INVESTIGATING THE EFFECTS OF VESSEL TRAFFIC ON MARINE MAMMAL VOCALIZATIONS IN GLACIER BAY NATIONAL PARK AND PRESERVE

Principal Investigators' Final project report
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PROJECT ABSTRACT: Nearly all visitors to Glacier Bay National Park and Preserve arrive via motor vessels, yet critical information is lacking on the impacts of vessel noise on marine mammal vocal behavior and the role of acoustic communication associated with vital functions. This information gap hampers an adequate assessment of the impacts of vessel traffic noise on the underwater sound environment. During two field seasons of data collection in Glacier Bay National Park and Preserve, researchers from Oregon State University and Syracuse University collaborated with the National Park Service to use passive acoustic monitoring in conjunction with land-based visual observations to study the behavior and distribution of humpback whales and harbor seals in relation to Glacier Bay National Park and Preserve vessel traffic. Oregon State University and the National Park Service analyzed and interpreted these data and developed products that: (1) increased our understanding of the vocal behavior and fine scale distribution of two predominant marine mammal species in Glacier Bay National Park and Preserve, (2) quantitatively assessed acoustic properties of the Glacier Bay National Park and Preserve soundscape, (3) assessed the impact of vessel noise on the vocal behavior of these species, and (4) were used to raise awareness of the importance of the underwater soundscape to these marine mammals through a variety of outreach and educational tools.

SUMMARY OF PROJECT PRODUCTS:

Publications
Published

1. Matthews, LP, Parks, S, Fournet, MEH, Gabriele, CS ,Womble, J, and H. Klinck (2017). Source levels and call parameters of harbor seal breeding vocalizations near a terrestrial haulout site in Glacier Bay National Park and Preserve. Journal of the Acoustical Society of America, Express Letters. EL274-EL280.

   Abstract: Source levels of harbor seal breeding vocalizations were estimated using a three-element planar hydrophone array near the Beardslee Islands in Glacier Bay National Park and Preserve, Alaska. The average source level for these calls was 144 dBRMS re 1 lPa at 1min the 40–500Hz frequency band. Source level estimates ranged from129 to 149 dBRMS re 1 lPa. Four call parameters, including minimum frequency, peak frequency, total duration, and pulse duration, were also measured. These measurements indicated that breeding vocalizations of harbor seals near the Beardslee Islands of Glacier Bay National Park are similar in duration (average total duration: 4.8 s, average pulse duration (3.0 s) to previously reported values from other populations, but are 170–220 Hz lower in average minimum frequency (78 Hz).

2. LP Matthews, CM Gabriele, SE Parks (2017). The role of season, tide, and diel period in the presence of harbor seal (*Phoca vitulina*) breeding vocalizations in Glacier Bay National Park and Preserve, Alaska Aquatic Mammals 43 (5), 537

   Abstract: Glacier Bay National Park and Preserve is a marine protected area in southeastern Alaska that is home to one of the largest seasonal aggregations of harbor seals (*Phoca vitulina*) in the region. Harbor seals, like the majority of phocids, are an aquatically breeding pinniped species. During the breeding season, male harbor seals use acoustic signals to defend

underwater territories from other males and possibly to attract females. We used a long-term passive acoustic dataset to examine the trends in harbor seal vocal behavior near a terrestrial haulout as a function of season, tides, and time of day. Seasonality analyses indicated a sharp increase in vocal activity during the months of June and July, which correlates with the estimated timing of the breeding at this location. Contrary to previous studies, there was no effect of tidal height on the documented calling behavior of harbor seals at this location, perhaps because the recordings were made farther from shore, within 10 km of the major haul-out area. Diel analyses showed that harbor seal males call throughout the day, but, similar to other populations, calling significantly increased at night when more seals are foraging. This analysis provides evidence that specific environmental parameters play a role in harbor seal acoustic behavior in Glacier Bay and allows for behavioral comparisons among different harbor seal populations across the globe to guide future research efforts working to protect harbor seals during the breeding season.

3. Fournet, MEH, Matthews, LM, Gabriele , CM, Mellinger, DK, and H Klinck. (2018). Source Levels of foraging humpback whale calls. Journal of the Acoustical Society of America, Express Letters. 143(3) EL105-EL111.

   Abstract: Humpback whales produce a wide range of low- to mid-frequency vocalizations throughout their migratory range. Non-song "calls" dominate this species' vocal repertoire while on high-latitude foraging grounds. The source levels of 426 humpback whale calls in four vocal classes were estimated using a four-element planar array deployed in Glacier Bay National Park and Preserve, Southeast Alaska. There was no significant difference in source levels between humpback whale vocal classes. The mean call source level was 137 dBRMS re 1 lPa @ 1m in the bandwidth of the call (range 113–157 dBRMS re 1 lPa @1m), where bandwidth is defined as the frequency range from the lowest to the highest frequency component of the call. These values represent a robust estimate of humpback whale source levels on foraging grounds and should append earlier estimates.

4. Fournet, MEH, Gabriele , CM, Culp, DC, Mellinger, DK, Sharpe, F, and H Klinck.) (2018) Some things never change: multi-decadal stability of humpback whale (*Megaptera novaeangliae*) calling repertoire on Southeast Alaskan foraging grounds. Scientific Reports.

   Abstract: Investigating long term trends in acoustic communication is essential for understanding the role of sound in social species. Humpback whales are an acoustically plastic species known for producing rapidly-evolving song and a suite of non-song vocalizations ("calls") containing some call types that exhibit short-term stability. By comparing the earliest known acoustic recordings of humpback whales in Southeast Alaska (from the 1970's) with recordings collected in the 1990's, 2000's, and 2010's, we investigated the long-term repertoire stability of calls on Southeast Alaskan foraging grounds. Of the sixteen previously described humpback whale call types produced in Southeast Alaska, twelve were detected in both 1976 and 2012, indicating stability over a 36-year time period; eight call types were present in all four decades and every call type was present in at least three decades. We conclude that the conservation of call types at this temporal scale is indicative of multi-generational persistence and confirms that acoustic communication in humpback whales is comprised of some highly stable call elements in strong contrast to ever-changing song.

5. Fournet MEH, Jacobsen L, Gabriele CM, Mellinger DK, Klinck H. (2018) More of the same: allopatric humpback whale populations share acoustic repertoire. *PeerJ* 6:e5365 https://doi.org/10.7717/peerj.5365

Abstract**: Background** Humpback whales (*Megaptera novaeangliae*) are a widespread, vocal baleen whale best known for producing song, a complex, repetitive, geographically distinct acoustic signal sung by males, predominantly in a breeding context. Humpback whales worldwide also produce non-song vocalizations ("calls") throughout their migratory range, some of which are stable across generations. **Methods** We looked for evidence that temporally stable call types are shared by two allopatric humpback whale populations while on their northern hemisphere foraging grounds in order to test the hypothesis that some calls, in strong contrast to song, are innate within the humpback whale acoustic repertoire. **Results** Despite being geographically and genetically distinct populations, humpback whales in Southeast Alaska (North Pacific Ocean) share at least five call types with conspecifics in Massachusetts Bay (North Atlantic Ocean). **Discussion** This study is the first to identify call types shared by allopatric populations, and provides evidence that some call types may be innate.

6. Fournet, MEH, Matthews LP, Gabriele, CM, Haver, S, Mellinger, DK and H Klinck. (In press). Humpback whales (*Megaptera novaeangliae*) alter calling behavior in response to natural and manmade sounds. Prepared for Marine Ecology Progress Series. https://doi.org/10.3354/meps12784

Abstract: Acoustically adept species in the marine environment have to contend with complex and highly variable soundscapes. In the ocean today, sounds from human sources contribute substantially to the underwater acoustic environment. We used a 4-element hydrophone array in Glacier Bay National Park to (1) identify primary drivers of ambient sound in this region, (2) investigate whether humpback whales (*Megaptera novaeangliae*) exhibit a Lombard response in response to ambient noise, and (3) investigate whether humpback whales adjust their calling activity in response to naturally-occurring and vessel-generated sounds We found that cruise ships and tour boats, roaring harbor seals (*Phoca vitulina*), and weather events were primary drivers of ambient sound levels and varied seasonally and diurnally. As ambient sound levels increased, humpback whales responded by increasing the source levels of their calls (non-song vocalizations) by 0.81 dB (95% CI 0.79 -0.90) for every 1 dB increase in ambient sound. There was no evidence that the magnitude of the observed response differed between natural sounds and man-made sounds. We also found that the probability of a humpback whale calling in the survey area decreased by 9% for every 1 dB increase in ambient sound. Controlling for ambient sound levels, the probability of a humpback whale calling in the survey area was 31-45% lower when vessel noise contributed to the soundscape than when only natural sounds were present.

In Prep

7. Fournet, MEH, Williams, L*, Klinck, H, and CS Gabriele. (in prep.) Fine scale spatial ecology on a humpback whale foraging ground. Prepared for Journal of Cetacean Research Management.

Abstract: Glacier Bay National Park and Preserve is a managed tourism destination and wilderness area that hosts a resident population of North Pacific humpback whales (Megaptera novaeangliae) and human visitors. As competition for space and resources between marine mammals and humans increases management of whale-human interactions becomes a necessity. Effective prevention of negative impacts on vital life functions of humpback whales and simultaneous preservation of human visitor experience is contingent on an understanding of how humpback whale space use relates to behavior. In this study we collected fine-scale behavioral and spatial data of humpback whales in the Beardslee Island complex in Glacier Bay, Southeast Alaska. Humpback whale behavior states were quantified and habitat use compared between foraging and traveling whales. Kernel density analyses revealed three discrete foraging

core regions connected by a single travel corridor (0.5 quantile). Significant differences in depth, slope, and occupancy range were observed between traveling and foraging whales (p= 2.2e-16). The results of this study indicate that space use varies by behavior state; foraging whales spread out along shallow, low velocity waterways, often within tidal headlands. Traveling whales were consistently concentrated crossing perpendicular to a single deep, high velocity channel. Managers can use the results of this study to implement vessel restrictions that reduce the likelihood of interrupting vital life functions, like foraging, and to anticipate humpback whale travel corridors.

8. Fournet, MEH, Culp, DC*, Klinck, H and CM Gabriele. (in prep.) Aerial sound production in Southeast Alaskan humpback whales. Prepared for the Journal of the Acoustical Society of America.

Abstract: It has been noted that humpback whales (*Megaptera novaeangliae)* produce blowhole generated aerial sounds throughout their migratory range. To date, no attempt to quantify these aerial sounds has been attempted, and the number of discrete sounds and their acoustic properties has not been described. A thorough description of these sounds is essential for investigating whether these sounds are produced intentionally, whether they are a byproduct of physical exertion, or whether they convey motivational content. This study investigates aerial sounds produced by humpback whales in Glacier Bay National Park and Preserve using data collected during the month of July 2016. Samples of 113 aerial sounds were analyzed using a three-part classification system, including aural visual analysis, statistical cluster analysis, and discriminant function analysis to describe and classify sounds. This study demonstrates that Southeast Alaskan humpback whales produce at least four unique aerial sounds that vary in degree of stereotypy. Based on this level of acoustic discretion we propose that at least one call type, the aerial purr, may serve a communication function.

9. Matthews, LP, Fournet, MEH, Gabriele, CM, Womble, J, Klink, H, and S Parks. (in prep). Vessel noise affects the reproductive advertisement behavior of an aquatically breeding pinniped. Prepared for PeerJ

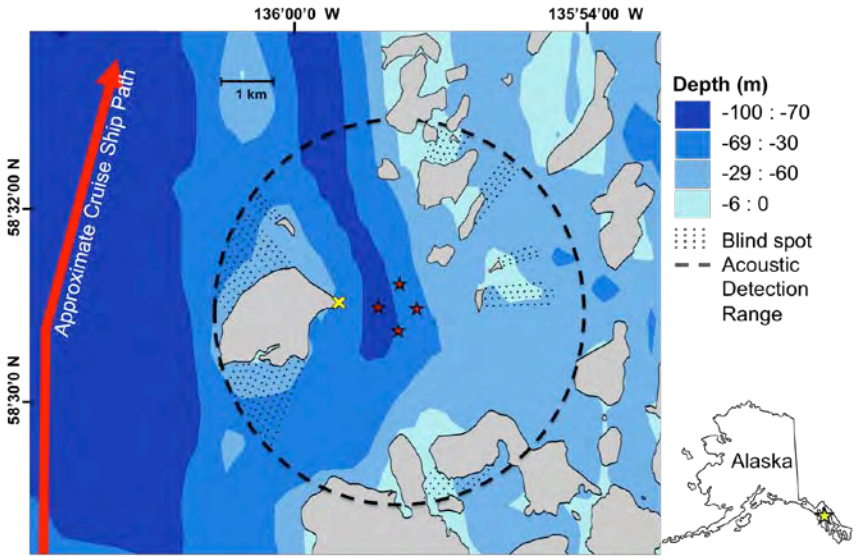
Abstract: The impacts of anthropogenic noise on marine mammals have been a major research focus for many years. However, little attention has been given to the potential for underwater noise to disrupt the mating behavior of pinnipeds. The majority pinniped species, including harbor seals, mate underwater and can be exposed to noise during this critical time. During the harbor seal breeding season, some males establish underwater territories and use vocalizations to defend these areas against intruder males and possibly to attract females. This study used passive acoustic monitoring to examine the vocal behavior of harbor seal males in Glacier Bay National Park and Preserve, Alaska and determine whether anthropogenic noise, specifically from passing vessels, affects breeding vocalizations. Vocalizations of individual males were examined before, during, and after vessel passages to assess changes in the source level, several call parameters (minimum frequency, peak frequency, total duration, and pulse duration), and call rate. In the presence of vessel noise, the source level and the minimum frequency of vocalizations increased. The total duration and pulse duration of vocalizations decreased during vessel passages and the calling rate was lower after vessel passages than before. We suggest that these changes in vocal behavior in the presence of vessel noise may alter the ability of males to hold underwater territories or attract females.

Datasets

Acoustics

Continuous acoustic array recordings (4-elements) from May 28, 2015- October 29, 2015 & April 29, 2016- October 28, 2016 stored on hard drives in Glacier Bay National Park headquarters (see Figure 1 for locations). Also archived at Oregon State University on the OSU/NOAA Cooperative

Institute for Marine Resource Studies server, and the Cornell Bioacoustics Research Program server.



Behavior/Visuals

Scan point surveys, focal follow surveys, and shore based photo ID for whales and harbor seals were conducted from June 22, 2015 – August 4, 2015 and June 27, 2016 – August 9, 2016. These data are archived on hard drives at Glacier Bay National park headquarters, and are backed up at the Cornell Bioacoustics Research Program.

Academic Outcomes

Dissertation: Matthews, LP. Harbor seal (*Phoca vitulina*) reproductive advertisement behavior and the effects of vessel noise. Defended May 2017, Syracuse University

Dissertation: Fournet, MEH. Investigating the impact of vessel noise on humpback whale calling behavior in Southeast Alaska: a study in acoustic ecology. Defended May 2018, Oregon State University

Senior Thesis: Culp, D.C., Aerial sound production in Southeast Alaskan humpback whales. Defended December 2016, Oregon State University

Senior Thesis: Williams, L. Fine scale spatial ecology on a humpback whale foraging ground. Defended March 2017, Oregon State University

Outreach/Engagement Outcomes

Blogs

Currents: Glacier Bay's Ocean Science Hub (8 related blog posts)
Michelle Fournet: Listening to oceans past and present (48 related blog posts)

Short Films

NPS Outside Science Inside Parks: "Underwater Conversations in Glacier Bay National Park"
Alaska Public Media/India Alaska: "We are Marine Acousticians"
NPS, Glacier Bay National Park: "Whups and Roars of Glacier Bay: Studying Underwater Acoustics of Humpback Whales and Harbor Seals"

Selected Public Presentations

10/2017 Academy of Lifelong Learning: "In the belly of the whale: history and research of industrialization and whales" Corvallis, OR (Fournet)

07/2017 NPS, Glacier Bay National Park Seminar: "Impact of anthropogenic noise on marine mammals in Glacier Bay" Gustavus, AK (public presentation & ranger brown bag, Fournet)

06/2016 NPS, Glacier Bay National Park Seminar: "Acoustic ecology of marine mammals in Glacier Bay National Park" Gustavus, AK (ranger brown bag, Matthews and Fournet)

03/2016 Hatfield Marine Science Center, Marine Mammal Seminar Series: "From form to function: the role of non-song calls in humpback whales" Newport, OR (Fournet)

02/2016 OSU, Engineering Department Marine Forum*: "Acoustic ecology and the changing marine soundscape" Corvallis, OR (Fournet)

Educational Materials

Middle school scientists worksheets and video: "Take your math outside!"
This project links a video produced in Glacier Bay National Park with a middle school level math worksheet. Students answer math problems based on real-world research methods outlined by researchers studying harbor seals and humpback whales. Students calculate harbor seal calling rates based on call counts and time, and use trigonometry to calculate the distance between land-based observers and humpback whales. All materials available on Glacier Bay National Park's website at https://www.nps.gov/glba/learn/education/take-your-math-outside.htm. Expected to be available on the soon-to be-updated National Park Service Teacher Portal website in the near future.

Editorials

Gabriele, CS, Fournet MEH, and LP Matthews. (2016). Whales, Seals, and Vessels: Investigating the Acoustic Ecology of Underwater Glacier Bay. Alaska Park Science 15(1), 61-67.

MANAGEMENT RECOMMENDATIONS:

The results of these studies on humpback whale and harbor seal acoustic communication support the following recommendations; 1. Maintain vessel speed limits in marine mammal hot spots, 2. continue to use vessel quotas to minimize acoustic overlap with humpback whales and harbor seals; and 3.limit the vessel speed in, and use of near intertidal areas and shallow (water depth >/=15 m) commonly used by both seals and whales for foraging, mate advertisement, and refuge from predators.

FUTURE RESEARCH RECOMMENDATIONS:

Most high-quality scientific studies point to new questions that merit study, as well as delivering answers to the study questions. In this case, we recommend the following. 1. Investigate humpback whale call function by linking acoustic activity with animal behavior states (foraging, travelling, resting); . 2. Find opportunities to measure the loudness humpback whale calls in highly trafficked areas of the park and Southeast Alaska; 3. Investigate and assess implications of missed signals due to vessel noise in acoustically active species, including the implication of animals missing acoustic cues; 4. Devise methods to understand biological consequences of acoustic masking for both harbor seals and humpback whales (i.e. reduction in harbor seal breeding success, reduced site fidelity in humpback whales); 5. Continue long term ambient noise monitoring in both high use and non-motorized areas throughout the park so that change over time can be detected.