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Combined physiological and behavioral observations to assess the influence of vessel encounters on harbor seals in glacial fjords of southeast Alaska

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ABSTRACT

Most studies examining disturbance of seals define disturbance as entry into the water. However, behavior alone may not be an accurate indicator of the timing, magnitude, or physiological cost of disturbances. This study examines changes in harbor seal heart rates in response to two levels of vessel disturbances; 1) 'incidental traffic' defined as presence of vessels in the area while seals were hauled out; and 2) 'experimental disturbance' defined as direct vessel approaches to seals until the seal entered the water. Incidental traffic resulted in a 4 bpm vessel^{-1} increase in heart rate while seals were hauled out. Mean incidental traffic during haulouts was 0.26 (range 0 to 8.95) vessels, and small vessels caused the largest increase in heart rate. Experimental disturbances resulted in a 5 bpm increase in heart rate upon initiation of vigilance, defined as the head-lift behavior. In-water heart rate was significantly lower after an experimental disturbance compared to other water entries, suggesting that seals shift to an energetically conservative mode in response to disturbances. During the haulout following an experimental disturbance, seal heart rate was significantly higher than other haulouts, suggesting that there is an added energetic cost of disturbance. Also, sex, mass, current and previous haul-out duration, in-water duration, day of year, hour of day, ambient temperature, and light level were found to have significant influence on harbor seal heart rates; demonstrating that a complex assortment of factors affect heart rate and careful consideration of these factors must be included in disturbance studies. Whereas previous findings have shown that vessel encounters alter seal behavior, this study presents evidence that encounters have energetic and physiological consequences while the seals are hauled out and these consequences persist for some time after the water entry behavior. Accordingly, exposure of harbor seals to increased vessel traffic may result in altered behavior, increased energetic expenditures, and increased exposure to stress, negatively affecting the health, condition, and reproductive success of harbor seal populations that reside in glacial fjords.

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1. Introduction

In several areas of the Gulf of Alaska, declines in harbor seal populations have been documented since the 1970s (Frost et al., 1999; Jemison et al., 2006; Mathews and Kelly, 1996; Pitcher, 1990; Small et al., 2003). Population counts in Glacier Bay show rapid declines since 1992 (Mathews and Pendleton, 2006; Womble et al., 2010) even though other harbor seal populations in the area are stable or increasing (Small et al., 2003). In the study area, Tracy and Endicott Arms, peak population counts of harbor seals declined by over 30% between 2001 and 2010, during the same time vessel traffic increased substantially (Lydon and Horn, 2010). There is an extensive body of work that examines short-term behavioral reactions of marine mammals to human-caused disturbances (see reviews Christiansen and Lusseau, 2014; Gordon et al., 2003; Kirkwood et al., 2003; Kucey and Trites, 2006; Weilgart, 2007); and human-caused disturbances have been linked to population declines in other marine mammals such as bottlenose dolphins (*Tursiops sp.*) (Bejder et al., 2006) and Hawaiian monk seals (*Monachus schauinslandi*) (Gerrodette and Gilmartin, 1990; Kenyon, 1972). It has been suggested that vessel disturbances could be a factor contributing to regional declines in some Alaskan harbor seal populations because vessel activity is relatively high in areas with declining populations (Jansen et al., 2010; Jansen et al., 2015). However, the consequences of vessel disturbance on harbor seals and its influence at the population level are currently unknown.

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In Southeast Alaska, glacier viewing is a popular tourist activity that results in frequent vessel traffic in glacial fjords. In these same areas, several populations of harbor seals congregate using floating icebergs as haul-out platforms (Calambokidis et al., 1987; Hoover, 1988; Jansen et al., 2010; Mathews and Pendleton, 2006). Harbor seals spend more time hauled out during late spring and early summer to accommodate breeding and pup rearing (Boulva and McLaren, 1979; Thompson, 1989; Thompson et al., 1989; Thompson et al., 1994), and during late summer and early fall to accommodate pelage molt (Daniel et al., 2003; Jemison and Kelly, 2001; Reder et al., 2003). In Tracy and Endicott Arms, these periods coincide with peak vessel presence from May to September (Lydon and Horn, 2010). The timing and frequency of vessel traffic and the narrowness of most fjords result in encounters between vessels and harbor seals during sensitive life-history periods such as breeding, pup rearing, and molting leading to some interest in determining whether encounters with vessels are contributing to harbor seal declines.

It has been established that vessel disturbances can cause harbor seals to abandon haul-out platforms and potentially leave the area (Allen et al., 1984; Calambokidis et al., 1987; Jansen et al., 2010; Jansen et al., 2015; Suryan and Harvey, 1999). Previous studies that examined the response of seals to vessels defined disturbance with the water-entry behavior (Allen et al., 1984; Jansen et al., 2010; Jansen et al., 2015; Johnson and Acevedo-Gutierrez, 2006; Renouf et al., 1981; Young et al., 2014), or with both water-entry and increased vigilance (Andersen et al., 2012; Henry and Hammill, 2001; Suryan and Harvey, 1999). Although a change in behavior may be a general indicator of a disturbance, there are reasons to believe that it might underestimate the effect of a disturbance. First, some animals will show little or no change in behavior in response to a disturbance. For example, few behavioral responses were documented in California sea lions (*Zalophus californianus*) when approached by humans (Holcomb et al., 2009), male gray seals (*Halichoerus grypus*) did not alter activity budgets in response to human presence (Bishop et al., 2015), and ringed seals (*Phoca hispida*) tolerated industrial noise with no significant behavioral responses (Blackwell et al., 2004). This can occur as a result of habituation or if a change in behavior has negative consequences such as increased exposure to predators, abandonment of young, or moving to an area with inadequate forage (Beale, 2007; Beale and Monaghan, 2004; Gill et al., 2001). Second, within an individual, behaviors can be influenced by differences in body condition. An individual in poor body condition may be less likely to respond to disturbances (Beale and Monaghan, 2004). Finally, behavioral responses can be easily missed or misinterpreted because some behavioral responses can be subtle and interpretation of behaviors can be very subjective (Fernández-Juricic et al., 2005). For harbor seals, behavioral studies show that they are reluctant to enter the water during breeding (Andersen et al., 2012; Renouf et al., 1981), molt (Cunningham et al., 2009; Henry and Hammill, 2001), or when alternate haul-out platforms are scarce (Young et al., 2014). This further suggests that behavioral responses might underestimate the effect of disturbance and that alternative methods for estimating disturbance may be needed.

Changes in heart rate have been used to characterize disturbances in seals (Perry et al., 2002), terrestrial mammals (MacArthur et al., 1979; MacArthur et al., 1982; Moen et al., 1982; Weisenberger et al., 1996), and birds (Culik and Wilson, 1991; Ellenberg et al., 2013; Nimon et al., 1995; Wilson et al., 1991). Reacting to disturbances can result in behavioral changes that include additional energetic costs. For example an increased energetic cost for minke whales (*Balaenoptera acutorostrata*) associated with vessels was estimated using changes in time energy budgets (Christiansen et al., 2013) and respiration rates (Christiansen et al., 2014). Similarly, for southern elephant seals (*Mirounga leonina*) environmental change led to behavioral modifications and decreases in body composition suggesting an increase in energetic costs (New et al., 2014). A direct link between disturbance and energetic cost would strengthen the inferences used in these studies. A benefit of using heart rate to measure disturbance is that it also provides a proxy for energetic expenditure (e.g. Baudinette, 1978; Butler, 1989; Green, 2011). Disturbances to harbor seals and the associated increases in energetic costs may lead to population-level effects through relocation (Allen et al., 1984; Henry and Hammill, 2001; London et al., 2012), decreased survival (Harding et al., 2005; Jansen et al., 2010), or disruptions during breeding and pup rearing (Lawson and Renouf, 1987; Newby, 1973; Suryan and Harvey, 1999).

For harbor seals, heart rate may be a better indicator of disturbance than behavior alone, especially because it is likely that the effect of disturbances continues beyond the moment that the seal enters the water. However, heart rate suppression due to the mammalian dive response uncouples the short-term relationship between heart rate and energetic cost once disturbances result in water entry (see review Kooyman et al., 1981), but the relationship between heart rate and energetic expenditure remains intact if the submerged and subsequent surface heart rates are averaged (Butler, 1993; Thompson and Fedak, 1993; Young et al., 2011). This suggests that the relationship between energetic expenditure and heart rate is retained over longer time scales and that heart rate can be used to estimate both the short- and long-term effects for individual harbor seals.

This study examines changes in harbor seal heart rates in response to two levels of vessel disturbances. 1) Incidental traffic defined as presence of vessels in the area while seals were hauled out. Changes in harbor seal heart rates were examined as vessels in the same area as the hauled out seal increased from zero to eight. 2) Experimental disturbance defined as direct vessel approaches to seals until the seal entered the water. Changes in heart rates and behaviors were examined while hauled out, after entering the water, and at the beginning of the subsequent haulout and were compared to other heart rates during haulouts, water entries, and subsequent haulouts that did not follow a known disturbance. To our knowledge, this is the first study to document fine scale physiological responses paired with behavioral observations of harbor seals confronted with vessel disturbances.

2. Methods

2.1. Deployment and instrumentation

Free-ranging harbor seals (23 F, 20 M) were captured by entanglement in monofilament gillnets among icebergs near Dawes Glacier in Inner Endicott Arm, Southeast Alaska (57.50°N, 132.94°W, Fig. 1) during April and May 2008, 2009, and 2010. To decrease variability in behaviors associated with breeding and reproduction, only seals that were estimated to be subadult and pre-reproductive were chosen for this study. Each seal was disentangled from the net, transferred to the primary research vessel, weighed to the nearest 0.1 kg, and sedated using an intravenous injection of Diazepam (dose, 0.25 mg kg^{-1}). While the seal was under manual restraint, the following devices were glued to its pelage using Devcon® 5-minute epoxy (Fedak et al., 1983): 1) a VHF transmitter (MM 340B, Advanced Telemetry Systems, Isanti, MN, USA) was attached to the top of the head; 2) a foam instrument backpack (described below) was glued anterior to the left hip; 3) two custom HRX electrodes, slightly modified from Fedak et al. (1988), were attached to the left and right of the dorsal midline equal distances anterior and posterior to the heart. The electrodes were connected via rope-covered leads to 4) an HRX transmitter (Wildlife Computers, Redmond, WA, USA) that was attached immediately anterior to the foam instrument backpack. After tag attachment, each seal was held in a pen until fully recovered from sedation and then allowed to enter the water on its own. The average time from capture to release was 6.5 ± 2 h. Captures, seal handling, and experimental disturbance vessel approaches were conducted under National Marine Fisheries research permit #358-1757 and Alaska Department of Fish and Game Animal Care and Use protocols.