2013

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Hoover-Miller, Anne; Bishop, Amanda; Prewitt, Jill; Conlon, Suzanne; Jezierski, Caroline; and Armato, Peter, "Efficacy of Voluntary Mitigation in Reducing Harbor Seal Disturbance" (2013). *Nebraska Cooperative Fish & Wildlife Research Unit -- Staff Publications*. 173. <http://digitalcommons.unl.edu/ncfwrustaff/173>

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Efficacy of Voluntary Mitigation in Reducing Harbor Seal Disturbance

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ABSTRACT Marine and coastal tourism has rapidly expanded worldwide in the past 2 decades, often occurring in once secluded habitats. In Alaska, tourism near tidewater glaciers has attracted millions of visitors and increased the presence of ships, tour vessels, and coastal development. Although sustainable tourism, resulting from balanced effects on wildlife and client satisfaction, is a goal of most tourism operators, it is not always achieved. Voluntary compliance with viewing guidelines and codes of conduct have been encouraged, but few assessments have the longitudinal scope to evaluate long-term changes in impacts on wildlife and the ability of vessel operators and kayak guides to sustain lower impact operating practices over time. This study assessed vessel and kayak visitation and resulting impacts on harbor seals in the Kenai Fjords National Park, southcentral Alaska. We obtained observations from 2002 to 2011, using remotely controlled video cameras located near Aialik and Pedersen Glaciers in the Kenai Fjords National Park. Overall, disturbance was associated with 5.1% of vessel sightings, 28% of vessel interactions (vessel observed within approx. 300 m of seals), 11.5% of kayak sightings, and 61% of kayak interactions. Results demonstrated that voluntary changes in operations significantly reduced vessel and kayak disturbance of seals by 60–80%. Even with prior establishment of operating guidelines, tour vessel captains were able to further reduce their effect on wildlife with more careful operations. Rapid growth of guided kayak excursions that occurred during this study caused greater disturbance to seals than motorized vessels but guide trainings helped reduce disturbances. Diminished impacts of motor vessels and kayakers persisted across years although effects of kayakers were less consistent than motor vessels, which reflected greater variability in inter-annual spatial use patterns by kayakers. Long-term monitoring, including assessments of wildlife responses to vessel and kayak operations, combined with 2-way communication with vessel operators and guides, enhanced the effectiveness of mitigation and facilitated adaptive adjustments to mitigation protocols over time. © 2013 The Wildlife Society.

KEY WORDS Alaska, disturbance, glacier, harbor seal, kayak, mitigation, *Phoca vitulina*, vessel.

Worldwide, expansion in marine wildlife ecotourism has provided substantial economic benefits to coastal regions and has increased human presence in previously remote locations. For instance, from 1981 to 1998, numbers of whale watchers increased 22-fold with more than a 73-fold increase in related economic benefits (Hoyt 2002). The demand for marine wildlife interactions, however, has challenged both the welfare of targeted organisms and the sustainability of

marine environments (Lück and Higham 2007). Protection of wildlife and ecosystems has lagged as mitigation strategies involving regulatory, physical, economic, and educational interventions continue to develop (Orams 1996).

In the United States, all marine mammals are protected from harassment by the Marine Mammal Protection Act of 1972 (MMPA; 16 U.S.C. § 1361 et seq.). All categories of unauthorized takes, which include any disruption in the animal's behavior, potentially may be prosecuted under the MMPA; however, enforcement has concentrated on actions that can cause direct marine mammal injury or death, particularly of endangered species (National Oceanic and Atmospheric Administration Office of the General Council, <http://www.gc.noaa.gov/enforce-office1.html>, accessed 15 Feb 2012). Mitigation of marine mammal harassment associated with vessel-based ecotourism is more often accomplished through voluntary compliance involving non-enforceable viewing

Received: 28 February 2012; Accepted: 9 October 2012

Published: 15 January 2013

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guidelines and codes of conduct (Garrod and Fennell 2004). Although generally endorsed by vessel operators, the effectiveness of voluntary efforts to reduce impacts of vessel disturbance on marine mammals is not well documented, particularly over long time scales after the initial motivation to comply wanes (Birtles et al. 2001, Lück and Higham 2007).

Attracted by scenic tidewater glacier fjords and wildlife viewing opportunities, more than 1 million passengers travel aboard cruise ships to coastal Alaska each summer (McDowell Group 2010). Smaller vessels, catering to independent travelers, transport thousands more passengers into tidewater glacial habitats each day. Ecotourism activities are intended to be benign and sustainable. Nevertheless, potentially adverse cumulative effects of tourism on marine wildlife are recognized worldwide (Duffus and Dearden 1990, Green and Higginbottom 2001, Reynolds and Braithwaite 2001, Catlin et al. 2011) including at glacial ice habitats in Alaska (Calambokidis et al. 1987, Jezierski 2009, Young 2009, Jansen et al. 2010).

The 51 tidewater glaciers in Alaska support unique biotic communities that include 10–15% of the state's harbor seals (*Phoca vitulina*; Bengtson et al. 2007, Molnia 2008). In Glacier Bay and Kenai Fjords National Parks, assessing and reducing impacts of tourism on harbor seals at secluded glacial ice habitats have been examined for more than 3 decades (Calambokidis et al. 1987; Young 2009; G. Streveler, National Park Service, unpublished reports; E. Mathews, National Park Service, unpublished reports; E. Murphy and A. Hoover, University of Alaska, Fairbanks, unpublished report). Although seals have demonstrated sensitivity to the presence of vessels and kayaks, and are appreciated by visitors, viewing seals is secondary to other experiences, including close encounters with glaciers and large whales. Such primary drivers of the marine tourism experience can have substantial influences on management policies and monetary investments enabling access to remote locations, whereas incidental features, such as pinniped viewing, often receive less management scrutiny (Newsome and Rodger 2007, Young 2009).

Among marine mammals, harbor seals are particularly susceptible to effects of vessel and kayak traffic because of their wary, vigilant, behavior and their reliance on nearshore haulouts, often located in areas accessed by humans (Allen 1991, Suryan and Harvey 1999, Henry and Hammill 2001, Johnson and Acevedo-Gutiérrez 2007, Jezierski 2009, Becker et al. 2011). Distributed in coastal temperate and sub-arctic habitats throughout the northern hemisphere, often in proximity of human concentrations, seals occupy diverse habitats including rocky shores, beaches, mud-flats, ice, and even man-made structures such as docks and floats (Hoover-Miller 1994). Harbor seals typically haul out in aggregations where they benefit from group vigilance to detect predators and other threats (da Silva and Terhune 1988). In situations where sources of threatening disturbance are frequent, seals may alter haul out times (Acevedo-Gutiérrez and Cendejas-Zarelli 2011), and abandon haulouts (Newby 1973, Allen 1991). In other instances, seals

have shown signs of habituation to frequent disturbance (Fox 2008).

Harbor seal pups are especially sensitive to effects of repeated disturbances. Disturbance near the time of parturition, when the mother–pup bond is just being established, can cause mother–pup separations that result in permanent abandonment and subsequent starvation of pups (Johnson 1977, Renouf et al. 1983, Osinga et al. 2012). Disturbances also disrupt nursing and resting times for pups. Young pups are born with relatively thin insulative blubber that is augmented during a 3- to 6-week nursing window (Bigg 1969, Newby 1973, Pitcher 1986, Hoover-Miller 1994). Pups swim shortly after birth and may spend about half of the day in the water (Jørgensen et al. 2001). However, if forced to spend more than 50% of their time in cold waters near tidewater glaciers, energetic models indicate that the increased metabolism required by pups to keep warm can cause an energy deficit that would adversely impact blubber deposition (Jansen et al. 2010). Frequent disturbances also can disrupt nursing, which may further diminish blubber stores (Jansen et al. 2010). Not reaching an adequate weaning weight has been documented to adversely affect first year survival (Harding et al. 2005).

Research evaluating the effects of vessels on the behavior of harbor seals in Alaska indicates that the distances from vessels when seals flush from the ice into the water varies between vessel type and activity (Calambokidis et al. 1987, Jezierski 2009, Jansen et al. 2010). Cruise ships cause seals to enter the water at increasing frequencies once ships approach within 500 m of resting seals (Young 2009, Jansen et al. 2010). Although large motorized vessels affect seal behavior at greater distances than smaller vessels, the engine noise of motorized vessels provides warning of the vessel's presence (Young 2009). In contrast, small vessels, such as zodiacs (E. Murphy and A. Hoover, unpublished report) and especially kayaks (Calambokidis et al. 1987, Jezierski 2009) are able to quietly approach resting seals and illicit a sudden, panicked response that can quickly spread to neighboring seals. Although kayaking has developed as a low-impact means of experiencing wilderness environments, kayaks tend to travel near shore and approach seals closer than motorized vessels, may linger near haulout sites longer than motorized vessels, and may have a predator-like appearance to seals (Allen 1991, Suryan and Harvey 1999, Henry and Hammill 2001, Johnson and Acevedo-Gutiérrez 2007, Fox 2008).

Mean numbers of harbor seals counted in Aialik Bay diminished 83% from 598 seals in 1980 to 100 seals in 2002, a decline which has been associated with a widespread decline of seals in the Gulf of Alaska and Aleutian Islands (Hoover-Miller et al. 2011). During the course of this study, trends stabilized and numbers of seals have begun to increase. Annual mean counts near Aialik Glacier ranged from 30 to 90 seals and maximum counts ranged from 213 to 418 seals. Near Pedersen Glacier, annual mean counts ranged from 19 to 109 seals and maximum counts ranged from 125 to 641 (A. Hoover-Miller, Alaska SeaLife Center, unpublished data).

Research, conducted from 1979 to 1981 in Aialik Bay, documented infrequent vessel activity (averaging 1 vessel/day, mostly present on weekends); with the exception of shrimp harvesters, few of those vessels entered ice-covered waters (E. Murphy and A. Hoover, unpublished report). Visitation to marine locations in the Kenai Fjords National Park increased an average of 24% annually from about 16,118 visitors in 1982 to 274,034 in 1997, after which annual growth diminished to about 2% (Table 1; National Park Service Public Use Statistics Office. <http://www.nature.nps.gov/stats/park.cfm>, accessed 27 Nov 2011). Tidewater glacier destinations of tour vessels in the Kenai Fjords National Park primarily include Holgate Arm, Aialik Glacier, and Northwestern Fjord (Fig. 1). In 2000, in response to increasing vessel traffic and concern about the impact motor vessel operations were having on marine mammals, the Kenai Fjords Tour Vessel Operators Association (KFTVOA), in collaboration with the North Gulf Oceanic Society, developed voluntary guidelines for viewing marine mammals in the wild to preserve viewing experience for visitors to the Kenai Fjords (KFTVOA, http://www.whalesalaska.org/viewing_guidelines.html, accessed 27 Nov 2011). In 2008, tourism infrastructure was further developed in Aialik Bay when the 16-unit Kenai Fjords Glacier Lodge was constructed on the eastern shore of Pedersen Lagoon (Fig. 1). Although designed to minimize visitor impact on wildlife, the presence of the lodge and associated infrastructure has increased small vessel traffic in upper Aialik Bay,

including kayak day-trips from Seward, and increased kayaker presence near Aialik Glacier.

This 10-year study assessed changes in vessel and kayak activities on disturbance rates of harbor seals near Aialik and Pedersen glaciers in the Kenai Fjords National Park. Objectives of the study were to determine whether 1) seals respond similarly to motorized vessels and kayaks; 2) altered operating practices used by vessels and kayaks affected rates of harbor seal disturbance as measured by seals flushing from the ice; 3) vessel and kayak operators were able to reduce frequency of disturbance on a long-term basis; and 4) factors other than vessel or kayak operations influenced harbor seal disturbance levels.

STUDY AREA

The Kenai Fjords National Park, established in 1980, is a remote, rugged, mountainous park stretching along the southern Kenai Peninsula, south central Alaska, that includes the 8 western-most tidewater glaciers in the northern hemisphere. Aialik Bay, located 23 km southwest of the town of Seward, is a 40-km long fjord with 3 tidewater glaciers (Fig. 1). Ice calved from Aialik Glacier, located at the northwest head of the bay and Pedersen Glacier, 6 km southwest of Aialik Glacier is regularly used by seals, whereas ice calved from Holgate Glacier located at the head of Holgate Arm, is infrequently used by seals. Although the terminus of Aialik Glacier fluctuates seasonally and between years, it has remained relatively stable during the past century

Table 1. Summary of total observation time and effort-corrected rates (incidences/hr) of harbor seal disturbances, interactions, and sightings associated with vessels and kayaks in Aialik Bay, 2002–2011. Parentheses denote numbers observed. Proportion disturbance indicates percent of interactions or sightings in which seals were disturbed. Number of sightings includes interactions and disturbances, and number of interactions includes disturbances. Total vessel passengers were estimated by the National Park Service based on 3 primary tour vessel operators visiting all locations in the Kenai Fjords National Park, including Aialik Glacier. Proportion kayak sightings near Pedersen Glacier are based on camera observations.

Year	Observation time (hr)	Days	Disturbances/hr	Interactions/hr	Sightings/hr	Proportion disturbance		Total vessel passengers / % of kayak sightings at Pedersen
						Interactions (%)	Sightings (%)	
Vessels								
2002	542	88	0.06 (35)	0.18 (98)	0.45 (244)	35.7	14.3	78,920
2003	502	81	0.03 (13)	0.09 (46)	0.24 (122)	28.3	7.7	69,295
2004	387	92	0.04 (14)	0.04 (14)	0.49 (189)	100.0	6.9	70,688
2005	551	92	0.01 (8)	0.06 (34)	0.49 (216)	23.5	3.2	88,972
2006	565	91	0.01 (3)	0.02 (14)	0.31 (173)	21.4	1.6	89,868
2007	893	92	0.01 (11)	0.03 (31)	0.50 (455)	35.5	2.3	102,067
2008	801	90	0.01 (9)	0.09 (75)	0.43 (342)	12.0	2.2	102,088
2009	423	86	0.01 (6)	0.04 (17)	0.17 (72)	35.3	6.7	70,478
2010	330	85	0.02 (6)	0.11 (36)	0.69 (229)	16.7	2.3	61,728
2011	194	70	0.01 (2)	0.04 (7)	0.36 (69)	28.6	2.6	66,559
Total	5,188	867	0.02 (107)	0.07 (372)	0.40 (2,101)	28.8	5.1	800,633
Kayaks								
2002	542	88	0.00 (0)	0.00 (1)	0.00 (1)	0.0	0.0	
2003	502	81	0.01 (3)	0.01 (3)	0.02 (12)	100.0	25.0	50%
2004	387	92	0.04 (15)	0.05 (20)	0.09 (36)	75.0	41.7	83%
2005	551	92	0.05 (30)	0.07 (37)	0.19 (106)	81.1	28.3	70%
2006	565	91	0.02 (9)	0.02 (13)	0.14 (81)	69.2	11.1	47%
2007	893	92	0.01 (7)	0.01 (12)	0.14 (124)	58.3	5.6	35%
2008	801	90	0.01 (9)	0.03 (25)	0.21 (265)	36.0	4.2	23%
2009	423	86	0.01 (4)	0.03 (12)	0.10 (41)	33.3	9.8	50%
2010	330	85	0.02 (5)	0.02 (8)	0.17 (57)	62.5	8.8	40%
2011	194	70	0.00 (0)	0.02 (3)	0.21 (41)	0.0	0.0	11%
Total	5,188	867	0.02 (82)	0.03 (134)	0.14 (711)	61.2	11.5	44%

Figure 1. Map of Aialik Bay illustrating the location of Aialik and Pedersen glacial ice habitats and camera sites used to observe interactions between harbor seals and watercraft, 2002–2011. Letters designate the location of the following remote video camera sites: A = Squab Island, B = Aialik Glacier, C = Pedersen Lake, D = Pedersen Glacier. E designates the location of a commercial lodge.

(Grant and Higgins 1913, Molnia 2008). Ice calved from Aialik glacier circulates around Squab Island (2 km east of the face of the glacier), and generally remains north of the Aialik Bay sill. Conversely, Pedersen Glacier is a receding glacier that terminated on the Aialik Bay shoreline in the late 1800s (Grant and Higgins 1913). Pedersen Lake, which accumulates ice calved from Pedersen Glacier, was completely covered by the Pedersen Glacier in 1960 and has been a haulout for harbor seals only since about 1992 (Hoover-Miller et al. 2011). A shallow 10-m deep sill (subsurface moraine) extends across Aialik Bay, 8 km southeast of Aialik Glacier's current terminus. The sill has excluded large cruise ships from visiting Aialik Glacier and a shallow stream entrance to Pedersen Lake restricts all but small skiffs and kayaks.

METHODS

Remote Video Monitoring: 2002–2010

Remotely controlled video monitoring equipment developed and maintained by SeeMore Wildlife, Inc. (Homer, AK) and

operated at the Alaska SeaLife Center (ASLC) in Seward, Alaska, was installed in June 2002 to observe harbor seals near Aialik and Pedersen Glaciers (Fig. 1). Hoover-Miller et al. (2011) describe the video system and survey protocols in detail. Briefly, the cameras provide real-time pan (360°), tilt and zoom capabilities of 25× (optical) and up to 300× (digital). We controlled cameras via computers located at the ASLC. Observers immediately recorded data from live images. Remote observations using video cameras are more similar to field observations than sampling using time-lapse images from fixed cameras (O'Connell et al. 2011) as we could move the camera much in the same way field observers move their binoculars or spotting scopes. Comparisons conducted by Jezierski (2009) between field and video camera observations indicated benefits and limitations in using video cameras for observations. Primary limitations were associated with receiving images from only 1 camera at a time, which limited the time cameras could be devoted to watching for and documenting interactions. Delays in transmitting commands affected movement of cameras, which sometimes compromised the ability to make continuous

detailed observations, especially affecting observations requiring structured sampling. Oblique viewing angles limited our ability to estimate distances, and the video system did not transmit sound, which excluded auditory cues of approaching vessels or aircraft. We concurrently took time-lapse recordings at a rate of >4 frames/second to provide a record of environmental conditions, seal distribution, interactions between humans and seals, and, when viewing opportunities were suitable (e.g., when seals occupied ice that was grounded or slowly drifting), the behavior of seals when humans were absent.

In 2002, the first year of the study, observation methods differed from subsequent years. Limited staffing required greater reliance on passive, recorded observations and less developed documentation of active observations. When we were not conducting active observations, cameras generally were pointed in a fixed position toward the glacier to detect movements of vessels and kayaks. We subsequently reviewed time-lapse video tapes to determine numbers of vessels and kayaks present. Although we could determine presence and sightings of vessels and kayaks from fixed position observations, we could only evaluate interactions and disturbances from active observations. This difference potentially could inflate the numbers of vessels detected relative to interactions. We, therefore, removed from analysis 138 of 399 vessel records that would not have been identified using monitoring schedules followed in subsequent years. We advise caution in interpreting relationships between interactions and sightings or presence in 2002 relative to other years because of differences in monitoring methods.

Experienced observers trained survey personnel at the beginning of each year to ensure consistency in observations from year to year. Data collection manuals and forms enhanced consistency in data collection within and between years. We conducted surveys on predefined schedules established each year based on the number of personnel and research priorities. Actual execution of surveys occasionally deviated from the schedule because of weather, camera performance problems, and other events; however, we concentrated active observations from 0900 through 1800, daily, except in 2011 when we primarily conducted observations from 1100 to 1700 (Fig. 2). Observation time reflected the amount of time observers were actively surveying seals and vessel activity at Pedersen and Aialik Glaciers. We determined minutes of active observation times (Fig. 3) for each hour, each day, and for each year from 2002 to 2011. To facilitate comparisons across years and between pupping (May–Jun), and molting (Jul–Aug) periods, we divided the daily frequency of vessels and kayaks sightings, interactions, and disturbances by the daily observation time, expressed in hours, to produce effort-corrected rates. We distinguished between observations of vessels and kayaks.

We preceded each by an ice scan of the entire area. Frequently, we detected vessels and kayaks prior to the watercraft entering ice affected areas. As we sighted vessels, during surveys or at other times, we could scan anticipated travel routes to predict potential interactions with seals.

Figure 2. Distribution of the times of day we initiated active observations (ice scans, harbor seal population surveys, vessel and kayak observations) from 2002 to 2011 in Aialik Bay.

We combined observations at Aialik and Pedersen Glaciers to represent vessel or kayak impacts on seals in upper Aialik Bay as a whole. Differences in vessel and kayak access and habitat characteristics exist at each location. Because few

Figure 3. Effort adjusted contour density of observation time (min) of harbor seals in Aialik Bay relative to day and year. Points represent distribution of observations relative to day and year (closely aligned points, indicative of sequential daily observations, appear as black bars, vertical gaps indicate multi-day breaks in observations).

motorized vessels are able to navigate the shallow stream entrance to Pedersen Lake, vessel interactions reflect activities near Aialik Glacier. Ice conditions associated with receding Pedersen Glacier changed in 2007 from a dominance of large bergs distributed throughout the lake and navigable access to the glacier face to a persistent dense ice pack that excluded kayak navigation near the glacier and provided secluded haulout habitat for seals.

We conducted this study under a National Marine Fisheries Service General Authorization for Scientific Research (Letter of Confirmation No. 881-1673 and 881-1918), a National Park Service Scientific Research Permit (KEFJ-2004-SCI-0001 and KEFJ-2008-SCI-0001), a Port Graham Corporation Memorandum of Understanding, a United States Fish and Wildlife Services Special Use Permit (74500-03-045 and 10-001), and a Department of Natural Resources Permit (09-KA-698). Research protocols were approved by Alaska SeaLife Center Institutional Animal Care and Use Committee (Protocols 06-003 and 09-002).

Disturbance Classifications

Observations of vessels or kayaks were classified as 1) sightings when the vessel or kayak's presence relative to seals was not distinguished, 2) present when vessels or kayaks were observed in areas not occupied by seals, or 3) interactions when the vessels or kayaks operated in the vicinity of seals (estimated to be within about 300 m of seals based on the length of the vessel) or the behaviors of seals changed (including movements toward the edge of the ice and attaining alert postures). We designated seal behavior as alert when they elevated their heads while closely watching the source of disturbance or the activities of neighboring seals. We designated seal behavior as disturbance when we observed seals flushing from the ice into the water or seals already in the water likely because of the presence of the vessel or kayak. Swimming seal behaviors indicative of disturbance included multiple seals grouped together in the water and orientated toward the source of disturbance. We frequently observed groups of apparently curious seals, recently flushed from the ice, approaching the source of disturbance, particularly kayaks. We did not use single seals approaching vessels or kayaks to assign disturbance, as individual swimming seals frequently approach kayaks and vessels but may not have been flushed from a haulout. Swimming seal behaviors used to designate disturbance contrast with behaviors of undisturbed seals in the water. Unlike seals that flush from ice, undisturbed seals generally swim singly (or with a pup) and investigate ice along their travel route for potential haulout or individuals may float quietly in the ice, maintaining a low profile. We classified events where seals were alert but did not enter the water as interactions rather than disturbances because of differences in the seal's energetic expenditure associated with remaining on the haulout versus entering the water (Harding et al. 2005). For analysis, we categorized our observations as 1) sightings to include all observations (sightings, present, interactions, and disturbances); 2) interactions, which included observations classified as interactions

and disturbances; and 3) disturbances, which included only observations classified as disturbances.

Changes in rates of disturbance can be the result of the frequency vessels visit areas occupied by seals and changes in operating practices while near seals. We determined daily ratios of disturbances:sightings to reflect the proportion of all vessels causing disturbance, whereas the ratio of disturbances:interactions assessed the likelihood of disturbance for only those vessels operating near seals.

Statistical Analysis

We used generalized additive models (GAMs) to smooth trends and identify significant deviations from the overall mean with consideration of covariate effects. These models allow the data to suggest the pattern of response function based on smoothing rather than specification of a parametric form prior to modeling (Hastie and Tibshirani 1990). We generated analysis of variance and GAMs using R v2.13.1 statistical programming language (R Development Core 2011) and the GAM package, mgcv version 1.7-6 (Wood 2006, 2011) with the link identity function. We conducted separate analyses for pupping and molt periods because of differing life-history events, potential differences in sensitivities, environmental conditions, and frequencies of vessel and kayak presence.

We initially developed 12 GAMs that included effects of year, day of year, interactive effects of year $\times$ day, and maximum daily count of seals near Pedersen and Aialik Glaciers on sightings, interactions, and disturbances involving vessels and kayaks during pupping and molting. Models involving vessels did not include maximum daily count of seals near Pedersen Glacier because vessels did not enter Pedersen Lake. For models where all terms did not significantly contribute to the model at a significance level of $P < 0.05$, we conducted backwards selection by sequentially dropping the single term with the greatest non-significant P -value from the model and re-fitting, until all terms were significant. We inspected GAM plots to identify time periods when the 95% confidence interval was entirely above or below 0 (the overall mean or zero effect).

RESULTS

Vessels

From May to September, 2002–2011, during 5,188 hours of observation, we sighted 2,101 vessels (Table 1) of which 372 were classified as interactions, including 107 vessels that caused disturbance (5.1% of all vessel sightings; 28.8% of interactions). Overall, we sighted 0.4 vessels/hour (annual range = 0.17–0.69 vessels/hr), however vessel sightings, and associated interactions and disturbances were not distributed uniformly by time of day (Fig. 4) or by year (Fig. 5). Vessel sightings peaked in presence during midday, with greatest numbers from 1200 to 1459 (time of day effect, $P < 0.001$, $R^2 = 0.571$), coinciding with maximum diurnal haulout abundance of seals (Fig. 4; Hoover-Miller et al. 2011).

Generalized additive models pertaining to vessel sightings included effects of year, day, interactive effects of year $\times$ day, and seal abundance near Aialik Glacier. During pupping and

Figure 4. Numbers of vessels and kayaks sighted in Aialik Bay overlaying a density plot of total numbers of harbor seals counted relative to time of day from 2002 to 2011 (A. Hoover-Miller, unpublished data). The density plot illustrates the concentration of specific counts relative to time of day throughout the study. Contour lines designate 5% quantile intervals; darker shades of gray represent greater quantiles.

molting, vessel sightings varied significantly by year but little overall trend among years was evident (Fig. 6). During pupping, vessel sightings were fewer prior to 9 June, reflecting the seasonal start of scheduled vessel tours. During molting, vessel sightings were less frequent from 25 July to 3 August. This time period coincided with high seal abundance on the ice during molting and may have been influenced by the additional time required to count seals.

Generalized additive models identified significant variation in vessel interactions during pupping that were elevated from 12 to 18 June, when pups were most abundant (Hoover-Miller et al. 2011). Interactions did not vary significantly by year. Vessel interactions during molting were most frequent in 2002 and diminished in subsequent years (Fig. 6). Interactions during molting were more frequent than the overall mean from 14 to 18 August. Frequency of interactions was greatest in 2002 and diminished significantly below the zero effect line from 2005 to 2007. Interactions subsequently increased to the mean, zero effect line (Fig. 6).

Of all vessel sightings, 16% of vessels operated near seals and 5% caused disturbance (29% of interactions resulted in disturbance). Generalized additive models indicated that vessel disturbances during pupping tended to be elevated 10–15 June, near peak pupping; however, rates of disturbances showed no significant trend by year. Vessel disturbances during molting were the most frequent in 2002 and diminished through 2005 when disturbance rates were significantly less than the overall mean and remained at low levels through 2011 (Fig. 6).

Kayaks

Kayakers used ice associated with both Aialik and Pedersen Glaciers. Of 697 kayaks observed during this study, 44%

Figure 5. Effort adjusted frequency of kayak (left) and vessel (right) sightings, interactions, and disturbances of harbor seals by year during pupping (top) and molt (bottom) in Aialik Bay. Wide error bars (95% CI) reflect high day-to-day variability.

Figure 6. Smooth-term components of generalized additive models for effort-corrected frequency of sightings (top), interactions (middle), and disturbances (bottom) associated with kayaks and vessels during harbor seal pupping (left) and molt (right) in Aialik Bay, each year from 2002 to 2011. Gray shadings represent the 95% point-wise confidence interval. The horizontal black lines at 0 represent zero effect. Significant deviations exist when both upper and lower 95% confidence interval curves are on either side of the zero effect line.

were located near Pedersen Glacier (Table 1). Increased sightings of kayaks from 2002 to 2005 corresponded to rapid growth in guided kayak trips (Figs. 5 and 6), particularly in Pedersen Lake (Table 1) where more than 70% of kayaks were sighted in 2004 and 2005.

Kayak presence was not as strongly predictable by time of day as motorized vessels (Fig. 4), but fewer sightings occurred during the morning than during midday and afternoon. Generalized additive models of kayak sightings included significant effects of year, day, year $\times$ day, and seal abundance near Aialik Glacier (Fig. 6). Kayak sightings during pupping, annually increased, whereas sightings during molting increased through 2005, then diminished (Fig. 6).

Generalized additive models of kayak interactions during pupping included effects of year, day, and seal abundance near Aialik Glacier. We found a weak but significant increase in interactions over the study period. During molting, modeled effects of year, day, and year $\times$ day indicated complex changes in rates of interactions with a rapid increase from 2002 to 2005 followed by a rapid decrease in interactions from 2005 to 2007. Interactions became elevated in 2009 then diminished in 2010 and 2011 (Fig. 6).

Of all kayak sightings, 19% of kayaks operated near seals and 12% caused disturbance (61% of interactions resulted in disturbance). During pupping, kayak disturbances were infrequent and did not change significantly from 2002 to 2011 (Fig. 6). Generalized additive models of kayak disturbances during molting included effects of year, day, and year $\times$ day. Disturbances followed similar patterns across years as identified for interactions with peak levels in 2004–2005 followed by a rapid decrease in disturbances from 2005 to 2007. As with interactions, disturbances became elevated in 2009 then diminished in 2010 and 2011 (Fig. 6).

Relative Impacts of Vessels and Kayaks

Daily ratios of disturbances:sightings (Fig. 7, top) and ratios of disturbances:interactions (Fig. 7, bottom) indicate differences in the response of seals to vessels and kayaks. Overall, kayaks caused greater proportions of disturbances:sightings than vessels, particularly from 2003 to 2005. Subsequent to 2005, kayak disturbances:sightings decreased and continued to decline through 2008, indicating kayakers avoided seals. In 2009 and 2010, coincident with enhanced access to Aialik Glacier, disturbance ratios increased.

Figure 7. Effort adjusted ratios of harbor seal disturbance relative to sightings (top) and disturbance relative to interactions (bottom) for kayakers and vessels in Aialik Bay from 2002 to 2011.

Disturbances:interactions ratios (Fig. 7, bottom) indicate that kayakers operating in the vicinity of seals had a greater likelihood of causing disturbances than vessels. Although kayakers were able to reduce disturbance:interaction ratios in later years, impacts by kayakers remained greater than those of vessels, indicating a greater sensitivity of seals toward kayakers. In 2011, mitigation was achieved by complete avoidance of seals.

DISCUSSION

Results of this study demonstrate long-term reductions in the number of incidents causing seals to enter the water. Collaborations and outreach provided feedback to vessel operators and guides regarding operating practices, environmental conditions, and responses of seals to vessels and kayakers.

Vessels

Near Aialik Glacier, motorized tour vessels typically follow patterned behavior of approaching the glacier then drifting for roughly 30 minutes with engines off before departing. The presence of seals, although an added value, is secondary

to the experience of floating in the ice near the glacier. Vessel operators are thus motivated to reach the face of the glacier.

From 2002 to 2004, vessel operators were able to significantly reduce disturbances, relative to both sightings and interactions, and sustain lesser rates of disturbance during subsequent years, even when frequencies of interactions were elevated (Fig. 6). Likewise, the greatest reduction in number of interactions occurred between 2002 and 2005, which we attribute to more careful operations on the part of captains, including slower approaches, maintaining greater distances from groups of seals, and encouraging passengers to remain quiet when floating near seals. The number of interactions varied between years and was influenced by ice dynamics, seal behavior, and tourism levels. Ice conditions near Aialik Glacier varied considerably during the day and across seasons with heaviest ice present during the pupping season. When ice circulated along the northern and eastern side of Aialik Bay, a clear path was available to vessels that allowed them access to the glacier with minimal interactions with seals. Throughout the study, numbers of vessels and seals peaked during the middle of the day, thus increasing the likelihood of mid-day interactions. We also observed that captains needed to sustain low speeds longer than expected when passing by groups of seals. Captains generally were careful in their approach to areas occupied by seals, but we observed instances where after departing the glacier or passing a group of seals, when seals were no longer visible to captains, the vessels abruptly accelerated. Nearby seals often responded by becoming alert and sometimes fleeing the ice.

Variation in vessel sightings in all years also were affected by the proportion of vessel operators conducting Aialik Bay excursions that chose to visit Holgate Glacier rather than Aialik Glacier, as exemplified by variation in sightings near Aialik Glacier relative to trends in numbers of vessels visiting the Kenai Fjords (Table 1, Fig. 6). We did not monitor Holgate Glacier, which has less floating ice and few seals. Visitation of Holgate Glacier was most frequent in early summer, when ice conditions reduced the likelihood of approaching Aialik Glacier and when elevated fuel prices of 2008 affected operation strategies in 2009. Heavier ice conditions near Aialik Glacier during pupping and the use of Holgate Glacier as an alternate destination reduced the presence of vessels in the ice near Aialik Glacier during pupping, in effect creating a partial, voluntary, time-area closure. The disturbance of pupping seals thus remained lower than observed during molting throughout this study.

Kayaks

Compared with motorized vessel operations, kayak ecotourism has had a shorter history in Aialik Bay and grew rapidly during our study. In 2002, we observed few kayakers. In 2003, interactions between kayakers and seals frequently caused disturbance. Interviews with individual kayakers and guides identified a strong desire to learn about operating techniques that would reduce their impacts on seals. Jezierski (2009) conducted research in Pedersen Lake that documented responses of seals to the presence of kayakers and in 2006 provided training to help guides operate more carefully

around seals. During subsequent observations in 2006, she demonstrated the effectiveness of those trainings resulting in a 60% reduction in disturbances/hour (Table 1). Results from this study show long-term benefits of guide trainings. The reduction in interactions and disturbances beginning in 2006 are strongly associated with research and mitigation guide trainings conducted by Jezierski (2009). Turnover rates of guides between years are greater than vessel captains, thus we kept communication pathways open and continued providing spring guide trainings. Our results, however, indicate that the most effective mitigation actions kayakers can take is to avoid interacting with seals by carefully watching the behavior of seals and ceasing further approach if seals become alert.

We presume noise from motor vessels announces the presence of vessels to seals long before the vessel's arrival. Seals may raise their head, but often will watch the progress of the vessel as it heads to and from the glacier. Seals infrequently entered the water in response to vessel interactions, unless they were directly approached. Kayakers, on the other hand, travel more slowly and quietly, and explore while en route to their destination. Although the flash of paddles could alert seals to kayakers at a distance, kayakers were able to quietly approach groups of seals specifically to watch the seals either by floating nearby or while traveling past. If kayakers closely approached resting seals, the seal's reaction typically was sudden, often rapidly fleeing to the water. In late 2007, ice conditions changed in Pedersen Lake, which provided seals opportunities to haul out deep in the ice, secluded from kayakers visiting the lake. In 2008, infrastructure developed providing for kayak day trips to Aialik Glacier. Accompanying that transition was an increase in numbers of kayaks observed near Aialik Glacier with an increase in interactions and disturbances (Fig. 6). Adjustments in operations that resulted in fewer approaches to areas occupied by seals, reduced interactions and diminished disturbances to negligible levels in 2011.

Affecting Change

Video records obtained by the cameras did not provide quantitative information on distances between vessels or kayaks and seals because of the oblique viewing angle; hence, we focused our trainings on observing the behavior of seals. Videos provided opportunities to review interactions to identify specific vessel and kayak activities that seals were sensitive to and capture behaviors and activities normally exhibited by seals in the absence of watercraft (Jezierski 2009). Video clips were especially valuable for illustrating effects of vessel and kayak activities on seal behavior during workshops, guide trainings, and other interactions with commercial vessel operators and guides.

Our long-term assessments of the responses of harbor seals to vessels and kayaks in Aialik Bay provided insight regarding the sensitivity of seals to watercraft and the ability of vessel operators and kayak guides to mitigate their impact on seals. With respect to our original objectives, we determined the following:

1. Seals did not respond similarly to motorized vessels and kayaks. Seals remained more sensitive to kayaks than vessels throughout the study (Fig. 7).
2. Altered operating practices affected rates of disturbance. Careful operations of vessels and kayaks reduced flushing of seals into the water while allowing for travel in glacial habitats.
3. Vessel and kayak operators were able to reduce frequency of disturbance. We documented long-term reduction in disturbance by both vessel operators and kayakers, but because of the apparent high sensitivity of seals to the presence of kayakers, we also observed the frequency of kayak disturbance fluctuate over time (Fig. 6).
4. Factors other than vessel or kayak operations also influenced disturbance levels. Glacial ice environments are highly dynamic (Table 2) and seals respond to those changes in ways we do not fully understand.

Table 2. Timeline of research, collaborations, and public and scientific outreach conducted compared with relative changes in Aialik Glacier terminus, and ice characteristics near Pedersen Glacier during the course of harbor seal research in Aialik Bay, Alaska, conducted from 2002 to 2011.

Parameter	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Research ^a	V	V	V	V, F	V, F	V	V	V	V	V
Focal kayak study ^b				F	O, F	O	O	O		
Stakeholder collaborations ^c				K	K				V	V
Education collaborations ^d		HS, I	HS, I	I	I	I	I	I	I	I
Pre-season guide and operator outreach ^e	W ^V	P ^{V/K}	W ^{V/K} , P ^{V/K}	P ^{V/K}	P ^{V/K} , W ^K	W ^K	W ^K	W ^K	P ^V , W ^K	W ^K
Public outreach ^f		D, O	D, Pb ¹	D, O	D, V, O, Pb ²	D, O	O, Pb ³	O, G	G	G
Scientific outreach ^g	SW	IC, IW		IC	SC, IC	SC	SC	Pb ⁴		
Aialik Glacier terminus ^h	R	R	R	R	A	A	A	A	A, R	R
Pedersen Glacier habitat ⁱ	N	N	N	N	N	N, D	D	D	D	D

^a V = video observations, F = field observations.

^b F = field study, O = outreach (Jezierski 2009).

^c K = research involving kayak guide companies, V = research involving vessel tour operators.

^d HS = high school student work experience, I = college internships.

^e W = workshops, P = presentations to stakeholders, V = vessel operator focus, K = kayak guide and operator focus.

^f D = daily public presentations at the Alaska SeaLife Center, V = SeaExtreme DVD video, O = other public presentation, Pb = publications for general public (Pb¹ = Hoover-Miller et al. 2004, Pb² = Jezierski 2006, Pb³ = Jezierski et al. 2008), G = "Give Pups a Break" handout.

^g SW = statewide workshop, SC = statewide conference presentation, Pb⁴ = publication (Jezierski 2009), IW = international workshop, IC = international conference.

^h R = retracted, A = advanced.

ⁱ N = Navigable access to glacier face and seals, D = dense ice pack (glacier face and most seals inaccessible).

Continued dialog with stakeholders enhances adaptive adjustments that can further reduce disturbance. For instance, Hoover-Miller et al. (2011) identified a persistent decline in numbers of pups in Aialik Bay. Although assessments of disturbance during pupping did not indicate direct cause and effect, an outreach effort “Give Pups a Break” was initiated in 2009 to inform vessel operators and kayak guides about vulnerabilities of young pups to excessive exposure to cold water and encourage extra caution when operating in the vicinity of pups. Kayak guide and vessel operator workshops, orientations, and other collaborations have enhanced 2-way dialogs and sustained communication pathways needed to adjust operations to changing conditions.

Effective disturbance mitigation also requires community involvement that reaches independent travelers and clients. This study included outreach in public and scientific venues (Table 2). Educational opportunities were provided to high school students, college interns, and graduate students. Our focal study on kayakers (Jezierski 2009) was a direct result of requests by independent kayakers and kayak guides to learn effective techniques for minimizing their impacts on seals when visiting glacial ice habitats. This focal study was successful in reducing seal disturbance, establishing communication pathways with local kayak outfitters, and developing outreach information delivered to independent travelers through printed materials, videos, and frequent presentations at the Alaska SeaLife Center, National Park Service Visitor Center, and other venues.

MANAGEMENT IMPLICATIONS

Success of sustainable tourism projects is enhanced by 1) community involvement in planning, development and management, 2) cooperation among partners, 3) environmental commitments of project promoters, and 4) continuous performance monitoring (World Tourism Organization 2000). Our study documented long-term reduction in disturbance resulting from voluntary actions to reduce adverse effects of vessel and kayak presence on seals. We also determined that feedback from independent monitoring improved mitigation success. Management strategies, whether they involve enforcement of regulations (e.g., MMPA), limitation in numbers of vessels (e.g., Young 2009), spatial restrictions or area closures (e.g., Jansen et al. 2010), or voluntary adherence to codes of conduct are vulnerable to changes in ecosystem conditions, animal behavior, and human motivation to adhere to or enforce operational practices. Independent assessments, whether provided by industry or management agencies, are vital for both generating metrics to evaluate the effectiveness of management actions and for assessing changes over time that may require adaptive adjustments to mitigation techniques and strategies.

ACKNOWLEDGMENTS

We wish to thank the numerous organizations, which have supported harbor seal monitoring in Aialik Bay including the National Park Service, Port Graham Corporation, National Maritime Wildlife Refuge System, and the Exxon Valdez Oil Spill Trustee Council. We also thank the many people

who spent endless hours conducting surveys and reviewing tapes including K. Felitz, S. Aughe, L. O'Brien, L. Dickinson, J. Follin, T. Mauro, M. Sternberg, K. Heffron, R. Pearce, A. Graefe, K. Stade, K. Williams, L. Cramer, G. Mills, K. Marino, S. Slaughter, T. Zaffarano, C. Youngflesh, M. Terwilliger, N. Beckmann, S. Hishmeh, J. Mahoney, L. Marcella, M. Caulfield, and J. Albers, A. Stanger, and J. Siskidis. In addition, we thank J. Senderling and S. Miller for their database and programming skills. Drafts of this manuscript were improved by recommendations and comments from M. Needham, B. Thompson, and 4 anonymous reviewers. Research and data synthesis was supported by the National Park Service, Ocean Alaska Science and Learning Center, Exxon Valdez Oil Spill Trustee Council, and the National Marine Fisheries Service.

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Associate Editor: Bruce Thompson.