HARBOR SEAL INVESTIGATIONS IN ALASKA
ANNUAL REPORT
NOAA GRANT NA87FX0300

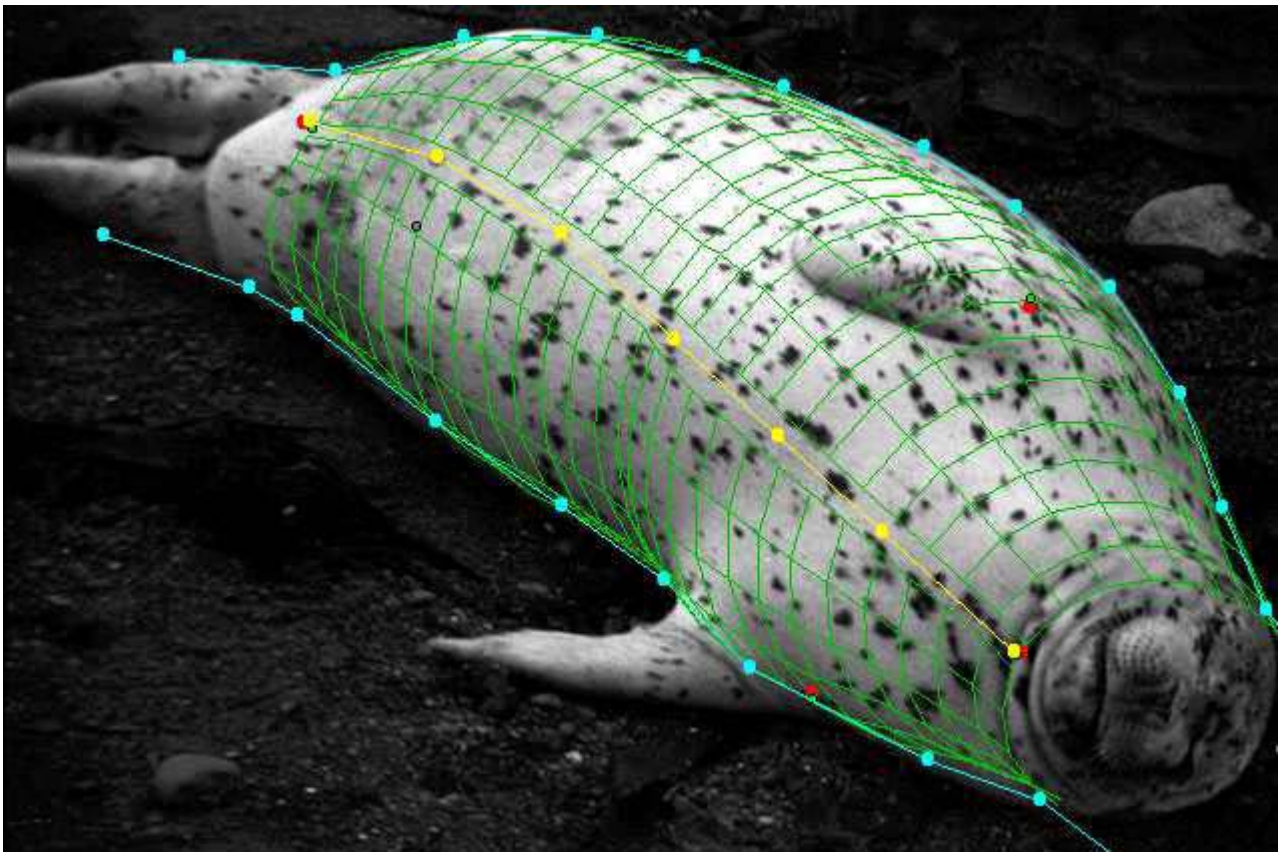

Photo by Shannon Crowley

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Division of Wildlife Conservation
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333 Raspberry Road, Anchorage, Alaska 99518

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EXECUTIVE SUMMARY

Monitoring harbor seal population trends in selected areas of Alaska is the first overall objective of this research program. Population trend routes in the Sitka area of Southeast Alaska (SE) and along the Kodiak Archipelago were surveyed in 1999, whereas the Ketchikan route was not flown as it is monitored on a biennial basis because of the high precision of the current increasing trend estimates. The trend estimate for the 30 haulout sites that comprise the survey route on the east side of Kodiak Island for 1993-1999 was 5.6%/year, representing the first documented increase in harbor seal numbers over a relatively broad area in the Gulf of Alaska. In the Sitka area of SE, a lower rate of growth was observed during both the 1984-1999 period (1.1%/year), as well as the more recent 1995-1999 period (0.9%/year). In the Ketchikan area of SE, the number of harbor seals increased 7.4%/year during 1983-1998, followed by a slightly lower rate of growth (5.6%/year) during the more recent 1994-1998 period. Environmental covariates substantially influenced the number of seals hauled out at sites within each of our three aerial survey routes, and thus our estimates of population trend. Survey date had the largest influence on trend estimates for each route, followed by time to midday and time to low tide. However, the relative influence of the covariates varied among the three routes and for the two time periods for which Ketchikan and Sitka trend estimates were based. Recognizing the biological significance of how covariates may influence trend estimates, the experimental design of Alaska harbor seal population surveys was evaluated by employing an operating model approach to simulate harbor seal population dynamics and haulout behavior. Simulation results and subsequent sensitivity analyses determined the magnitude of the biases and decreased accuracy caused by specific covariates, and should be utilized to increase the robustness of survey experimental design.

A new ADF&G trend survey route was established in 1998 along the north side of the Alaska Peninsula from Port Moller northeast to Kvichak Bay. This new "Bristol Bay" trend route was flown again in 1999, with subsequent annual surveys planned to estimate population trend in this southeast region of the Bering Sea. The 34 trend route sites are all on sandbars that are exposed only during low tides. The total mean count was quite similar in 1998 and 1999, at 10,941 and 11,202 seals, respectively. The 1999 count was 43.4% higher than the count (7,785) obtained in 1995 by the NMFS; however, the 1999 survey was conducted ~3 weeks earlier than the 1995 survey. Assuming a similar relationship of increasing counts with earlier survey dates as quantified in the Prince William Sound (PWS) covariate based population trend analysis (Frost *et al*. 1999), a comparison between the 1995 and 1999 raw counts indicates, preliminarily, harbor seal numbers were stable for the Bristol Bay trend route area during 1995-1999. However, this crude comparison does not take into account the other covariates that are known to substantially influence the number of seals hauled out; *i.e.*, time of day and time relative to low tide.

Land-based counts and covariate data were collected at two 'index' sites, Tugidak Island (40 kilometers southwest of Kodiak Island) and Nanvak Bay (in northern Bristol Bay) to monitor the number of harbor seals and identify factors that influenced counts. Although counts of seals at these index sites do not provide an estimate of total population abundance, they have been used to estimate population trend and as indices of local and regional seal abundance (Pitcher 1990). Trends were estimated and adjusted for covariates (date, time of day, tide, weather variables, and count quality) using mixed generalized linear models (Poisson errors and log link) (Littell *et al.* 1996). At Tugidak Island, four separate trends in harbor seal abundance were estimated: pups and all seals during the 1994-1999 pupping period, and all seals during the molting periods of 1994-1999 and 1976-1999. The harbor seal population on Tugidak Island declined from 1976 through the late

1980s, stabilized during the early to mid 1990s, and is now increasing. From 1994–1999, the trend estimate (6.7%/year) among all seals during the pupping period was similar to the molting period estimate (4.9%/year). The estimated rate of increase among pups (13.6%/year) during the 1990s, however, was more than twice the trend estimates for all seals during the pupping and molting periods. Despite increasing trends, the population remains greatly reduced from the 1970s. At Nanvak Bay, two separate trends were estimated for all seals for the 1990–2000 (excluding 1999) period, with the 9.2%/year increase during the pupping period higher than the 2.1%/year increase during the molting period. Date and time of day were significant covariates in all analyses at both Tugidak Island and Nanvak Bay. At both sites, maximum numbers of seals were ashore during the afternoon. Overall, the influence of weather and tide variables were not consistent between areas or within seasons, although precipitation and wind speed were significant in most analyses.

The investigation of factors that affect harbor seal populations is the second overall objective of this research program. Such factors may include reduced prey availability, either by environmental changes or through commercial exploitation, human-caused mortality through harvest or incidental take in fisheries, diseases, pollutants, and predation. In 1993, available data indicated a stable or increasing population in SE compared to declining seal numbers in PWS and Tugidak Island. Similar geographic differences in Steller sea lion populations had been recorded, adding support to the hypothesis that some factor(s) influences the two pinniped species differently in SE as opposed to the Gulf of Alaska. Comparative research studies were thus initiated, with the goal of determining whether certain factors differed between the two geographic regions.

The current status of harbor seals in the Gulf of Alaska varies geographically. The number of seals on Tugidak Island and the overall Kodiak region has been increasing since the mid 1990s, yet remains greatly depressed since the 1970s. A population decline continued in PWS through at least 1997 (Frost *et al.* 1999). Thus, a comparison between the Kodiak region and SE may not currently represent a direct comparison between declining and increasing seal populations. Regardless, determining what factors affect seal populations in different regions of Alaska must continue to be a research priority for this project. Due to the dramatic population decline in the Kodiak region, it remains a key area for such research. SE presents the opportunity to study a stable or increasing population. In PWS, the long-term research investigation of a decreasing population continued through 2000. Research efforts have expanded to include the relatively large number of seals along the north side of the Alaska Peninsula in the Bering Sea. Overall, these investigations will provide a greater understanding of the proximate and ultimate factors that regulate harbor seal populations throughout their range in Alaska, which is required to develop effective management and conservation strategies. The results of the various research projects presented in this report, and summarized below, represent progress towards such an understanding.

To examine foraging strategies and dive behavior of subadult and adult seals, satellite-depth-recorders (SDRs) were deployed on 62 subadult and adult harbor seals from Kodiak Island and SE Alaska during 1993 to 1996. Retention rate of SDRs was high with units deployed post-molt in the fall retained for a median of 221 days. Maximum dive depths recorded were to 500 –508 meters (the limit of the measurement capabilities of the SDRs), made by several SE seals. Effects of season, time of day, sex, age, and region (Kodiak and SE) on three dive parameters (time wet, dive focus, and preferred depth bin) were examined using repeated measures mixed models that accounted for temporal autocorrelation in the data. Seals spent significantly less time in the water during the summer and day than during the winter and night in both regions. Proportion time wet averaged approximately 0.70-0.75 across sexes, ages, seasons, and regions. Dive focus provided a measure of the diversity of depth bins used by seals (of 6 depth bins possible), where focus could range from

0.167 to 1.0, and a focus value of 0.50 indicated the majority of dives occurred in one depth bin. Dive focus ranged from 0.50 to 0.80 in Kodiak, and 0.40 to 0.65 in SE. Diving was most focused during the day in both regions. In Kodiak only, diving of adult females was more focused than other age-sex groups. Average preferred depth bin ranged from 2.0 to 2.5 for Kodiak seals and 2.0 to 4.0 for SE seals. SE seals dived deeper during the winter than in the summer, and during the evening than during the day. No significant seasonal or diurnal patterns in dive depth were observed for Kodiak seals. These analyses indicated that both bathymetry, and pupping and breeding activities likely played a significant role in shaping dive behavior. Kodiak seals (with access to nearshore water depths ranging from 20 to 100 meters) dove to shallower depths with greater dive focus, than SE seals (with access to nearshore water depths ranging from 100 to 750 meters). Future analyses will combine dive depth, duration, frequency, and bathymetry data to describe foraging strategies of Alaskan harbor seals.

To increase our understanding of the movements, haulout use patterns, and foraging areas of harbor seals we captured and deployed satellite-linked depth recorders (SDRs) on adult (n=43) and subadult (n=20) harbor seals captured in spring prior to the pupping period and in fall after the molting period in SE (n=34) and the Kodiak Archipelago (n=29). During 1993-1997, movement patterns and 'foraging area' size did not differ between these two regions that have exhibited distinctly different population dynamics over the last 20 years. Subadult seals consistently moved longer distances and used larger 'foraging areas' compared to adult seals. The large majority of at-sea locations were within 50 km of haulouts, as has been observed in other harbor seal populations outside of Alaska (Thompson 1993). Three-fold differences in 'foraging area' size were observed among sub-regions in both Kodiak and Southeast, a result that may be due to the availability of relatively large open water areas. The cumulative distance traveled among haulouts increased in May, and 'foraging area' size increased in May and July. These increases may not be associated with increased foraging, as preliminary analyses of the concurrent diving behavior suggest diving effort decreased from April through July.

Tugidak Island studies on movements and dive behavior of pups, pupping and molting phenology, and using photo identification to track individual seals continued in 1999 and 2000. Twenty-five harbor seal pups were captured on Tugidak Island in June 1999, and 9 were fitted with satellite-linked time-depth-recorders (SDRs) in the last year of a three-year study. The objectives of this study were to describe patterns of haulout usage, examine development of movement and diving behavior, and identify at-sea areas used for feeding by harbor seals over the first year of life. Instruments deployed on 16 of the 28 animals tagged over the three years remained functional most of the first year of life. Data collected from June 1997 – July 2000 on movements, dive behavior, and haulout usage has been edited and archived and are ready for statistical analysis. Preliminary summaries of the data indicate some general patterns and trends. Diving depth and duration increased steadily from deployment through late winter then decreased the following spring. As dives became deeper and longer, frequency of dives per day decreased. Haulout bout length decreased rapidly in the first 2 months then remained relatively constant until late winter. Diurnal haulout patterns showed clear seasonal differences. Tagged animals used one-third of the known haulouts in the study area, and we identified two new potential haulouts. Almost all at-sea activity was concentrated over the continental shelf, with most locations shallower than 200 meters. Several clusters of at-sea activity were identified for further study.

Documentation of pupping and molting phenology continued throughout the May – September period in 1999. The date of peak pupping was 15 June, 3-4 days later than the previous five years. The final season of data collection for a molting phenology study was completed, and the progression and

timing of the molt was documented for yearlings, subadults, adult females and adult males. In all years (1997–1999), the timing of the pre molt and active molt differed among sex/age classes, whereas timing of the post molt differed among sex/age classes except subadults and yearlings in 1997 and 1998. Yearlings began molting first, followed by subadults, then by adult females, and lastly adult males. The timing of the active molt was similar among sex/age classes in 1997 and 1998, whereas in 1999 molting occurred 3-6 days later for all sex/age classes except yearlings. The number of seals hauled out was, in general, positively related to the proportion of seals in the active molt and negatively related to the post molt. The precise timing of molting is not known for most areas in Alaska. Knowledge of the spatial variation in the timing of molting and the differences in timing among sex/age classes should be considered in determining optimal survey dates for population size and trend estimates.

A photo-identification study to track individual harbor seals on Tugidak Island was conducted from 1997-1999. A photograph matching technique was initiated in which observers classified pelage patterns on the ventrum of individuals in photographs using the variables: sex, color phase, spot to background ratio, spot complexity, and ring density. Scores of these variables were entered into a relational database to reduce the number of photographs checked by eye. This technique allowed photographs to be scored and entered into a database at a rate of 1.5 minutes per photograph, and 100-120 photographs to be checked for matches per day when experienced observers and a total database size of 1,940 photographs were available. A photograph matching error rate has not yet been determined for this method. Another photograph matching technique was evaluated in which a computer program provided a numerical description of standard "fingerprint" regions on the head for each photograph by first fitting a computer model of a harbor seal head to photographs and reading the gray-scale intensities at coordinates within the fingerprint region. All numerical descriptions were compared using specialized software to determine matches and final matches were checked by eye. By the end of 1999, the database size for the head view was 5,288 photographs. Preliminary photograph matching error rate (probability of false negatives) was 5-6% whereas animal matching rate is expected to be 2-3%. The matching efficiency, or proportion of non-matching photographs that did not have to be checked visually, was >0.99. Preliminary assessment of resighting rates showed between-year resighting rates of 0.26-0.71, which would be adequate for estimation of annual parameter estimates (such as annual survival). Within-season resighting rates ranged from 0.01-0.10 and were likely too low to precisely estimate within-season parameter estimates (such as population size and reproductive rate). To improve within-season resighting rates in 2000, a computer model of the ventrum will be developed, and the ventrum view and digital photography will be used to increase sample size of photographs acquired per year.

In order to find a suitable site for conducting land-based observations of molting phenology of seals in SE, we evaluated haulout sites from the air in conjunction with the Sitka and Ketchikan trend route surveys, and during SE scat collections. One site, a small island off the north shore of Lemesurier Island in Icy Strait, appeared suitable for land-based observations. A camp was established on this island from 24 July – 18 August, with research focused on conducting multiply daily counts and documenting molting phenology of yearlings, subadults, adult females and adult males. The first day of counts went well, but on subsequent days the seals regularly spooked into the water during observations. It appeared that seals were entering the water due to olfactory cues. Attempts to observe seals without eventually causing some animals to enter the water were unsuccessful and so the camp was closed. The maximum count during the observation period was 123 on 14 August. Based on the limited sex/age composition data collected, it appeared that most

animals using the haulout were adult males. Efforts will continue to locate a site in SE where land-based observations can be conducted.

Scientists at the Southwest Fisheries Science Center of the NMFS have been using molecular genetic techniques to investigate population subdivision and movement patterns of harbor seals in Alaska. Variation in mitochondrial and nuclear markers is being examined to resolve population structure and estimate levels of dispersal, providing the framework for delineating stock boundaries. To date, 749 samples, primarily from Alaska but also a small number from Japan, Russia, and California, have been sequenced. The fact that harbor seals are continuously distributed presents problems when investigating population subdivision and has resulted in innovative methods of statistical analysis. Currently two distinct but complementary approaches to analyzing mtDNA data and identifying management stocks are being pursued. Additionally, methods to extract DNA from genetic material other than tissues (i.e., scat, hair, blood, birth evidence, formalin-fixed tissues) are being developed.

The investigation of the diet of Alaskan harbor seals continued in 1999 and 2000 with the collection and examination of scats and stomachs, and the collection of blubber and seal prey to compliment fatty acid studies. The goals of the diet work are to establish baseline information on the diet of harbor seals in different regions of Alaska, to monitor changes in diet at certain index sites, and, where possible, to compare current diet with historical data. A total of 1,345 scats were collected from 1990–1999 in SE, along the Kodiak Archipelago, and in the Bering Sea; of these, 1,304 had identifiable prey remains. Preliminary results identified the most frequently occurring prey in 558 scats from SE as walleye pollock (*Theragra*; 50%) and arrowtooth flounder (*Atheresthes*; 33%). Top ranking prey identified from 321 scats from the Kodiak Archipelago were Irish lord (*Hemilepidotus*; 43%) and sandlance (*Ammodytes*; 25%). In the Bering Sea, 425 scats were analyzed with sandlance (45%), rock sole (*Lepidopsetta*; 44%), flounders (Pleuronectidae; 33%), sculpin (Cottidae; 33%), yellowfin sole (*Limanda*; 28%), rainbow smelts (*Osmerus*; 26%), and tomcod (*Microgadus*; 24%) ranking as top prey. Preliminary results suggest regional differences in diet diversity.

From 1995–1999, 301 stomachs were collected and processed. Ninety-two percent (278) of the stomachs were collected in SE and PWS; of these stomachs, 72% (199) contained prey items and the rest were empty. Based on percent occurrence, top ranking prey items were similar in SE and PWS, including herring (*Clupeidae*), cephalopods, and pollock. Biases occur with both methods of studying diet; *e.g.*, some prey, such as cephalopods, may be over represented in stomachs but underrepresented in scats (Pitcher 1980).

Blubber samples were collected from 25 pups tagged on Tugidak Island and from 24 seals harvested by subsistence hunters in SE. Previous analyses of blubber samples collected from seals along the Kodiak Archipelago, Yakutat, and SE show different fatty acid patterns, suggesting differences in diet among these regions (Iverson *et al.* 1997). At present, little information is available on the variability of fatty acids within a prey species across regions. One hundred twenty-seven herring samples from six regions of SE were collected and shipped to Sara Iverson at Dalhousie University to examine spatial variation of fatty acid profiles. Additional prey samples have been collected from SE and Kodiak; these samples are being prepared (sorted and measured) and will be shipped for analysis.

Several methods for enumerating harbor seals at glacial haulouts were explored in 1999. Glacial ice sites in PWS were photographed (n = 415 aerial photographs) to test if a GPS-linked large-format camera system developed by ADF&G would be sufficient at acquiring images from which a broad composite photograph could be constructed for counting seals accurately and

efficiently. While the GPS-link and software worked well and met the needs for control of coverage and creating the composite photograph, seal images were small (0.5-1.0 mm) and nearly impossible to distinguish in areas of dirty ice, and the number of photographs required for large sites made complete counts of photographs impractical. The ADF&G and National Marine Mammal Lab continue to develop efficient and accurate means of counting seals at glacial sites.

Preliminary results indicate that growth layers measured in the dentin of harbor seal teeth will allow accurate assessments of variation in growth for the fetal period and the first two years of life. Comparisons of growth patterns can be made among cohorts, geographic regions, or time periods. The degree of variation that can be expected among dentine layers, when comparing time periods or geographical regions, is unknown; in order to understand this variation, 100–200 teeth from each time period or region need to be prepared and analyzed. Cementum layers in harbor seal teeth do not provide a clear record of growth and thus cannot be used in this manner. A transition zone in the widths of the cementum layers can be used to estimate age of sexual maturity. A transition zone was estimated from 13 harbor seal teeth from SE. The estimated age of sexual maturity was 5.5 years for females (n=4) and 5.1 years for males (n= 9). Of the 44 teeth that did not exhibit a transition zone, 3 females and 8 males were older than the average age of sexual maturity; the remaining teeth were from young animals, most of which had likely not matured.

The need to compile available information on the characteristics of harbor seal habitat with their abundance and distribution in a GIS format has been identified. Such a snapshot will be valuable for future management and conservation needs as well as provide researchers with baseline distribution data. Metadata describing the availability, location, and quality of digital habitat data were compiled. These data describe: bathymetry, freshwater streams, haulout substrate, major fisheries, vessel traffic lanes, estimated subsistence take, and estimated incidental take from commercial fisheries. Information on coastline complexity and tidewater glaciers is still being researched. The compiled metadata list of resources is the first step in building a geospatial database of harbor seal habitat characteristics.

Several studies continued monitoring the health and condition of harbor seals in 1999 and 2000. From 1997-1999, 119 pups were captured at Tugidak Island and in PWS to allow morphometric and blood chemistry comparisons between sexes and among regions, and assess overall health of pups. Pups from Tugidak Island had lower body mass and lower relative body fat than pups from PWS. For Tugidak Island pups, females had higher hemoglobin levels than males. Tugidak Island pups had elevated hemoglobin, MCHC (mean corpuscular hemoglobin content), hematocrit, monocyte, eosinophil, sodium, liver enzyme, and blood urea nitrogen levels, with a greater number of individual outliers (9 out of 71 pups) than PWS pups. Liver enzymes were more prevalent than other blood parameters responsible for individual pup outliers. No outliers were detected in the PWS population. Although regional differences were statistically significant, clinical significance could not be determined and pups from neither region appeared clinically “unhealthy”. Regional differences in morphometrics and blood parameters may have resulted largely from differences in development, where Tugidak Island pups may have been younger than PWS pups when captured. Because several blood parameter reference ranges differed among regions, a reference range must be established for each population if outlier methods are to be used to assess health.

The serologic survey of exposure of harbor seals to disease pathogens also continued in 1999 and 2000. Over the past 25 years, presence of antibodies to *Leptospira interrogans* (n=289 samples) and phocine distemper virus (n=167) was rare at <1%, demonstrating little threat of these pathogens to Alaskan populations. Prevalence of antibodies to *Brucella* spp. was 27% (n=129) and to

Toxoplasma gondii 13% (n=128) for all geographic areas combined. Effects of infection by these pathogens on marine mammals are not well understood. Similar to previous studies, the presence of antibodies to phocid herpesvirus-1 was common with antibody prevalence ranging from 57-100% among geographic regions (n=272 total samples). However, no clinical cases of the disease have been reported and the phocid herpesvirus has apparently not been highly pathogenic for Alaskan harbor seals. Contaminant levels in Alaskan harbor seals are poorly documented. In 1999 and 2000, the ADF&G explored options and costs for monitoring contaminant loads in harbor seals statewide with plans to begin collection of blubber, liver, kidney and muscle samples from subsistence hunted seals in 2000-2001.

RECOMMENDATIONS

1. Annual trend count surveys should continue in the Sitka, Kodiak, and Bristol Bay regions. The Ketchikan survey should remain on a biennial schedule, with the next surveys conducted in 2000 and 2002. The level of precision associated with the Sitka and Kodiak trend estimates should be evaluated to determine if a biennial survey schedule is appropriate for those two routes. Alternative methods of obtaining an accurate estimate of the number of harbor seals at large glacial sites should continue to be explored.

2. Methods for the statistical analysis of population trend should continue to be refined.

3. Long-term monitoring of seals at land-based 'index' sites on Tugidak Island and at Nanvak Bay should continue during the pupping and molting periods.

4. Explore the use of telemetry equipment designed to obtain information on harbor seal foraging ecology and habitat use not previously collected with satellite-linked time-depth recorders. Specifically, information is needed to determine (1) which aspects of foraging behavior are most likely to indicate differences in foraging effort and prey availability; and (2) the spatial and temporal characteristics of habitats critical for successful foraging.

5. Harbor seal sera should continue to be archived for future disease testing. Relationships of ages of animals and exposure rates should be investigated when adequate samples are available.

6. Tissue samples for genetic analyses should be routinely collected from all capture efforts, and samples sent to the SWFSC of NMFS to be archived and analyzed. Directed sampling programs need to be developed and bio-sampling efforts focused in specific locations where additional samples are most needed to increase the statistical power necessary for further refinement of stock identification.

7. The information from samples obtained through the bio-sampling program could further advance genetic, diet, contaminant, and life history studies. The understanding of harbor seal habitat, distribution, and movements could be increased with the incorporation of traditional knowledge. Thus, develop a stronger relationship with the Alaska Native Harbor Seal Commission, including the discussion of future research objectives and cooperative projects.

Collection of appropriate specimens in cooperation with Alaska Native subsistence hunters should continue and be expanded to assist in collection of biological samples.

8. Methods to estimate harbor seal vital rates (i.e., survival, reproduction, and dispersal) should continue, including photo-identification as an application of the mark-recapture technique.

9. Research on the diet of harbor seals should continue with scat collections at long-term monitoring sites to provide an index of annual variation in diet. Sampling efforts should also be intensified to include additional sites and conducted on a monthly basis in specific study areas to provide the spatial and temporal coverage necessary to partition total prey consumption among prey species.

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INTRODUCTION

Dramatic declines in the number of harbor seal (*Phoca vitulina richardsi*) have been documented near Kodiak Island and in Prince William Sound (PWS), Alaska. Specifically, the number of seals decreased by approximately 90% between 1976 and 1995 on Tugidak Island (Pitcher 1990, Lewis *et al*. 1996), 40 km southwest of Kodiak Island, and in PWS numbers decreased by 63% between 1984 and 1997 (Frost *et al*. 1999). A research program to investigate the possible cause(s) of the population decline in Alaska was initiated in 1993 by the Alaska Department of Fish and Game (ADF&G) through funds allocated by the U.S. Congress. This research program has continued with annual grants awarded to ADF&G and administered by the National Marine Fisheries Service (NMFS), Alaska Region, of the National Oceanic and Atmospheric Administration (NOAA). This report presents the progress of the investigation of harbor seals in Alaska achieved during the 1999 performance period (1 July 1999 – 31 March 2000), fulfilling the reporting requirements under NOAA grant number NA87FX0300.

Overall, the status and trend of harbor seals in Alaska was poorly understood when ADF&G began their research investigations in 1993. Aerial trend routes had been established in PWS, and the Sitka and Ketchikan areas of Southeast Alaska (SE) in 1983 as a means to collect population data in a standardized, repetitive manner. These trend routes were surveyed again in 1984, but none were flown again until 1988 when the PWS and Ketchikan routes were surveyed. Annual surveys of the PWS route have been conducted since the *Exxon Valdez* oil spill in 1989. With the start of the NOAA-funded harbor seal research program in 1993, trend route surveys were re-initiated in SE and an additional route was established in the Kodiak Island area. In 1991, NMFS began the first year of a four-year statewide survey designed to estimate the total number of harbor seals in Alaska. Aerial surveys were conducted in Bristol Bay, along the north side of the Alaska Peninsula, and in PWS in 1991; the remaining areas of the Gulf of Alaska, including the Copper River Delta, were completed in 1992. NMFS then surveyed SE in 1993 and the Aleutian Islands in 1994. NMFS also conducted research projects during 1994 in SE and during 1996 near Cordova to estimate 'correction factors' that can be used to extrapolate counts of the number of seals hauled out during aerial surveys to an estimate of the total population size. NMFS conducted the second statewide abundance survey between 1995-1999, with accompanying correction factor studies. ADF&G researchers funded by this NOAA contract have assisted NMFS in their research projects on harbor seals in Alaska.

An understanding of harbor seal population dynamics, ecology, and behavior is necessary to determine what proximate and ultimate factors may cause populations to fluctuate. In addition, an understanding of the genetic structure of Alaskan harbor seals is required to properly delineate distinct population stocks for which conservation and management strategies can be effectively implemented. Such knowledge was also limited or did not exist in 1993. Recognizing this lack of necessary information, a diverse research program was initiated to increase our general understanding of harbor seal biology, and to address specific hypotheses related to the population decline.

The decline of harbor seal populations must be considered within the context of the Gulf of Alaska and Bering Sea ecosystems. Declines in other marine mammal populations have occurred, most notably the western stock of the Steller sea lion (*Eumetopias jubatus*), which was classified as endangered in May 1997. The northern fur seal (*Callorhinus ursinus*), whose numbers decreased by over a million animals (>50%) between 1950 and 1983, was designated as depleted under the Marine Mammal Protection Act in 1988. Significant population decreases of several seabird species have also been documented (Springer 1993). Changes in fish species composition have been

recorded, with substantial increases in some species, such as walleye pollock (*Theragra chalcogramma*), and decreases in others (Alton *et al*. 1987, Piatt and Anderson 1996). Whether such population fluctuations are inherent to the dynamic nature of the ecosystems or are the result of specific perturbations, perhaps anthropogenic, is unknown. Regardless, because harbor seals are predators near the top of the trophic structure, knowledge of population status and trends of species interacting with seals, particularly prey species, should be integrated into hypotheses aimed to determine the cause of seal declines.

Work undertaken in 1999 and 2000 marks the completion of seven years for the NOAA-funded harbor seal research program. Considerable progress has been made since 1993. Current (1994-1999) population trend estimates are available for the Ketchikan and Sitka areas, allowing comparisons with earlier trend estimates based on counts in the early 1980s. Although seal numbers remain substantially depressed in the Kodiak Archipelago, the 5.6% annual rate of increase during 1993-1999 for the east side of Kodiak Island represents the first documented increase in harbor seal numbers over a relatively broad area in the Gulf of Alaska. A new "Bristol Bay" aerial trend survey route was established along the north side of the Alaska Peninsula in 1998, and surveyed again in 1999. Further progress has been made on how to obtain more accurate and precise estimates of harbor seal numbers on glacial ice haulouts. Analyses have been completed for counts obtained at two land-based "index" sites, providing robust estimates of population trend during the 1990s at Nanvak Bay (northern Bristol Bay) and since the mid-1970s for Tugidak Island. Additional studies documented the age- and sex-specific molt phenology of harbor seals on Tugidak Island, as well as continued documentation of pupping phenology. Population survey design has been evaluated based on simulations from a model of harbor seal population dynamics and haulout behavior, providing information on how to reduce biases and increase accuracy. Photo identification techniques have been developed and successfully applied to the Tugidak Island population, and thus long-term studies of vital rates has begun. Statistical analyses of data collected from 64 adult and subadult seals monitored with satellite-linked depth recorders (SDRs) have been completed, describing diving behavior, seal movements, and haulout patterns. Data collected from 25 pups captured in 1997-1999 and monitored with SDRs have been summarized, providing information on the development of dive behavior and movements during the first year of life. Food habit studies of seal scat, stomach contents, and fatty acids have expanded to further examine regional differences in diet. Genetic research focused on delineating management stocks of Alaskan harbor seals has made substantial progress with the sequencing of over 750 samples, and the development of new analytical techniques to delineate stock boundaries. Body condition indices based on blood chemistry and hematology have been further refined, blood sera collected from 1975-1999 has been analyzed for antibody prevalence exposure to disease agents, and a contaminants monitoring program design has been developed. Studies of harbor seal tooth fine structure indicate that growth layers measured in the dentin will allow accurate assessments of variation in growth for the fetal period and the first two years of life, potentially allowing comparisons of growth patterns among cohorts, geographic regions, and time periods. Lastly, metadata describing the availability, location, and quality of digital habitat data were compiled.

However, much work remains. Results and progress made in the last seven years must be synthesized and integrated for a more thorough understanding of the results, which can then be used to determine the most effective and efficient means to provide further knowledge of Alaskan harbor seals.

As stated in the project proposal, the focus of the 1999-2000 research program was four-fold:

1. Monitor the trend in harbor seal numbers in selected areas.

2. Investigate factors that may be affecting harbor seals in those areas.

3. Complete statistical analysis and reporting of existing data.

4. Provide information to NMFS that can be used for designing a conservation and management program for harbor seals.

The specific objectives to meet these overall research goals were as follows:

Objective 1 Monitor population trends of harbor seals at selected sites in Alaska

Objective 2 Describe the movements and diving behavior of adult and juvenile harbor seals in Southeast Alaska and the Kodiak region, including temporal and spatial patterns of haulout use

Objective 3 Determine the genetic structure of harbor seals in Alaska

Objective 4 Determine prey utilization by harbor seals in various locations throughout Alaska

Objective 5 Examine the movements, diving behavior, and haulout patterns of harbor seal pups in the Kodiak Archipelago

Objective 6 Monitor the pupping and molting phenology on Tugidak Island and in Southeast Alaska

Objective 7 Examine new methods to census seals at glacial ice haulouts

Objective 8 Develop methods for estimating vital life history parameters of harbor seals

Objective 9 Compile available information on harbor seal habitat with estimates of abundance and distribution in Alaska

Objective 10 Determine the prevalence of some infectious diseases of harbor seals in Southeast Alaska and the Kodiak Archipelago

Objective 11 Provide support to studies by other investigators that will examine the health and nutritional status, and energetic requirements of harbor seals

These 11 objectives were addressed by a diverse group of research scientists from several state and federal agencies and universities working cooperatively with ADF&G. In this annual report, the results of these research efforts are presented in separate chapters prepared by the individual scientists, and in the summary. The literature cited in this Introduction is presented at the end of the Executive Summary.

NOTE: Relative to Objective 1, a grant was awarded by the *Exxon Valdez* Trustee Council to the principal investigator to evaluate harbor seal population survey design. The results of that research are presented in this report due to their application towards estimating population trends. Objective 3 includes the specific objectives in the supplemental proposal submitted 1 June 2000.

COVER PAGE PHOTOGRAPH DESCRIPTION: The cover page photograph was taken on Tugidak Island by Shannon Crowley as data collected for the photo-identification project of harbor seals (see pages 146-168). The image was enhanced by Lex Hiby of Conservation Research Ltd. by fitting over the image a three-dimensional model of a harbor seal ventrum (shown by colored lines and grid) that mimics natural movement patterns and corrects for differences in posture and viewpoint among photographs. After fitting this model to photographs, specialized software is used to (1) measure gray-scale intensities within standard regions on the ventrum to determine unique numerical descriptions or "fingerprints" for seals; and (2) compare "fingerprints" in the database to objectively and efficiently match photographs, and determine resightings of individuals for a mark-recapture study.

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The 1999-2000 Alaskan harbor seal research program was a joint effort by many individuals associated with several agencies and academic institutions. Contributions from the following individuals were instrumental to the success of the project. From ADF&G: Shannon Crowley and Raychelle Daniel for another year of monitoring seals on Tugidak Island, and numerous insights on harbor seal behavior and biology; Carol Coyle for digging into many databases associated with seal habitat; Chris Curgus for logistical support, equipment preparation, and counting seals from slides; Rob Delong for development of software to manage and analyze satellite tag data; Kathy Frost for assistance in the analysis of satellite tag data and fatty acid research; Kelly Hastings for leading the analysis of SDR dive data, development of photo-id techniques on Tugidak Island, and designing a contaminants monitoring program; Lauri Jemison for leading the Tugidak Island and Nanvak Bay "index site" monitoring programs and data analyses, food habits studies, and the biosampling program; Lloyd Lowry for oversight of the program; Grey Pendleton for statistical analysis and conducting trend counts in the Sitka area; Ken Pitcher for discussions of historic data; Mike Rehberg for database development and management, and GIS support; Chad Rice for processing stomach and scat samples; Dick Sellers for logistical support and knowledge of the Bristol Bay area; Gay Sheffield for database preparation and maintenance, and permit reporting; Vicki Vanek for the collection of specimens from Alaska Native subsistence hunters, and Randy Zarnke for disease analysis. ADF&G administrative support was provided by Cheryl Craig, Diana Ground, Jean Lampe, Lauri Ritter, and Linda Troutman.

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Thanks are also due to Monica Riedel and Harold Martin of the Alaska Native Harbor Seal Commission for their efforts to help organize the collection of specimens from Alaska Native subsistence hunters, and for insight on how traditional knowledge can be incorporated into the co-management of harbor seals in Alaska. Additional thanks go to the Alaska Native hunters that provided samples through the biosampling program.

Special thanks go to John and Midge Garber for all their help in making the work on Tugidak Island more enjoyable and productive. Finally, thanks to the numerous pilots who often flew in adverse conditions for extended periods.