Apr 12th, 2:30 PM - 3:50 PM

Factors affecting whale detection in a highly used marine environment

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Ship strikes are a pressing conservation issue for marine mammals across the globe. Collisions represent a significant cause of whale injury and mortality, and can even limit population recovery, a current problem for the critically endangered North Atlantic right whale (Fujiwara and Caswell, 2001). As marine vessel traffic increases and whale populations continue recovery following whaling moratoria, it is imperative to reduce the probability of collisions to ensure successful wildlife management in highly-used marine areas. To minimize anthropogenic impacts, vessel operators can attempt to avoid collisions, however avoidance maneuvers are only possible if the whale is detected, which can be difficult given that whales only spend a small proportion of their time at the water's surface, and detected in enough time to change the course or speed of the vessel. Thus, consistent and timely marine mammal detection is a key component in lowering ship strike risk, particularly for large vessels. In the marine environment, detection can be affected by environmental, animal behavior and vessel operation variables.

Southeast Alaska is a particularly suitable area to study the marine mammal-ship collision conservation issue. Between 1978 and 2011, 108 whale-vessel collisions have been reported in southeast Alaska alone (Nielsen et al., 2012). Within southeast Alaska, Glacier Bay National Park (GBNP) is a highly productive tidewater glacier ecosystem that serves as an important feeding area for humpback whales (*Megaptera novaeangliae*) of the central North Pacific stock. This national park is also well known as a destination for visitors to experience glaciers and marine wildlife. Cruise ships are the chief instrument for tourist visitation in GBNP. The ships travel in bay waters from late April through late September, covering the major part of the important humpback whale feeding season. Humpbacks are often aggregated in large feeding groups and are regularly encountered by ships in many areas of the bay. These encounters vary in the severity in their effects on humpback whales, and other marine mammals, and the consequences of these encounters to wildlife are largely not understood. At least two humpback whales have been killed by ships in recent years. This represents a highly conservative and minimum number, as collisions are often underreported due to simply being unaware that a whale was hit or for fear of repercussions.

To examine variation in detection probabilities, we used whale-vessel encounter data to measure factors that influence detection probability of humpback whales in GBNP. Shipboard observers recorded encounters between humpback whales and cruise ships from 2006 to 2012, collecting information on distance between whale and ship, behavior of the whale, direction and orientation of movement of the whale, weather covariates and operating conditions of the ship. Under the assumptions of distance sampling theory (Buckland et al., 2001), we estimated the probability of detection as a function of distance between the observer and whale and examined the potential effects of visibility, sea state, group size, and ship speed on detection probability.

Our results indicate that the probability of detection decreases strongly with increasing distance. Fitted detection functions indicate that probability of detection decreased markedly after 250m. Group size, visibility, sea state and whale behavior all significantly affect detection probability. Our results suggest that ship operator attentiveness should be increased in conditions of lowered visibility and in areas where whales may be in a movement mode that results in less physical manifestation above water, such as a transit mode, or involved in activities that result in small group sizes. Awareness of these conditions

that lower detection probability will allow vessel operators to more actively avoid and reduce the likelihood of potential collision situations.