# Underwater Noise from Skiffs to Ships

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**Abstract.** How loud are the underwater sounds emitted by skiffs, work boats, tour vessels, and cruise ships? The answer to this question is an important element of any effort to assess potential impacts of vessel operations on marine life. It is also important from a vessel management standpoint as managers attempt to understand whether oversight of individual vessels, vessel types, and vessel operating conditions can help to control levels of manmade underwater sound. This paper details the results of an effort to establish underwater sound levels emitted by a variety of vessels that are common to Glacier Bay, Alaska. For these vessels, levels ranged from 157 to 182 decibels re 1 microPascal at 1-yard.

## Introduction

The underwater sound from 38 cooperating vessels was measured directly under controlled conditions between 1999 and 2003. Vessels ranging in size from 14 to 962 feet were evaluated, including outboard engine equipped skiffs and workboats, jet-powered cabin cruisers, diesel powered work boats and research vessels, tour vessels from 104 to 257 feet in length, and cruise ships above 600 feet in length. This paper contains an overview of the results of these measurements, which were conducted as 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. The data were collected as part of an effort to assess the impact of manmade underwater sound on Glacier Bay's underwater sound environment.

## Methods

Since May 2000, a hydrophone has been continuously monitoring underwater noise 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 was used to conduct the sound measurements for the vessels below 600 feet in length. The underwater sound levels of the large cruise ships were performed at the Navy's Southeast Alaska Acoustic Measurement Facility (SEAFAC) near Ketchikan, Alaska.

In both cases the vessels, with several exceptions, passed by the measurement hydrophones at a range of 500 yards and the sound level measurements were performed using calibrated hydrophones and measurement systems designed for this purpose. The water depth in the measurement area in lower Glacier Bay ranges from 100 to 220 feet. At SEAFAC the water depth is approximately 1,200 feet.

## Results

The underwater sound levels for these vessels ranged from 157 to a maximum of 182 dB re 1 microPascal at 1 yard for the 10-knot test condition. The sound levels reported here represent the sum of all of the acoustic energy present in the measured frequency band (i.e. from 10 to 35,000 Hz) for a vessel moving at 10 knots. Several vessels motored at speeds less than 10 knots, including: Ursa, 7 knots; Quintessence, 5 knots; tug, 7 knots.

In several cases the vessels passed by the hydrophone at ranges substantially different than the specified 500-yard distance. These data points are shown with white bars in figure 1 to distinguish these data from the standard 500-yard data points. Even though the distances were different, their actual ranges to the hydrophone were used to correct the measured levels to 1-yard levels.

To examine the potential for dependence of sound levels on vessel size, the sound levels shown in figure 1 were grouped into vessel size categories and graphed as shown in figure 2. The data points in figure 2 represent the average sound levels for each category with the bars indicating the minimum and maximum levels. The data point for the *more than 600 ft* category is shown in a different color because these data were collected at the Navy's Ketchikan, Alaska facility where the water depth is substantially greater. Until the authors can be satisfied that the difference in the measurement locations did not have a significant effect on the large vessel data points, these levels will be treated with caution for comparison purposes.

In a number of cases, vessel sound levels were measured for more than one speed condition. Vessel sound levels generally increased substantially with speed, as shown in figure 3. Speed dependence was more dramatic for some vessels than others. Possible exceptions included several of the diesel-electric cruise ships. While these ships showed increased propeller noise at higher speeds, in some cases their electric propulsion-related sound levels were relatively speed independent, or levels were lower at higher speeds.

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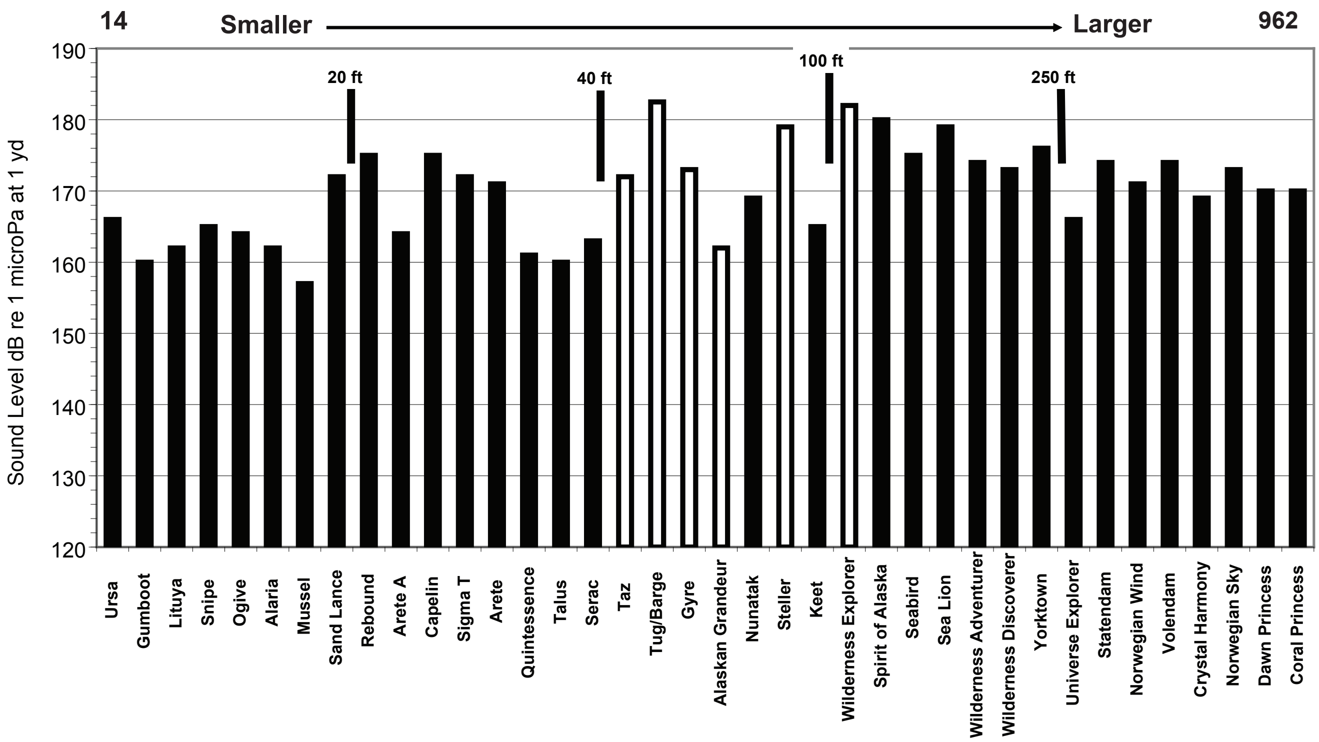


**Figure 1.** 10-knot sound level by vessel.

Vessel propulsion type and horsepower can also be important factors in the intensity of underwater sound emitted by powered vessels. Figure 4 shows that, for small vessels, underwater sound from propeller-powered craft were generally greater for higher horsepower vessels. It also shows that, for their power rating, the two jet powered vessels were noticeably quieter than their comparably powered propeller-driven counterparts.

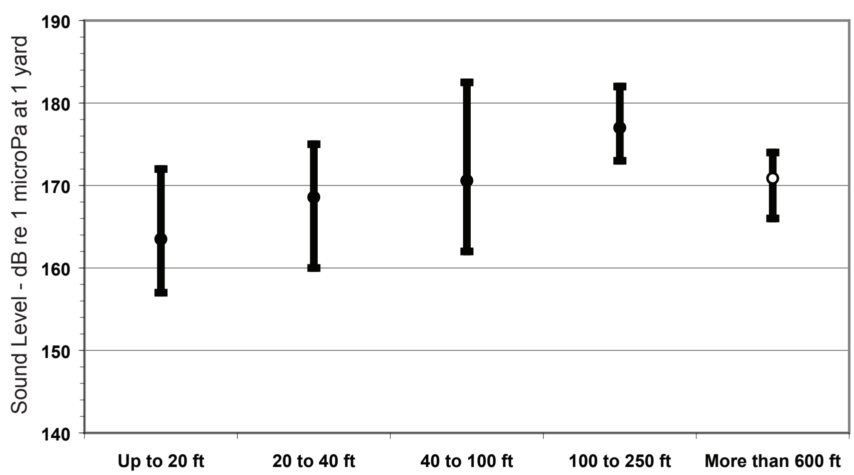


**Figure 2.** Range of 10-knot sound levels by vessel category.

## Discussion and Conclusions

Under controlled measurement conditions, the 10-knot underwater sound levels ranged from a minimum of 157 to a maximum of 182 dB for the 38 vessels that were evaluated. Sound levels showed an increasing trend with increasing vessel size, with the large cruise ship category as one possible exception—although the authors are treating this data point with caution, as cited above. Most vessel noise levels increased with increasing speed. Also, vessel sound levels showed dependence on propulsion type and horsepower.

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. The in-water intensity level is in fact 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.

Also, the sound levels reported here are given as *1-yard source levels*, which means that the levels have been projected from the distance at which they were measured to the levels that one would measure at 1 yard from the vessel, if it were possible to do so. As a result, the levels that would be expected at reasonable distances from these vessels would be substantially lower than those listed here. For example, at 100 yards they would be expected to be about 40 dB lower than the 1-yard level, and about 53 dB lower at one-quarter mile.

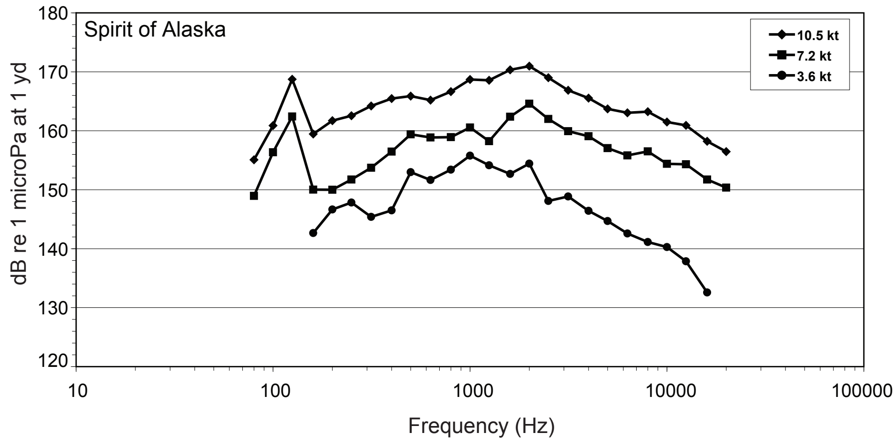


**Figure 3.** Representative speed dependence of underwater sound levels.

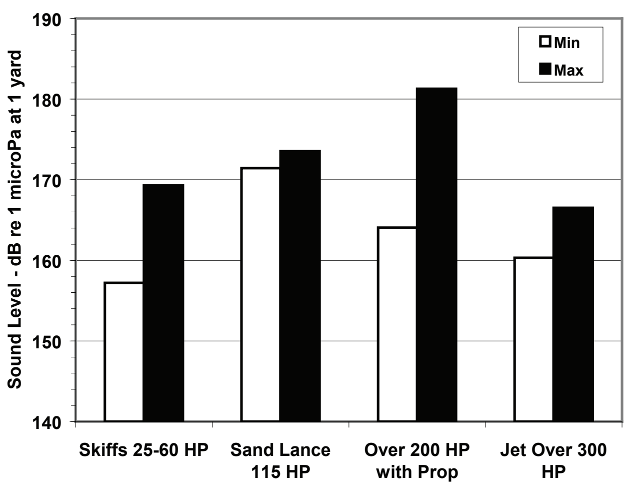


**Figure 4.** Range of sound levels by small craft type and power rating.

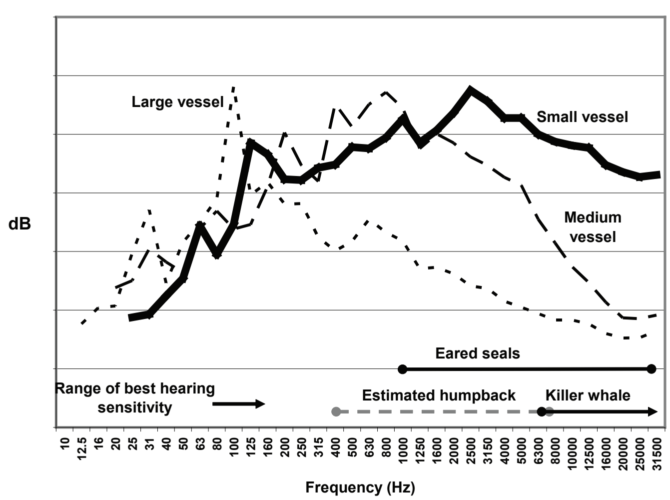


**Figure 5.** Representative underwater sound spectra.

It is also important to account for dependence of hearing sensitivity on frequency. Like humans, marine animals are more sensitive to sounds at certain frequencies. For this reason the distribution of sound as a function of frequency is an important factor when weighing the potential impacts of underwater sound. For example, a killer whale, which is more sensitive to higher frequency sounds, would be more likely to hear the high pitch sounds emitted by a high speed outboard engine than the low frequency rumble of a cruise ship, for the same sound levels in both cases. So, in addition to the overall sound level discussed above, which represents all of the sound energy emitted by a vessel, the vessel's underwater sound spectrum is also important. Representative sound spectra for three vessel types are shown in figure 5.

## Management Implications

While this study has expanded the knowledge of underwater sounds emitted by vessels that frequent the waters of 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. Small craft noise may be more important than large vessel noise, or vice versa, for certain animals;
2. Vessel speed is typically an important factor;
3. Vessel equipment, primarily propulsion type and horsepower, can be an important factor;
4. Sound levels were generally greater for larger vessels, but not in all cases, and the sound spectrum and hearing sensitivities of marine life must be considered when assessing potential impacts; and
5. Increasing the separation between vessels and marine life will reduce the level of noise exposure.

## Acknowledgments

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## Selected References

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