
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AN “ACOUSTIC NICHE” FOR ANTARCTIC KILLER WHALE AND LEOPARD SEAL SOUNDS¹

A “niche” is the functional role a species plays in its environment. By developing a niche, competition for resources is reduced among coexisting species. Although a niche usually refers to the function in an ecosystem of one species relative to another, we wondered whether marine mammals develop an “acoustic niche” to reduce competition among species that share the same acoustic environment.

There is some evidence that aquatic animals adjust the characteristics of their signals when it is adaptive. Heiligenberg (1975) demonstrated that electric fish (*Gymnarchus niloticus*) avoid jamming electrolocation signals by raising or lowering the frequency of their signals when other electric fish are in the vicinity. Au *et al.* (1985) showed that a beluga (*Delphinapterus leucas*) increased the peak frequency and amplitude of echolocation pulses when noise from snapping shrimp was present. In an analysis of sounds made by southern right whales (*Balaena glacialis australis*), Clark (1982) noted that frequency characteristics were influenced by ambient noise conditions. Recently, it was reported that belugas changed the frequency of their sounds when vessel noise was present (Lesage *et al.* 1999). It is our hypothesis that by partitioning frequency, time, and/or amplitude characteristics of their sounds, a species “carves out” its own acoustic space. Such an acoustic niche would facilitate better signal detection in an environment shared by species. This study examines only the frequency dimension of a possible acoustic niche.

Killer whales (*Orcinus orca*) and leopard seals (*Hydrurga leptonyx*) are predators that coexist during December near the ice edge of the Ross Sea in Antarctica, where food sources such as krill (*Euphausia superba*), Adelie penguins (*Pygoscelis adeliae*), Weddell seal pups (*Leptonychotes weddellii*), and crabeater seal pups (*Lobodon carcinophagus*) are abundant. Killer whales and leopard seals are soniferous during December, producing a variety of underwater sounds. By January few leopard seal sounds are heard, but killer whales sounds are common (Thomas *et al.* 1987).

To test the “acoustic niche” hypothesis, we examined the characteristics of underwater sounds made by killer whales in December when leopard seals are

¹ This article is dedicated to Dr. Ken Norris, a founder of The Society for Marine Mammalogy, with appreciation and admiration for his insights into cetacean behavior and acoustics. Dr. Norris' ideas and research provided a foundation for many policies that currently promote conservation of marine mammals. He was a natural teacher, always finding time to speak with students. Dr. Norris' ideals and knowledge will be perpetuated through the many students he encouraged and advised throughout his career. He is missed by the marine mammal community.—Jeanette Thomas, Past-President of SMM

vocal and in January when leopard seals are silent (or absent from the area). If killer whales developed an acoustic niche to avoid competition with leopard seal sounds, we would find a difference in the frequency range of killer whale sounds in December recordings compared to January recordings.

Underwater sounds of leopard seals and killer whales were recorded during the last week of December 1977 and the first week of January 1978 in the Ross Sea. J. Thomas used an Ithaco 601C hydrophone positioned under water near the ice edge at Cape Evans and recorded sounds on a Nagra III (system frequency response linear to 15 kHz \pm 3 dB). From these recordings, 108 killer whale sounds (57 in December and 51 in January) and 47 leopard seal sounds (all in December) were analyzed using RTS real-time spectrogram software. No noise compensation or filtering was used. Killer whale echolocation clicks were not examined. Representative spectrograms from both species are shown in Figure 1, 2.

Killer whales and leopard seals were observed in the immediate vicinity during recordings. Crabeater seals, minke whales (*Balaenoptera acutorostrata*), and Weddell seals also were present from time to time, but these marine mammals make distinct sounds (Stirling and Siniff 1978, Thomas and DeMaster 1982, Thomas and Kuechle 1982, Leatherwood *et al.* 1982) that are easily discernible from leopard seal sounds (Thomas and Golladay 1995) and killer whale sounds (Awbrey *et al.* 1982). Therefore, we are relatively certain that the killer whale and leopard seal sounds were correctly identified in this study.

Leopard seal sounds were classified into one of four types: M1, M2, M3, and M4 (Thomas and Golladay 1995). For each call type, we calculated the average minimum and maximum frequencies. We designated this interval as the frequency range of the call type. Of the 47 leopard seal sounds, 10 were M1 (frequency range 594–749 Hz), 24 were M2 (frequency range 2,777–3,802 Hz), 9 were M3 (frequency range 1,685–2,072 Hz), and 5 were M4 (frequency range 666–1,371 Hz).

Unlike the stereotyped leopard seal sounds, killer whale sounds were highly variable whistles, often with harmonics. For each whistle, we measured: (1) the duration, (2) the beginning, ending, minimum and maximum frequencies, and (3) the frequency-modulation points (FM-points). We defined FM-points (Fig. 3) as the frequencies at which a killer whale sound had a detectable change in slope. We visually scored all FM-points of the dominant part of the signal (darkest trace on the sonogram) in killer whale sounds, producing a total of 1,455 FM-points.

We used the FM-point method to examine frequency change within a sound. This interest stemmed from a suspicion that FM-points convey information in the signal. The method is similar to that developed by McCowan (1995) in which 20 points were assigned to describe each sound. However, our method allowed an unlimited number of frequency modulation points for each sound. The scoring of FM-points was subjective, but we do not believe the scoring was biased, because the analysis of killer whale sounds was completed before the leopard seal sound analysis began. All variables for killer

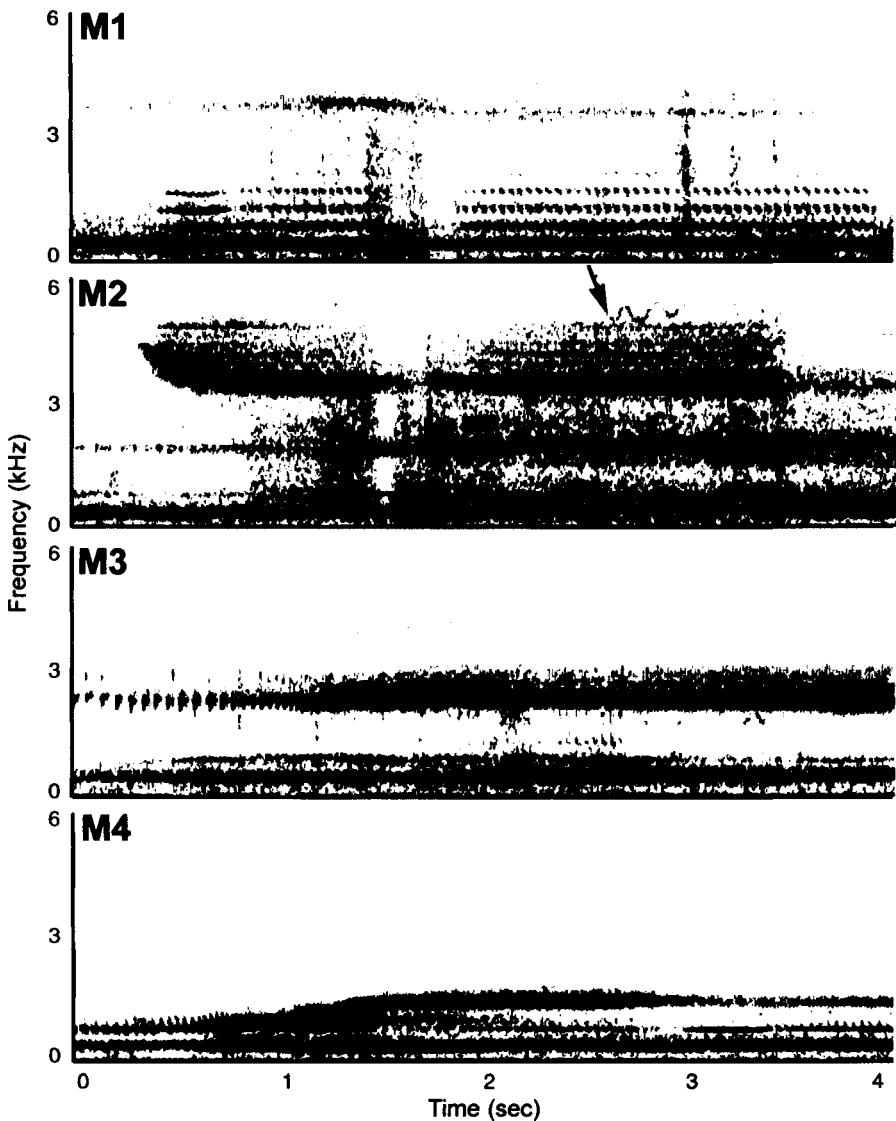


Figure 1. Spectrograms of some leopard seal sounds: M1, M2 (arrow indicates simultaneous killer whale sound), M3, and M4.

whale sounds were compared between December and January recordings, using the chi-square approximation of the Kolmogorov-Smirnov two-sample test (Goodman 1954) with $\alpha = 0.05$ and $df = 2$.

The most common leopard seal sound (M2) has a broad bandwidth that could mask other sounds in the same frequency range. Therefore, to avoid bias, killer whale sounds that occurred at the same time as the M2 sound were not analyzed.

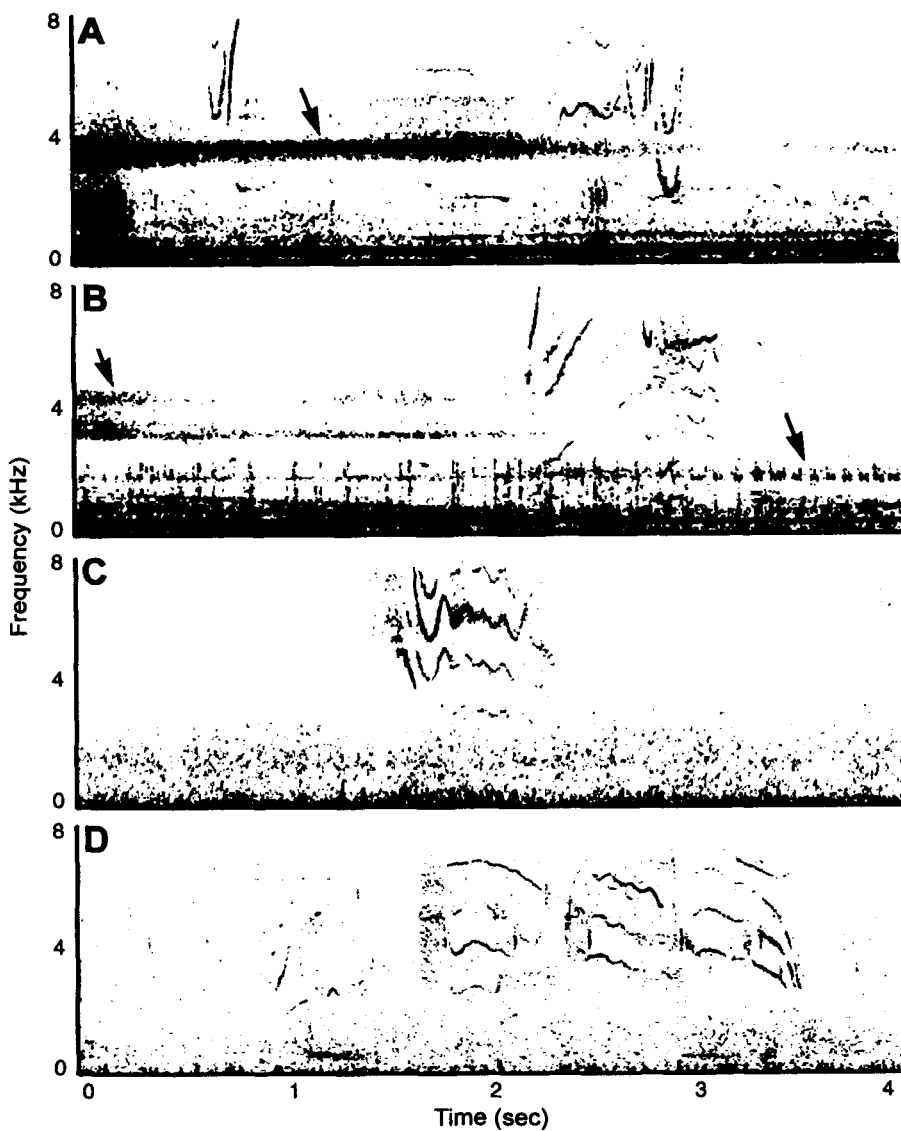


Figure 2. Spectrograms of some killer whale sounds: A, B from December recordings (arrows indicate leopard seal sounds); C, D from January recordings.

In December a gap in the FM-point distribution occurred between 2,500 and 3,750 Hz (Fig. 4B). This gap coincided with the frequency range (2,777–3,802 Hz) of the most common leopard seal sound, M2 (Fig. 4A). In January, when no leopard seal sounds were present, the FM-points shifted to a tighter distribution centered at a higher frequency, and a gap was not seen (Fig. 4C). The FM-point distribution of killer whale sounds was significantly dependent on the recording month ($\chi^2 = 126.79$, $P < 0.0001$). The mean number of

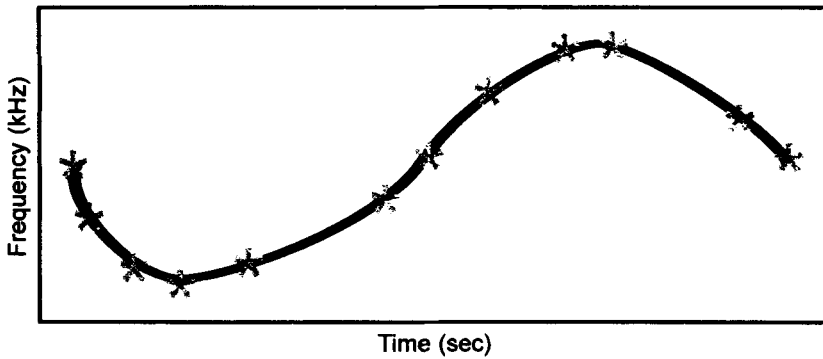


Figure 3. Spectrogram of hypothetical killer whale sound. Frequency-modulation points (marked as *) defined as detectable changes in frequency slope.

FM-points per killer whale sound was not significantly different in January and December recordings ($\chi^2 = 5.25$, $P > 0.05$), and there was no significant difference in the average duration of killer whale sounds between December and January data ($\chi^2 = 4.09$, $P > 0.05$).

Examining the FM-point distribution of killer whale sounds provided a method to detect the active avoidance by killer whales of the frequency range of leopard seal sounds; *i.e.*, there is a gap in the December distribution that disappears in January. Analysis of traditional frequency measures, such as beginning, ending, maximum, and minimum frequencies, did not reveal a gap. However, significant differences in the distributions of these traditional measures between months further support an active change in killer whale sounds, depending on the presence or absence of leopard seal sounds (beginning frequency $\chi^2 = 16.29$, $P < 0.001$; ending frequency $\chi^2 = 17.35$, $P < 0.001$;

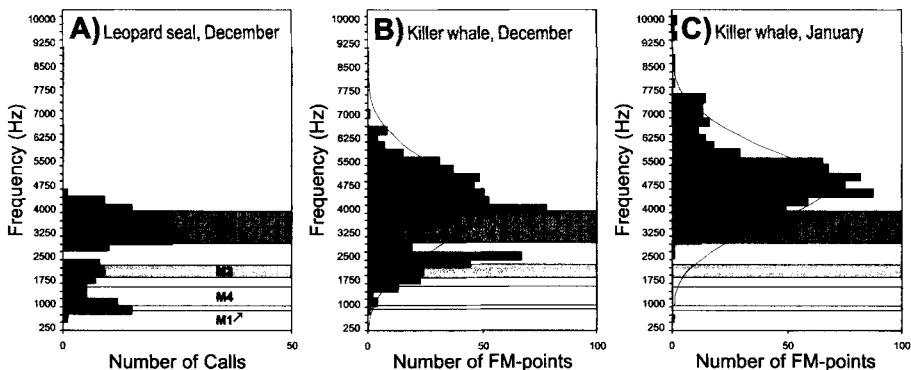


Figure 4. A) Distribution of frequency ranges of leopard seal calls from December recordings. Average frequency range of each leopard seal call type (M1–M4) marked. No leopard seal calls heard in January. B) Distribution of FM-points from killer whale sounds recorded in December when many leopard seal sounds were heard. C) Distribution of FM-points from killer whale sounds recorded in January when few leopard seal sounds were heard. Curves show normal distribution.

maximum frequency $\chi^2 = 20.13$, $P < 0.001$; minimum frequency $\chi^2 = 22.20$, $P < 0.001$).

Killer whales and leopard seals are predators sharing the same acoustic environment. During periods when both species are exploiting this environment, killer whales develop an "acoustic niche" above and below the frequency range of the most common leopard seal sound (M2). We believe the shift between December and January frequency distributions reflects the development of this niche by killer whales. It should be pointed out that killer whale sounds in December did contain frequencies between 2,777–3,802 Hz; however, when killer whales modulated their sounds it was likely to be above or below this frequency range. These data lead us to believe that killer whales used frequency modulation as an adaptation to exploit their acoustic niche when leopard seal sounds were also present.

ACKNOWLEDGMENTS

This work was conducted under NSF Polar Programs Grants (DPP-77-21946 and DPP-77-21646), awarded to Donald Siniff, University of Minnesota. The analysis was conducted in the Bioacoustics Laboratory of the John G. Shedd Aquarium. The comments of anonymous reviewers improved this paper. Thanks to Dr. Steve Zecker for statistical advice.

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MARINE MAMMAL SCIENCE, 15(4):1357–1364 (October 1999)
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AGE STRUCTURE AND REPRODUCTIVE RATES OF RINGED SEALS (*PHOCA HISPIDA*) ON THE NORTHWESTERN COAST OF HUDSON BAY IN 1991 AND 1992¹

There are few data on the biology of ringed seals (*Phoca hispida*)² anywhere in Hudson Bay that can be used to compare them to their conspecifics in other areas, evaluate the hypotheses about their ecology, or aid in their conservation. In this paper, we present baseline data on some biological parameters for ringed seals in northwestern Hudson Bay that were collected as part of a long-term study of ecological relationships between ringed seals and polar bears (*Ursus maritimus*) throughout the Canadian Arctic (Stirling and Øritsland 1995).

During May–June and October of 1991 and 1992, samples were collected

¹ This paper is dedicated to the memory of Ken Norris with much appreciation of his leadership, his lifelong contribution to marine mammal science, and his dedicated training of many young marine mammal scientists.

² The genus *Phoca* is used here rather than *Pusa* (as indicated by Rice 1998), following the recent molecular analysis of pinniped relationships (Árnason *et al.* 1995).