Glacier Bay Underwater Soundscape

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Abstract. Are humpback whales and other marine animals that frequent Glacier Bay adversely affected by underwater sounds resulting from human activities? Will underwater noise levels be significantly affected by changes in vessel visitation patterns? Before questions such as these can be addressed, the manmade and naturally occurring underwater noise in Glacier Bay must be measured and characterized, i.e. the underwater soundscape must be defined. This paper discusses the results of a two-year underwater sound monitoring project that was conducted in lower Glacier Bay where the prevalence and magnitude of manmade and naturally occurring underwater sounds was determined.

Introduction

This paper is part of an ongoing collaborative project between Glacier Bay National Park and Preserve, Gustavus, Alaska, and the Naval Surface Warfare Center Detachment in Bremerton, Washington, to characterize Glacier Bay's underwater acoustic environment. To date this project has consisted of the direct measurement of underwater sound from cooperative vessels, and the collection and analysis of automatically collected sound samples from a single point in lower Glacier Bay. This paper addresses the results of the latter effort.

Typical underwater ambient noise fields in open water environments are variable in terms of noise levels and contributing noise sources. At any given time and location the observed acoustic noise field may be entirely due to natural sources such as wind-generated surface noise. Then, within a matter of minutes, noise from marine vessel operations may become the primary contributor of noise energy. Sounds from marine life may also contribute to the observed underwater sound spectrum.

For this investigation, underwater acoustic energy originating from biologic sources such as whales is important. In lower Glacier Bay, humpback whales, and occasionally killer whales, are the main biologic sources of underwater noise that are observed.

Manmade noise in Glacier Bay is primarily due to motorized marine vessel traffic. Typical vessels range from small outboard engine-powered pleasure craft, work-boats, and open skiffs; to fishing boats with inboard diesel engines; to small 200-foot cruise ships; to large cruise ships over 600 feet in length.

The goal of this project was to establish the relative importance of these sources in lower Glacier Bay's underwater sound environment. To accomplish this end, the prevalence and seasonal occurrence of each of these sources was assessed and related underwater sound level statistics were developed.

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Methods

Since May 2000, a hydrophone has been continuously monitoring underwater sound levels along the eastern side of lower Glacier Bay, just south of the entrance to Bartlett Cove. The hydrophone is connected to a shore-based data acquisition system that acquires a 30-second underwater sound sample once per hour, 24 hours per day. Almost 10,000 hourly underwater sound samples were obtained during 20 months between August 2000 and August 2002. These samples were archived and later retrieved for analysis and entry into a database. Using these data, underwater noise level trends were investigated and typical sources of underwater sound were identified. Some of the issues of interest included: contributions, types, and prevalence of natural and manmade sources of underwater noise, including frequency of occurrence and types of sound from marine life. Seasonal trends of underwater sounds were also of interest.

Results

Naturally occurring and manmade underwater sounds contributed to the overall underwater sound environment of Glacier Bay. At times only one source of underwater sound dominated the environment; at other times a combination of sounds was present. The primary sources of underwater sound in Glacier Bay were: sound from wind agitation of the water surface, rain noise, biologic related sounds such as humpback whale sounds, and sound from operation of motor vessels.

The primary contributor of natural underwater sound was wind-generated surface noise, which averaged 84 dB (one-third octave band level re 1 microPa at 1 kHz) and ranged from 67 to a maximum of 102 dB. Figure 1 shows the statistical distribution of all of the sound samples that were dominated by wind noise. The distribution shows that a substantial proportion (40 percent) of levels occurred in the 84 to 90 dB range. Additional results regarding distribution of wind noise levels include: (1) 52 percent of logged wind noise levels occurred at levels above the mean level of 84 dB, (2) 47 percent of logged wind noise levels were below the mean, (3) 27 percent of logged wind noise levels occurred in a 6 dB range centered about the mean (i.e. 84 dB+/-3 dB).

Noise due to rainfall was present in an average of 2.1 out of 24 samples per day and was not especially prevalent in winter versus other seasons. Rain noise levels at 16 kHz averaged 91 dB and ranged as high as 110 dB.

Humpback whales were the most common source of biologic sounds. These sounds included various grunts, whoops, and squeaks as well as songs. Killer whale sounds were also observed in a number of samples. Humpback whale sounds were present in more than three times the number of samples as killer whale and other biologic sounds. As shown in figure 2, humpback whale sounds were most common August through November, and 61 percent of all humpback songs were observed in October 2000.

The occurrence of humpback whale sounds correlated well with humpback whale survey data collected by NPS, especially August to September 2000. Months where humpback whale sounds were frequently logged corresponded to periods where NPS personnel observed whales in lower Glacier Bay and also when the 10-knot whale waters speed limit was in effect. Also, particularly in 2000, whale sounds were frequently observed in October and November, after the NPS whale-surveying season concluded.

By far the most prevalent source of identifiable manmade noise in this study was related to operation of motorized marine vessels. The statistical distribution of peak vessel noise levels in figure 1 shows that the average level was 94 dB, 10 dB greater than the average wind noise level. The highest vessel level recorded was 129 dB, but only about 5 percent of the peak vessel noise levels exceeded 110 dB at the hydrophone.

As expected, vessel noise was most common during summer. Figure 3 shows that in summer, about 40 percent of the noise samples were free of vessel noise; however, in winter, October through April, roughly 90 percent contained no vessel noise. In May and September, approximately 60 percent of the samples were free of vessel noise. On average, over the entire survey period, 7.7 out of 24 samples per day contained vessel noise. The rate of vessel noise presence ranged from a low of 1.7 samples per day (out of 24 samples per day) in December 2000 to a high of 16.5 in August 2000.

Vessel sounds were categorized by vessel size: small, up to 50 feet in length; medium, 50 to 200 feet; and large, over 200 feet. Figure 4 shows that medium sized vessels were the most prevalent vessel type, which was true for all times of year. They constituted 68 percent of all vessel types observed. At most, large ships were observed in four samples per day. Noise from small craft was most common from May to August.

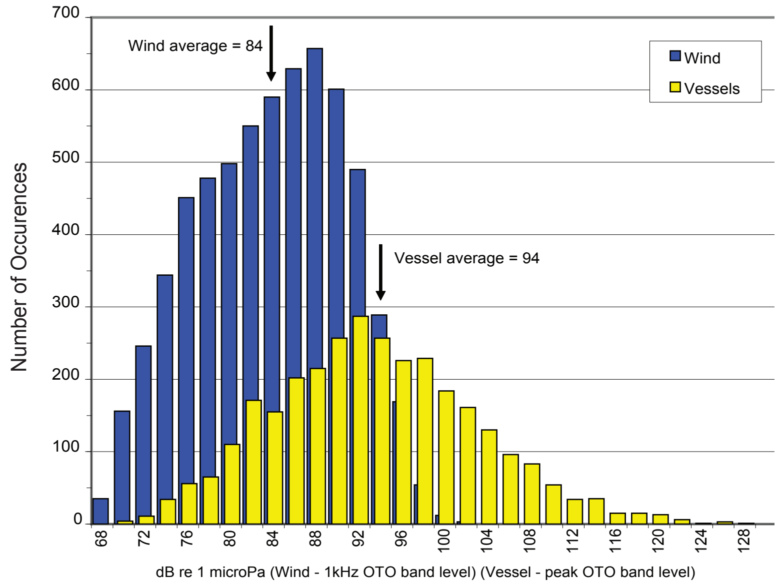

Figure 1. Distribution of underwater sound levels—wind vs. vessels.

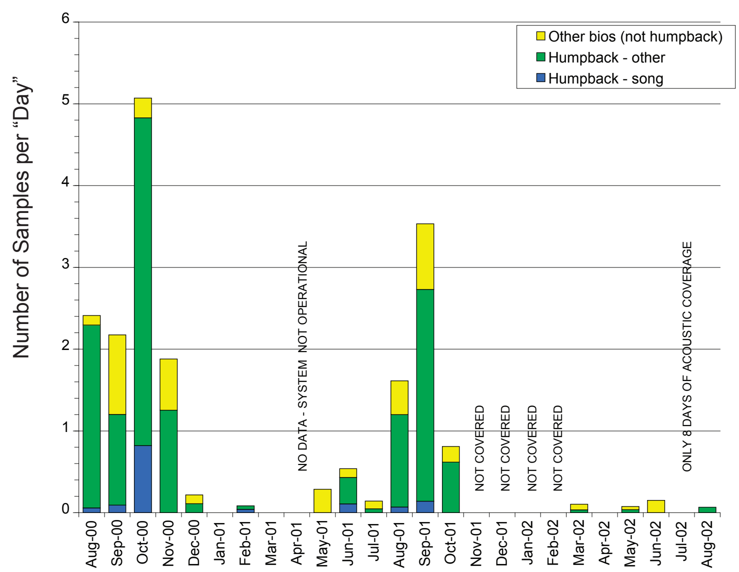

Figure 2. Samples per day containing biologic sounds.

On average, large vessels were slightly louder at the hydrophone than medium and small craft. Large vessels averaged 99 dB, while the average noise levels for medium and small vessel were 92 and 97 dB, respectively. The maximum large vessel level was 129 dB. The maximum level for both medium and small vessels was 126 dB.

Vessel noise levels were lower during periods when a 10-knot speed limit was in effect, especially for large and small vessels. In August 2000 and August 2002, average noise levels for large and small vessels were 2 to 4 dB lower during the 10-knot period compared to the 20-knot period. The average 10 and 20-knot medium vessel noise levels were comparable. Maximum vessel levels for a given vessel category were as much as 9 dB lower when the 10-knot speed limit was in effect.

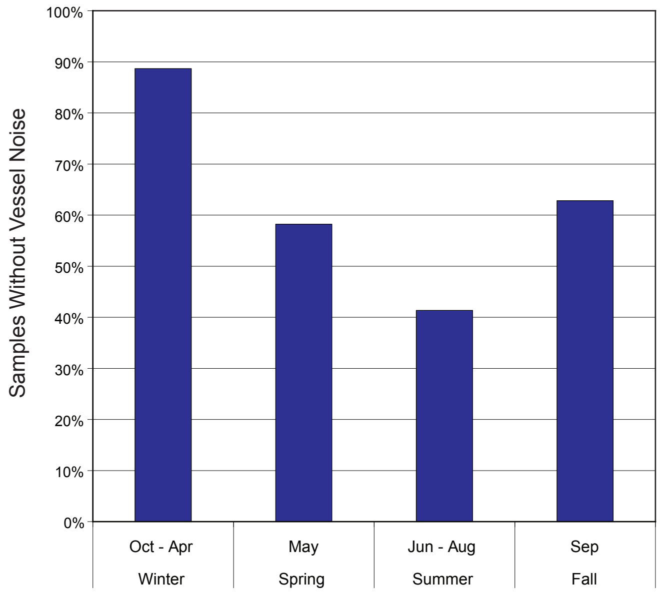

Figure 3. Proportion of ambient noise samples without vessel noise by season.

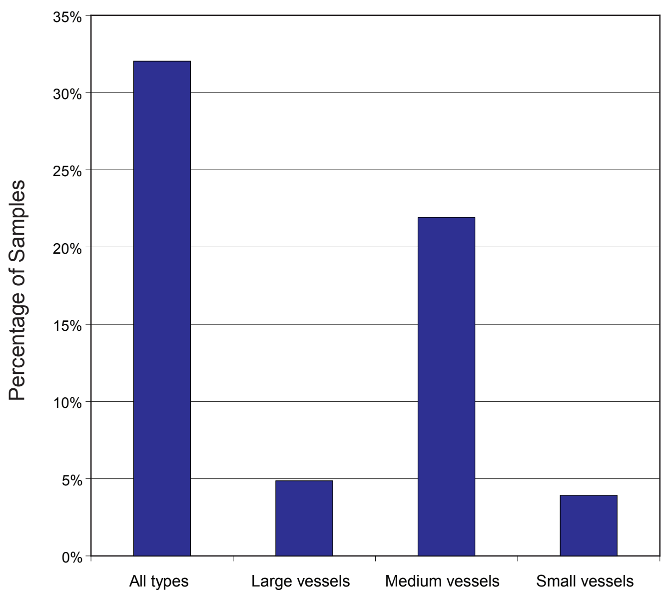

Figure 4. Samples containing vessel noise by type.

Discussion and Conclusions

This study has expanded the knowledge of the sound environment in lower Glacier Bay. The types, prevalence, seasonal occurrence, and intensity of natural and manmade underwater sounds have been established, as detailed in the previous section. The next step is to combine these results with knowledge of underwater sound propagation and marine animal hearing capabilities and sensitivities to assess potential acoustic impacts.

Some further soundscape characterization is recommended. For the seasons covered by this study, humpback whale acoustic activity was variable from year-to-year depending on changes in whale presence in lower Glacier Bay. Because of this variability, it is recommended that acoustic monitoring and noise trend investigation continue for fall 2002 data and for August to November 2003 and perhaps beyond, to determine if typical humpback whale acoustic patterns can be established.

Management Implications

While this study has made significant progress toward defining the soundscape in lower Glacier Bay, a better understanding of the hearing capabilities of marine animals and their behavioral reactions to sound is required before specific management guidelines can be formulated. However, some general guidelines may be offered:

1. Vessel noise prevalence, presence of some species in Glacier Bay, and acoustic activity of specific species are seasonal. For example, humpback whale sounds were most prevalent in late summer and early fall in the lower bay, which may be an important time of year for whale communication via underwater sound. Awareness of these trends may help formulate management policy.

2. Vessel speed limits in whale waters measurably reduced vessel noise levels, on average, and most vessel sound levels exhibited significant speed dependence. Speed limits can be beneficial from an underwater sound management perspective.

3. Even though some vessel types were, on average slightly louder or quieter than other types, the differences were not substantial enough, nor is present knowledge of other bio-acoustic factors sufficient, to warrant discrimination by vessel type for acoustic reasons.

4. Vessel noises, and biologic sounds, are more likely to be masked by naturally occurring surface generated sound on windy days.

The soundscape data obtained through this study established an important foundation for addressing a number of "what if" questions that park managers might face. Such questions might include: At what distance would vessel sound be effectively masked by natural sound sources? To what degree would acoustic communications between marine mammals be masked by manmade sound sources versus natural sources? Addressing all such hypothetical questions is not practical here, but the knowledge gained through this study has the potential to be used to answer, or at least bound, a variety of management questions related to underwater sound in the park.

Acknowledgments

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Notes

Note that the underwater sound decibel scale is different than the more familiar in-air decibel scale. This means that a 100 dB in-air sound does not represent the same intensity level as a 100 dB in-water sound. In fact, the in-water intensity level is lower than for the equivalent in-air dB value. As a result, until becoming familiar with the in-water dB scale, one must resist the temptation to interpret in-water sound levels based on experiences with the in-air scale.

The sound levels in this paper are one-third octave band levels in dB re 1 microPa as measured at the hydrophone face. They have not been adjusted to account for distance from the sound source. For point sources such as marine vessels, the measured noise levels depend strongly on the distance from the source to the hydrophone. For this reason, the measured levels are *received levels*, not *source levels*. In a sense, they represent the sound one would experience at a single location in lower Glacier Bay.

Suggested Citation

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Crillon Lake, looking northeast toward Crillon Glacier. (Photograph by Bill Eichenlaub, National Park Service.)