*Exxon Valdez* Oil Spill
Gulf Ecosystem Monitoring and Research Project Final Report

# Harbor Seal Monitoring in Southern Kenai Peninsula Fjords

GEM Project 050749
Final Report

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Habitat and Restoration Division
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**Study History:** Population studies of harbor seals using glacial ice in Aialik Bay were first conducted from 1979-1981 (Hoover 1983) and were continued intermittently through 1995 (NPS unpublished, Hoover-Miller unpublished). Beginning in 2002, the National Park Service's Ocean Alaska Science and Learning Center supported the development and use of remotely controlled video cameras to document information on numbers of seals at haulouts and haulout attendance relative to local environmental conditions. Intermittent and infrequent counts of harbor seals have been conducted in Day Harbor since 1983. Although both locations have provided long-term information on population trends of harbor seals on the southern Kenai Peninsula, intermittent monitoring from 1982-2001 diminished the applicability of the data for assessing population trends. Funding provided by the *Exxon Valdez* Oil Spill Trustee Council supported continued remote video monitoring in Aialik Bay from 2005-2007 and funded a feasibility evaluation of using still digital cameras to document haulout of seals at rocky terrestrial sites in Day Harbor.

**Abstract:** Numbers of harbor seals at haulouts in the Gulf of Alaska diminished by more than 80% since the mid-1970s. Harbor seals in Aialik Bay, a tidewater glacial fjord on the Kenai Peninsula, have been monitored since 1979 by field observations and remotely controlled video cameras. From 1980-2002 standardized mean pup counts declined 83% from 133 to 22 pups and remained stable at low numbers from 2002-2007. Standardized mean numbers of seals counted during the molt declined 80% from 786 in 1980 to 152 seals in 2002. Since 2002, numbers rapidly increased 20% annually. Results indicate that Aialik Bay, especially Pedersen Lake, is a favorable molt location, but low pup counts indicate continued poor recruitment.

Kayak interactions and seal behavior were evaluated from 2004-2007. Results showed seals in Pedersen Lake abandoned the ice more frequently when humans were present. Although guided trips caused less impact than unguided trips, mitigation training provided to guides resulted in a further reduction in numbers of seals abandoning the ice.

Digital still camera systems developed for monitoring seals in Day Harbor showed insufficient reliability and field of view for application in remote steep rocky habitats. They did show potential for less constrained applications.

**Key Words:** Harbor seal, *Phoca vitulina richardsi*, population trend, Gulf of Alaska, glacier, vessel disturbance, kayaks.

**Project Data:** *Description of data* – Two primary data sets are produced by the video monitoring project: one that includes counts, environmental co-variates, video camera performance, and general video tape log, and another that includes video observations pertaining to vessel interactions. *Format* – Primary data associated with video monitoring have been incorporated into two Access databases. Original video images are stored on VHS video tape; a digital conversion of a subset of records is planned for 2008. Paper records of counts, vessel interactions and snapshot images taken through video capture software are stored in folders, identified by camera date, and time. *Custodian* – Contact Anne Hoover-Miller, Harbor Seal Program Manager, Alaska SeaLife Center, P.O. Box 1329, Seward, AK 99664. Phone: (907) 224-6331, Email: anneh@alaskasealife.org. *Access limitations* – access to some fields of the vessel interaction database has been limited; contact custodian for access.

**Citation:**

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## EXECUTIVE SUMMARY

Harbor seals monitored at various locations in the Gulf of Alaska have undergone extensive population declines since the mid-1970s for unknown reasons (Pitcher 1980, Small *et al.* 2003). Subsequent to 1994, counts taken near Kodiak Island began to recover, while numbers of seals in Prince William Sound continued to decline (Frost *et al.* 1999, Jemison *et al.* 2006). Harbor seals that inhabit glacial ice in Aialik Bay have been monitored since 1979, although the frequency and completeness of counts were suboptimal for many years from 1982-2001. In 2002, with support from the Ocean Alaska Science and Learning Center, the Port Graham Corporation, U.S. Fish and Wildlife Service and National Marine Fisheries Service, remotely controlled video cameras were installed in Aialik and Pedersen Glaciers to continue observations of seals and the glacial ice environment.

The objectives of this study were to use remotely controlled video cameras in Aialik Bay to continue monitoring long term population trends of harbor seals, assess the influence of environmental conditions on seal attendance, evaluate effects of vessel traffic (particularly kayaks) on harbor seals, and test the feasibility of using still digital cameras to monitor seals in Day Harbor.

Video monitoring took place 25km southwest of Seward at glacial ice habitats near Aialik and Pedersen Glaciers near the northern extent of Aialik Bay in the Kenai Fjords National Park. The study area is bounded by the coordinates 59.96°N (north), 59.87°N (south), -149.65°W (east) and -149.79°W (west). Aialik Glacier has been a relatively stable glacier since 1900, while Pedersen Glacier has been steadily retreating and currently calves ice into Pedersen Lake, which was completely covered by the glacier in 1961. The part of the study testing the use of digital still cameras to monitor seals occurred in Day Harbor, which is a fjord located 20km southeast of Seward bounded by a rectangle marked by 60.03°N, -149.08°W, 60.00°N, -149.02°W.

Remotely controlled video monitoring equipment developed and maintained by SeeMore Wildlife Inc. and operated at the Alaska SeaLife Center in Seward, Alaska, were installed near Aialik and Pedersen Glaciers in June 2002 to observe harbor seals, vessel interactions, and glacial activity near Aialik and Pedersen Glaciers. The equipment included visible light, commercially available block video cameras with 25X optical and up to 300X digital zoom. The cameras were mounted in weatherproof housings that include remote-controlled pan, tilt, zoom, and windshield wiper/washer assemblies. Cameras were controlled via computers located at the Alaska SeaLife Center. Observers immediately recorded data from live images. Time-lapse recordings were taken concurrently to provide a record of environmental conditions, seal distribution, interactions between humans and seals and, when viewing opportunities were favorable, the behavior of seals. During 2002, censuses were conducted by methodically scanning the ice during mid-day (11:30-13:30) and at other times as opportunity allowed. In 2003-2004 censuses were conducted at approximately 09:00, 11:30, 13:00, 15:00, 17:00. From 4-6 June, 11-14 June and 1-8 August (2004 - 2007), censuses were conducted at approximately 07:00, 08:00, 09:00, 10:00, 11:30, 13:00, 15:00, 17:00, and 19:00 for more frequent monitoring during times of maximum expected attendance of pupping and molting seals.

*Population monitoring.* Prior to analysis, counts were screened to include only complete, good quality, counts. Counts were removed from analysis if any of the following occurred: (1) sustained winds speeds exceeded 15 knots – due to effects on ice availability; (2) moderate to heavy rain – conditions when seals may leave the ice and visibility is obscured; (3) camera malfunctions that resulted in compromised viewing; or (4) when observers, for any reason, ranked the overall quality of the surveys as less than 2 (good) on a scale of 1 (excellent) to 4 (poor).

Counts representing seal attendance during pupping (25 May-25 June) included combined counts of total seals (including pups) and pups from near Aialik and Pedersen Glaciers. During the molt (25 July-25 August) total seal counts were analyzed for Aialik Glacier and Pedersen Lake combined. Counts representing upper Aialik Bay as a whole were determined from sequential surveys of both sites.

Using stepwise multiple linear regression, the optimum survey window was determined to be within four hours of solar noon ($T_{SN}$), five days from Julian day 162 (~6-16 June) for pup counts and within four days of Julian day 221 (~5-13 August) for molt counts. For counts taken within optimum survey windows, generalized linear models using exponential distributions and log-link functions were developed for optimized pup counts and for molt counts taken over the complete survey window (25 July-25 August). Models were tested for over-dispersion parameters estimated by Pearson $\chi 2$ /Degrees of Freedom (DF). Results showed that from 2002-2007 numbers of pups have remained stable at low numbers, but molt counts showed rapid growth at an average 20% per year. Population trends indicated by the numbers of pups born differed substantially from trends indicated by molt counts. These results suggest that expanding habitat adjacent to Pedersen Glacier is attracting molting seals into the region from other areas and/or seals are spending additional time hauled out during the molt. Alternatively, pup productivity is abnormally low and is not increasing. Future analysis will be conducted to compare results with trends indicated from aerial surveys at haulouts along the southern Kenai Peninsula.

*Vessel Interactions:* Tourism is the fastest growing industry in Alaska and worldwide. Marine and ecotourism are expanding at the highest rates, and assessments of the impacts of tourist activities on wildlife and the ecosystems are needed. Kenai Fjords National Park was established in 1980 and has increased in popularity for both large vessel tours and kayakers. In the summer of 2005 an in-depth study on the impacts of kayaks in Pedersen Lake was initiated after increasing numbers of kayaks were observed in this secluded haulout. The objectives of this study were to: 1) determine if the frequency at which seals abandon the ice increases in the presence of kayakers or hikers, 2) develop paddling recommendations based on observations of kayak interactions, 3) compare inter-annual variation in behavior and disturbances and 4) determine whether mitigation training helps to reduce disturbance.

Kayak interactions and seal behavior were recorded during the molt from early July through early September via the remote video system and by direct field observation in mid-July- August. The rate of seals abandoning the ice during 2005 or 2006 was not significantly impacted by tide or time of day; in 2004, the number of seals abandoning the ice was significantly impacted by time of day. Results for all years indicate harbor seals abandon the ice at a significantly greater frequency in the presence of sea kayakers or people walking along the shore than when humans are absent (P<0.001). After analyzing 2005 data and disturbance rates, mitigation training was provided to the guides based out of Seward, Alaska. Guided groups (regardless of training) caused fewer seals to abandon the ice than unguided groups (P<0.001). Guides with mitigation training caused fewer seals to abandon the ice than other guided groups (P<0.001). There was no significant difference in seals abandoning the ice when guided groups with mitigation training were present and humans were absent from the lake (P<0.5), although seals were more alert than when humans were absent. Education and training was effective in changing the behavior of guides and resulted in significant reduction of seals abandoning the ice.

Prototype fixed still cameras were evaluated for potential use in long-term monitoring of harbor seals using land haulouts in Day Harbor. Nikon Coolpix 5700, 8700, and 8800 cameras were mounted in modified Pelican cases that included a glass window. Cameras were tested with an external intervalometer (Harbortronics) or internal intervalometer (Coolpix 8700 and 8800). The units tested included a 12-volt gel cell battery, 6 amp charge controller and external solar panel. Testing showed that Coolpix 8700 and 8800 were highly sensitive to power fluctuations, resulting in system failures and damage to circuitry controlling the lens. Limitations in the maximum numbers of images that could be stored by the camera required cameras to be downloaded every two weeks, an insufficient amount of time for continuous operation during fall, winter and spring in remote field settings. Our experience indicated that the camera system using the Coolpix 8700 or 8800 cameras showed promise for some types of remote field applications. Mounted in the Pelican 1500 case, the camera unit was portable and easy to set up. At least twice the battery capacity and solar generation capability of the original design is preferred to enhance power management in partially shaded locations and during periods of reduced sun exposure. This system had good functionality in non-critical applications where access could be assured on a frequent basis. We found that in the rocky haulout sites in Day Harbor, limitations in access to camera sites and adequate field of view severely impacted our ability to obtain suitable coverage. Therefore, we did not pursue continued implementation of the cameras for remote population monitoring.

## INTRODUCTION

Harbor seals at monitored locations in the Gulf of Alaska have undergone extensive population declines since the mid-1970s for unknown reasons (Small *et al.* 2003). Tugidak Island, located about 24 km southwest of Kodiak Island, was the location of one of the largest concentrations of harbor seals in the world where, in 1976, more than 12,000 seals were counted (Pitcher 1990). By 1994, only about 1,000 seals remained (Jemsion and Kelly 2001). Subsequent counts have shown recovery, although numbers remain low (Jemison *et al.* 2006). In Prince William Sound, numbers of seals diminished 63% between 1984 and 1997 (Frost *et al.* 1999).

Reduced numbers of seals in the 1980s also were observed on the Kenai Peninsula. In glacial ice haulouts in Aialik Bay, more than 1,600 seals were counted in 1980, but by the mid-1990s, only about 250 seals were observed (Hoover-Miller unpublished, NPS unpublished, OASLC/ASLC unpublished). Counts of seals in Day Harbor were taken less frequently, but they also indicated a decline from the 226 seals counted in 1983 to only 61 in 1994. Figure 1 contrasts relative changes in numbers of seals counted at Tugidak Island, with changes in numbers of seals counted in Aialik Bay and Day Harbor (Figure 2), relative to counts in 1983 (Hoover 1983, Hoover 1989, Tetreau 1998, Pitcher 1990, Jemison *et al.* 2006, Hoover unpublished, NPS unpublished). All areas indicated diminishing trends in the 1980s. The period following 1994 suggests that seals in both Tugidak Island and, potentially, Day Harbor have shown stability and initial recovery by 2002. However, the suggested trends for Aialik Bay and Day Harbor are weakened by data gaps, paucity of counts and inconsistent monitoring effort.

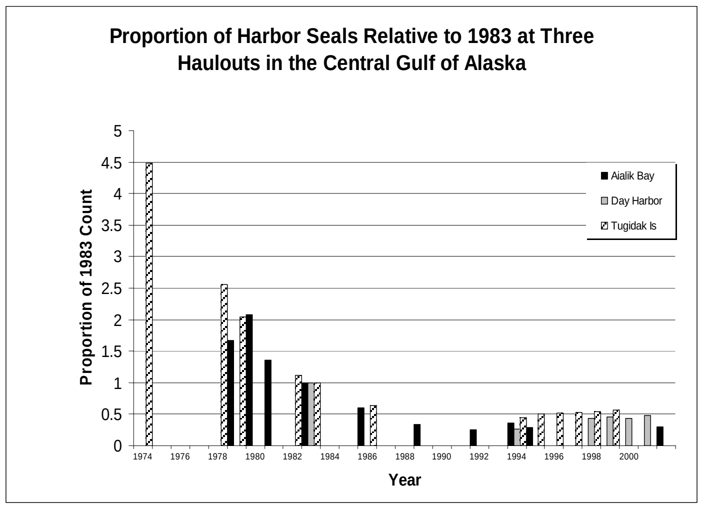



**Figure 1.** Population trends of harbor seals at three sites in the Gulf of Alaska relative to 1983 counts derived from Hoover 1983, Hoover 1989, Tetreau 1998, Pitcher 1990, Jemison and Pendleton 2001, OASLC/ASLC unpublished, Hoover unpublished, NPS unpublished.

Nature-based recreation and tourism are rapidly increasing in popularity in Alaska (Colt *et al.* 2002). Kayaking and wildlife viewing are projected to increase by nearly 30% by 2020 (Bowker 2001). Coastal areas are perceived by most individuals as the best location to recreate. Unfortunately, the impact of increased visitor use can be magnified in these areas (Gormsen 1997). Visitation to Kenai Fjords National Park, a coastal park located outside of Seward, Alaska on the Kenai Peninsula, increased nearly 300% from the early 1980s to the late 1990s (Colt *et al.* 2002).

Popular in Kenai Fjords National Park, sea kayaking is a non-consumptive recreational activity offered by several ecotourism operations. Ecotourism has been perceived as a valuable alternative to resource-consumptive activities. However, there are concerns about how non-consumptive and sustainable ecotourism really is (Corkeron 2004) and how effective education programs are as a management tool (Orams 1995). A review of the impact of non-consumptive recreational activities indicated that in 81% of the studies, wildlife was negatively impacted by recreationists (Boyle & Samson 1985).

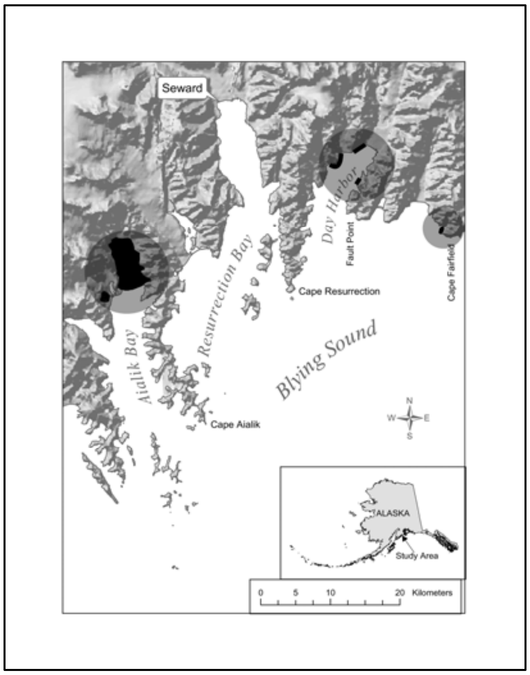



**Figure 2.** Kenai fjords harbor seal study area includes six haulout areas identified in black within three shaded areas: Aialik Glacier and Pedersen Glacier in Aialik Bay, three coastline areas in Day Harbor and the Cape Fairfield haulout on the outer coast.

Several studies have assessed the impact of disturbance, including recreation and tourism on marine mammals in general (Williams *et al.* 2002, Bejder *et al.* 2006, Lusseau 2006) and harbor seals in particular (Allen *et al.* 1984, Suyran & Harvey 1998, Henry & Hammill 2001). Researchers documented potential disturbance by vessels in Aialik Bay in 1979 and 1980. During that period only one to three boats visited Aialik Bay daily and most did not venture into the glacial ice, a practice that reduced the numbers of seals abandoning the ice (Murphy & Hoover 1981). In 1980, Kenai Fjords National Park was established, after which the number of vessels (both motorized and sea kayaks) visiting the Aialik Bay area increased.

The potential impact of sea kayakers on harbor seal behavior was examined using remotely operated cameras and direct field observation in Pedersen Lake, a glacial lake adjacent to Aialik Bay. Research objectives were to: 1) determine if abandoning frequencies and activity levels of harbor seals increase in the presence of humans, 2) determine the effectiveness of using a remotely operated camera system for disturbance studies, 3) develop recommendations based on human/seal interactions observed and 4) determine if education of guides regarding kayaking techniques for minimizing disturbance actually reduces disturbance.

Approximately 10% of harbor seals in Alaska use glacial ice environments (Bengston *et al.* 2007). Besides being affected by factors that precipitated the steep Gulf of Alaska population declines observed during the 1980s, seals using glacial ice must adjust to changes in the status and activity of the glaciers during a period of time when most glaciers in Alaska are thinning and receding (Molnia 2008). Although most tidewater glaciers are located within regions protected by the National Park Service and National Forest Service, adjacent waters have become popular tourist attractions, causing increased interactions between seals and humans. Long-term monitoring of harbor seals and glacial ice environments in Aialik Bay provides unique opportunities to understand how seals use glacial ice habitats and how they respond to environmental change over time. Long-term monitoring also provides a rare opportunity to document tidewater glacial habitat variability and the responses of glaciers to seasonal events and long-term climate variability.

In 2002, the National Park Service (NPS), through the Ocean Alaska Science and Learning Center (OASLC), National Marine Fisheries Service (NMFS), Port Graham Corporation (PGC), and the US Fish and Wildlife Service (USFWS) collaborated with the Alaska SeaLife Center (ASLC) to install and operate a remotely-controlled video camera system, developed by SeeMore Wildlife Inc., near Aialik and Pedersen Glaciers. This project uses video technology to observe harbor seals and glacial ice environments in Aialik Bay, Kenai Fjords National Park. In 2005, the EVOS Trustee Council provided funding through the Gulf Ecosystem Monitoring (GEM) program to complete the installation of the system and continue monitoring and assessments of harbor seal populations, environmental variability, and human activities from 2005-2007.

The first objective of this study included the assessment of current harbor seal population trends in Aialik Bay, with consideration of variability in environmental conditions that affect haulout, and the number of seals that are counted. Results showed that in Aialik Bay, mean numbers of pups have not increased over time, but since 2002, mean numbers of seals counted during the molt rapidly increased at 20% annually. Concurrent research on vessel interactions associated with kayaking indicated interactions frequently caused seals to abandon the ice in Pedersen Lake. Kayak guide training associated with this study increased the guides' awareness of the seal behavior and by following kayak viewing guidelines, guides have greatly reduced the frequency and intensity of adverse impacts in Pedersen Lake. The second objective of the study, testing of prototype still video cameras, yielded insufficient reliability and capability for widespread use of digital cameras to monitor harbor seal haulout in Day Harbor over prolonged periods of time.

**OBJECTIVES**

1. Use remotely controlled video camera monitoring in Aialik Bay to contribute to studies on long-term population trends of harbor seals, and the influence of environmental conditions on seal attendance. Hypotheses associated with long term monitoring include:
   a) Evaluation of population trends.

      $H_o$: number of seals without pups are the same between years.

      $H_o$: number of female/pup pairs are the same between years.

      $H_o$: number of seals during peak haulout during the molt (first week of August) are the same between years.

      $H_o$: number of seals during the optimal trend monitoring period used by ADF&G (approximately 17 August) are the same between years.

   b) Evaluation of haulout activity relative to environmental conditions.

      $H_o$: haulout activity relative to covariates date, time of day, time, and weather conditions in current years are the same as during baseline studies.

$H_o$: haulout activity relative to covariates date, time of day, time, and weather conditions in recent years are the same between years.

c) Evaluation of vessel traffic and tourism on harbor seals.

$H_o$: the response of seals to vessels is the same between years.

$H_o$: vessel behavior is the same between years.

$H_o$: haulout covariates, including day of year, time of day, tide and weather, have the same influence during periods of high and low vessel activity.

2. Evaluate prototype still digital cameras (originally developed by the NMFS National Marine Mammal Lab) in Day Harbor to evaluate if still camera imagery provides suitable imagery for more economical, less labor intensive monitoring of haulouts in Day Harbor (a nearby fjord lacking tidewater glaciers).

## OBJECTIVE 1: REMOTELY CONTROLLED VIDEO CAMERA MONITORING

### Methods

*Study Area*

Video monitoring of harbor seals and glacial ice habitats near Aialik and Pedersen Glaciers took place near the northern extent of Aialik Bay on the southeastern Kenai Peninsula in southcentral Alaska. Located 25 km southwest of Seward, in the Kenai Fjords National Park, the study area is bounded by the coordinates 59.96°N (north), 59.87°N (south), -149.65°W (east) and -149.79°W (west).

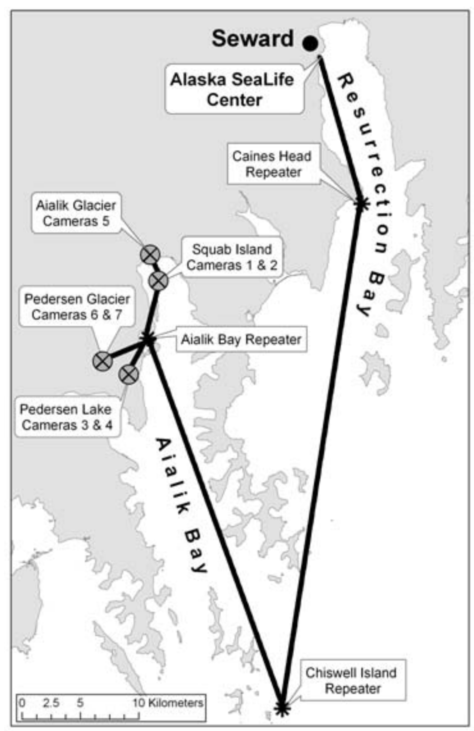



**Figure 3.** Map of remote video camera sites in upper Aialik Bay and transmission pathways to the Alaska SeaLife Center in Seward.

Aialik Bay is a 30 km long fjord that opens directly to the Gulf of Alaska. Aialik Glacier is located on the northwest shore at the head of the fjord and terminates directly into Aialik Bay. Pedersen Glacier is located on the western side of the bay and terminates in Pedersen Lake, a tidally influenced lake west of the Aialik Bay sill (underwater moraine). Aialik Glacier has been a relatively stable glacier since 1900, while Pedersen Glacier has been steadily retreating and currently calves ice into Pedersen Lake, which was completely covered by the glacier in 1961. A shallow (13 m deep) sill, east of Pedersen Glacier separates Aialik Bay's 9-km-long upper basin from the lower fjord. Harbor seals haul out on ice calved from both Aialik and Pedersen Glaciers.

*Data Collection*

**Population Trends**

Baseline field studies were conducted in upper Aialik Bay from 17 May-17 August, 1979, 15 May-23 August 1980, and 21 May-12 June, 1981 (Hoover 1983). Censuses of marine mammals were conducted at the head of Aialik Bay from the northern end of Squab Island by observers using 7X35 binoculars and, in most years, a 15-45X spotting scope. For each census the date, time, tide, weather (percent cloud cover, wind direction, wind velocity, precipitation) ice density and direction of ice movement were recorded. The location of ice and seals were mapped. Multiple censuses were conducted daily (n=125 in 1979; 130 in 1980, and 36 in 1981). Counts during periods of fog, heavy rain, and wind speeds exceeding 10 m/s (20 kn) were not always completed because of poor visibility and reduced numbers of seals. During each census, total numbers of all marine mammals observed on the ice and in the water were recorded; only seals on ice were used in analysis.

Remotely controlled video monitoring equipment developed and maintained by SeeMore Wildlife Inc. and operated at the Alaska SeaLife Center in Seward, Alaska, were installed in June 2002 to observe harbor seals in Aialik Bay. Cameras were installed on Squab Island, at the head of Aialik Bay, and on the south side of Pedersen Lake, near Pedersen Glacier (Figure 2). The equipment included visible light, commercially available block video cameras with 25X optical and up to 300X digital zoom. The cameras were mounted in weatherproof housings that include remote-controlled pan, tilt, zoom, and windshield wiper/washer assemblies. Cameras were controlled via computers located at the Alaska SeaLife Center. User-selected control signals were transmitted more than 90 km to the desired camera via UHF frequencies and video signals were transmitted along the reciprocal path to the ASLC via a series of microwave repeaters (Figure 2). Observers immediately recorded data from live images. Time-lapse recordings were concurrently taken to provide a record of environmental conditions, seal distribution, interactions between humans and seals, and, when viewing opportunities were favorable, the behavior of seals. In 2003, the system expanded to include a camera site on the north side of Aialik Glacier to observe the glacier-face environment, and in 2005 a site was installed on the south side of Pedersen Glacier.

From 2002-2007, surveys were initiated with the Squab Island camera. An ice scan using eleven predefined positions captured a panorama of images covering a 360 degree view to show the ice distribution and general survey conditions (cloud cover, precipitation, and sea state). The ice and water from Squab Island to shore was methodically scanned by following parallel tracks to shore at differing magnification. When seals were located, magnification was adjusted as needed to improve accuracy of counts and to distinguish seals from sea otters, which also hauled out on the ice. Seals present on ice were immediately recorded on data forms with the date and time. Swimming seals were distinguished from seals on ice and were not included in the count. Weather conditions including percent cloud cover, wind direction, wind velocity (based on a modified Beaufort scale reflecting the reduced fetch of the upper bay), precipitation, composite weather (1= full sun, 2=partial clouds to overcast, 3=precipitation and wind >20kts), and general direction of ice movement was recorded. From 2004-2007, temperature, barometric pressure, wind speed, wind direction and humidity were measured by a weather station located on Squab Island and recorded for each survey.

Sequential counts at both locations made up a complete upper Aialik Bay survey. Surveys were conducted during mid-day (11:30-13:30) and at other times as opportunity allowed. In 2003-2004 censuses were conducted at approximately 09:00, 11:30, 13:00, 15:00, 17:00. From 4-6 June, 11-14 June and 1-8 August (2004 - 2007), censuses were conducted at approximately 07:00, 08:00, 09:00, 10:00, 11:30, 13:00, 15:00, 17:00, and 19:00 for more frequent monitoring during times of maximum expected attendance of pupping and molting seals.

Methods and survey areas differed between the 1979-1981 baseline research and this study. Overall, the ability to detect seals and quality of counts from Squab Island made using video cameras are comparable to those made by observers using binoculars on Squab Island. However, during 1979-1981 study, counts were less frequently taken than since 2002. Although seals are regularly observed and counted in Pedersen Lake, they were not observed to haul out in Pedersen Lake prior to the mid-1990s (NPS unpublished, Hoover 1983).

Prior to analysis, counts were screened to include only complete, good quality, counts. Counts were removed from analysis if any of the following occurred: (1) sustained winds speeds exceeded 15 kts, due to effects on ice availability; (2) moderate to heavy rain, conditions when seals may leave the ice and visibility was obscured; (3) camera malfunctions that resulted in compromised viewing; or (4) when observers, for any reason, ranked the overall quality of the surveys as less than 2 (good) on a scale of 1 (excellent) to 4 (poor).

Counts representing seal attendance during pupping (25 May-25 June) included combined counts of total seals including pups and pups from near Aialik and Pedersen Glaciers. During the molt (25 July-25 August) total numbers of seals were analyzed for Aialik Glacier and Pedersen Lake combined. Counts representing upper Aialik Bay as a whole were determined from sequential surveys of both sites.

Multiple daily counts obtained throughout the summer over multiple decades provided an opportunity to identify favorable sampling conditions and assess trends based on different indices in a glacial ice environment. Counts were evaluated using the following indices: (a) maximum counts (the maximum count obtained during the survey window), (b) maximum daily counts (the maximum count obtained within a day), (c) mean counts (mean counts during the entire pupping or molting window), (d) optimized mean counts (the mean of counts taken during optimal survey windows determined through multiple linear regression analysis), and (e) adjusted counts (counts adjusted for standardized survey conditions using general linear regression models). Multiple linear regression analysis and general liner regression models were developed independently for the decadal periods 1979-1981 and 2002-2007. Adjusted counts were derived for each survey based on the appropriate decadal General Linear Model predictions.

Other covariates potentially affecting the number of seals hauled out were determined for each survey. Tidal effects were based on the time and height of the tide forecasted for the Seward Tide station (9455090). NOAA tide predictions are identical between Seward and North Aialik Bay with respect to time and height of high tides. Low tides in Seward occur 12 minutes later than North Aialik Bay and are 2% greater in height. Seward is used as the reference site because of extensive records of predicted and actual tidal change. Tide velocity (m/min) was calculated as the difference in tide height (m) predicted for the onset of the survey hour and the predicted tide height at the onset of the hour subsequent to the survey divided by 60 minutes. Negative values correspond to falling tides while positive values correspond to rising tides. Sunrise, sunset and lunar stage (percent of moon's visible disk illuminated) were obtained from the U.S. Naval Observatory, Astronomical Applications Department. Solar noon was calculated as the midpoint between sunrise and sunset and was adjusted for Daylight Savings Time and the 1983 change in Alaska Time Zones. Potential influence of vessel presence was evaluated for surveys conducted from 2002-2007 based on the number of vessels observed from 1 hour prior to each survey to 2 hrs after initiation of the survey. Vessel presence was determined for surveys conducted at Aialik glacier during pupping and at both Aialik and Pedersen glaciers during molting.

**Kayak Interactions**

Human recreational activity and harbor seal behavior was monitored from mid-July to mid-September, the time of the annual harbor seal molt. Data were collected from the remotely operated cameras from 2004-2006. Ambient harbor seal behavior and kayak disturbances were recorded on time-lapse tapes prior to the initiation of this study. Therefore, data for the summer of 2004 were collected from the archived time-lapsed tapes. Data were collected in the field 20-28 July, 2005 and 16 July-8 August, 2006. Variables collected and categories used for statistical analysis are listed in Table 1; sample sizes for each treatment are presented in Table 2.

Daily counts and behavioral observations began between 08:00 and 12:00 and ended between 17:00 and 20:00. Thus, the midday hours when the highest number of harbor seals haul out on glacial ice and the times in which kayakers are most likely to be present in the lake were encompassed (Calambokidis *et al.* 1987, Boveng *et al.* 2003). If weather compromised visibility, observations were canceled until viewing conditions improved.

A focal group of seal(s) was selected from a section in the lake and their behaviors were recorded. The focal group consisted of a group of seals hauled out together on one iceberg or group of icebergs in close proximity to one another. In the field, seal behaviors were observed with a spotting scope mounted on a tri-pod; a maximum of six seals were monitored as part of a focal group. When the remotely operated camera system was used, the camera focused on the focal group of seals. Camera operators repositioned the camera to ensure the seals on drifting ice stayed within the camera frame. The number of seals concurrently observed using cameras was unlimited. Observations were recorded on digital time-lapsed tapes for later review. When humans were present, the activity of the kayakers and walkers was concurrently monitored. Humans were considered present in the lake when a group of kayakers or people walking along the shore passed the spit in the lake. For all behavioral observations, harbor seal behavior was categorized as resting (lying down or comfort movements including grooming), alert (head up, neck extended, eyes open, actively scanning or fixed stare), or abandoning (leaving the ice berg by entering the water). Additionally, breaks in the observations were noted as (B); or a seals temporarily out of view were noted as (O). A behavior was recorded every ten seconds for a maximum of twenty minutes. The time of day, tide, and precipitation were recorded before every round of observations. All harbor seal behavior sampling methods were based on those in Altman (1974).

Four companies in Seward, Alaska offered guided sea kayak tours in Kenai Fjords National Park during the years of this study. Every year the guides employed by these companies undergo a period of training. During May 2006, research results from the 2005 season were presented. During the 2006 field season each group of recreationists that entered the lake was classified as a guided verses unguided group, a group receiving mitigation training verses not receiving training, or a group of unknown/mixed training level. All unknown/mixed training level observations were disregarded during the analysis.

**Table 1.** Variables collected and categories applied for statistical analysis.

| Variable | Collection Method | Category |
|---|---|---|
| Method of data collection | Field or remote camera observation | field or camera |
| Date | Month/Day/Year | year |
| Tide | Southcentral Alaska tide table, Resurrection Bay | high or low tide |
| Time of day | Hour/minutes | morning (08:00-10:59), noon (11:00-14:59), or afternoon (15:00-20:00) |
| Precipitation | Weather log from remotely operated camera system | rain or no rain |
| Human presence | Human activity in lake area | absent, kayaker, or walker |
| Training classification mitigation /mixed | Level of training to minimize disturbance to seals; used only for 2006 field data | guided or unguided; trained or not; unknown |

**Table 2.** Number of behavior observations collected per year, method of collection, and human presence.

| | Absent | Kayaker | Walker | Total |
|---|---|---|---|---|
| 2004 Camera | 263 | 43 | 29 | 335 |
| 2005 Camera | 492 | 342 | 39 | 873 |
| 2005 Field | 181 | 40 | 0 | 221 |
| 2006 Camera | 96 | 128 | 19 | 243 |
| 2006 Field | 467 | 238 | 100 | 805 |
| Total | 1499 | 791 | 187 | 2477 |

## Analysis

### Population trends

*Statistical Analysis*

This study included multiple daily counts conducted throughout the summer. Numbers of seals hauled out may vary in response to season, time of day, tides, weather, and unknown environmental variables (Hoover-Miller 1994). In this study, seasonal periods used for analysis were defined as pupping (25 May – 25 June) and molting (25 July - 25 August). Surveys from each decade (1979-1981 and 2002-2007) were evaluated separately. Indices of trends in numbers of seals were evaluated for each entire season as well as an optimized subset of dates and survey times described below. Multiple linear regression was used to identify covariates that significantly contributed to model variability. Because counts were initially screened to include only complete counts obtained under good viewing conditions, conditions that are known to affect haulout adversely (e.g., high winds and heavy rain) were not evaluated as potential covariates analysis. Generalized Linear Models (GLM) were then developed using significant covariates to adjust counts in accordance with those covariates at the time of surveys. Each decade was modeled separately but predicted values were combined for trend analysis.

*Peak Haulout Dates.* Potential Julian dates associated with highest seasonal counts during pupping and molting were identified based on distribution of maximum seasonal counts for each decade. Absolute values of deviations from that Julian date ($\Delta$ JD) were determined for each survey. (Absolute values were used to simplify modeling using a linear fit of symmetrical variation around the midpoint of the sampling window.) Linear regressions of numbers of seals by date were used select the Julian Day that provided highest regression coefficients. Based on this analysis, peak haulout dates were identified as Julian day 161 (11 June) for pupping and Julian day 162 (6 August) for molting.

*Covariate analysis.* Stepwise multiple linear regression was used to assess the significance of potential covariates associated with count variability. Potential covariates included: time of day relative to solar noon ($T_{SN}$), year, JD, lunar cycle stage, tide velocity, tide height, and vessel activity were considered based on all counts. Analysis was conducted separately for pupping and molting periods in each decade.

*Optimized survey windows*: Influences of $T_{SN}$ and Julian date (JD) were used to identify optimized sampling windows for pupping and molting periods in upper Aialik Bay. Within the optimized survey windows, counts reflect seasonal peaks, but the range in JD and $T_{SN}$ are sufficiently restricted to a range where they fail to contribute significantly to count variability. Multiple regression linear models including $\Delta$ JD and $T_{SN}$ as covariates were repetitively run. If $\Delta$ JD and $T_{SN}$ significantly contributed to the model, the range of the included covariate was reduced and the model was re-run. This process was repeated until $\Delta$ JD and $T_{SN}$ failed to contribute significantly to the model.

Generalized linear models (GLM), using exponential distributions and log-link functions were developed for optimized pup counts, for molt counts taken over the complete survey window (25 July-25 August) and for the optimized survey windows. Separate models were calculated for the decadal periods 1979-1981 and 2002-2007. Models were tested for over-dispersion parameters estimated by Pearson $\chi 2$ /DF. Predicted values, adjusted for environmental conditions, were determined for each survey based on separate models developed for each decadal period (1979-1981 or 2002-2007) and season (pupping or molting).

All analysis was based on Julian day; calendar dates shown in this paper are presented for reference but do not reflect leap year. Statistics were calculated using JMP 7.01 (SAS Institute).

**Kayak Interactions**

The following two measures of seal behaviors were calculated in the presence and absence of humans: abandoning frequency and activity level. Abandoning frequency was calculated as the ratio of the number of observations in which seals were observed abandoning the ice to the number of observations in which seals were not observed abandoning the ice. The second analysis looked at a finer scale of disturbance, the activity level of the seals. The activity level of every seal was calculated by summing the behavior values (0=resting, 1=alert, 2=abandon ice) and dividing this sum by the total number of behaviors recorded for each seal during an observation period. The median activity level for each group of observations was determined using the activity levels of the individual seals.

SigmaStat (SYSTAT, SSI., Inc. San Jose, CA) was used for the analyses of all data. A Chi-square test or Fisher Exact test was used to detect differences in abandoning frequencies between or among groups. The Mann-Whitney U rank sum test was used to detect differences between the median activity levels of two groups and the Kruskal-Wallis One Way Analysis of Variance on Ranks test to detect differences among three groups. A Bonferroni adjustment was made to individual test p-values for groups of tests performed on one data set. If a Bonferroni adjusted p-value was greater than one, it was revalued at one. For all statistical tests, a significance level of $\leq 0.05$ was used.

To minimize variability between data collected when humans were absent and present, behavioral observations made when humans were absent were analyzed by multiple variables (Table 1). Different methods of collection have been shown to produce different results when used for count data (Allen *et al.* 1984, Bengston *et al.* 2004). Data were divided into camera and field observations and the abandoning frequencies and median activity levels of the harbor seals were statistically compared. Data collected each year were contrasted to determine significance of interannual variability in abandoning frequency or median activity level. Effects of tide, time of day, rain and environmental variables that can impact the haulout behavior of harbor seals (Pauli & Terhune 1987, Boveng *et al.* 2003) were also tested. If, for a given data set, any combination of tide, time of day or rain were significantly different, the data were further divided to test for an interaction.

## Results

**Co-variates of harbor seal haulout.**

Results of least squares multivariate regression models developed for each decade, age class (seals with and without pups) and season (pupping and molting) are summarized in Table 3. Seals exhibited a high degree of variability that was not accounted for by monitored covariates. The proportion of variation accounted for by the covariates ($R^2$) was highest for mother-pup pairs and molting seals during 2002-2007. Greater variability detected for 1979-1981 samples may be a function of the frequency that seals were counted as well as changes in environmental conditions associated with declining and stable/recovering populations. Multiple linear regression analysis of all high quality pup counts obtained from 25 May-25 June indicated significant effects of

$T_{SN}$, year, and Δ $JD_{162}$ (11 June). Lunar cycle stage, tide velocity, tide height, and vessel activity did not significantly contribute to the variance. During the molt (25 July-25 August) significant effects were associated with $T_{SN}$, year, and Δ $JD_{221}$. Vessels also contributed significantly to the model but the correlation was positive and likely reflected the coincidence of vessels and seals being present in greatest numbers during mid-day, rather than vessels attracting seals to the haulouts. Effects of vessels were, therefore, not included in GLM modeling.

During pupping, the optimum survey window, when counts were highest and Julian day and $T_{SN}$ did not significantly contribute to the variance, was determined to be within 4 hours of solar noon ($T_{SN}$) and 5 days from $JD_{162}$, 6-16 June, for pup counts. During the molt, the optimum survey window was determined to be within 4 days of $JD_{221}$ (9 August), 5-13 August. The optimum survey windows did not differ between decades. For each sampling window, the maximum count and mean count were determined for each year (Tables 4and 5).

**Population trends**

Overall examination of counts taken of harbor seals in Aialik Bay since 1979 indicate that numbers of seals experienced a steep decline from 1980 to the mid-1990s. However, total numbers of seals (Figure 4 top) have rapidly increased since 2002. Numbers of pups (Figure 4 bottom) also showed declining numbers in the 1980s, but numbers have remained relatively stable since 2003.

*Pup Trends*. Numbers of pups were used to indicate productivity of the core sub-population associated with Aialik Bay. Table 4 summarizes counts taken from 25 May-25 June, for the years 1979-1981 and 2002-2007. During that period, maximum numbers of pups declined 85% from 358 in 1980 to 38 in 2002, and mean counts declined 87% from 133 to 17 pups.

The mean of maximum daily counts, summarized in Table 4, indicates a decline of 90% from 238 pups to 25 pups. Due to potential differences in survey methods and the large difference in numbers of seals present further covariate analysis was applied separately to the 1979-1981 and 2002-2007 time periods.

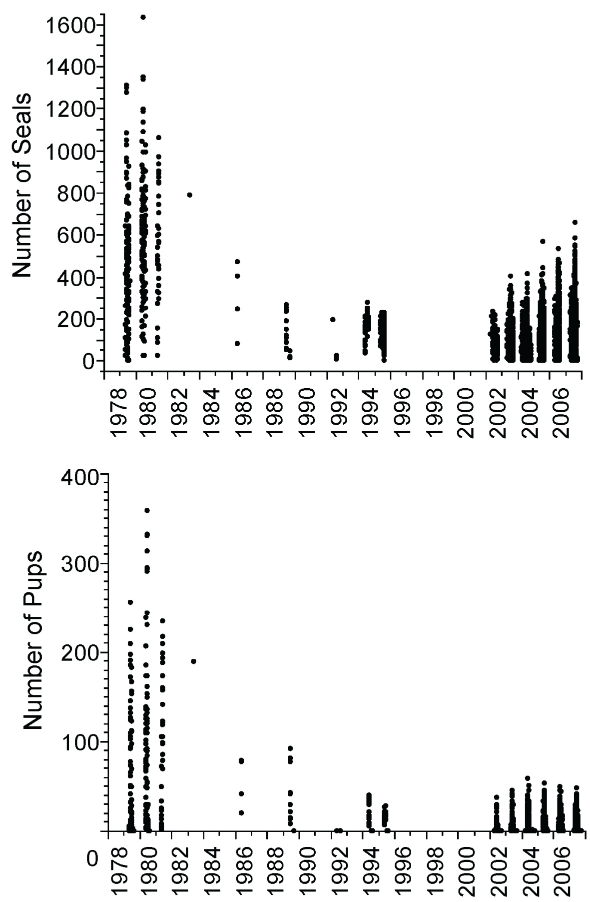



**Figure 4.** Counts of harbor seals in upper Aialik Bay from 1979-2007. Top panel shows total number of seals counted, including pups; the bottom panel shows numbers of pups counted. Each point indicates total numbers of seals counted during each survey.

Generalized Linear Models of counts, that included effects of year and day Δ JD, and TSN were used to generate counts adjusted for Julian day and time from solar noon. Models were developed separately for pupping and molting for each decadal period (Table 6). Adjusted counts, predicted by the model for the time period 6-16 June, are summarized in Table 4 and Figure 5 (top). Based on GLM adjustments to pup counts, mean adjusted counts diminished 86% from 128 in 1980 to 18 by 2002. Since 2002, no significant change has occurred.

*Molt Trends*. Numbers of seals counted during the molt, provides an index commonly used to monitor harbor seal population trends in Alaska, is summarized in Table 5 for counts taken from 25 July-25 August during the years 1979-1981 and 2002-2007. Maximum numbers of seals declined 78% from 1,029 in 1980 to 219 in 2002. The optimized sampling window for molt counts was determined to be within 4 days of $JD_{221}$ and 4 hours TSN. As with pup counts, optimized molt counts were modeled using GLM separately for the periods 02-07 and 79-80 (Table 6). Adjusted counts, predicted by the model, are summarized in Table 5 and Figure 5 (bottom). Based on GLM adjustments to molt counts obtained from 5-13 August within 4 hours TSN, 82% fewer seals were counted in 2002 (mean=141) than in 1980 (mean=786) indicating an average 7% annual rate of decline over the entire time period. Subsequent to 2002, adjusted optimal molt counts (Figure 5) showed rapid growth from 2002-2007. Unlike pup counts, mean adjusted numbers of seals increased an average 20%/yr (Range=17%-23%) from 152 in 2002 to 376 seals in 2007 (Table 5).

**Table 3**. Summary of least squares multivariate regression models developed for each decade, age class (seals with and without pups) and season (pupping and molting). Bold values reflect significant covariance. $R^2$ indicates the proportion of count variability that can be attributed to the modeled covariates.

| Year Group | Age Group | $R^2$ | Year | $\Delta JD_{162}$ | $\Delta JD_{221}$ | $\Delta T_{SN}$ | Lunar | Tide Velocity | Tide Height | Vessels |
|---|---|---|---|---|---|---|---|---|---|---|
| **Pupping: 25 May – 25 June** | | | | | | | | | | |
| 1979-1981 | Females with pups | 0.15 | 0.91 | **<0.0001** | -- | **0.0017** | 0.23 | 0.52 | **0.01** | 0.46 |
| 1979-1981 | Seals without pups | 0.12 | **<0.0001** | **0.01** | -- | **0.01** | **0.02** | **0.04** | 0.65 | 0.79 |
| 2002-2007 | Females with pups | 0.38 | 0.87 | **0.0001** | -- | **0.0002** | 0.61 | 0.25 | 0.62 | 0.10 |
| 2002-2007 | Seals without pups | 0.05 | 0.06 | 0.32 | -- | 0.25 | 0.21 | 0.59 | 0.24 | 0.22 |
| **Molting: 25 July-25 August** | | | | | | | | | | |
| 1979-1981 | Total Seals | 0.25 | 0.64 | -- | **0.01** | 0.84 | **0.04** | **0.05** | 0.86 | -- |
| 2002-2007 | Total Seals | 0.41 | **<0.0001** | -- | **0.001** | **0.009** | 0.48 | 0.12 | 0.14 | **0.009** |

**Table 4.** Maximum, mean and GLM adjusted counts of pups and maximum and mean counts of seals without pups in Aialik Bay from 25 May-25 June and during peak pupping from 6-16 June. SD equals standard deviation of the means.

| | 25 May-25 June (Pupping) | | | | | | | | 6-16 June (Optimized) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Seals without pups | | | | Pups | | | | Pups | | | | | |
| | | | | | | | | | GLM | | | | | |
| Year | N | Max | Mean | SD | N | Max | Mean | SD | N | Mean | SD | N | Mean | SD |
| 1979 | 51 | 1083 | 382 | 234.1 | 53 | 256 | 91 | 76.7 | 50 | 98 | 66 | 50 | 88 | 74 |
| 1980 | 53 | 917 | 428 | 177.8 | 53 | 358 | 133 | 89.8 | 53 | 128 | 56 | 53 | 133 | 90 |
| 1981 | 33 | 684 | 357 | 177.1 | 33 | 235 | 103 | 70.6 | 33 | 109 | 75 | 33 | 103 | 71 |
| 2002 | 21 | 175 | 75 | 46.9 | 20 | 38 | 17 | 10.5 | 10 | 18 | 3 | 10 | 22 | 11 |
| 2003 | 129 | 171 | 49 | 36.1 | 129 | 45 | 8 | 9.1 | 56 | 16 | 4 | 56 | 11 | 9 |
| 2004 | 288 | 212 | 60 | 41.6 | 192 | 59 | 14 | 12.0 | 74 | 16 | 3 | 74 | 19 | 10 |
| 2005 | 124 | 267 | 85 | 58.7 | 147 | 53 | 16 | 10.8 | 41 | 16 | 4 | 41 | 18 | 10 |
| 2006 | 171 | 230 | 54 | 52.8 | 185 | 50 | 9 | 9.9 | 58 | 15 | 3 | 58 | 13 | 11 |
| 2007 | 204 | 285 | 100 | 69.2 | 212 | 48 | 11 | 9.9 | 90 | 16 | 4 | 90 | 17 | 11 |

**Table 5.** Maximum, mean and GLM adjusted mean numbers of harbor seals counted in Aialik Bay during the molt from 25 July-25 August and from 5-13 August, when highest number of seals are counted. SD equals standard deviation of the means.

| Total Seals: 25 July-25 Aug (Molt) | | | Total Seals: 5-13 August, <4hr Solar Noon | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | GLM | | | | | | |
| YEAR | N | Max | N | Mean | SD | N | Max | Mean | SD |
| 1979 | 27 | 923 | | | | | | | |
| 1980 | 30 | 1029 | 10 | 786 | 146 | 10 | 1029 | 786 | 81 |
| 2002 | 27 | 219 | 6 | 152 | 8 | 6 | 219 | 141 | 61 |
| 2003 | 108 | 401 | 28 | 187 | 11 | 28 | 359 | 207 | 68 |
| 2004 | 111 | 415 | 26 | 218 | 15 | 26 | 415 | 198 | 92 |
| 2005 | 160 | 565 | 35 | 262 | 18 | 35 | 444 | 257 | 81 |
| 2006 | 118 | 536 | 32 | 315 | 22 | 32 | 483 | 313 | 117 |
| 2007 | 101 | 660 | 31 | 376 | 26 | 31 | 549 | 383 | 101 |

**Table 6**. Generalized Linear Model Equations used to adjust numbers of pups and molting seals in relation to favorable standardized environmental conditions. Yr = Year, $\Delta T_{SN}$ = absolute value of time from solar noon, and $\Delta\ JD_{162}$ = absolute value of number of days from Julian day 162 for pupping counts; $\Delta\ JD_{221}$ = absolute value of number of days from Julian day 221 for molting counts.

| | |
|---|---|
| Females with Pups: 1979-1981<br>6 – 16 June | Log(*mu*) = Exp (-417.4 + (0.214 X Year) + (-0.055 X $\Delta JD_{162}$) + (-0.109 X $\Delta T_{SN}$)) |
| Females with Pups: 2002-2007<br>6 – 16 June | Log(*mu*) = Exp (5.39+ (0.0001 x Yr) + (-0.075 x $\Delta JD_{162}$) + (-0.098 x $T_{SN}$)) |
| Molt 1980<br>5-13 August | Log(*mu*) = Exp (6.58+ (-0.08 x $\Delta Jul_{221}$) + (-0.033 x $\Delta T_{SN}$)) |
| Molt 2002-2007<br>5-13 August | Log(*mu*) = Exp (-379.83 + (0.19 x Yr) + (-0.04 x $\Delta Jul_{221}$) + (-0.051 x $\Delta T_{SN}$)) |

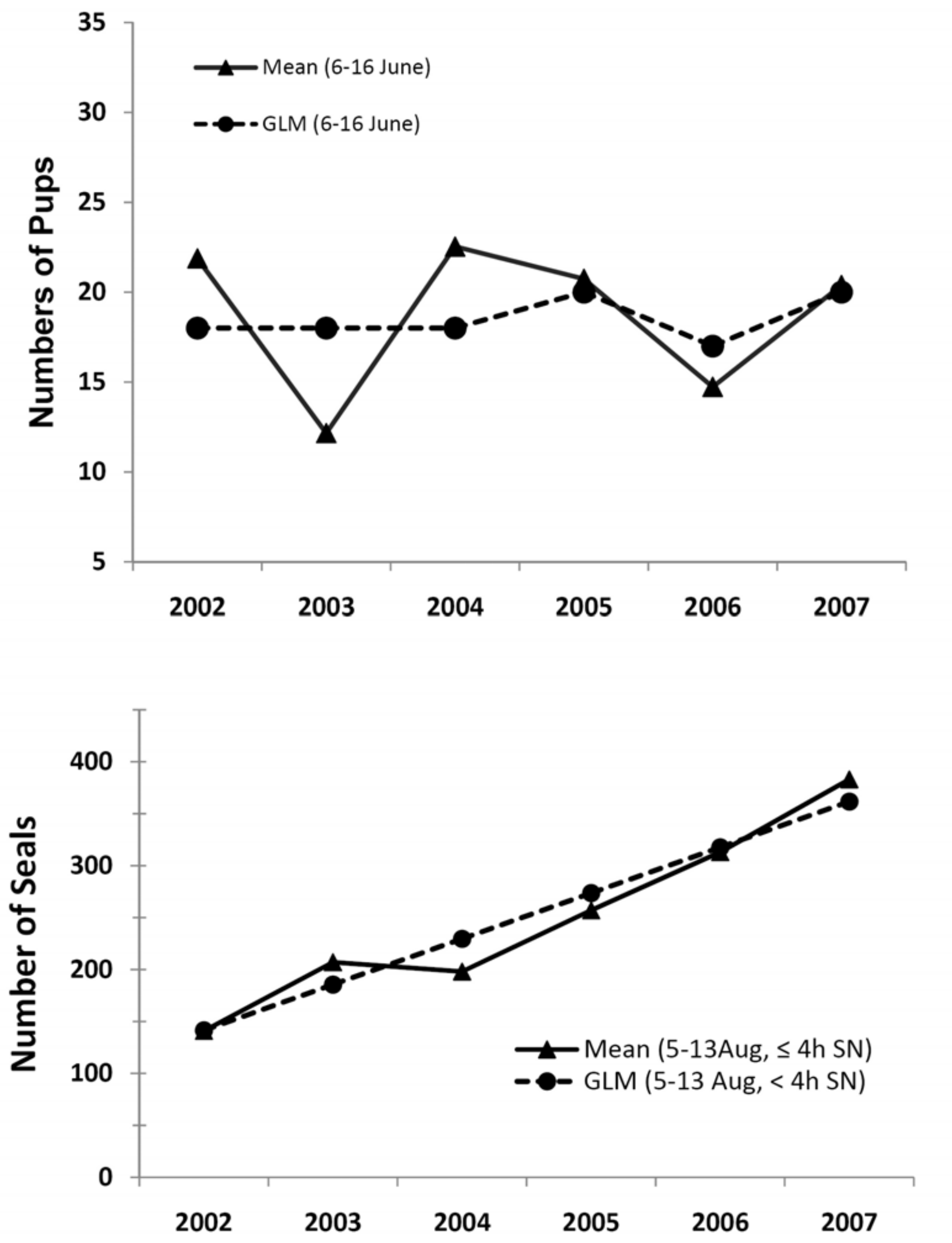



**Figure 5.** Mean numbers and GLM counts adjusted for time relative to solar noon and date for pups (top panel) and molting seals during optimal sampling dates.

## Kayak Interactions

A total of 2,477 harbor seals were observed during the project. Of the observations made, 60.5% were made when humans were absent, 32.0% when kayakers were present, and 7.5% percent when walkers were present. Approximately 43% of the observations were made each year in 2005 and 2006; less than 15% of the data were collected in 2004.

Data were collected for a total of 148 groups of recreationists. Thirty-two groups of recreationists were observed via the camera system in 2004, 55 groups in 2005, and 24 groups in 2006. Direct field observations were made of eight groups in 2005 and of 31 groups in 2006. On 32% of those days, a single group of recreationists was observed in Pedersen Lake. Two groups were observed on 19%, three groups on 5%, four groups on 3%, and five groups were observed on 1% of the days. Group size ranged from one to nine kayaks with a mean group size of three kayaks. Number of people per group ranged from one to fourteen with an average of four people per kayak group. The greatest number of people observed in the lake on one day was 21.

One hundred and six counts of seals were conducted in the field during 2005 and 2006. Number of counts per day ranged from zero to five with an average of three counts per day. The number of seals observed hauled out on the ice ranged from zero to 340. Eighty-five percent of the seals were counted in the upper portion of Pedersen Lake; fifteen percent were counted in the lower portion of the lake.

During 2005 and 2006, the percentage of observations made with the remotely operated camera system and in the field was not equivalent. In 2005, 80% of the observations were made via the camera system and 20% were made in the field (Table 7). Conversely, in 2006, 23% of the observations were made via the camera system and 77% were made in the field.

The abandoning frequency and median activity level of harbor seals and the number of recreationists observed in the lake were not equivalent for camera and field observations. For both 2005 and 2006, the abandoning frequencies of the seals were significantly different than camera and field observations (2005: $X^2 = 12.443$, $p \leq 0.001$; 2006: $X^2 = 6.593$, $p = 0.010$). While the median activity levels of the seals were not significantly different for camera and field observations, in 2005 ($U = 58081.5$, $p = 0.192$), they were significantly different for 2006 ($U = 21164.5$, $p \leq 0.001$). In 2005, groups of recreationists were observed a total of six times during seven days via the cameras. Four of these six groups were observed to disturb harbor seals. In comparison, during the same seven days, eleven groups of recreationists were observed by the field researcher. Eight of these eleven groups were recorded disturbing harbor seals.

Interannual variability in abandoning frequency and median activity level was observed between some years and methods of collection. When humans were absent the abandoning frequencies of seals were significantly different between 2005 and 2006 field observations and between 2004 and 2005 camera observations, but not between 2005 and 2006 camera observations (Figure 6). The median activity levels of the seals when humans were absent were not significantly different between the 2005 and 2006 field observations or the 2004 and 2005 camera observations, but were significantly different between the 2005 and 2006 camera observations. When kayakers were present, the abandoning frequencies of the seals for 2004 and 2005 camera observations were significantly different, but not between 2005 and 2006 camera or field. All comparisons for median activity levels of the seals when kayakers were present were significantly different. The abandoning frequencies and median activity levels of the seals when walkers were present for camera observations were significantly different between 2004 and 2005, but not between 2005 and 2006 (Figure 6).

**Table 7.** Interannual variability results for statistical tests for abandoning frequency and median activity of harbor seals between years and methods of collection for periods when humans were absent, kayakers were present and walkers were present.

| **Absent** | Number | Test Statistic [b] | p-value |
|---|---|---|---|
| *Abandoning Frequency* | *a, s; a, s* [a] | | |
| Camera 2004 vs. 2005 | 7, 256; 51, 441 | $X^2$ = 16.418 | ≤ 0.001 |
| Camera 2005 vs. 2006 | 51, 441; 4, 92 | $X^2$= 2.946 | 0.086 |
| Field 2005 vs. 2006 | 3, 178; 67, 400 | $X^2$ = 20.502 | ≤ 0.001 |
| *Median Activity Level* | | | |
| Camera 2004 vs. 2005 | 263, 492 | U = 95338.500 | 0.154 |
| Camera 2005 vs. 2006 | 492, 96 | U = 22459.5 | ≤ 0.001 |
| Field 2005 vs. 2006 | 181, 467 | U = 55985.5 | 0.199 |

| **Kayakers** | Number | Test Statistic [b] | p-value |
|---|---|---|---|
| *Abandoning Frequency* | *a, s; a, s* [a] | | |
| Camera 2004 vs. 2005 | 27, 16; 98, 244 | $X^2$=18.773 | ≤ 0.001 |
| Camera 2005 vs. 2006 | 98, 244; 25, 103 | $X^2$ = 3.554 | 0.059 |
| Field 2005 vs. 2006 | 13, 27; 111, 127 | $X^2$ = 2.228 | 0.136 |
| *Median Activity Level* | | | |
| Camera 2004 vs. 2005 | 43, 342 | U = 6897.500 | 0.042 |
| Camera 2005 vs. 2006 | 342, 128 | U = 20344.000 | ≤ 0.001 |
| Field 2005 vs. 2006 | 40, 238 | U = 4307.500 | 0.007 |

| **Walkers**[c] | Number | Test Statistic [b] | p-value |
|---|---|---|---|
| *Abandoning Frequency* | *a, s; a, s* [a] | | |
| Camera 2004 vs. 2005 | 0, 29; 6, 19 | Fisher Exact Test | 0.007 |
| Camera 2005 vs. 2006 | 6, 19; 6, 13 | $X^2$ = 0.0473 | 0.828 |
| *Median Activity Level* | | | |
| Camera 2004 & 2005 | 29, 39 | U = 735.500 | 0.001 |
| Camera 2005 vs. 2006 | 39, 19 | U = 565.500 | 0.941 |

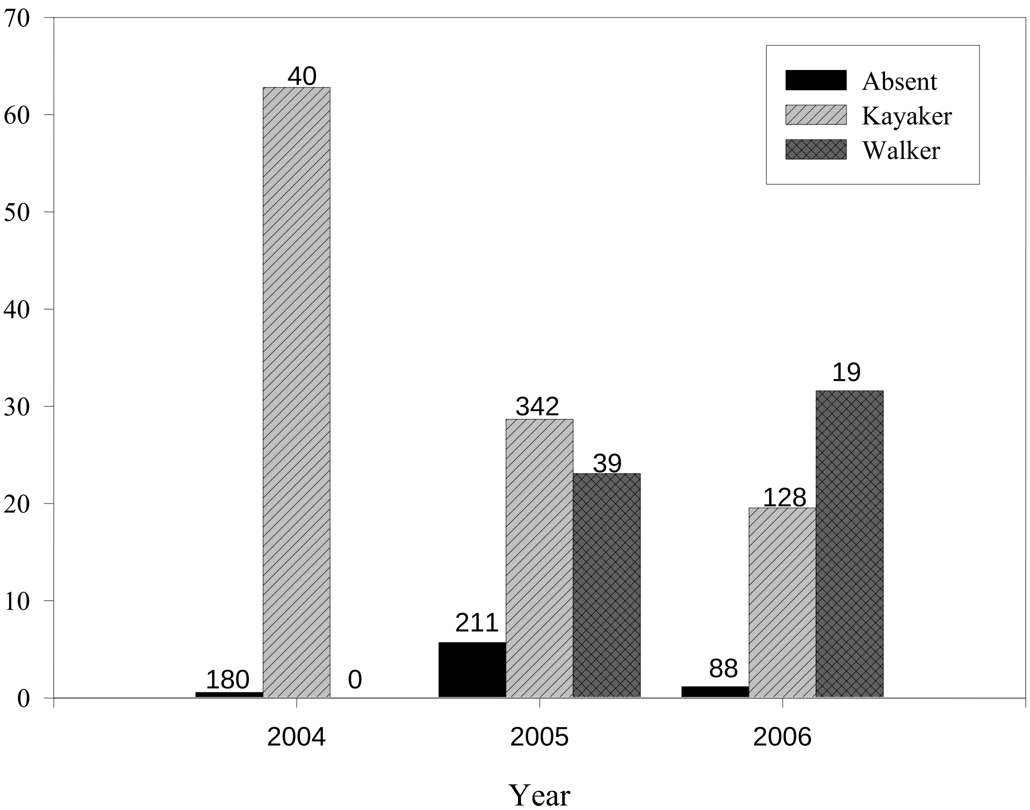



**Figure 6.** Percentage of observations in which harbor seals abandoned the ice observed by camera for year and human presence. Sample size above bars.

[a] Abbreviation explanation for *a, s; a, s*: the number of observations are divided into number of seals that abandoned and number that stayed for each variable being tested.
[b] The test statistics are $\chi^2$ for Chi-square and U for Mann-Whitney Rank Sum. Degrees of freedom for all tests are one.
[c] No walkers were observed during field observations in 2005.

The three physical variables examined altered either the abandoning frequency or median activity level of harbor seals when humans were absent. Data collected via the camera system were more affected by physical variables than data collected in the field. Two-thirds of the camera data sets were significantly affected by physical variables (Table 8). This is compared to one-quarter of the data sets collected while in the field (Table 9). The data collected during 2005 via the camera system were the only set of data in which two environmental variables were found to significantly alter seal behavior. When the interaction between high tide and rain was tested, it was found that there was no significant difference in the abandoning frequency at high tide when it was raining and not raining (Table 8). Seals abandoned the ice at a significantly higher rate when the tide was low than when it was high. The abandoning frequency of the seals was significantly higher in the morning than the noon or afternoon hours for 2004 camera data. Time was not found to have a significant impact on seal behavior for any other data set (Table 8). Rain was the environmental variable that had the greatest impact on seal behavior. The median activity level of the seals was significantly higher when it was raining than when it was not raining for 2004 camera and 2005 field data (Tables 8 & 9). In addition, the abandoning frequencies of the seals were significantly higher when it was raining for 2005 and 2006 camera data (Table 8).

**Table 8.** Statistical results for abandoning frequency and median activity of harbor seals from data collected via the remotely operated camera system for 2004-2006. Test results for physical variables that were non-significant are not included in this table except for the results of interactions between variables.

| | Number | Test Statistic | p-value | Bonferroni p-value |
|---|---|---|---|---|
| *Abandoning* | *a , s ; a , s* [a] | | | |
| High vs. Low Tide | 0, 93; 7, 163 | $X$ = 2.505 | 0.113 | 0.678 |
| Morning vs. Noon vs. Afternoon | 6, 77; 1, 127; 0, 52 | $X$ = 9.852 | 0.007 | 0.042 |
| Noon vs. Afternoon (n&a) | 1, 127; 0, 52 | $X$ = 0.218 | 0.64 | 1.000 |
| Rain vs. No Rain | 6, 82; 1, 174 | $X$ = 6.573 | 0.01 | 0.060 |
| Absent n&a vs. Kayaker [c] | 1, 179; 27, 16 | $X$ = 116.838 | $\leq$ 0.001 | $\leq$ 0.006 |
| Absent n&a vs. Walker [c] | 1, 179; 0,29 | $X$ = 1.097 | 0.295 | 1.000 |
| *Activity Level* | | | | |
| High vs. Low Tide | 93, 170 | U = 11541.5 | 0.213 | 1.000 |
| Morning vs. Noon vs. Afternoon | 83, 128, 52 | H = 2.888 | 0.236 | 1.000 |
| Rain vs. No Rain | 88, 175 | U = 15290.5 | $\leq$ 0.001 | $\leq$ 0.006 |
| Absent vs. Kayaker- No Rain [e] | 199, 43 | U = 8452.5 | $\leq$ 0.001 | $\leq$ 0.006 |
| Absent vs. Walker- No Rain [e] | 180, 29 | U = 3733.0 | 0.01 | 0.060 |

| 2005 Camera Results | Number | Test Statistic | p-value | Bonferroni p-value |
|---|---|---|---|---|
| *Abandoning* | *a , s ; a, s* [a] | | | |
| High vs. Low Tide | 12, 199; 39, 242 | $X$ = 7.844 | 0.005 | 0.030 |
| Morning vs. Noon vs. Afternoon | 15, 127; 12, 147; 24, 167 | $X$ = 2.058 | 0.357 | 1.000 |
| Rain vs. No Rain | 30, 356; 21, 85 | $X$ = 11.979 | $\leq$ 0.001 | $\leq$ 0.006 |
| High No Rain vs. High Rain | 10, 157; 2, 42 | $\chi^2 = 0.301 \times 10^{-5}$ | 0.999 | 1.000 |
| Absent High vs. Kayaker [f] | 12, 199; 98, 244 | $X$ = 41.770 | $\leq$ 0.001 | $\leq$ 0.006 |
| Absent High vs. Walker [f] | 12, 199; 9, 30 | $X$ = 10.775 | 0.001 | 0.006 |
| *Activity Level* | | | | |
| High vs. Low Tide | 211, 281 | U = 53719.5 | 0.274 | 1.000 |
| Rain vs. No Rain | 386, 106 | U = 28101.0 | 0.128 | 0.640 |
| Morning vs. Noon vs. Afternoon | 142, 159, 191 | H = 4.073 | 0.131 | 0.655 |
| Absent vs. Kayaker | 492, 342 | U = 190172.0 | $\leq$ 0.001 | $\leq$ 0.005 |
| Absent vs. Walker | 492, 39 | U = 15164.5 | $\leq$ 0.001 | $\leq$ 0.005 |

[a] Abbreviation explanation for *a, s; a, s*: the number of observations are divided into number of seals that abandoned and number that stayed for each variable being tested.
[b] The test statistics are $\chi^2$ for Chi-square and U for Mann-Whitney Rank Sum. Degrees of freedom for all tests are one.
[c] No morning data for kayakers and/or walkers.
[e] No data for when it was raining for kayakers and/or walkers.
[f] No low tide data for kayakers and/or walkers.

**Table 8 continued**. Statistical results for abandoning frequency and median activity of harbor seals from data collected via the remotely operated camera system for 2004-2006. Test results for physical variables that were non-significant are not included in this table except for the results of interactions between variables.

| 2006 Camera Results | Number | Test Statistic | p-value | Bonferroni p-value |
|---|---|---|---|---|
| *Abandoning* | *a , s ; a , s* [a] | | | |
| High vs. Low Tide | 1, 72; 3, 20 | Fisher Exact Test | 0.042 | 0.210 |
| Morning vs. Noon vs. Afternoon | 0,2; 4, 92; 0, 21 | $X$ = 0.992 | 0.609 | 1.000 |
| Rain vs. No Rain | 3, 5; 1, 87 | Fisher Exact Test | 0.002 | 0.012 |
| Absent No Rain vs. Kayaker [e] | 1, 87; 25, 103 | $X$ = 14.973 | ≤ 0.001 | ≤ 0.005 |
| Absent No Rain vs. Walker [e] | 1, 87; 6, 13 | $X$ = 18.968 | ≤ 0.001 | ≤ 0.005 |
| *Activity Level* | | | | |
| High vs. Low Tide | 73, 23 | U = 1328.0 | 0.069 | 0.345 |
| Morning vs. Noon vs. Afternoon | 2, 73, 21 | H = 2.465 | 0.292 | 1.000 |
| Rain vs. No Rain | 8, 88 | U = 486.0 | 0.196 | 0.980 |
| Absent vs. Kayaker | 96, 128 | U = 8090.0 | ≤ 0.001 | ≤ 0.005 |
| Absent vs. Walker | 96, 19 | U = 1925.0 | ≤ 0.001 | ≤ 0.005 |

**Table 9.** Statistical results for abandoning frequency and median activity of harbor seals from data collected in the field during 2005-2006. Test results for physical variables that were non-significant are not included in this table except for the results of interactions between variables.

| 2005 Field Results | Number | Test Statistic [b] | p-value | Bonferroni p-value |
|---|---|---|---|---|
| *Abandoning Frequency* | *a , s ; a, s* [a] | | | |
| High vs. Low Tide | 2, 105; 1, 73 | *X* = 0.105 | 0.746 | 1.000 |
| Morning vs. Noon vs. Afternoon | 0, 27; 3, 88; 0, 66 | *X* = 3.224 | 0.199 | 0.796 |
| Rain vs. No Rain | 1, 147; 2, 31 | *X* = 2.065 | 0.151 | 0.604 |
| Absent & Kayaker | 3, 178; 13, 27 | *X* = 41.925 | ≤ 0.001 | ≤ 0.004 |
| *Activity Level* | | | | |
| High & Low Tide | 74, 107 | U = 5917.5 | 0.019 | 0.076 |
| Morning vs. Noon vs. Afternoon | 27, 88, 66 | H = 8.206 | 0.017 | 0.068 |
| Rain vs. No Rain | 33, 148 | U = 3934.0 | ≤ 0.001 | ≤ 0.004 |
| Absent No Rain vs. Kayaker [c] | 148, 40 | U = 5048.0 | ≤ 0.001 | ≤ 0.004 |

| 2006 Field Results | Number | Test Statistic [b] | p-value | Bonferroni p-value |
|---|---|---|---|---|
| *Abandoning Frequency* | *a , s ; a , s* [a] | | | |
| High vs. Low Tide | 42, 247; 25, 153 | *X* = $0.104 \times 10^{-3}$ | 0.992 | 1.000 |
| Rain vs. No Rain | 28, 216; 39, 184 | *X* = 2.957 | 0.086 | 1.000 |
| Morning vs. Noon vs. Afternoon | 5, 65; 43, 248; 19, 87 | *X* = 4.104 | 0.128 | 1.000 |
| Absent vs. Kayaker | 67, 400; 111, 127 | *X* = 85.401 | ≤ 0.001 | ≤ 0.012 |
| Absent vs. Walker | 67, 400; 17, 83 | *X* = 0.273 | 0.601 | 1.000 |
| *Activity Level* | | | | |
| High vs. Low Tide | 289, 178 | U = 43305.5 | 0.243 | 1.000 |
| Rain vs. No Rain | 223, 244 | U = 54630.0 | 0.093 | 1.000 |
| Morning vs. Noon vs. Afternoon | 70, 291, 106 | H = 0.460 | 0.794 | 1.000 |
| Absent vs. Kayaker | 467, 238 | U = 113565.0 | ≤ 0.001 | ≤ 0.012 |
| Absent vs. Walker | 467, 100 | U = 35755.5 | ≤ 0.001 | ≤ 0.012 |

[a] Abbreviation explanation for *a, s; a, s*: the number of observations are divided into number of seals that abandoned and number that stayed for each variable being tested.
[b] The test statistics are $\chi^2$ for Chi-square and U for Mann-Whitney Rank Sum. Degrees of freedom for all tests are one.
[c] No data when it was raining for kayakers.

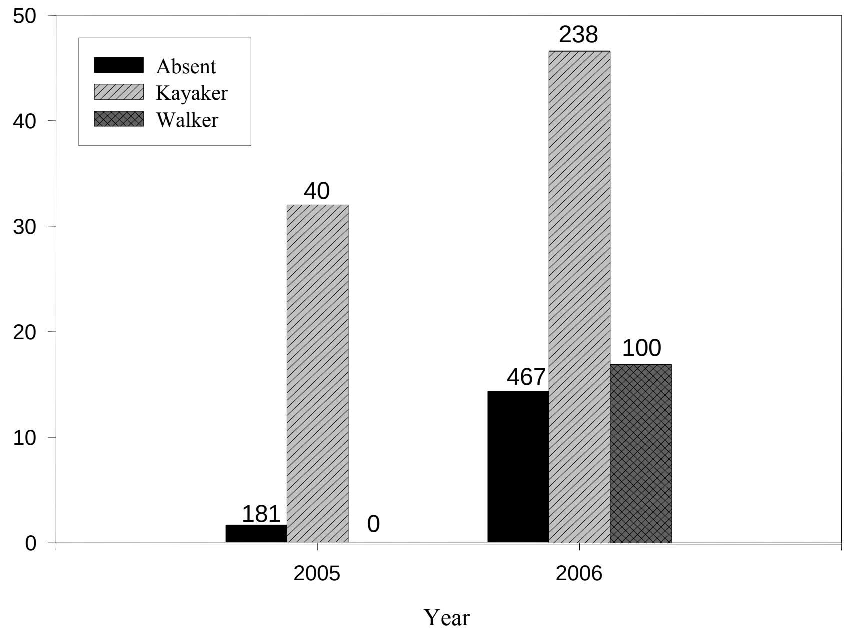



**Figure 7.** Percentage of observations in which harbor seals abandoned the ice observed in the field for year and human presence category. Sample size above bars.

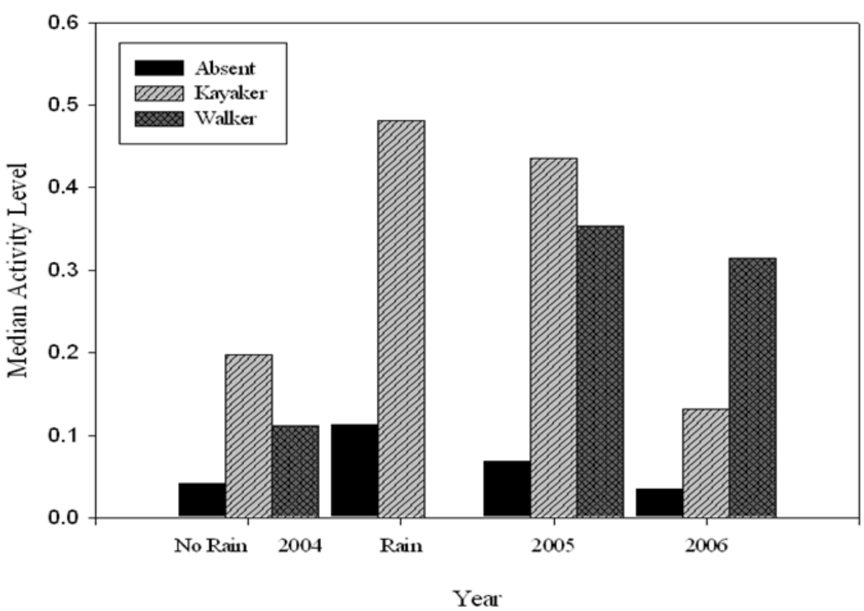



**Figure 8.** Harbor seal median activity level recorded by camera by year and human presence. 2004 data are divided into categories of rain and dry.

When humans were present, harbor seal behavior was altered. The abandoning frequencies and median activity levels of the seals were significantly higher when kayakers were present (Figures 7 & 8). The presence of walkers only affected abandoning frequencies of harbor seals for 2005 and 2006 camera observations. However, median activity levels of the seals were significantly higher when walkers were present in 2005 camera observations and 2006 field and camera observations (Figures 7 & 8).

Significant differences in the degree of disturbance were observed between different groups of recreationists (Table 10). Guided kayak groups had a significantly less negative effect on the abandoning frequency and median activity level of harbor seals than unguided kayak groups (Figures 9-11). Groups with a guide trained in mitigation had a significantly lower impact on the abandoning frequency and median activity level of harbor seals than any other group. When guides who were trained in mitigation techniques led kayak trips into Pedersen Lake, there was no effect on the abandoning frequencies of the seals; however, the median activity levels of the seals were higher (Figure 9). When any group of walkers was present, the abandoning frequencies of the seals were not significantly different from when humans were absent but the median activity levels of the seals were significantly higher (Figure 9).

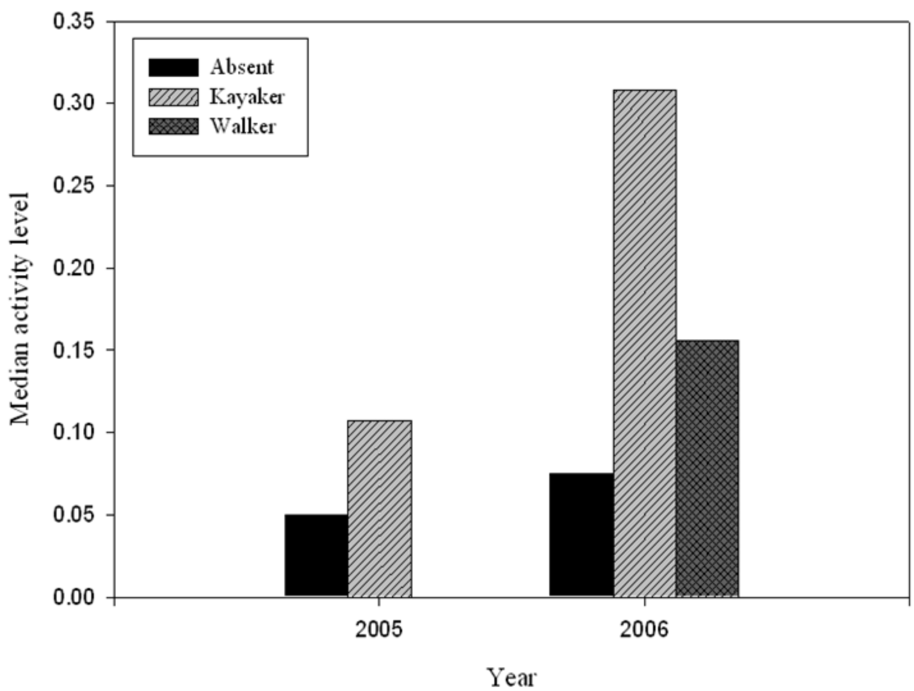



**Figure 9.** Harbor seal median activity level recorded in the field by year and human presence.

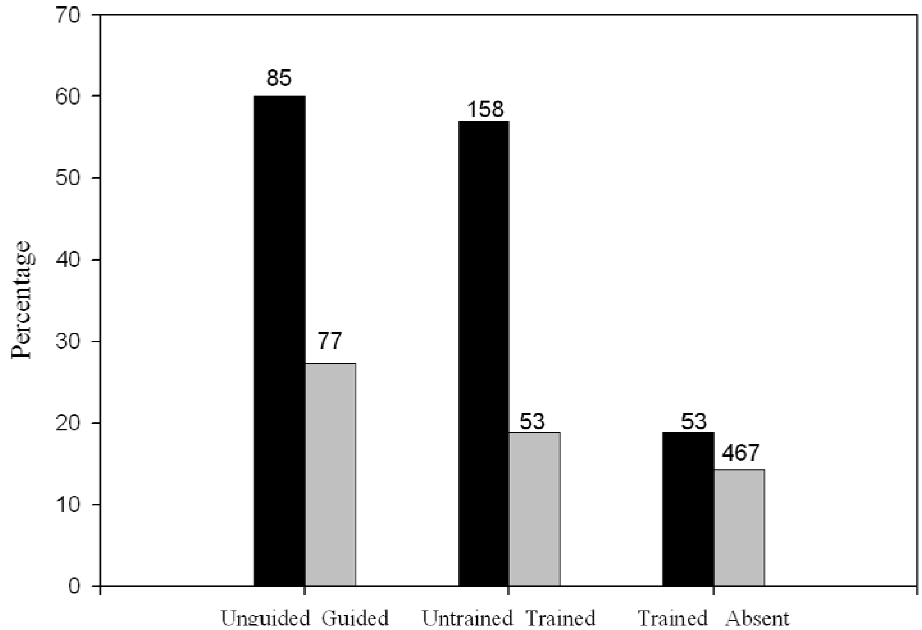



**Figure 10.** Percentage of kayak observations in which harbor seals abandoned the ice by kayak group training level and when humans were absent. Sample size above bars.

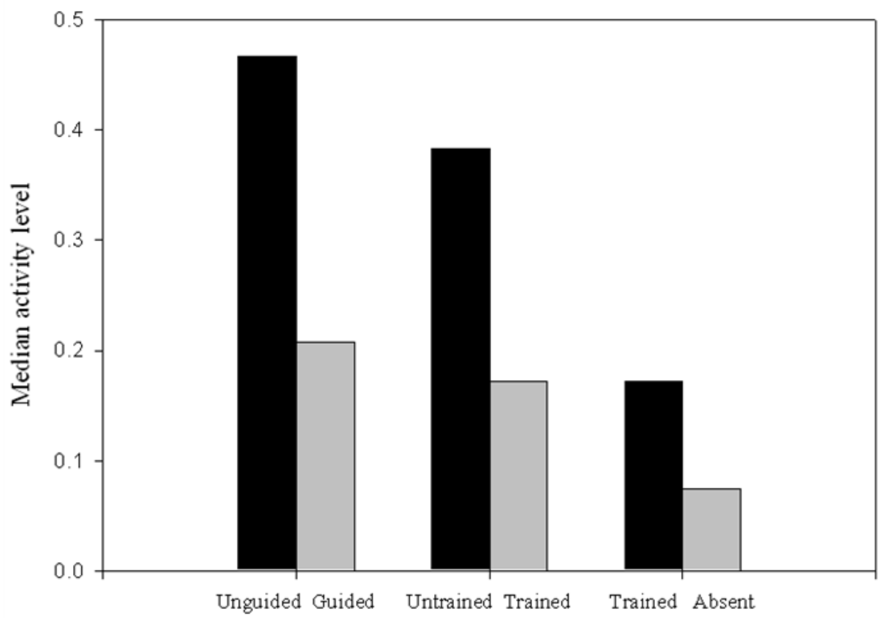



**Figure 11.** Harbor seal median activity level by kayak group training level and when humans were absent.

**Table 10.** Statistical results for abandoning frequency and median activity level of harbor seals for guided verses unguided, mitigation training verses no mitigation training, and mitigation training verses when humans are absent.

| Training Results | Number | Test Statistic [b] | p-value | Bonferroni p-value |
|---|---|---|---|---|
| *Abandoning Frequency* | *a, s; a, s* [a] | | | |
| Guided vs. Unguided Kayaker | 21, 56; 51, 34 | $\chi^2 = 16.225$ | ≤ 0.001 | ≤ 0.012 |
| Trained vs. Untrained Kayaker | 10, 43; 90, 68 | $\chi^2 = 20.843$ | ≤ 0.001 | ≤ 0.012 |
| Trained vs. Untrained Walker | 4, 27; 9, 36 | $\chi^2 = 0.248$ | 0.619 | 1.000 |
| Absent vs. Trained Kayaker | 67, 400; 10, 43 | $\chi^2 = 0.454$ | 0.500 | 1.000 |
| Absent vs. Guided Walker | 67, 400; 13, 62 | $\chi^2 = 0.251$ | 0.616 | 1.000 |
| Absent vs. Untrained Walker | 67, 400; 9, 36 | $\chi^2 = 0.639$ | 0.424 | 1.000 |
| Absent vs. Trained Walker | 67, 400; 4, 27 | $\chi^2 = 0.00182$ | 0.966 | 1.000 |
| *Median Activity Level* | | | | |
| Guided vs. Unguided Kayaker | 77, 85 | U = 5227.000 | ≤ 0.001 | ≤ 0.012 |
| Trained vs. Untrained Kayaker | 53, 158 | U = 4079.000 | ≤ 0.001 | ≤ 0.012 |
| Trained vs. Untrained Walker | 31, 45 | U = 1152.000 | 0.665 | 1.000 |
| Absent vs. Trained Kayaker | 467, 53 | U = 17282.500 | ≤ 0.001 | ≤ 0.012 |
| Absent vs. Guided Walker | 467, 75 | U = 25559.500 | ≤ 0.001 | ≤ 0.012 |
| Absent vs. Untrained Walker | 467, 45 | U = 14426.000 | 0.002 | 0.024 |
| Absent vs. Trained Walker | 467, 31 | U = 10216.500 | 0.001 | 0.012 |

[a] Abbreviation explanation for *a, s; a, s*: the number of observations are divided into number of seals that abandoned and number that stayed for each variable being tested.
[b] The test statistics are $\chi^2$ for Chi-square and U for Mann-Whitney Rank Sum. Degrees of freedom for all tests are one.

## Discussion

### Population Trends

Population trends of harbor seals in Aialik Bay from 1979-2007 provide additional temporal and spatial information on the Gulf of Alaska population decline. The most extensive documentation of the decline occurred at Tugidak Island, where numbers on the southwest beach decreased approximately 85% from nearly 7,000 seals in 1976 to about 1,000 seals in 1988. The rate of decline was most rapid from 1976-1978 when numbers diminished 21% per year; from 1978-1988 numbers declined at a lower rate of 7% per year (Pitcher 1990). Numbers of seals stabilized between 1988 and 1994, and began increasing at a rate of 3.0% per year from 1994-2000 (Jemison and Kelly 2001, Jemison *et al.* 2006). A comparison of counts taken at five other sites around eastern Kodiak Island between the mid-1970s and early 1990s indicated a 66% decline (range 35%-79%); from 1993 through 2001 trend sites in the eastern Kodiak Island area began increasing at a rate of 6.6% per year (Small *et al.* 2003). In Prince William Sound, numbers of harbor seals counted in central and eastern Prince William Sound diminished 63% from 1984 to 1997 (Frost *et al.* 1996, Ver Hoef and Frost 2003) with an average rate of decline of 4.6% per year. Between 1989 and 1995 counts taken during the molt decreased 19% while those taken during pupping decreased 31% (Frost *et al.* 1996, 1999)

Numbers of seals in Aialik Bay declined from 1980 through the mid-1990s then remained low through 2002 (Figure 4). In 2003, numbers of seals counted during the molt began increasing at a rate of 20% per year; however, numbers of pups remained low. Although both Aialik Bay and Tugidak Island declined during the 1980s, initial recovery observed in numbers of molting seals began nine years later at Aialik Bay than on Tugidak Island. To date, numbers of pups counted have not increased in Aialik Bay. The discrepancy between pup and molt trends probably reflects immigration of seals from surrounding areas (most likely from Northwestern Fjord) and potentially increased time hauled out, perhaps in response to improved foraging or haulout conditions. Variability in haulout location observed in molting seals in Aialik Bay indicates that seals may adjust their distribution during the molt. The consistently high rates of population increase (20% per year) during the past five years is not sustainable by observed reproductive rates, nor does it appear to be contributing to improved recruitment.

### Kayak Interactions

Disturbance by humans can elicit the same response in wildlife as true predators (Beale & Monaghan 2004). Despite good intentions of recreationists, the presence of kayakers and hikers disturbs harbor seals. Harbor seals increase their time spent alert and scanning, the purpose of which is to observe alarm signals and react to the present danger or a predator (Terhune 1985, da Silva & Terhune 1988). These behaviors are considered the orienting response and precede the defense response if a danger is identified (Gabrielsen & Smith 1995). Therefore, by increasing the frequency in which they abandon their haulout in the presence of humans, harbor seals are responding in a manner similar to that of presence of a predator. Increased activity level and abandoning frequency found in this study parallels the results from other studies (Allen *et al.* 1984, Suryan & Harvey 1998, Henry & Hammill 2001).

Results indicated that mitigation training provided to kayakers resulted in significantly lower incidences of harbor seal abandonment of the ice, although activity levels of seals on ice were elevated over levels when humans were not present. People who walked along the shore have a more predictable path than kayakers, which may account for the decreased abandoning frequency associated with walkers relative to kayakers. Different tour companies, as well as guides within the tour companies, have preferred paddle routes within the lake. Because harbor seals in Pedersen Lake haul out on glacial ice, the location of the seals can change throughout the day and season. Therefore, the ideal kayaking and/or walking route may change over time. Guides educated in observing seal behavior were more effective at choosing routes that minimized their disturbance to seals.

## OBJECTIVE 2: EVALUATE STILL DIGITAL CAMERA SYSTEM

### Methods

*Study Area*

Day Harbor is a fjord located 20 km southeast of Seward. Seals primarily haul out at four general areas, bounded by a rectangle marked by 60.03°N, -149.08°W, 60.00°N, -149.02°W. Ellsworth Glacier terminates in a freshwater lake that is located 3 km from the head of the bay. Harbor seals have not been observed in the lake, but haulout on the rocky coastline, primarily along the northwest shoreline extending from the head of the bay to a small lagoon 4 km southwest. A smaller group of seals use a haulout near Anchor Cove. Day Harbor is one of three primary haulout areas of seals that use terrestrial haulouts between Prince William Sound and Aialik Bay.

Prototype fixed still cameras were evaluated for potential use in long-term monitoring of harbor seals using land haulouts in Day Harbor. In Day Harbor approximately100 seals use terrestrial haulouts at known locations. At land haulouts, fixed cameras potentially would be able to capture count data without the need for labor-intensive real-time camera operations. Two types of camera systems were evaluated: a Nikon Coolpix 5700 cameras in weather proof housing operated by a time-lapse controller board, a design developed by the NMFS NMML (Boveng, NMFS, pers. comm.), and a modified design using Nikon Coolpix 8700 and 8800 cameras with internal intervalometers.

Camera systems (e.g., Figure 12) were evaluated for (1) reliability of operation, (2) image degradation resulting from weather, temperature, lighting, and other field conditions, (3) ability of cameras to capture images suitable for counting seals, (4) the ability of cameras to capture images with sufficient clarity to recognize markings of individual seals, (5) assessment of image processing time and (6) quality of results. If successfully implemented, results would be compared with bi-monthly aerial surveys to evaluate the adequacy of the technology in reflecting regional haulout site attendance as well as to assess the sampling frequency needed to monitor seal haulout activity.

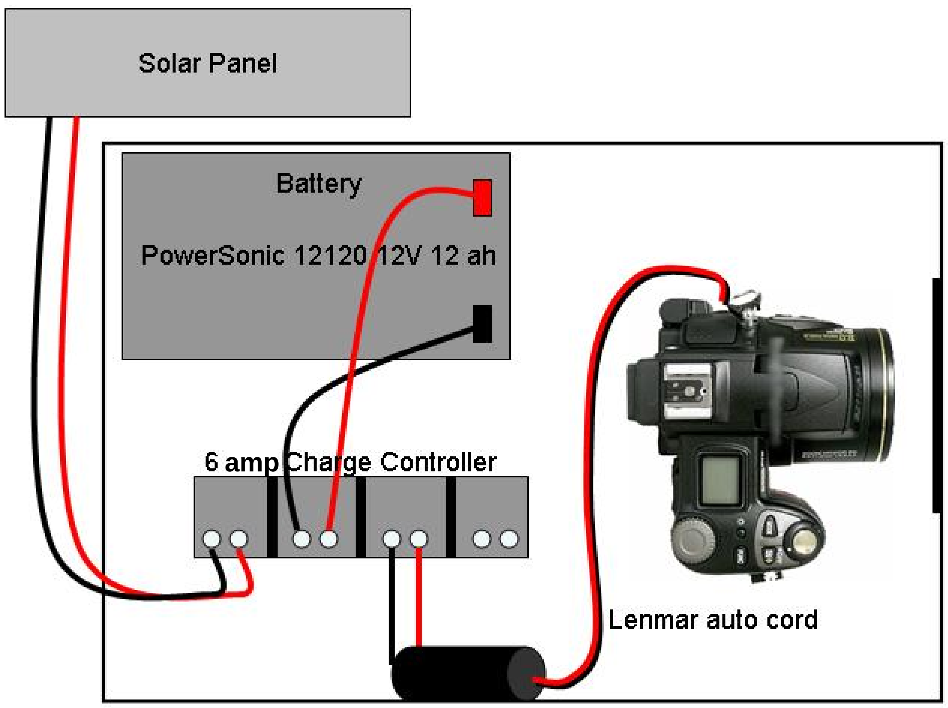
*Camera System Design*

The following three camera models were evaluated:

(1) Nikon Coolpix 5700 with 1-2 GB Compact flash card (1 GB = about 6 mo in winter at "fine" resolution)

- Minimum voltage ~5 volts. Prefers 9-12 volts
- Requires use of an external intervalometer (DigiSnap 2800 by Harbortronics. (4-18 volts)) for time-lapse image control.

(2) Nikon Coolpix 8700 with internal intervalometer




(3) Nikon Coolpix 8800 with internal intervalometer

**Figure 12.** Diagram of camera configuration, wiring, and associated equipment.

Image Storage: The Coolpix 5700 is limited to 2 GB storage while the Coolpix 8700 and 8800 were provided with 4 GB compact disk for image storage.

Housing

Two types of housing were evaluated:

(1) Extreme CCTV EX28 Camera Housing. An insulated video camera housing, although not designed to be waterproof, was designed for reduced condensation in cold weather.

(2) Pelican cases (1500 and 1550) were used for housing. They were modified by cutting a 4-inch diameter hole and attaching a glass window over the hole using 3M 5200 marine adhesive/sealant.

Batteries and Power

Uni-Solar 12 v, 11 watt, flexible solar panels (21.8x16.7 in) could potentially provide up to 8.67 amp hrs of power over 14 hrs on sunny days and 6.08 amp hrs per 14 hr on cloudy days if ideally positioned during the summer; during the winter power would not exceed 2-3 amp hrs per day.

A Morningstar SS-6, 6 amp, 12 volt photovoltaic power controller was used to regulate charging and discharge of sealed 12 volt batteries used in the system.

Nikon auto power cord for Coolpix 8700. Reduces power from a maximum of 28 volts to 8.46 volts used by the Coolpix 8700. The power cord was adapted for use with the Coolpix 8800 by attaching the DC plug from an EH-54 AC adapter for Coolpix 8800 to the output of the Coolpix 8700 12 v auto power cord. The output voltage of the EH-54 also is 8.4 volts and the modified power cord appeared to work well.

**Results and Discussion**

Testing during winter conditions was conducted in Seward where cameras could be monitored. The Coolpix 5700 (5 megapixel) cameras with Harbortronics intervalometer provided inconsistent results where, on an irregular basis, the camera ceased operating without automatically restarting. Conditions that resulted in loss of operation were not identified, but occurred more frequently when the battery's voltage dropped below 9 volts. Low voltage did not cause all failures. Symptoms were similar to those experienced with P. Boeving, NMFS NMML (pers. comm.)

The Coolpix 8700 and 8800 (8 megapixel) cameras have built-in intervalometer that allows time-lapse photography for up to 1,800 images which reduced the footprint and power requirements of the camera system.

Based on data from HarborTronics, the Coolpix 5700 camera running from external power (with internal battery removed), without the HarborTronics controller, used 120-200 mw while resting and 3.5 watts when active. Therefore, the camera required 0.5 amp hours (ah) per day to capture images every 30 minutes during a 24-hour period during the summer; during the winter power requirements doubled to 1 ah per day.

The Coolpix 8700 and 8800 cameras performed well and the system appeared considerably more energy efficient than the original design using the Coolpix 5700 and HarborTronics 2800 controller. Nevertheless, the cameras were sensitive to power variability and were plagued with fatal "lens error" problems that required multiple repairs and adversely impacted reliability.

The cameras were repeatedly tested during the winter in Seward. Besides the problems previously identified, difficulties were associated with maintaining sufficient power during cold temperatures in low sunlight conditions. Field tests were conducted at two locations: in Anchor Cove and at a rocky haulout on the west side of Day Harbor. The Anchor Cove camera viewed open waters at the head of the cove. Camera performance was excellent during summer operations. The primary limitation was with the number of time-lapse images that could be taken. With images taken every 30 minutes, the camera required downloading on a monthly basis; with images taken every 15 minutes (the preferred interval for monitoring harbor seal haulout) the camera required downloading every two weeks. Although these limitations can be accommodated during the summer when weather and sea conditions are favorable, they limit the usefulness of the cameras in spring, fall and winter. The camera set up at the rocky haulout site illustrated further limitations. Exposure to sunlight was limited in the steep cliff setting (Figure 13). The close quarters of cliff-lined haulout areas, limited locations suitable for placing cameras. In addition, the distribution of harbor seals shifted among haulout rocks, resulting in insufficient coverage of nearby seals just outside the field of view. Although this limitation could be mitigated by multiple cameras, doing so could greatly increase the number of cameras needed to cover the convoluted coastline as well as the number of images requiring processing. The packaging in the Pelican 1500 case was compact and durable. A strong storm coincided with spring tides during testing. The camera, fastened to bolts drilled into the rock, was repeatedly washed by storm waves. Although one bolt broke loose from the rock and the camera's position was altered, the internal equipment remained intact and dry, and the system continued to obtain images on schedule.

**Figure 13.** A sample image illustrating seals hauled out on a cliff-lined rocky shoreline in Day Harbor.

Our experience indicated that the camera system using the Coolpix 8700 or 8800 cameras showed promise for some types of remote field applications. In the Pelican 1500 case, the camera unit was portable and easy to set up. At least twice the battery capacity and solar generation capability than found in the original design is needed to enhance power management in shaded locations and during periods of reduced sun exposure. This system had good functionality in non-critical applications where access could be assured on a frequent basis. We found that in the rocky haulout sites in Day Harbor, limitations in access to camera sites and adequate field of view severely impacted our ability to obtain suitable coverage. Therefore, we did not pursue continued implementation of the cameras for remote population monitoring.

## CONCLUSIONS

Harbor seals population trends are monitored by counts taken when seals molt. These counts are presumed to reflect overall population trends and should parallel counts taken during pupping. Harbor seals are monitored at only a few locations by repetitive counts taken during pupping and molting periods (e.g., Jemison and Kelly 2001, Jemison *et al.* 2006, Mathews and Pendleton 2006). These studies, although limited in geographic scope, provide extensive information on harbor seal attendance. During this study, population trends indicated by the numbers of pups born differed substantially from trends indicated by molt counts. These results suggest that expanding habitat adjacent to Pedersen glacier is attracting seals to move into the region from other areas and/or spend additional time hauled out during the molt. It may not reflect population change associated with the local sub-population that contributes to recruitment. We have yet to determine if observed differences are associated with abnormally low reproductive success, potentially resulting from late maturation, diseases or other causes. Increasing numbers of seals counted during the molt do not necessarily indicate that the seals resident to and reproducing in Aialik Bay are recovering. Future analysis will contrast findings with results of aerial surveys conducted along the southern Kenai Peninsula to determine whether trends indicated in Aialik Bay are reflected elsewhere on the Kenai Peninsula.

Expanding habitats in Pedersen Lake also attract kayakers who are able to paddle among large ice bergs or walk along the shoreline and enjoy the secluded environment. The use of remotely operated camera system for investigating human disturbance to wildlife provides useful information for monitoring interactions between humans and harbor seals although data are not equivalent to field observations. However, video observations provide a permanent visual record of animal behavior and human disturbance that can be reviewed at a later time and by multiple researchers. The recorded images can also be used for educational purposes. Video clips of interactions were found to be particularly valuable for sea kayak guide trainings. Observing disturbances recorded on video provided insight to the guides on the progression of seal behavior leading up to a disturbance. This study has shown that humans can recreate in the same area as harbor seals without causing significant disturbance if they are properly educated in how to minimize their disturbance and are motivated to follow those guidelines. Education has been found to be effective in reducing human disturbance on other species of wildlife (Gerrodette & Gilmartin 1990, Calambokidis & Jefferies 1991, Fagen & Fagen 1994). Tourists prefer to be more educated about the areas they are visiting and animals they are viewing (Lück 2003). This was true for the local guides as well, as evidenced by the increase in requests for information both during the training period as well as throughout the summer season.

Our evaluation of the use of automated still digital photography in rocky haulout habitats provided disappointing results. Unreliability of the cameras and limitations on the numbers of images that could be stored mandated the need for frequent site visitation. The close confines and limited locations at which cameras could be mounted and accessed compromised coverage. Although this technology was unsuitable for haulouts in Day Harbor, it showed potential for application at more accessible shorelines, particularly where harbor seals are concentrated along beaches.

In a region such as Aialik Bay, a glacial habitat impacted by climate change and increased visitor activity, sustained video monitoring is providing a unique and valuable record through real-time observations and retrospective analysis of images. The use of video technology provides a rich record of the extent of the effects that climate change has on glacial habitats, as well as the resiliency of organisms that are associated with this diminishing environment. Use of video monitoring technology has also been instrumental in reducing the impact of humans on seals as numbers of visitors and the breadth of their activities increase over time. Continued monitoring will be important for clarifying discrepancies between population trends indicated by pup and molt counts, evaluating aspects of ice environments that attract harbor seals, documenting environmental changes associated with glacial activity, and continuing investigations of techniques that help visitors experience the beauty and uniqueness of the region, while minimizing their impact on wildlife.

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