

The Occurrence and Significance of Humpback Whale Songs in Glacier Bay, Southeastern Alaska

This article was prepared by Christine Gabriele, National Park Service, Glacier Bay National Park, and Adam Frankel, Marine Acoustics Incorporated, Arlington, Virginia.

Humpback whale songs are among the longest and most complex vocalizations made by any animal. Underwater acoustic monitoring in Glacier Bay National Park since May 2000 has revealed that humpback whales sing much more frequently in the late summer and early fall than previously believed. Prior to this study, humpback whale songs had rarely been recorded in Alaskan waters. By describing the occurrences of Alaskan whale song and comparing them with recordings made in Hawaii, we hope to learn more about the functions of song and the importance of high-latitude feeding areas to the humpback whale mating system. The presence of whale songs also highlights the potential effects of vessel-generated noise on endangered humpback whales in Glacier Bay.

Humpback whales are migratory baleen whales that spend summers in high-latitude feeding grounds and migrate to tropical mating and calving grounds in the winter. The humpback whales in the Glacier Bay area are part of the southeastern Alaska feeding herd, comprising approximately 1000 individuals. For these humpbacks, the winter migration entails a 2500-mile swim to the Hawaiian Islands, the largest of three main wintering areas in the North Pacific. The other humpback whale wintering areas in the North Pacific are in Mexican waters off the Baja Peninsula and in the western Pacific near Japan and the Philippines. The greatest numbers of humpbacks occur in Hawaiian waters in January through April each year, although some whales can be found there from November through June. Biologists employed by commercial whalers in the mid-twentieth century examined many thousands of carcasses and discovered that humpbacks don't feed on their winter grounds and that male and female reproductive organs are inactive in the summer.

A "song" is essentially a series of sounds made in a predictable order. In the case of humpback whales, the song is typically about 15 minutes long, punctuated when the whale surfaces to

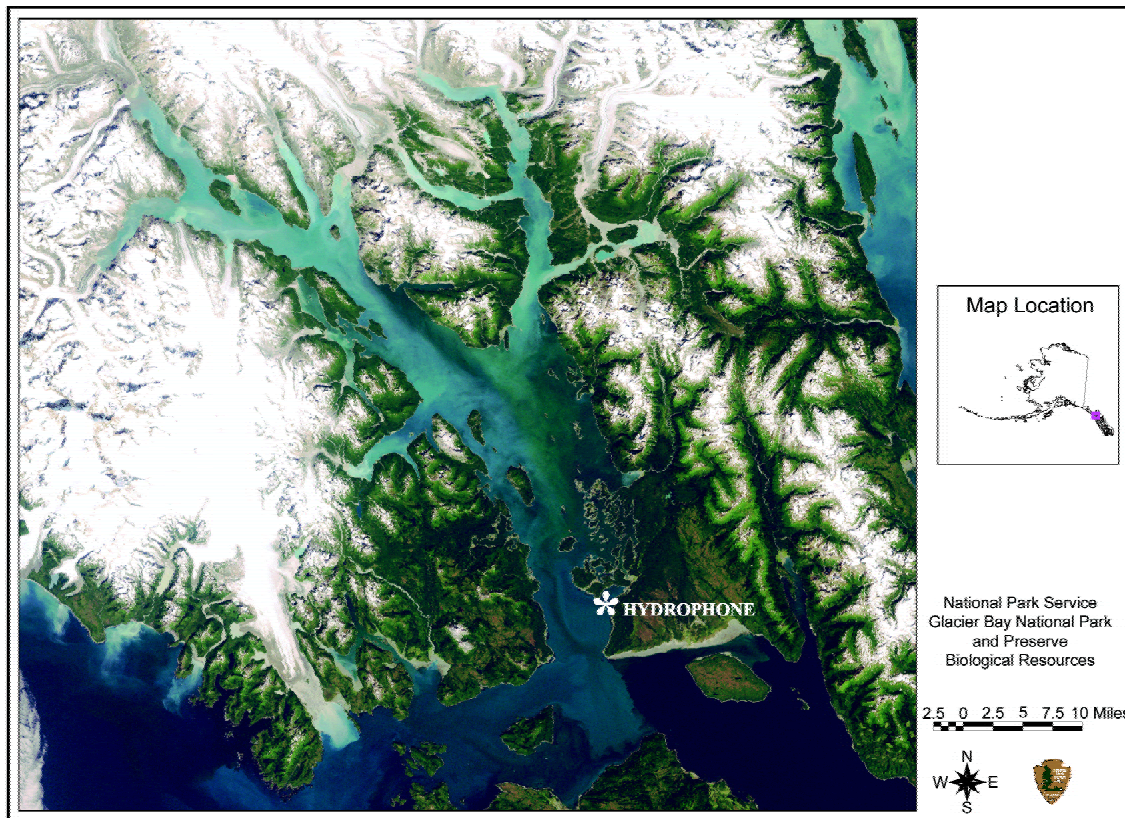
breathe. It is thought to be a mating-related display because it primarily occurs during the winter and is performed only by males. All males on a breeding ground sing essentially the same song, but singers adopt changes during the winter that result in progressive change in the song.

Despite much research in the years since song was first scientifically described in 1971, the functions of the song remain unclear. The leading theories on why male humpbacks sing include sexual advertisement to females, male-male coordination, and maintenance of space between competing males. Male-male competition is a key feature of the humpback whale mating system because most females give birth every other year, increasing the ratio of males to available females to at least 2:1. Many researchers believe that song may be a form of acoustic competition, analogous to the vigorous and sometimes injurious physical competition among males for access to females. Although scientists don't fully understand song function, its importance to humpback whale social life is clear, given that an individual male will sing for hours on end, and a chorus of whale song can be heard all day and all night during the winter in Hawaii.

Recording and Processing Alaskan Whale Songs

The humpback whale songs reported here were recorded during passive acoustic monitoring to characterize ambient and vessel-generated noise in Glacier Bay National Park, a steep-walled glacial fjord system in southeastern Alaska. The seafloor in the area is the remnant of a glacial moraine that is flat and sporadically rocky at a fairly stable depth of 40–60 meters. The park's humpback whale population monitoring shows that Glacier Bay and the surrounding area is inhabited by 50–100 humpback whales between June and August, with fewer whales from September to May. Approx-

Map of Glacier Bay, showing the location of the anchored hydrophone.



imately 355 humpbacks have been individually identified in the Glacier Bay area since 1985, including at least 36 mature males. Although the long-term population monitoring program focuses on individually identified whales, we monitored songs remotely, so there were no opportunities to determine the identity of individual singers or whether non-continuous episodes of song were made by the same whale.

Alaska Recordings

We listened to and made digital recordings of underwater sound using an anchored hydrophone and computerized monitoring system near the mouth of Glacier Bay, southeastern Alaska. A submerged five-mile cable connects the hydrophone to a custom-built control unit at park headquarters that provides power to the hydrophone and is the

electrical interface between the hydrophone, the computer, and the recorder. We recorded humpback whale vocalizations with a digital audio tape recorder or directly onto a computer hard disk. All recordings were archived onto compact disc for later analysis.

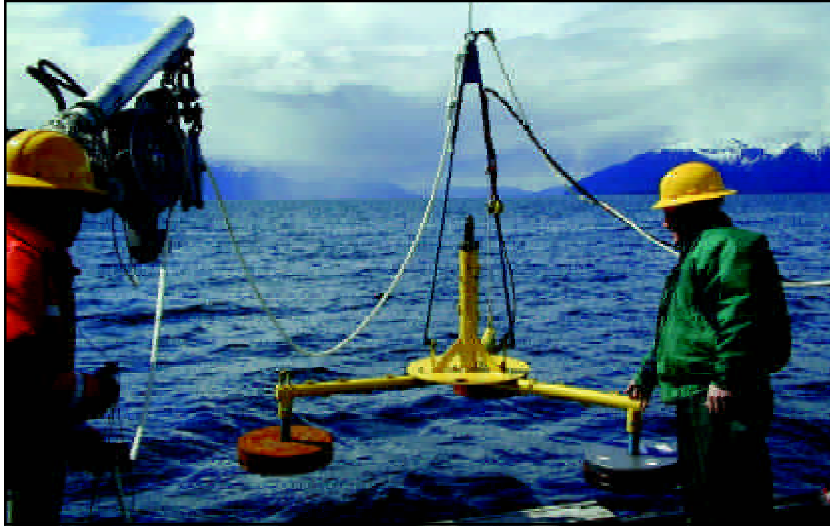
We listened from May 20, 2000, to March 8, 2001, and from July 13, 2001, to June 20, 2002. Although the acoustic monitoring system is automated to make 30-second ambient noise recordings on a set schedule, longer recordings of whale vocalizations could only be made if a person was there to detect the song and make a recording. Acoustic monitoring effort varied during the summer months because staff were in the field several days per week but was more consistent at 30–40 hours per week from September through March. No acoustic monitoring was possible between March and late June 2001 because of equipment problems, so we did not have the chance to detect spring singing as whales arrived in the area. However, acoustic monitoring in March through mid-June 2002 detected no whale song.

Tail flukes of a mature male humpback whale first identified in the Glacier Bay area in 1978.



Comparison to Hawaii Recordings

We compared the highest-quality Alaska recordings with a small sample of songs recorded off the



A hydrophone, mounted on a customized aluminum anchor, being installed in Glacier Bay.

whales' winter range in the Hawaiian Islands in the winter of 2000 and 2001, and we measured their degree of similarity on a variety of acoustic parameters. We extracted individual song units (notes) from the digitized recordings using customized detectors written in Matlab computer software. We used the computer program Acoustat, developed at Woods Hole Oceanographic Institution, to make 97 measurements of each unit's frequency, temporal, and contour characteristics. We used a SAS (Statistical Analysis System) principal components analysis to reduce the dimensionality of the measurements, determining how many principal components accounted for 80% of song unit variance. A SAS discriminant analysis classified the resulting 18 principal components by year and region.

Glacier Bay Song Characteristics

We discovered that humpback whales frequently sing while they are in the Glacier Bay area in August–November. We heard no song earlier than August, despite the presence of whales. We heard no song later than November, probably because the whales had left the area. Humpbacks probably continue to sing after November, resulting in the songs heard during migration by other investigators monitoring vocalizations in the open ocean in the North Atlantic and North Pacific. Acoustic monitoring continued approximately 40 hours per week through mid-January 2001 and 2002, but no additional whale songs were heard. The absence of song in the spring of 2002 as whales moved back into the Glacier Bay area suggests that song is not as prevalent in spring as it

is in the late summer and fall.

The songs we heard were solos, not the multi-whale chorus that is typical in the wintering grounds. We rarely heard any other whale vocalizations in the background, although feeding whales can be quite vocal. On eight occasions, song sessions were preceded by or ended with episodes of unstructured vocalizations. Song sessions were much shorter than reported in the Hawaii wintering grounds, where whales commonly sing continuously for hours. The longest song session observed during this study was on November 8, 2000, when a single whale sang almost continuously for 4.5 hours; most sessions were much shorter. Song sessions were quite variable in length and were significantly longer in 2000 than in 2001. Singers recorded in 2001 also tended to be farther away from the hydrophone than singers in 2000, based on the apparent loudness and quality of the recordings. Both the apparent decrease in singing in 2001 and their increased distance from the hydrophone were probably due to a lack of whales in the area, based on population monitoring in lower Glacier Bay during the summer and fall.

Hawaii and Alaska songs from the same year were similar. Statistical analysis quantified this similarity by using the song unit measurements to blindly assign a given unit or "note" to a particular region and year. Hawaii 2001 and Alaska 2000 and 2001 were similar to one another, as measured by the number of times that song units from one area and year were misclassified as being from a different area or year. Alaska 2000 and 2001 song units were quite similar, because they were the most frequently mistaken for one another. Hawaii 2000 song units were so distinct from the other areas and years that they were rarely misclassified. However, we had only one recording of Hawaii song for each year, so we couldn't draw definitive conclusions about which areas and years were most similar to each other. We collected song recordings in Hawaii in 2002 and plan to continue these analyses with additional data in the future.

The song unit measurements also showed that Hawaii and Alaska songs were statistically distinct

Statistics on song occurrences in Glacier Bay, 2000 and 2001.

	2000	2001
No. of Days Song Observed	18	11
No. of Hours of Song Observed	21.9	2.8
Date of First Song	Aug. 29	Aug. 23
Date of Last Song	Nov. 16	Nov. 9
Mean session length in minutes	73.1	15.7
Maximum session length in minutes	270	48

Song unit similarity by region and year shown by principal components classification of song units. Cells contain the number of observations (% classified). Misclassifications of song units from one region-year into a different region-year indicate similarity. Song units for a given region-year were correctly classified 46–86% of the time. Hawaii 2000 song units were rarely misclassified.

	Alaska-2000	Alaska-2001	Hawaii-2000	Hawaii-2001	TOTAL
Alaska-2000	605 (60.87)	238 (23.94)	0 (0)	151 (15.19)	994 (100)
Alaska-2001	7 (33.33)	14 (66.67)	0 (0)	0 (0)	21 (100)
Hawaii-2000	9 (9.00)	3 (3.00)	86 (86.00)	2 (2.00)	100 (100)
Hawaii-2001	4 (30.77)	2 (15.38)	1 (7.69)	6 (46.15)	13 (100)

Song unit distinctiveness by region and year shown by discriminant analysis Mahalanobis Distances (and their probabilities). All region-year combinations were statistically significant except Alaska 2001 vs. Hawaii 2001, probably because of the small Hawaii sample size.

	Alaska-2000	Alaska-2001	Hawaii-2000	Hawaii-2001
Alaska-2000	0	1.6 (0.021)	20.6 (0.0001)	2.3 (0.047)
Alaska-2001	1.6 (0.021)	0	21.8 (<0.0001)	3.5 (0.0748)
Hawaii-2000	20.6 (0.0001)	21.8 (<0.0001)	0	22.4 (<0.0001)
Hawaii-2001	2.3 (0.047)	3.5 (0.0748)	22.4 (<0.0001)	0

Sample phrases from Alaska and Hawaii humpback whale songs show the similarity between areas and years. Sound spectrograms show changes in pitch (frequency) over time, with louder sounds appearing darker.

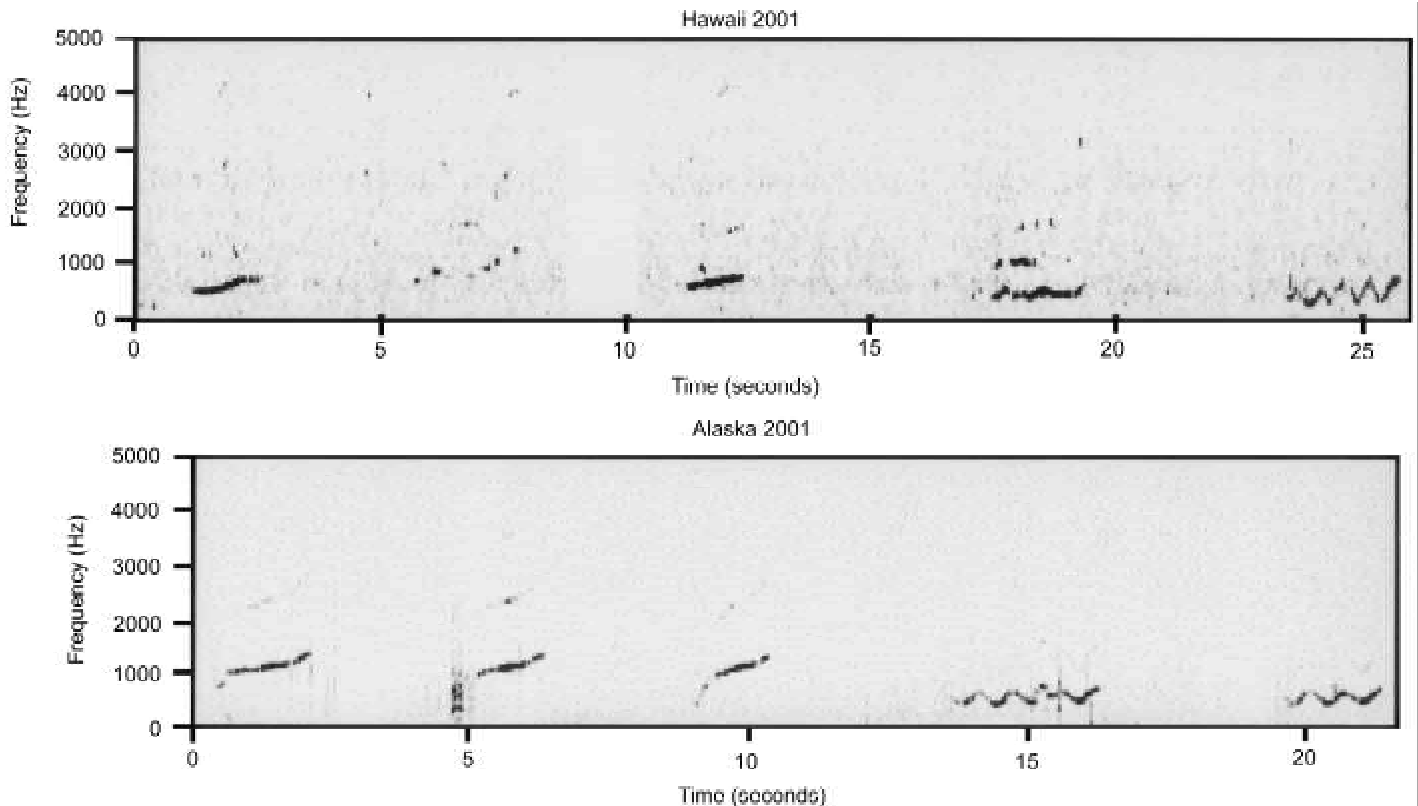
from one another by year and area, as shown by a statistical technique called discriminant analysis Mahalanobis Distances. Some of the distinctiveness comes from the individual variability of singers. Within the Alaska samples, there was enough song unit variability to suggest that several singers were recorded. However, the similarity between the highest-sample-size areas of Alaska 2000 and

2001 indicates that individual differences probably do not account for all the variance shown.

Comparisons With Previous Studies

Prior to this study, humpback whale songs had rarely been recorded in Alaskan waters. In one study in southeastern Alaska, researchers reported hearing singing from one or more whales in a group in late December 1979 and early January 1980. In a different study, researchers detected only two occurrences of humpback whale song in five summers of effort and concluded that whale song in southeastern Alaska was rare. Two factors probably account for the difference from our results. First, we suspect that these investigators did not monitor in September and October, although the dates of their monitoring were not specified. Second, our study used passive acoustic monitoring of a remote hydrophone, allowing us much greater acoustic monitoring effort and giving us much greater flexibility with regard to weather, sea conditions, and daylight.

The humpback whale songs we recorded in Glacier Bay occurred earlier and were much more prevalent than songs previously documented in



Visit the *Glacier Bay National Park* web site to listen to recordings of whale vocalizations made during this study and learn more about acoustic monitoring and the humpback whale population study: <http://www.nps.gov/glba/learn/preserve/projects/index.htm>

For additional information on whale sounds and the effects of man-made sounds, look at the web site for the *Bioacoustics Research Program at the Cornell University Laboratory of Ornithology*: <http://www.ornith.cornell.edu/brp/ResWhale.html>

Disturbed humpback whales are more likely to perform aerial behavior, like this head-slap. (This photograph was taken during research authorized under National Marine Fisheries Scientific Research Permit #945-1499-00.)



any feeding area. Humpback whales appear to sing quite commonly in late summer and fall in Glacier Bay, corroborating research findings from Stellwagen Bank (off Cape Cod) of whale songs in November and May. However, it is not clear why southeastern Alaska song began in late August, while the Stellwagen Bank song was not observed until November, since humpbacks are present in both areas throughout that time period. Details of acoustic monitoring effort in the Stellwagen Bank study may reveal the source of this difference.

Autumn Humpback Whale Song in High Latitudes

Based on our results, it appears that (presumably male) humpbacks sing sporadically between feeding bouts in the autumn. Since we have no visual observations of the singers we recorded, we can say very little about their behavior or the presence, proximity, or identity of other whales in the vicinity. Humpback whale song in mid-summer appears to be rare or nonexistent, although other vocalizations are heard. Our acoustic monitoring effort was lower in the summer, but we do not believe this accounts for the lack of songs in May through late August. We predict that with sufficient acoustic monitoring effort, song recordings could be made in any area where humpback whales congregate in the autumn.

We speculate that the increase in song in late summer and fall corresponds with the beginning of seasonal hormonal activity in male humpbacks prior to the migration to the winter grounds. During twentieth-century whaling, studies of the

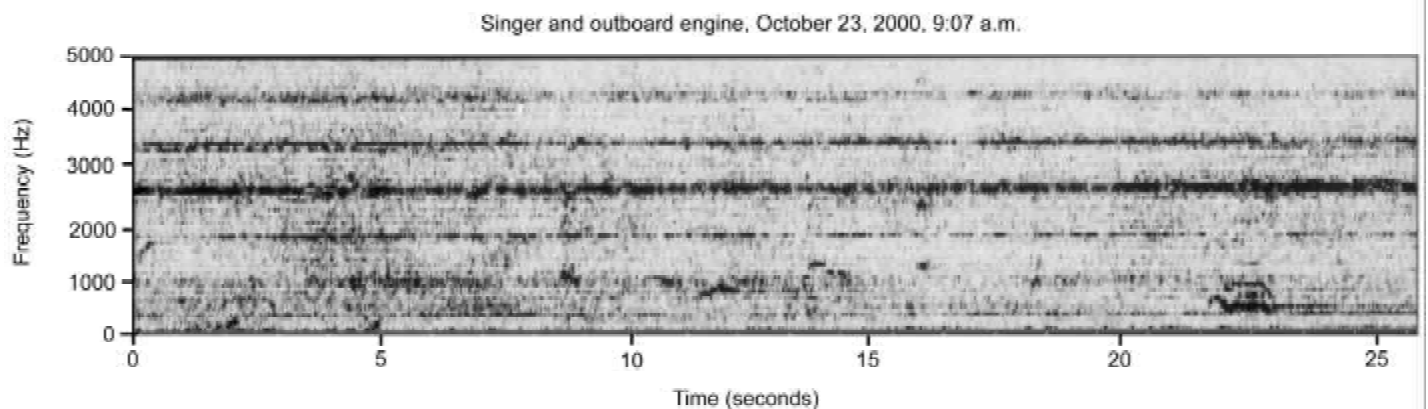
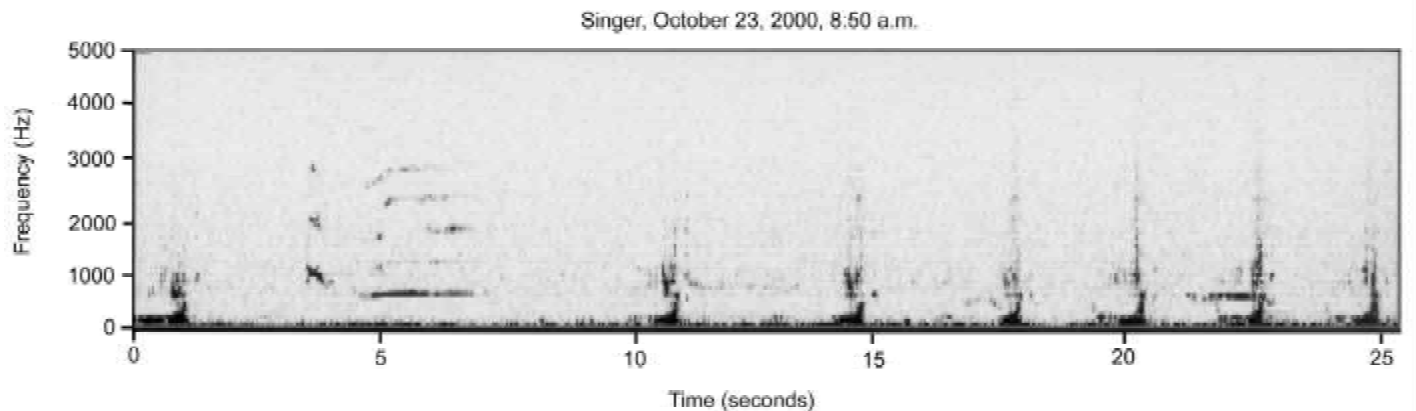
reproductive tracts of male humpbacks revealed that testis weights in the wintering areas are much greater than in the feeding areas. Behavioral indications of increased male hormonal activity in the autumn are probably often subtle, but overt observations have included singing and agonistic behavior between whales in Sitka Sound in December and January (observed by University of Alaska Southeast researcher Jan Straley) and a known mature male apparently pursuing a known mature female in Glacier Bay in September.

We do not know whether autumn humpback whale songs or other behaviors directly result in reproductive success. It is also unknown whether the prevalence of humpback whale song in Alaska indicates that the full range of mating behavior occurs in the autumn and winter in high-latitude waters. Recent findings by Straley indicate that some male and female humpbacks of various ages overwinter in southeastern Alaska. The occurrence in southeastern Alaska of humpback whale singing and other behavior typical of the mating season may indicate that even when mature males and females forgo migration they may not be sacrificing the opportunity to mate. We hope that continued investigations will shed light on the importance of high-latitude song to humpback whale mating strategies.

Implications for Human Impacts on Whale Habitat

Reports by the National Research Council indicate growing concern about the effects of man-made noise on marine mammals. The underwater acoustic monitoring program that made our study possible originated from concerns that vessel-generated noise could harm endangered humpback whales in Glacier Bay. Baleen whales such as the humpback could be considered auditory specialists, because their acute hearing appears to be essential to their ability to navigate, socialize, detect predators, and find food and mates. These whales seem to rely more on acoustic cues, which can travel for miles, than visual cues, which are limited by underwater visibility, especially in plankton-rich feeding habitats such as Alaska.

Adding man-made noise to typical ocean noise originating from wind and rain makes it harder for whales to hear vocalizations, interferes with passive listening for predators and prey, and can change vocal behavior. For example, studies have shown increases in humpback whale song tempo



Spectrograms of humpback whale songs in Glacier Bay before (top) and during (bottom) pass-by of a vessel with an outboard engine in close proximity. In the bottom spectrogram the whale song is dimly visible in the background of the strong horizontal lines near 300 Hz, the dominant frequencies of the outboard engine noise. To hear these and other examples of whale sounds, visit the Glacier Bay National Park web site.

and length in the presence of vessel noise and other man-made sound sources. Typical non-vocal reactions of whales to disturbance include changes in swim speed and respiration as well as increases in the occurrence of aerial behavior. Now that we know that humpbacks sing in Glacier Bay, we wonder about the potential effects of vessel noise on singers and listeners. An outboard engine passing by at close range can almost completely overshadow a whale song. Underwater noise pollution is an important form of habitat degradation for marine species, becoming ever more pervasive as human use of coastal and offshore waters increases. Continued research into the functions of whale vocalizations, and the effects of man-made noise on the production and reception of sounds, will help focus concerns about the recovery and long-term conservation of many species of endangered whales.

Suggestions for Further Reading

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