NOAA Technical Memorandum NMFS-AFSC-218

Diving Behaviors and Movements of Juvenile Steller Sea Lions (*Eumetopias jubatus*) Captured in the Central Aleutian Islands, April 2005

by
M. E. Lander, D. S. Johnson, J. T. Sterling, T. S. Gelatt, and B. S. Fadely

U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
National Marine Fisheries Service
Alaska Fisheries Science Center

March 2011

NOAA Technical Memorandum NMFS

The National Marine Fisheries Service's Alaska Fisheries Science Center uses the NOAA Technical Memorandum series to issue informal scientific and technical publications when complete formal review and editorial processing are not appropriate or feasible. Documents within this series reflect sound professional work and may be referenced in the formal scientific and technical literature.

The NMFS-AFSC Technical Memorandum series of the Alaska Fisheries Science Center continues the NMFS-F/NWC series established in 1970 by the Northwest Fisheries Center. The NMFS-NWFSC series is currently used by the Northwest Fisheries Science Center.

This document should be cited as follows:

Lander, M. E., D. S. Johnson, J. T. Sterling, T. S. Gelatt, and B. S. Fadely. 2011. Diving behaviors and movements of juvenile Steller sea lions (*Eumetopias jubatus*) captured in the central Aleutian Islands, April 2005. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-AFSC-218, 41 p.

NOAA Technical Memorandum NMFS-AFSC-218

Diving Behaviors and Movements of Juvenile Steller Sea Lions (*Eumetopias jubatus*) Captured in the Central Aleutian Islands, April 2005

by

M. E. Lander, D. S. Johnson, J. T. Sterling, T. S. Gelatt, and,

B. S. Fadely

Alaska Fisheries Science Center

7600 Sand Point Way N.E.

Seattle, WA 98115

www.afsc.noaa.gov

U.S. DEPARTMENT OF COMMERCE

Gary F. Locke, Secretary

National Oceanic and Atmospheric Administration

Jane Lubchenco, Under Secretary and Administrator

National Marine Fisheries Service

Eric C. Schwaab, Assistant Administrator for Fisheries

March 2011

This document is available to the public through:

National Technical Information Service
U.S. Department of Commerce
5285 Port Royal Road
Springfield, VA 22161

www.ntis.gov

ABSTRACT

Population counts and pup production for Steller sea lions (*Eumetopias jubatus*) in the central Aleutian Islands (CAI) of the western distinct population segment (wDPS) continue to decline for unknown reasons. Due to paucity of telemetry data for this region, satellite-linked depth recorders were deployed on 16 juvenile Steller sea lions from 19 April to 2 May 2005 to gain a better understanding of their diving behaviors and habitat use**.** Overall, depths of dives (n = 89,993, $\bar{x}$ = 11.8 m, SD = 12.6, med = 8.0, and range = 5.0 to 255.0), durations of dives (n = 155,620, $\bar{x}$ = 0.8 min, SD = 0.6, med = 0.5, and range = 0.5 to > 13.0), trip durations (n = 553, $\bar{x}$ = 14.0 hours, SD = 19.6, med = 10.7, and range = 0.3 to 280.0), and shore durations (n = 589, $\bar{x}$ = 10.5 hours, SD = 7.1, med = 10.7, and range = 1.0 to 58.7) were similar to findings for Steller sea lions previously tagged in the CAI. Diel behaviors, ontogenetic trends, and movements displayed by juvenile Steller sea lions also were similar to past accounts. Relative to data reported for Steller sea lions from the eastern DPS, however, trip durations of sea lions reported herein were longer, whereas depths of dives were shallower and durations of dives were shorter.

A continuous-time correlated random walk model that was applied to the telemetry data was used to examine areas of predicted diving activity with respect to Steller sea lion designated critical habitat. Overall, the proportions of predicted locations associated with diving to > 4 m within zones of critical habitat appeared to reflect the proportions of Argos data well and results were similar to other reports. Additional models will be useful for examining sea lion movements and diving behaviors among regions and with respect to spatial management measures and environmental features.

CONTENTS

INTRODUCTION

From the late 1970s to the early 1990s, the endangered western distinct population segment (wDPS) of Steller sea lions (*Eumetopias jubatus*) in the United States declined to less than 75,000 animals, equating to a reduction of approximately 80% (Loughlin 1998, Calkins et al. 1999). Initially, a precipitous decline was observed during the 1970s in the eastern Aleutian Islands (Braham et al. 1980) and then it spread east to the central Gulf of Alaska and west to the central Aleutian Islands (CAI) during the late 1980s (Merrick et al. 1987). The rate of decline decreased during the 1990s (NRC 2003) and from a regional perspective, rates of decline were greater at the fringes of the wDPS' geographical range than at the center (Fritz et al. 2008).

Population trends, which are dependent on the temporal scale examined, have varied among sub-regions of the U.S. wDPS, including the eastern, central, and western Gulf of Alaska, and eastern, central, and western Aleutian Islands (including the eastern Bering Sea). Overall, the population of Steller sea lions has stabilized in many areas since 2002 (Sease and Gudmundson 2002), but recent trends in the western Aleutian Islands (WAI) and western CAI have been negative, suggesting a stable or slight negative trend for the population as a whole (Fritz et al. 2008). Over the past decade counts of non-pups in the CAI appeared to be stable for a brief period (i.e., 2000-2004; Fritz and Stinchcomb 2005, Lander et al. 2009), but recent trends indicate the population has since declined by 16% from 2004 to 2008 (Fritz et al. 2008). Within the CAI, however, there were different trends west and east of 178°W (Tanaga Island, Samalga Pass). West of this apparent boundary, counts continuously decreased from 2000 to 2008, whereas east of this boundary counts increased by 15% from 2000 to 2004, but then declined by 17% through 2008 (Fritz et al. 2008). Similar to non-pups, 178°W also separates declining pup numbers in the west (Delarof and Rat Islands) from stable or slightly increasing pup numbers in the east (Andreanof and Fox Islands). Overall, however, pup production in the CAI has declined at a rate of 1.6% per year since 1994 (DeMaster 2009) and 0.9% per year since 2000 (NMFS 2010).

Factors causing the decline or limiting the recovery of Steller sea lions in western Alaska are not well understood, but understanding the foraging behaviors and habitat requirements of animals from this area are necessary for assessing the effects of top-down and bottom-up forces on the population. This information is also critical for evaluating the efficacy of management and conservation efforts (NMFS 1992, NMFS 2000, NRC 2003), but unfortunately, telemetry data from these areas are limited (Loughlin et al. 2003, Fadely et al. 2005, Rehberg 2005, Call et al. 2007, Lander et al. 2009). To address this need, satellite transmitters were deployed on juvenile Steller sea lions in the CAI during the spring of 2005 as part of an on-going study by the National Marine Mammal Laboratory (NMML) and Alaska Department of Fish and Game (ADF&G) to compare sea lion habitat use and behavior between the wDPS and eastern DPS (eDPS). This report summarizes the diving behaviors, trip durations, and movements of those animals. Additionally, these data were examined with respect to Steller sea lion designated critical habitat.

MATERIALS AND METHODS

From April to May 2005, juvenile Steller sea lions were opportunistically captured using hoop nets on land or SCUBA methodologies as described in McAllister et al. (2001) at haul-out sites within the CAI. Satellite-linked depth recorders (SDR-T16, 13.5 x 4.5 x 3.7 cm, 330 g; Wildlife Computers Ltd., Redmond, WA) were attached to the dorsum of each animal using 5-

minute epoxy (Devcon products, Riviera Beach, FL) while they were anesthetized following procedures of Heath et al. (1997). All transmitters were optimized to provide locations at sea and on land and to transmit three classes of messages including dive histograms, timelines, and status messages. All data were obtained through Service Argos, Inc., a satellite-based location and data collection system (Argos 1996) and decoded using Satpak software (Wildlife Computers Inc., Redmond, WA). For dive histograms, SDRs were programmed to summarize and store information for dive durations, maximum dive depths, and time at depth (TAD) into 14 bins, each of which contained counts for a given range of depth or duration (Merrick et al. 1994, Merrick and Loughlin 1997). Upper bounds of maximum duration histograms were 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, and > 13 minutes. Upper bounds of maximum depth histograms were 4, 6, 10, 20, 34, 50, 74, 100, 124, 150, 174, 200, 250, and > 250 m, whereas upper bounds of TAD histograms were 0, 4, 6, 10, 20, 34, 50, 74, 100, 124, 150, 174, 200, and > 200 m. Duration and depth histogram bins contained the number of dives that fell within the bin's range, whereas the count within each TAD histogram bin represented the fraction of the 6-hour period that the animal spent in each depth range. Setting the upper bound of the first data bin to 0 for TAD bins allowed for calculating the percentage of time spent hauled out for each 6-hour period. Counts of dives were further accumulated into four 6-hour periods (period 0 = 13:00–18:59, period 1 = 19:00–00:59, period 2 = 01:00–6:59, period 3 = 07:00–12:59; Greenwich Mean Time) per day, which were converted to local time (period 0 = 21:00–02:59, period 1 = 03:00–08:59, period 2 = 09:00–14:59, and period 3 = 15:00–20:59).

The SDRs, which were equipped with a saltwater switch to assess conductivity readings every 20 minutes, recorded whether the majority of those readings were "dry" or "wet." These data were compiled into timeline messages detailing when the animals were dry (hauled out) or wet (at sea) for 20-minute increments every 24 hours. Additionally, status messages provided information on the operating conditions of the SDR along with the maximum depth recorded for 24-hour periods (Wildlife Computers 1997).

Diving Behaviors

Only dives exceeding 4 m in depth were considered a dive and mean (± 1 SD) and median dive depth and duration were calculated for each animal by summing counts of dives from the histograms and using the range midpoint of each bin as the depth or duration for all dives in that bin (Merrick et al. 1994, Merrick and Loughlin 1997). Furthermore, daily maximum dive depths obtained from the status messages were examined with respect to day of the year (also accounting for age) and corresponding percentage of the moon's visible illuminated disk for the CAI (Naval Oceanography Portal; http://www.usno.navy.mil/) using a two-step process. First, the presence/absence of maximum depth data was examined with respect to day of year and moon phase using generalized linear mixed models (binomial family; package lme4, R Development Core Team 2006). Secondly, for those days containing a maximum depth data point, the data were log transformed and also examined with respect to day of year and moon data using generalized linear mixed models (Gaussian family, package lme4). Individual sea lion was included as a random effect in all models and response variables were examined with respect to independent predictor variables, additive predictor variables, and full models. Akaike's information criterion (AIC) was used for model selection.

Trip Durations

Means (± 1 SD) and medians of trip and shore durations were calculated for each animal after extracting data (departure and arrival times at haulouts) from the timeline messages using the algorithm described in Call et al. (2007).

Movements

All daily locations from SDRs were filtered using a swim speed of 2 m/s with the algorithm described by McConnell et al. (1992) after deleting duplicate and Z locations. Timeline data, status messages, and dive data were used to determine if locations were on shore, at sea, or at sea with assumed diving activity. All locations associated with diving > 4 m were pooled among individuals, projected to an Albers equal-area conic projection defined for the state of Alaska, plotted, summarized, and examined within zones of designated critical habitat for Steller sea lions (50 CFR 226.202), including 0-3 nautical miles (nmi), 3-10 nmi, and 10-20 nmi from the nearest major haulout or rookery and three large offshore foraging areas around Shelikof Strait, Bogoslof, and Seguam Pass (ArcMap 9.3, ESRI, Redlands, CA). To be consistent with previous analyses, locations within the 0-3 nmi and 3-10 nmi zones were pooled to form one 0-10 nmi zone. The GIS shape files used for the analysis (akland and Steller_10_20_Transit_Forage) are described in NMFS (2003).

To further examine the movements of sea lions, the filtered data were processed with a continuous-time correlated random walk (CTCRW) model as described in Johnston et al. (2008). This model is incorporated into a state-space model framework with a Kalman filter and was used to predict uniformly spaced animal locations for 20 minute intervals (Johnson et al. 2008). This model allowed for inclusion of measurement error in telemetry locations and parameter estimation using maximum likelihood (Johnson et al. 2008). In addition to the dry time covariate described in Johnson et al. (2008), the model was also generalized to account for the frequency of diving while at sea by allocating the number of dives reported for each 6 hour period to each 20 minute interval defined as “wet” within that period. For periods reported as dry, but dive data were collected, the dry time covariate was assigned a value of 0.5 for all 20 minute intervals within that period. Because the CTCRW model performs poorly with missing covariate data, dive frequencies for all missing periods for each individual were predicted from a generalized additive model (GAM) that fit dive frequency as a function of day of year (with integrated smoothness estimation) and period (quasiPoisson family, R 2.4.1, R Development Core Team 2006). Period of day was included as a predictor variable in the model because previous studies of juvenile Steller sea lions indicated most diving activity occurred during night when sea lions may have been foraging on vertically migrating prey (Loughlin et al. 2003, Fadely et al. 2005, Call et al. 2007, Lander et al. 2010).

All predicted locations that were generated with the CTCRW model were pooled among individuals. Predicted locations associated with diving to > 4 m as well as predicted locations associated with periods containing a dive frequency greater than the average frequency were also examined within zones of designated critical habitat for Steller sea lions outlined above (ArcMap 9.3). To illustrate the full range of uncertainty in the individual movement models (due to location error), 20 tracks were sampled from the posterior distribution of 100 simulations of the fitted CTCRW models and plotted (R Development Core Team 2006).

RESULTS

Satellite depth recorders were deployed on 16 juvenile (10.5 months at capture) Steller sea lions (n = 7 F, 9 M) from six locations within the CAI from 19 April to 2 May 2005 (Table 1, Fig. 1). Deployment periods lasted an average of 43 days (SD = 23, range = 8 to 90).

Diving Behaviors

Overall, depths of dives (n = 89,993) averaged 11.8 ± 12.6 m (med = 8.0) and ranged from 5.0 to 255.0 m (range of means = 5.4 to 15.9, SD = 3.0; Table 2), whereas durations of dives (n = 155,620) averaged 0.8 ± 0.6 minutes (med = 0.5) and ranged from 0.5 to > 13.0 minutes (range of means = 0.6 to 1.0, SD = 0.1; Table 2). The majority of dives occurred during nocturnal hours (period 0, 21:00 – 2:59 local time; Fig. 2). Additionally, a greater percentage of time at depth occurred at night, whereas a greater percentage of time was spent hauled out during the day (period 2, 9:00-14:59; Fig. 3).

Model selection indicated that day of year was the best covariate for predicting whether juvenile Steller sea lions displayed any diving activity (Table 3). In other words, juvenile sea lions had an increased probability of diving at least once a day over time (and with age). Additionally, maximum depth increased with day of year, but maximum dive depths also become shallower as a greater percentage of the moon was illuminated (Table 3). The latter inverse relationship appeared more apparent as sea lions became slightly older (Fig. 4).

Trip Durations

Overall, pooled trip durations (n = 553) at sea ranged from 0.3 to 280.0 hours ($\bar{x}$ = 14.0, med = 10.7, SD = 19.6), whereas shore durations (n = 589) ranged from 1.0 to 58.7 hours ($\bar{x}$ = 10.5, med = 10.7, SD = 7.1). From an individual perspective, mean trip durations ranged from 7.0 to 35.9 hours and mean shore durations ranged from 8.7 to 14.5 hours (Table 4). Similar to the dive data, median values are also provided because the data were skewed (Table 4).

Summary of Steller Sea Lion Movements

Steller sea lions were captured at six different haul-out sites (Table 1). Two Steller sea lions (DBID 11246 and 11247) were captured and tagged at Silak Island. DBID 11246 remained at Silak Island for approximately 5 weeks before traveling around Chaika Rock to Ragged Point, Sharp Cape, and Kaga Point on Kagalaska Island. With the exception of a few sporadic locations, this animal remained on the continental shelf within the 100 m isobath. Unlike DBID 11246, DBID 11247 remained around Silak Island for the duration of the deployment period.

Only one Steller sea lion (DBID 11248) was captured and tagged at Little Tanaga Strait. That animal first moved to Oglala Point, Kagalaska Island for a couple of days before spending the rest of his time near Cape Azamis, Little Tanaga Island.

Half of the Steller sea lions were captured and tagged at Lake Point, Adak Island and movements varied among individuals. Two animals (DBID 11250 and 11252) remained at Lake Point, one animal (DBID 11253) made multiple trips from Lake Point to many points of interest around the perimeter of Kanaga Island (Round Head, Ship Rock, Eddy Rock, and Capes Chlanak, Chunu, and Tusikand), and one animal (DBID 11262) swam over to Ship Rock, Kanaga Island 3 days after being tagged to remain within the general vicinity of that area. The remaining four animals (DBID 11249, 11251, 11260, and 11261) tagged at Lake Point traveled to multiple islands and displayed some longer ranging movements. For example, DBID 11249 remained near Lake Point and Cape Yakak for approximately 3 weeks before heading north to Eddy Island (between Argonne and Careful Points, Adak Island). He then proceeded to travel over the northernmost point of Adak Island (between Capes Kigua and Adagdak) and over to the northern area of Great Sitkin Island. He then made a brief trip south to Anagaksik Island, headed north to Asuksak Island, and west to Little Tanaga Island (Cape Lises), Kagalaska Island (Black Point), and Adak Island. DBID 11251 remained close to Lake Point for 2 weeks before traveling to northern Adak Island, spending substantial time at Capes Kiguga and Moffett. He then moved north to the eastern side of Great Sitkin Island (between Teapot Rock and Sulphur Point), spent a few days in Great Sitkin Pass, and then traveled to Tagalak and surrounding islands for the remainder of transmitter life (with the exception of a quick trip to western Atka Island). The remaining two sea lions (DBID 11260 and 11261) made trips into pelagic waters. DBID 11260 traveled from Lake Point over northern Great Sitkin Island, proceeded south to swim the perimeter of Igitkin Island, before turning back to Great Sitkin Island. DBID 11260 then went on a 6-day trip to sea, approximately 200 km from Atkin Island and then spent the remainder of his time around western Atkin Island. DBID 11261 remained at Adak Island for almost 2 weeks before going to sea for 13 days, approximately 435 km north of Cape Adagdak, Adak Island, over the waters of Bowers Ridge. He then traveled back down around the southern end of Semisopochnoi Island before resting on Tanaga Island for a few days. This male sea lion then embarked on an 11-day trip to Buldir Island, looping widely north of Semisopochnoi Island and then swam south (bypassing Buldir Island) into waters south of the Near Islands, before turning back to Buldir Island. He remained there for 3 days before taking a 2-day trip over to Shemya Island and remained around the Semichi Islands until signal cessation.

Two Steller sea lions (DBID 11255 and 11256) were captured and tagged at Ship Rock, Kanaga Island. DBID 11255 primarily remained along the shoreline within ~ 8 km of Ship Rock, whereas DBID 11256 used areas similar to those of DBID 11253 around the perimeter of Kanaga Island.

Two Steller sea lions (DBID 11257 and 11258) were captured and tagged at Kagalaska Island. DBID 11257 traveled from Kagalaska Island to Crone Island (south of Adak Island), before heading over to Capes Kagigikak and Yakak. DBID 11258 traveled to Quail Bay (southern Kagalska Island) and over to Little Tanaga (Cape Chisak) and Chisak Islands before settling at Lake Point, Adak Island.

Lastly, a single Steller sea lion (DBID 11259) was captured and tagged at Semisopochnoi Island and remained near shore around the northern area of the island.

Individual Movement Models

A total of 5,233 locations from the 16 sea lions was obtained from Service Argos, Inc. ($\bar{x}$ = 327 locations per individual, SD = 215, range = 77 to 757), 4,044 locations were retained after filtering the data ($\bar{x}$ = 253, SD = 163, range = 60 to 581), and 2,839 locations were associated with diving to > 4 m ($\bar{x}$ = 177, SD = 128, range = 12 to 429; Fig. 5). A total of 41,958 predicted locations was generated using the CTCRW ($\bar{x}$ = 2,622 locations per individual, SD = 1,493, range = 502 to 6,232; Fig. 6), 26,878 of which were locations associated with diving to > 4 m ($\bar{x}$ = 1,680, SD = 1,147, range = 241 to 4,388; Figs. 6 and 8), and 9,243 of which were locations associated with periods during which the frequency of diving exceeded more than the average frequency ($\bar{x}$ = 578, SD = 453, range = 88 to 1,613; Figs. 7 and 8). The CTCRW had to be modified (i.e., set to mimic Brownian Motion) for five individuals (DBID 11246, 11247, 11250, 11252, and 11262), possibly due to limited data or the lack of directional persistence relative to the amount of data collected.

Plotting all of the data sets with respect to designated critical habitat illustrated that only a slightly greater proportion of locations occurred farther from shore as the data became more detailed (i.e., ranging from filtered Argos locations to enhanced foraging locations; Table 5). Plots depicting the uncertainty of predicted data sets are illustrated in Figure 9.

DISCUSSION

Collectively, the data summarized for this report corroborated findings for Steller sea lions previously tagged in the CAI (Loughlin et al. 2003, Fadely et al. 2005, Rehberg 2005, Call et al. 2007, Rehberg and Burns 2008, Lander et al. 2010). Dive statistics, diel behaviors, ontogenetic trends, trip durations, and movements reported here were similar to past accounts despite the annual differences in data collection. With a few exceptions, dives conducted by juvenile Steller sea lions from the CAI were generally short and shallow; deeper diving occurred during nocturnal hours as did a greater proportion of diving activity (Loughlin et al. 2003, Rehberg and Burns 2008, Lander et al. 2010). Depths of daily maximum dives increased significantly with age (Pitcher et al. 2005), but this relationship was confounded by lunar illumination.

Daily maximum dives of Steller sea lions were examined with respect to lunar data because not only did they increase over time when plotted, but they appeared cyclical. Unlike other pinniped studies (Horning and Trillmich 1999, Lea et al. 2010), daily maximum depth was inversely related to lunar illumination. This was unexpected for a predator reputed for feeding on shallow, vertically migrating prey such as walleye pollock (*Theragra chalcogramma*), which tend to rise in the water column during the night (Sinclair et al. 1994). However, Atka mackerel (*Pleurogrammus monopterygius*), which comprise a large portion of the diet for sea lions from the CAI (Sinclair and Zeppelin 2002, Call and Loughlin 2005, Lander et al. 2009), display opposite behaviors. For example, Nichol and Somerton (2002) used archival tags to relate the diurnal vertical migration of Atka mackerel to light intensity and found a positive relationship. Additionally, Atka mackerel displayed surface directed vertical excursions only during diurnal hours and little to no vertical migration during night (Nichol and Somerton 2002). Hence, if the deepest of dives performed by Steller sea lions indicate when they are targeting Atka mackerel, it makes sense that they will be deeper as lunar illumination decreases (assuming little vertical migration occurs at night).

For the duration of instrument deployment, sea lions exhibited both central place and multiple central place foraging (Raum-Suryan et al. 2004). Trip durations were relatively short, albeit a few males displayed some long-range movements (i.e., 11260, 11261). This was not surprising as branded animals from the CAI have been observed in the Commander Islands, Russia (NMFS 2008) and long-range movements of branded and tagged sea lions have been reported elsewhere (Merrick and Loughlin 1997, Loughlin et al. 2003, Raum-Suryan et al. 2002, Raum-Suryan et al. 2004). Relative to data collected for Steller sea lions tagged in the eDPS, trip durations of sea lions reported here were longer (Raum-Suryan et al. 2004, Pitcher et al. 2005, Call et al. 2007), but dive depths and durations were shallower and shorter, respectively (Loughlin et al. 2003, Raum-Suryan et al. 2004, Pitcher et al. 2005). However, the data sets are not easily comparable due to a myriad of caveats, including annual, seasonal, and age related effects, differences in data collection and defining behaviors (e.g., depth considered a dive or distance considered a trip), and others discussed in Pitcher et al. (2005).

After applying CTCRW models to the telemetry data, the proportions of predicted locations associated with diving to > 4 m within zones of designated critical habitat were similar to the proportions of Argos data (Table 5). Additionally, proportions in 0-10 nmi of critical habitat across datasets in Table 5 corroborated the CAI summer data reported in NMFS (2010), which was an updated analysis of the distribution of juvenile Steller sea lions at sea prepared for the Draft Groundfish Biological Opinion (NMFS 2003). However, proportions in the 10-20 zones doubled that presented in NMFS (2010), whereas proportions outside of critical habitat were less than half of that presented in NMFS (2010). These differences were likely a result of different filtering techniques or sample sizes.

The CTCRW models were advantageous for predicting locations at short temporal intervals, for retaining small-scale movements (Johnson et al. 2008), and for generating data that were less likely to be collected as a result of biases due to the transmission and reception of telemetry data (i.e., animal behavior; Fadely et al. 2005). Because the original satellite data served as the foundation for the CTCRW models, some of those biases were retained in the results. However, the models were still useful for elucidating general areas where a greater frequency of diving occurred. Employing CTCRW models to archived data sets collected from western areas of the wDPS will continue to be useful for examining areas of enhanced foraging activity and corresponding telemetry error with respect to critical habitat and other fishery regulations. Given the contrasting sea lion demographics opposite of 178°W, additional models will also be useful for comparing regional differences within the wDPS.

As specified in the Revised Steller sea lion Recovery Plan (NMFS 2008), the documented variation in the rate of population decline among regions within the wDPS demonstrates the need to employ a recovery strategy that accounts for the spatial and temporal variation of essential habitat characteristics. Additionally, NMFS (2008) reiterated the importance of using telemetry studies to obtain refined information on sea lion foraging ecology and the effects of habitat features (i.e., bathymetry, continental shelf, and the spatial and temporal variability of essential oceanographic processes) on behavior. Upon visual inspection of the data it appeared that some of the animals utilized bathymetry, shelf gradients, and ridges and these observations warrant further investigation. In the future, movement models will be examined with respect to environmental covariates, which is not only necessary for understanding how sea lions respond to their environment, but ultimately needed before modeling movement as a function of those covariates.

ACKNOWLEDGMENTS

Special thanks to Kate Call and Rod Towell of the National Marine Mammal Laboratory (NMML), Kimberly Beckman, Jamie King, Dennis McAllister, Ken Pitcher, and Greg Snedgen of the ADF&G, Bill Taylor (Wildlife Veterinary Services), Kathy Burek (Alaska Veterinary Pathology), Lisa Hoopes (University of Central Florida), and the crew of the MV *Stimson* for all of their support and assistance capturing sea lions. This report was improved with reviews by Carey Kuhn and Alex Zerbini (NMML) and James Lee (AFSC). This work was conducted under Federal Marine Mammal Permits 358-1564 and 782-1532. The use of trade, product, or firm names in this publication is for descriptive purposes only and does not imply endorsement by the U.S. Government. The findings and conclusions in the paper are those of the authors and do not necessarily represent the views of the National Marine Fisheries Service.

CITATIONS

Argos. 1996. User's Manual, Satellite Based Data Collection and Location System. Service Argos Inc., Landover, MD, USA. 176 p.

Braham, H. W., R. D. Everitt, and D. G. Rugh. 1980. Northern sea lion decline in the eastern Aleutian Islands. J. Wildl. Manage. 44:25-33.

Calkins, D. G., D. C. McAllister, K. W. Pitcher, and G. W. Pendleton. 1999. Steller sea lion status and trend in Southeast Alaska: 1979-1997. Mar. Mammal Sci. 15:462-477.

Call, K. A., B. S. Fadely, A. Greig, and M. J. Rehberg. 2007. At-sea and on-shore cycles of juvenile Steller sea lions (*Eumetopias jubatus*) derived from satellite dive recorders: A comparison between declining and increasing populations. Deep-Sea Res. Part II 54:298-310.

Call, K. A., and T. R. Loughlin. 2005. An ecological classification of Alaskan Steller sea lion (*Eumetopias jubatus*) rookeries: a tool for conservation/management. Fish. Oceanogr. 14(Suppl. 1):212-222.

DeMaster, D. 2009. Aerial Survey of Steller Sea Lions in Alaska, June-July 2009 and Update on the Status of the Western Stock in Alaska. AFSC memorandum available at: http://www.afsc.noaa.gov/nmml/species/species_steller.php.

Fadely, B. S., B. W. Robson, J. T. Sterling, A. Greig, and K. A. Call. 2005. Immature Steller sea lion (*Eumetopias jubatus*) dive activity in relation to habitat features of the eastern Aleutian Islands. Fish. Oceanogr. 14(Suppl. 1):243-258.

Fritz, L., M. Lynn, E. Kunisch, and K. Sweeney. 2008. Aerial, ship, and land-based surveys of Steller sea lions (*Eumetopias jubatus*) in Alaska, June and July 2005 and 2007. U.S. Dep. Commer., NOAA Tech Memo. NMFS-AFSC-183, 70 p.

Fritz, L. W., and C. Stinchcomb. 2005. Aerial, ship, and land-based surveys of Steller sea lions (*Eumetopias jubatus*) in the western stock in Alaska, June and July 2003 and 2004. U.S. Dep. Commer., NOAA Tech Memo. NMFS-AFSC-153, 56 p.

Heath, R. B., R. DeLong, V. Jameson, D. Bradley, and T. Spraker. 1997. Isoflurane anesthesia in free ranging sea lion pups. J. Wildl. Dis. 33:206-210.

Horning, M., and F. Trillmich. 1999. Lunar cycles in diel prey migrations exert a stronger effect on the diving of juveniles than adult Galápagos fur seals. Proc. R. Soc. Lond. B: 1127-1132.

Johnson, D. S., J. M. London, M. Lea, and J. W. Durban. 2008. Continuous-time correlated random walk model for animal telemetry data. Ecology 89:1208-1215.

Lander M. E., T. R. Loughlin, M. G. Logsdon, G. R. VanBlaricom, and B. S. Fadely. 2010. Foraging effort of juvenile Steller sea lions *Eumetopias jubatus* with respect to heterogeneity of sea surface temperature. Endanger. Species Res. 10:145-158.

Lander, M. E., T. R. Loughlin, M. G. Logsdon, G. R. VanBlaricom, B. S. Fadely, and L. W. Fritz. 2009. Regional differences in the spatial and temporal heterogeneity of oceanographic habitat used by Steller sea lions. Ecol. Appl. 19:1645-1659.

Lea, M. A., D. Johnson, S. Melin, R. Ream, and T. Gelatt. 2010. Diving ontogeny and lunar responses in a highly migratory mammal, the northern fur seal (*Callorhinus ursinus)*. Mar. Ecol. Prog. Ser. 419:233-247.

Loughlin, T. R. 1998. The Steller sea lion: a declining species. Biosphere Conserv. 1:91-98.

Loughlin, T. R., J. T. Sterling, R. L. Merrick, J. L. Sease, and A. E. York. 2003. Diving behaviors of immature Steller sea lions, *Eumetopias jubatus*. Fish. Bull., U.S. 101: 566–582.

McAllister, D. C., D. G. Calkins, and K. W. Pitcher. 2001. Underwater capture of juvenile Steller sea lions with scuba: a narrated video presentation. Pages 53-56 In Cold water diving for science. Alaska Sea Grant College Program, University of Alaska Fairbanks, USA. AK-SG-01-06.

McConnell, B. J., C. Chambers, and M. A. Fedak. 1992. Foraging ecology of southern elephant seals in relation to the bathymetry and productivity of the Southern Ocean. Antarct. Sci. 4:393-398.

Merrick, R. L., and T. R. Loughlin. 1997. Foraging behavior of adult female and young-of-the-year Steller sea lions in Alaskan waters. Can. J. Zool. 75: 776–786.

Merrick, R. L., T. R. Loughlin, G. A. Antonelis, and R. Hill. 1994. Use of satellite-linked telemetry to study Steller sea lion and northern fur seal foraging. Polar Res. 13:105-114.

Merrick, R. L., T. R. Loughlin, and D. G. Calkins. 1987. Decline in abundance of the northern sea lion, *Eumetopias jubatus*, in Alaska, 1956-86. Fish. Bull., U.S. 85:351-365.

National Marine Fisheries Sevice (NMFS). 2010. Bering Sea and Aleutian Islands (BSAI) and Gulf of Alaska (GOA) Groundfish Fisheries Section 7 Consultation – Draft Biological Opinion. National Marine Fisheries Service, Alaska Region. 836 p.

National Marine Fisheries Sevice (NMFS). 2008. Recovery Plan for the Steller Sea Lion *(Eumetopias jubatus*). Revision. National Marine Fisheries Service, Silver Spring, MD. 325 p.

National Marine Fisheries Sevice (NMFS). 2003. Addendum to the Endangered Species Act-Section 7 Consultation, Biological Opinion and Incidental Take Statement of October 2001. NMFS, Alaska Region, Protected Resources Division.

National Marine Fisheries Sevice (NMFS). 2000. Endangered Species Act-Section 7 consultation Biological Opinion and Incidental Take Statement on the authorization of the Bering Sea and Aleutian Islands groundfish fishery under the BSAI FMP and the authorization of the Gulf of Alaska groundfish fishery under the GOA FMP. Silver Spring, Maryland.

National Marine Fisheries Sevice (NMFS). 1992. Recovery Plan for the Steller Sea Lion *(Eumetopias jubatus*). Prepared by the Steller Sea Lion Recovery Team for the National Marine Fisheries Service, Silver Spring, Maryland. 92 p.

National Research Council (NRC). 2003. Decline of the Steller sea lion in Alaskan Waters: Untangling Food Webs and Fishing Nets. The National Academies Press, Washington, D.C., USA. 204 p.

Nichol, D. G., and D. A. Somerton. 2002. Diurnal vertical migration of the Atka mackerel *Pleurogrammus monopterygius* as shown by archival tags. Mar. Ecol. Prog. Ser. 239:193-207.

Pitcher, K. W., M. J. Rehberg, G. W. Pendleton, K. L. Raum-Suryan, T. S. Gelatt, U. G. Swain, and M. F. Sigler. 2005. Ontogeny of dive performance in pup and juvenile Steller sea lions in Alaska. Can. J. Zool. 83:1214-1231.

R Development Core Team. 2006. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. ISBN 3-900051-07-0, URL http://www.R-project.org

Raum-Suryan, K. L., K. W. Pitcher, D. G. Calkins, J. L. Sease, and T. R. Loughlin. 2002. Dispersal, rookery fidelity and metapopulation structure of Steller sea lions (*Eumetopias jubatus*) in an increasing and a decreasing population in Alaska. Mar. Mammal Sci. 18:746-764.

Raum-Suryan, K. L., M. J. Rehberg, G. W. Pendleton, K. W. Pitcher, T. S. Gelatt. 2004. Development of dispersal, movement patterns, and haul-out use by pup and juvenile Steller sea lions (*Eumetopias jubatus*) in Alaska. Mar. Mammal Sci. 20:823-850.

Rehberg, M. J. 2005. Pattern matters: changes in the organization of swimming and diving behavior by Steller sea lion juveniles in coastal Alaska waters. M.S. Thesis, University of Alaska, Anchorage, USA. 87 p.

Rehberg, M. J., and J. M. Burns. 2008. Differences in diving and swimming behavior of pup and juvenile Steller sea lions (*Eumetopias jubatus*) in Alaska. Can. J. Zool. 86: 539-553.

Sease, J. L., and C. J. Gudmundson. 2002. Aerial and land-based surveys of Steller sea lions (*Eumetopias jubatus*) from the western stock in Alaska, June and July 2001 and 2002. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-AFSC-131, 45 p.

Sinclair, E., T. R. Loughlin, and W. Pearcy. 1994. Prey selection by northern fur seals (*Callorhinus ursinus*) in the eastern Bering Sea. Fish. Bull., U.S. 92:144-156.

Sinclair, E. H., and T. K. Zeppelin. 2002. Seasonal and spatial differences in diet in the western stock of Steller sea lions. J. Mammal. 83:973-990.

Wildlife Computers Ltd. 1997. Satellite-Linked Time-Depth Recorder Instruction Manual. 72 p.

Table 1.-- Capture location (including latitude and longitude) and data for 16 juvenile Steller sea lions (*Eumetopias jubatus*), as indicated by their identification (DBID).

DBID	Location	Lat (°N)	Long (°W)	Date tagged	Date last transmission	Sex
11246	Silak I.	51.815	-176.246	4/19/2005	6/12/2005	F
11247	Silak I.	51.815	-176.246	4/19/2005	5/11/2005	F
11248	Little Tanaga Strait	51.819	-176.229	4/20/2005	5/14/2005	M
11249	Lake Point, Adak I.	51.625	-176.992	4/22/2005	6/12/2005	M
11250	Lake Point, Adak I.	51.625	-176.992	4/22/2005	5/21/2005	M
11251	Lake Point, Adak I.	51.625	-176.992	4/22/2005	6/25/2005	M
11252	Lake Point, Adak I.	51.625	-176.992	4/22/2005	5/11/2005	M
11253	Lake Point, Adak I.	51.625	-176.992	4/22/2005	6/17/2005	F
11255	Ship Rock, Kanaga I.	51.778	-177.345	4/24/2005	5/7/2005	F
11256	Ship Rock, Kanaga I.	51.778	-177.345	4/24/2005	7/1/2005	M
11257	Kagalaska I.	51.871	-176.310	4/25/2005	6/1/2005	M
11258	Kagalaska I.	51.871	-176.310	4/25/2005	6/28/2005	F
11259	Semisopochnoi I.	51.963	-179.481	5/1/2005	5/9/2005	M
11260	Lake Point, Adak I.	51.625	-176.992	5/2/2005	7/31/2005	M
11261	Lake Point, Adak I.	51.625	-176.992	5/2/2005	6/21/2005	M
11262	Lake Point, Adak I.	51.625	-176.992	5/2/2005	6/5/2005	F

Table 2.-- Steller sea lion identification (DBID), number of dives (n), and mean, median, standard deviation (SD), and maximum (max) of dive depths (meters) and durations (minutes). Minimum dive depths (5 m) and durations (0.5 min) were equal to the midpoint of the first data bin.

	Depth (m)					Duration (min)				
DBID	n	Mean	Median	SD	Max	n	Mean	Median	SD	Max
11246	10,342	10.4	8	7.9	62	12,981	0.8	0.5	0.6	5.5
11247	2,948	8.2	8	4.5	27	5,265	0.7	0.5	0.5	> 13
11248	1,339	8.0	8	4.0	27	4,599	0.6	0.5	0.4	4.5
11249	8,056	10.3	8	7.2	162	13,009	0.9	0.5	0.7	> 13
11250	1,439	8.5	8	4.6	27	2,725	0.6	0.5	0.3	2.5
11251	8,941	9.7	8	7.9	112	16,983	0.9	0.5	0.8	10.5
11252	1,544	8.9	8	4.8	27	3,236	0.6	0.5	0.3	4.5
11253	6,490	14.4	8	19.5	225	13,677	0.8	0.5	0.6	5.5
11255	548	6.4	5	2.3	15	1,046	0.6	0.5	0.3	2.5
11256	11,054	9.3	8	5.8	87	18,910	0.9	0.5	0.6	> 13
11257	3,446	7.9	8	4.5	42	5,634	0.6	0.5	0.4	9.5
11258	5,357	13.7	15	9.2	112	8,238	1.0	0.5	0.8	4.5
11259	139	5.4	5	1.3	15	954	0.6	0.5	0.4	3.5
11260	17,776	15.9	8	19.5	187	25,669	0.8	0.5	0.7	4.5
11261	9,858	13.8	8	12.9	187	20,148	0.8	0.5	0.6	9.5
11262	716	8.3	8	4.2	27	2,546	0.6	0.5	0.2	3.5

Table 3.-- Results for linear mixed effects models. For the first four binomial models dive presence (DP) was examined with respect to day of year (DOY) and lunar illumination (LI). For daily maximum dive depth (MD), only one model is presented for the Gaussian analyses because ΔAIC > 2 for the remaining models. Asterisks indicate significance (α = 0.05 or high Z-values).

Model and predictor variables (fixed effects)	Estimate	SE	Z-value	P
DP ~ DOY (AIC=266.3)				
DOY*	0.04913	0.01172	4.193	2.75e-05
DP ~ LI (AIC=288.2)				
LI	-0.004954	0.004671	-1.061	0.289
DP ~ DOY + LI (AIC=267.8)				
DOY*	0.048091	0.011660	4.125	3.7e-05
LI	-0.003550	0.004756	-0.746	0.4554
DP ~ DOY + LI + DOY:LI (AIC=267.2)				
DOY	0.0211257	0.0190496	1.109	0.267
LI	-0.0674502	0.0409183	-1.648	0.099
DOY:LI	0.0004956	0.0003156	1.571	0.116
MD ~ DOY + LI (AIC=141.3)				
DOY*	0.0078889	0.0007393	10.671	
LI*	-0.0020580	0.0003567	-5.769	

Table 4.-- Steller sea lion identification (DBID); number of trips (n); and mean, median, standard deviation (SD), minimum (min), and maximum (max) amount of time on shore and at sea (hours).

	Time on shore (hour)						Time at sea (hour)					
DBID	n	Mean	Median	SD	Min	Max	n	Mean	Median	SD	Min	Max
11246	51	8.7	8.0	4.9	1.3	22.3	51	15.2	15.7	8.7	0.3	42.7
11247	19	9.7	10.7	7.3	1.0	26.7	18	17.7	13.2	16.6	0.3	66.7
11248	23	14.5	10.7	13.8	2.3	58.7	22	11.0	9.2	7.3	2.7	37.3
11249	36	9.8	8.0	5.9	2.3	26.7	33	12.6	10.7	7.9	2.7	45.3
11250	24	10.8	9.3	7.4	1.0	26.7	23	9.5	8.0	5.6	0.3	26.7
11251	61	9.3	8.0	5.4	1.0	24.0	58	13.7	13.0	7.3	0.3	34.7
11252	23	9.0	8.0	5.2	2.3	18.3	21	9.5	10.7	3.5	2.7	16.0
11253	43	11.8	10.7	6.7	2.7	32.0	37	16.7	13.0	14.1	2.7	77.3
11255	14	10.8	9.3	8.3	2.3	29.3	14	9.6	8.0	8.0	2.7	29.3
11256	51	11.4	10.7	8.3	1.3	40.0	52	15.6	10.7	16.2	0.3	74.7
11257	39	9.8	8.0	6.3	1.0	24.0	37	10.3	8.0	7.1	0.3	29.3
11258	55	10.1	8.0	5.3	2.3	21.3	47	10.5	10.3	4.5	2.7	24.0
11259	9	8.9	10.7	6.0	1.0	18.7	8	11.0	6.7	12.2	0.3	39.7
11260	74	11.7	10.7	7.0	1.3	37.3	71	17.1	10.7	21.5	0.3	160.0
11261	26	10.6	12.0	5.0	1.3	21.3	23	35.9	10.7	74.1	0.3	280.0
11262	41	10.3	10.7	9.9	1.0	38.3	38	7.0	6.5	4.8	0.3	21.0

Table 5.-- Percentages of Argos locations associated with diving to > 4 m (Fig. 5), predicted locations associated with diving to > 4 m generated from CTCRW models (Fig. 6), and predicted locations associated with periods during which the frequency of dives exceeded the average dive frequency (Fig. 7) in zones of designated critical habitat. Sample sizes in parentheses denote number of Steller sea lions.

Critical Habitat Zone	Argos Locations Diving > 4 m (n = 16)	Predicted Locations Diving > 4 m (n = 16)	Predicted Locations > ave. dive frequency (n = 16)
0 – 10 nmi	68.30	69.49	65.37
10 – 20 nmi	23.71	23.69	26.21
Foraging Areas (> 20 nmi)	0.04	0.00	0.00
> 20 nmi	7.96	6.82	8.42

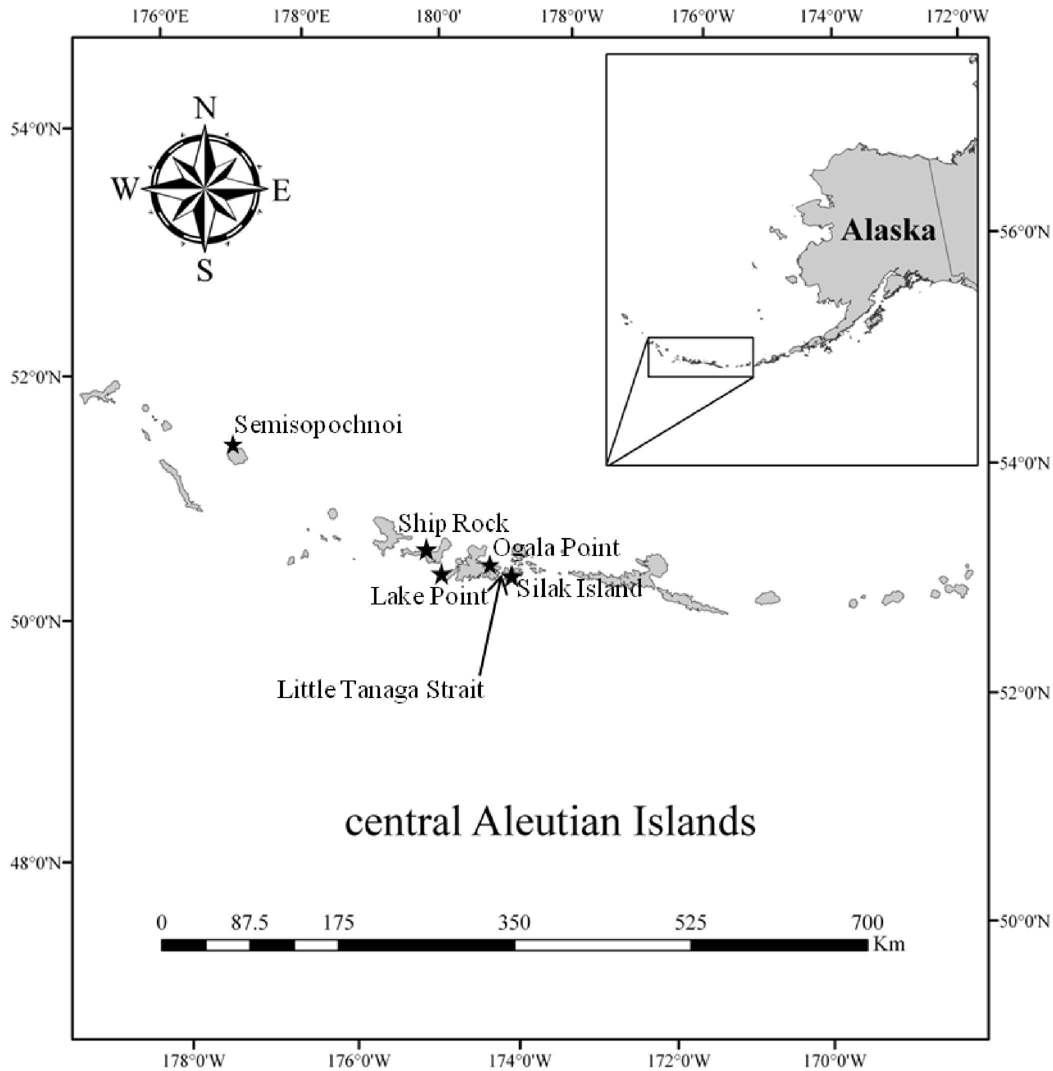
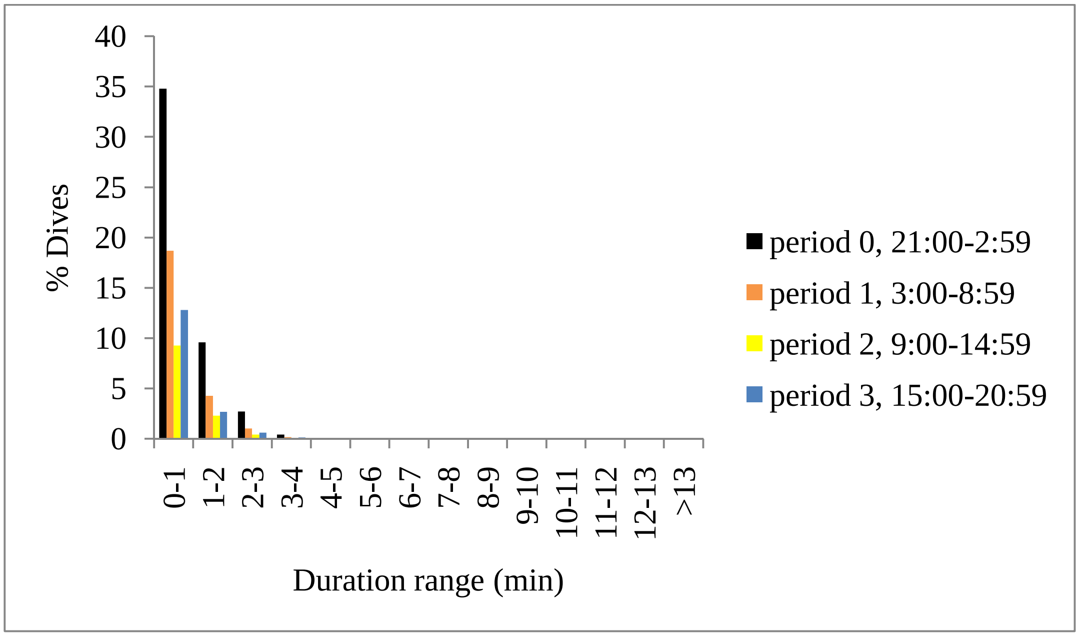


Figure 1.-- Capture locations (★) for 16 juvenile Steller sea lions (*Eumetopias jubatus*) in the central Aleutian Islands, Alaska.

A)



B)

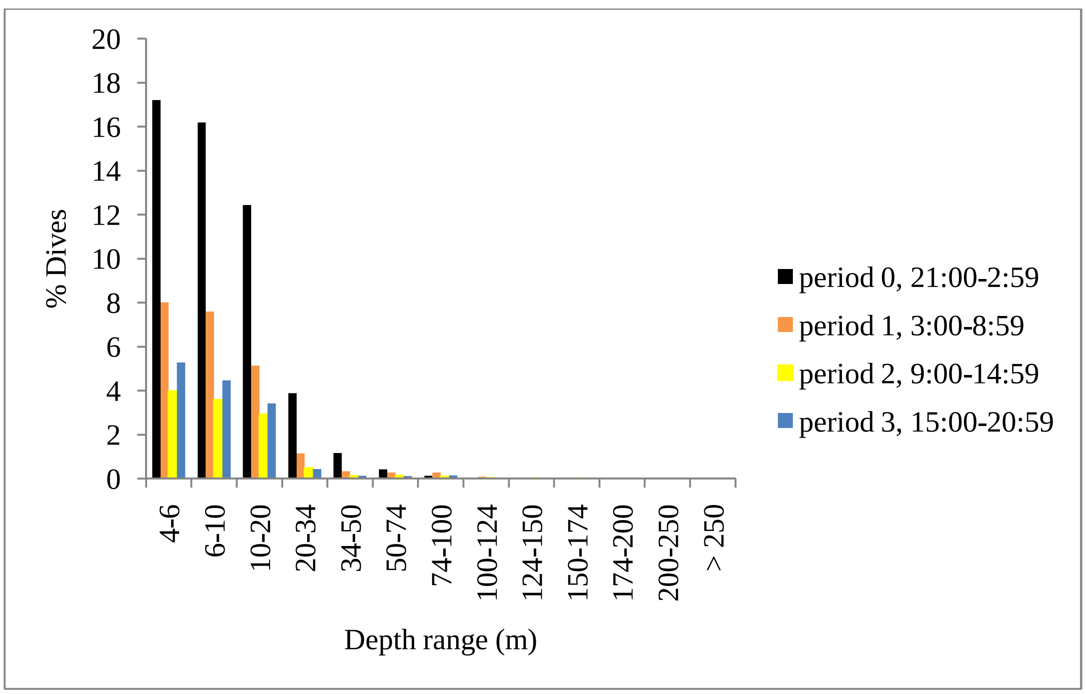
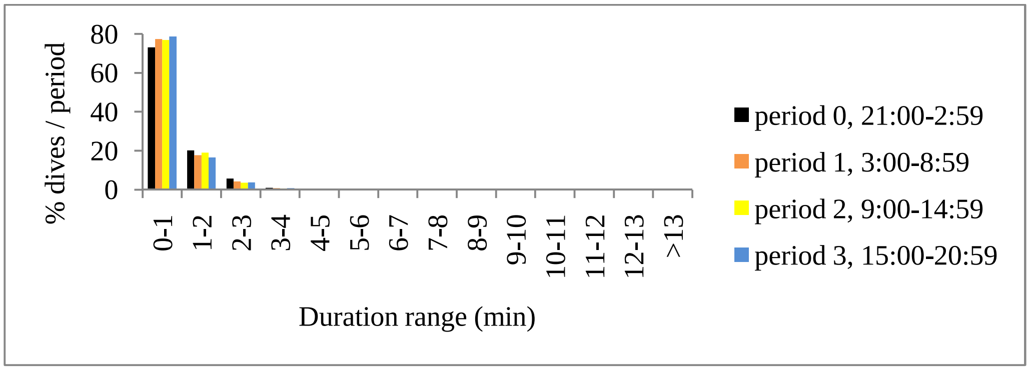
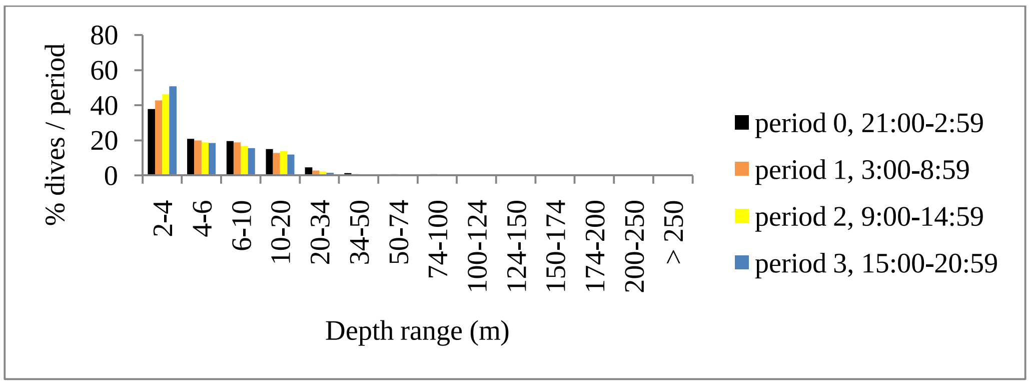


Figure 2.-- Percentage of dives in duration bins (A; n = 155,620 dives) and depth bins (B; n = 89,993 dives). Minimum depth considered a dive was > 4 m. Data are parsed into four 6-hour periods (local time) as indicated in the legend.

A)



B)



C)

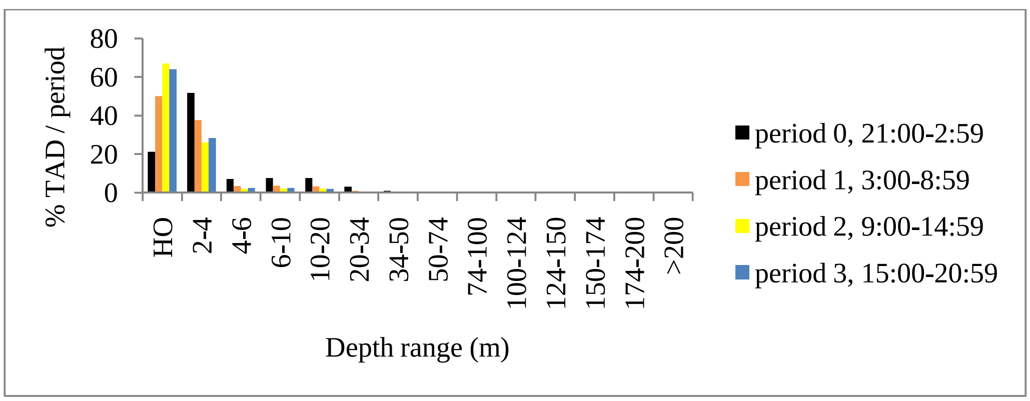


Figure 3.-- Percentage of counts in each duration (n = 155,620 counts; A) and depth (B; n = 155,503 counts) bin for each period of the day (local time). Percentage of time spent at depth (TAD) and percentage of time spent hauled out (HO) are also provided for each period of the day (C; n = 635, 967 counts). All data bins are presented.

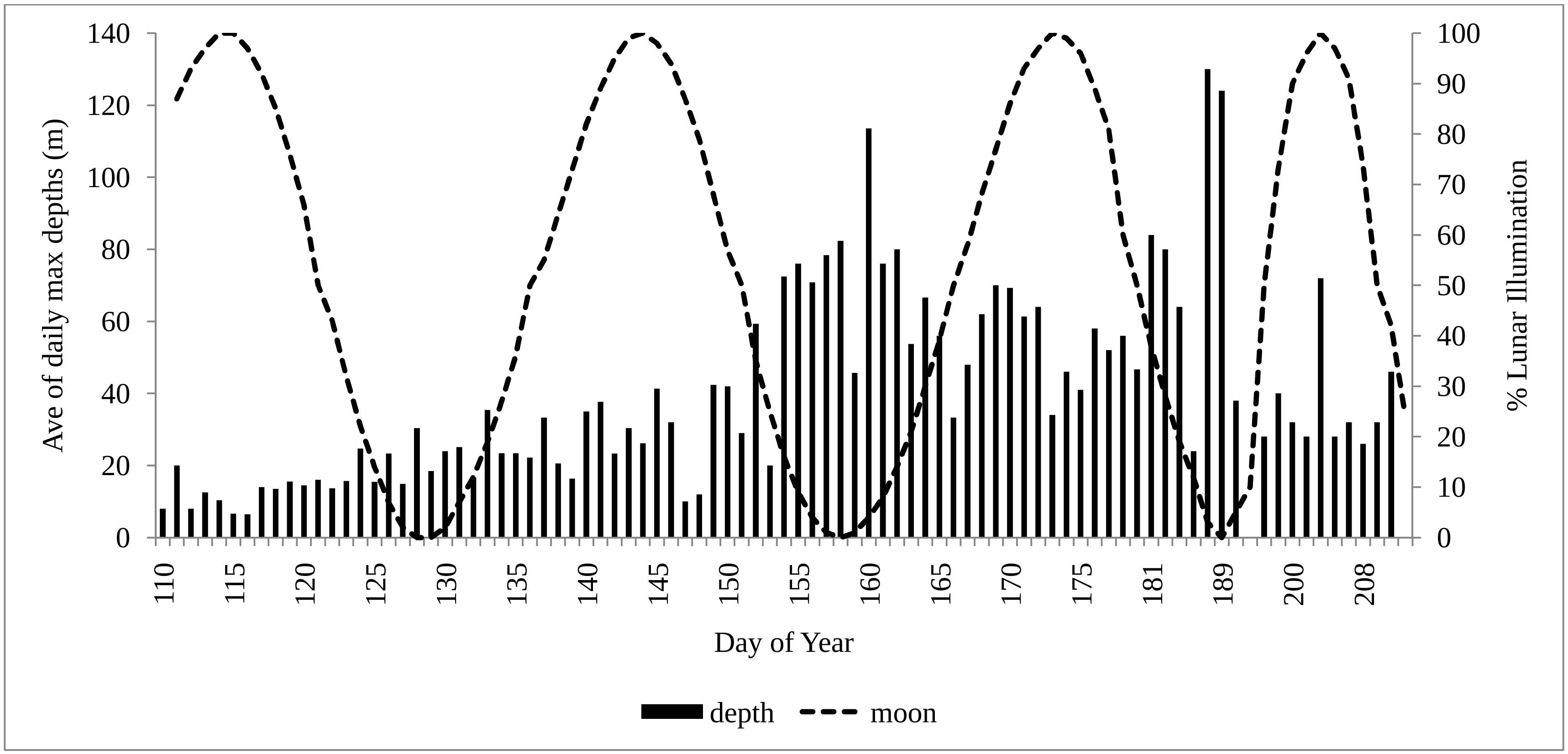


Figure 4.-- Average daily maximum depths (m) of Steller sea lions (n = 16; primary axis) and percentage of the moon's visible illuminated disk (secondary axis) plotted with respect to day of year. Note the x-axis is compressed over time as transmissions cease for individuals.

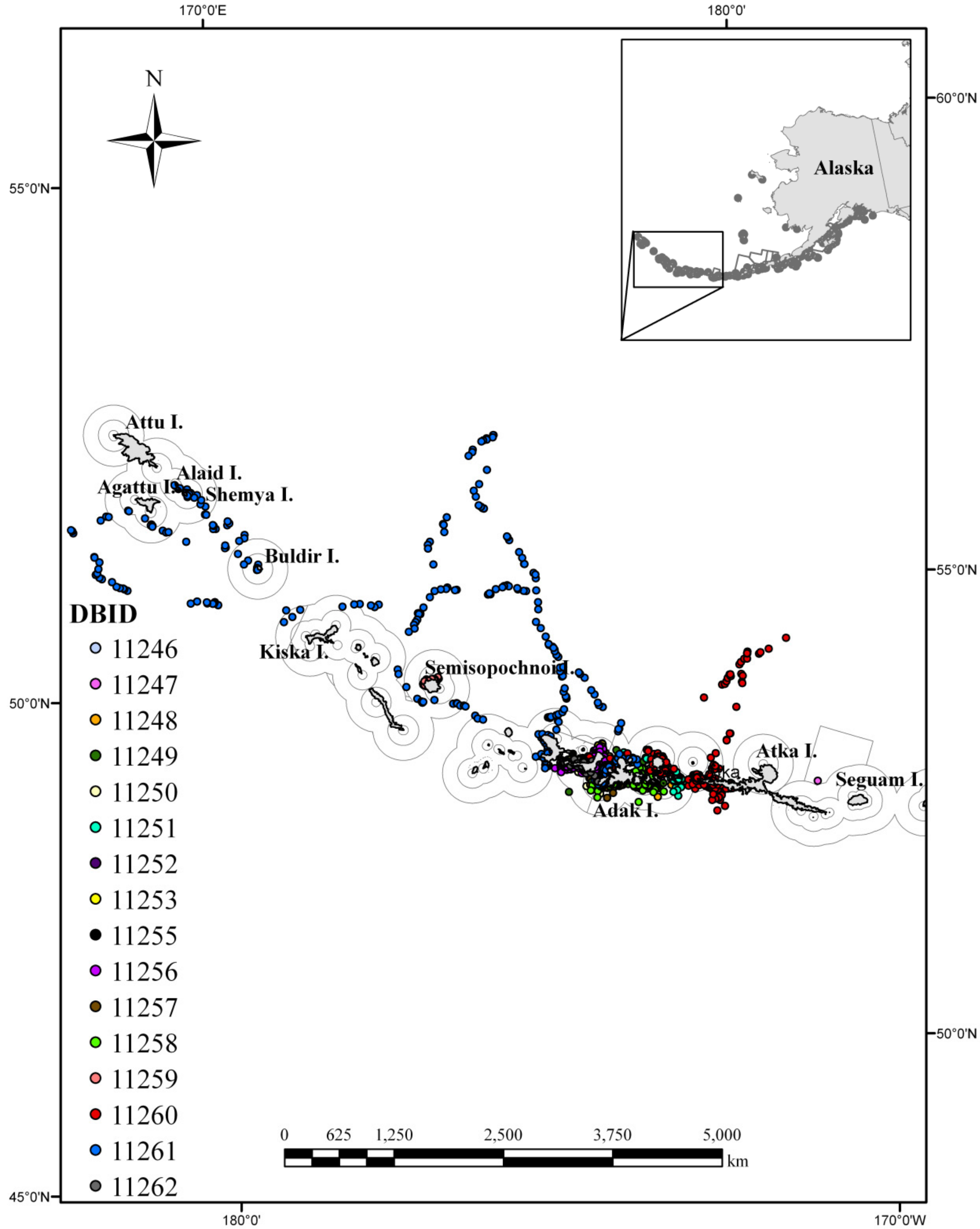


Figure 5.-- Locations (n = 4,044) of 16 juvenile Steller sea lions after filtering the raw diagnostic data and plotted with respect to designated critical habitat depicted in gray (0-3 nmi, 3-10 nmi, 10-20 nmi, and foraging areas > 20 nmi from haulouts and rookeries). Note that locations associated with diving to > 4 m (n = 2,839) produce a similar plot.

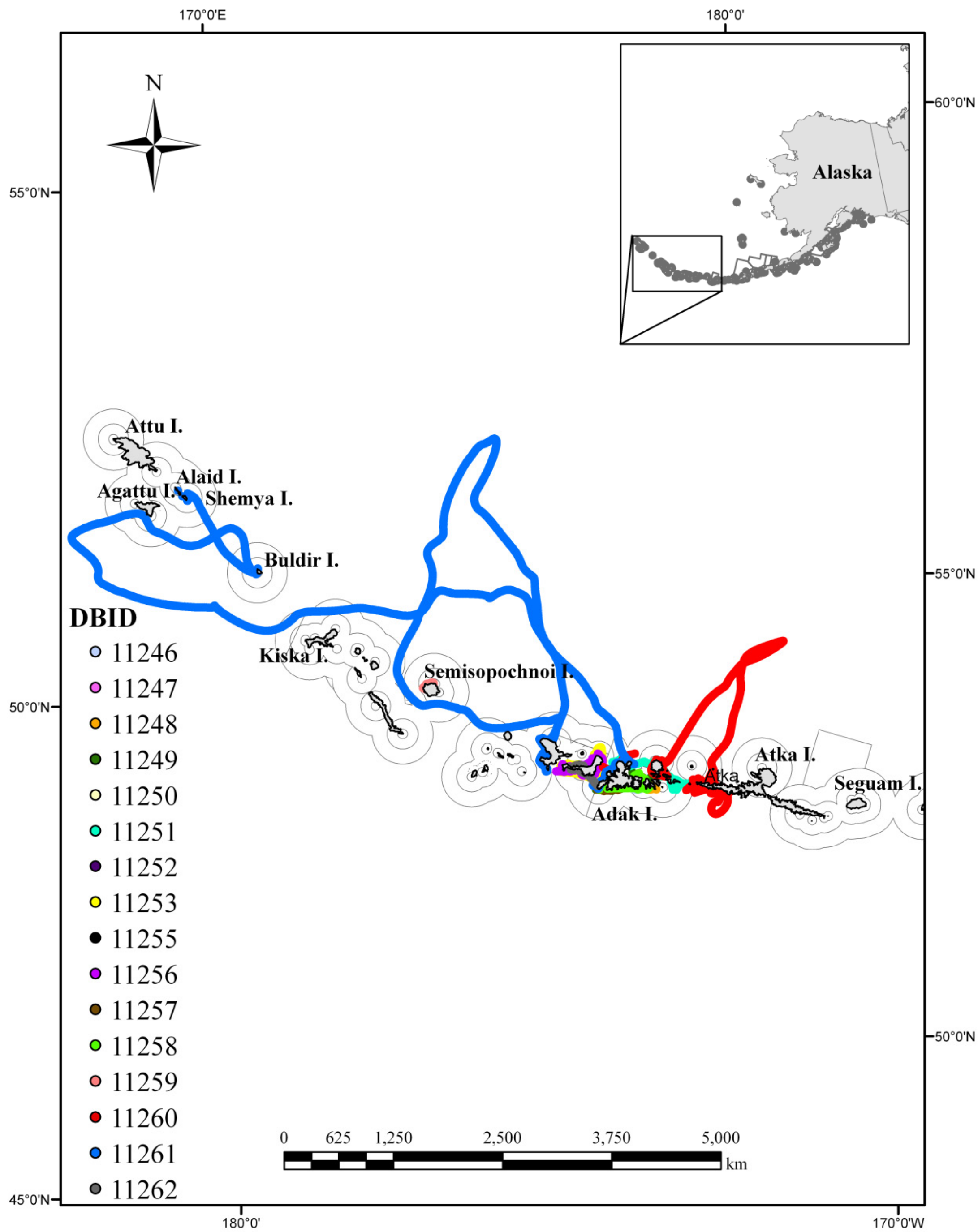


Figure 6.-- Predicted locations (n = 41,958) that were generated with the CTCRW model, pooled among individuals (n = 16 Steller sea lions), and plotted with respect to designated critical habitat depicted in gray (0-3 nmi, 3-10 nmi, 10-20 nmi, and foraging areas > 20 nmi from haulouts and rookeries). Note the CTCRW models do not account for land. Additionally, predicted locations associated with diving to > 4 m (n = 26,878) produce a similar plot.

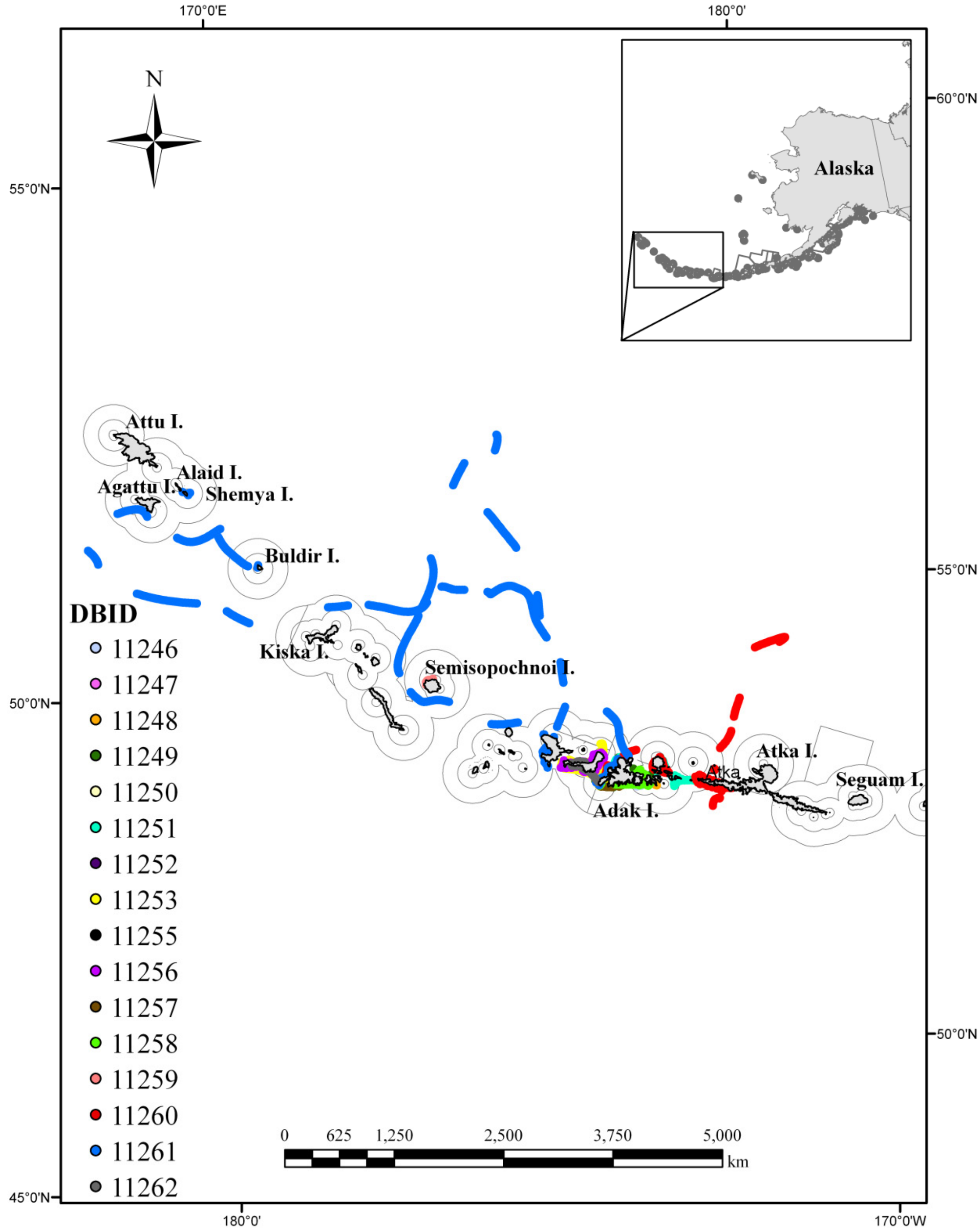


Figure 7.-- Predicted locations (n = 9,243) associated with periods during which the frequency of dives for each individual (n = 16 sea lions) exceeded the average dive frequency. Locations are plotted with respect to designated critical habitat (0-3 nmi, 3-10 nmi, 10-20 nmi, and foraging areas > 20 nmi from haulouts and rookeries).

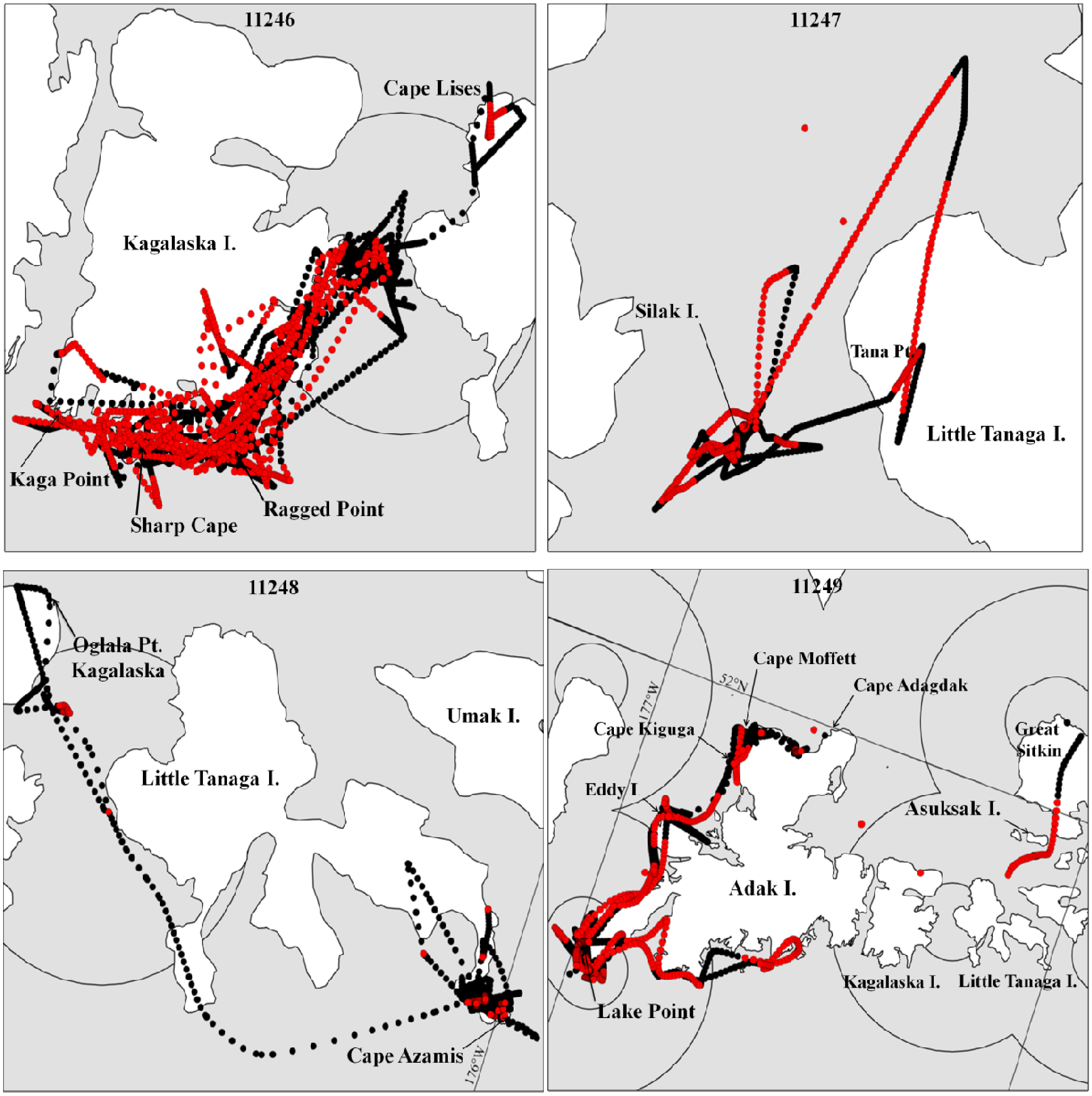


Figure 8.-- Predicted locations associated with diving to > 4 m (●) generated with the CTCRW model for 16 individual Steller sea lions as indicated by their DBID on the top of each map. Predicted locations associated with periods during which the frequency of dives exceeded the average dive frequency (●) overlay all predicted locations. Locations are plotted with respect to designated critical habitat depicted in gray (0-3 nmi, 3-10 nmi, 10-20 nmi, and foraging areas > 20 nmi from haulouts and rookeries). Scales of plots differ among individuals (projection: NAD83 Albers).

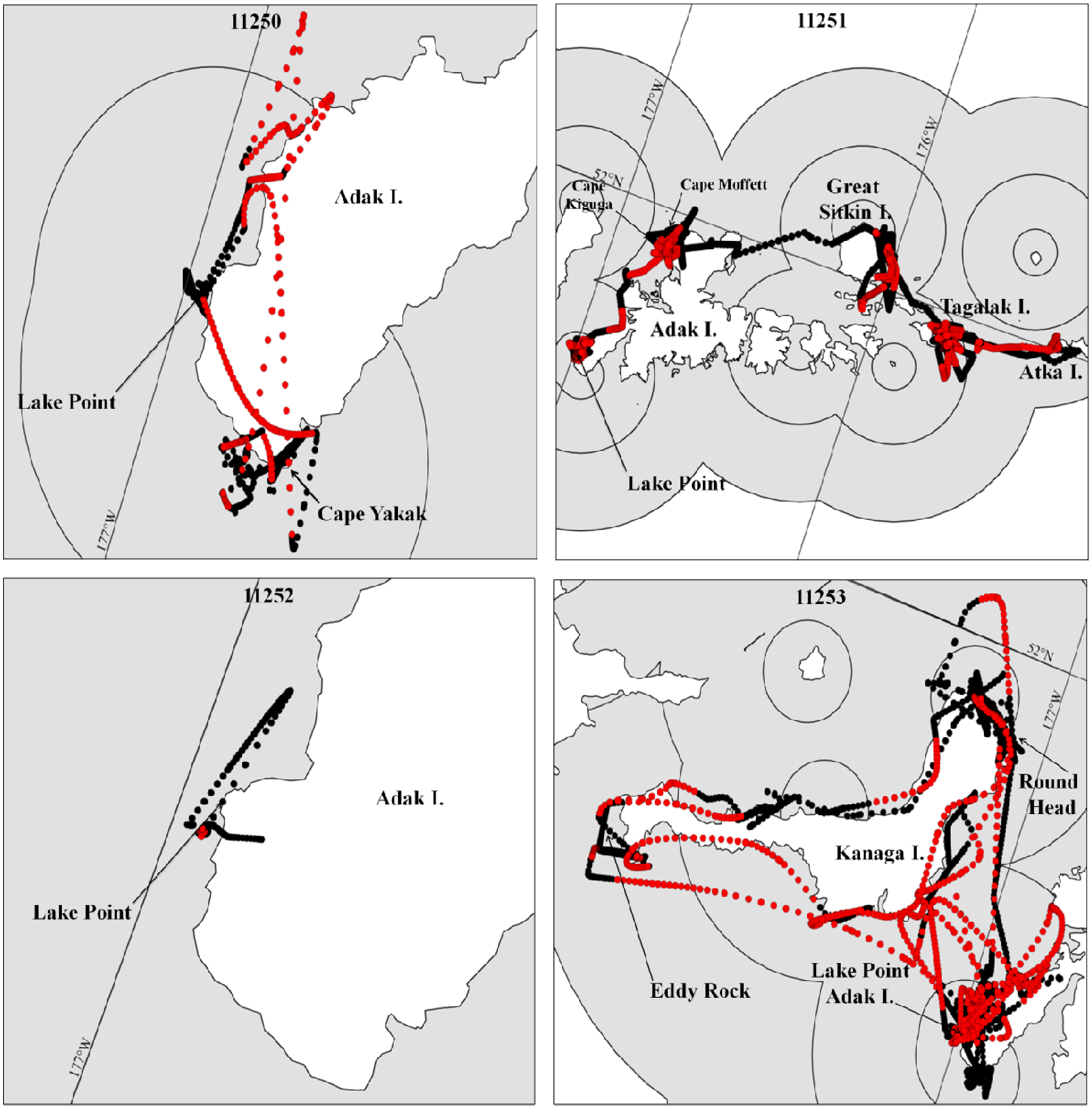


Figure 8.-- Continued.

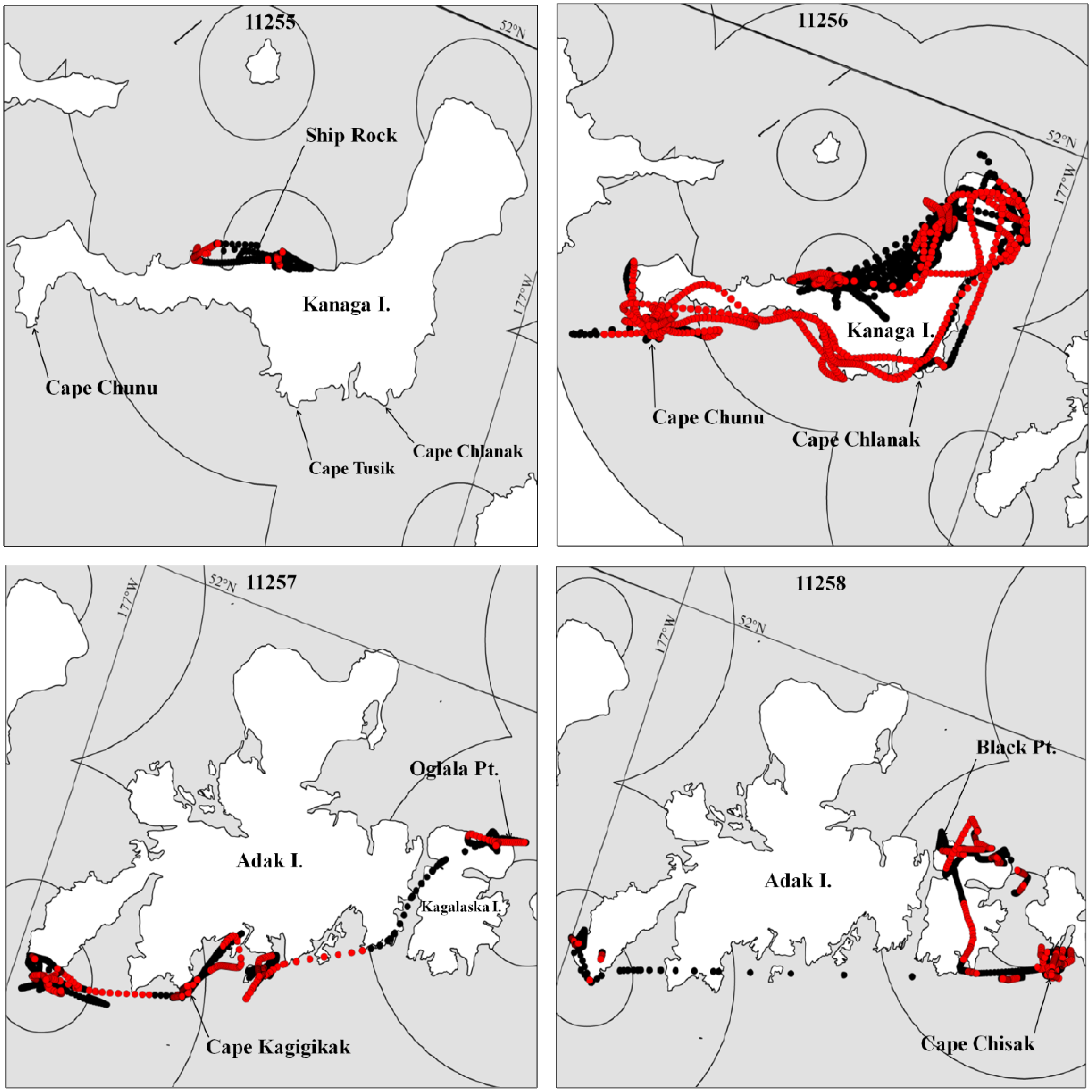


Figure 8.-- Continued.

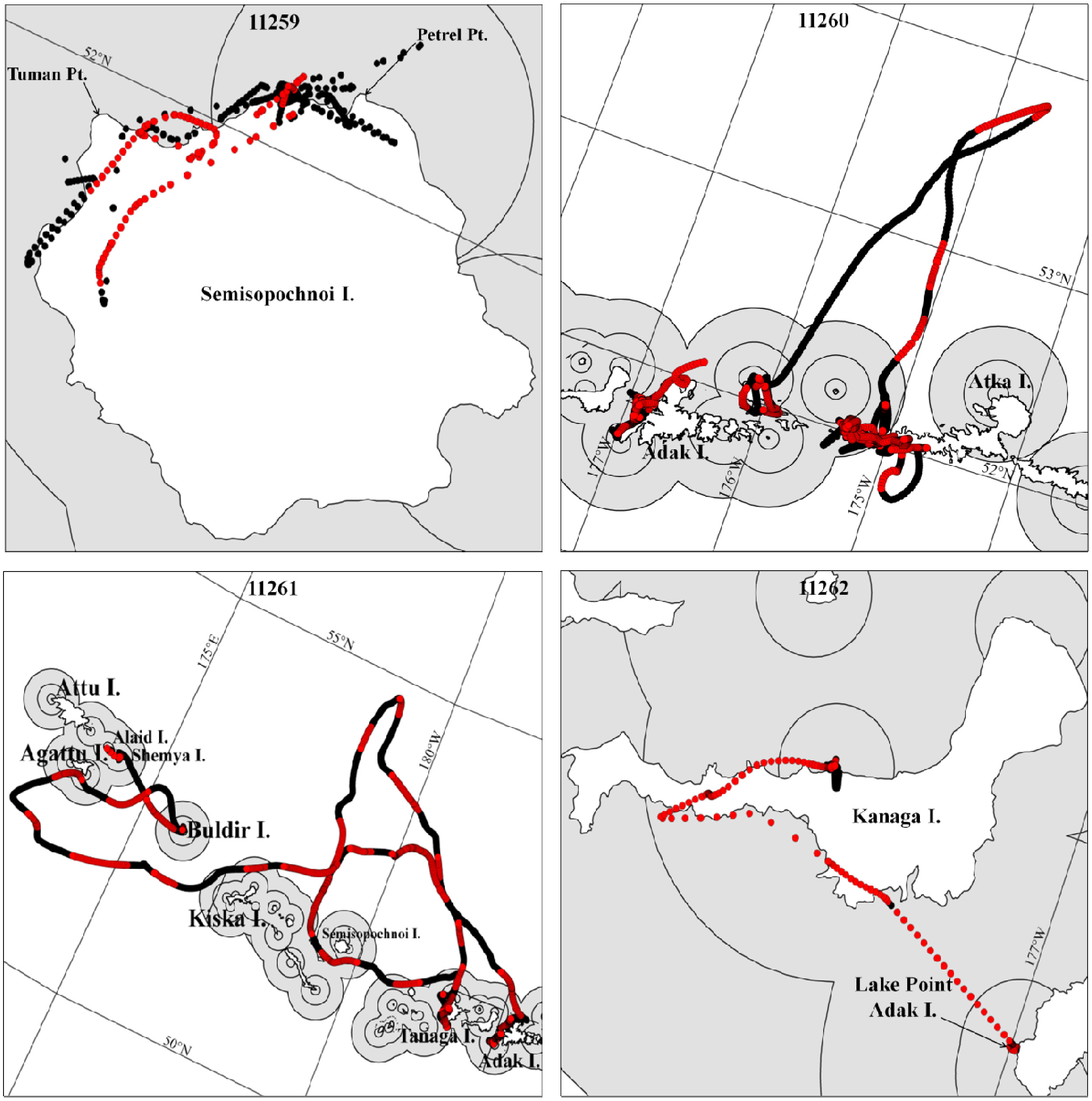


Figure 8.-- Continued.

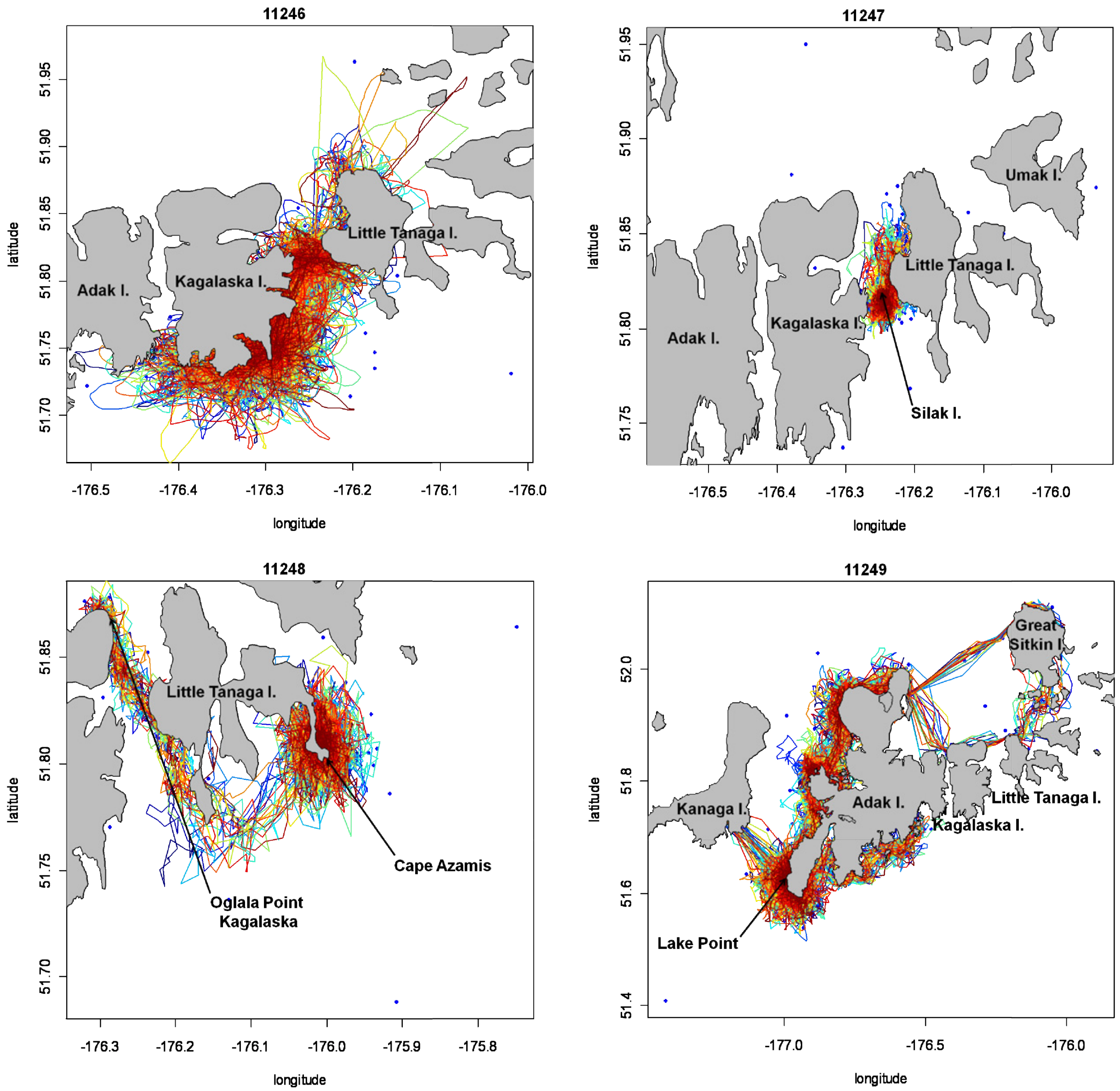


Figure 9.--Illustrations of the variance associated with the predicted tracks (i.e., 20 tracks sampled from the posterior distribution) for 16 juvenile Steller sea lions. Individual DBID is indicated on top of each map and axes differ among individuals. Note the data were not projected as they were for Figures 5-8.

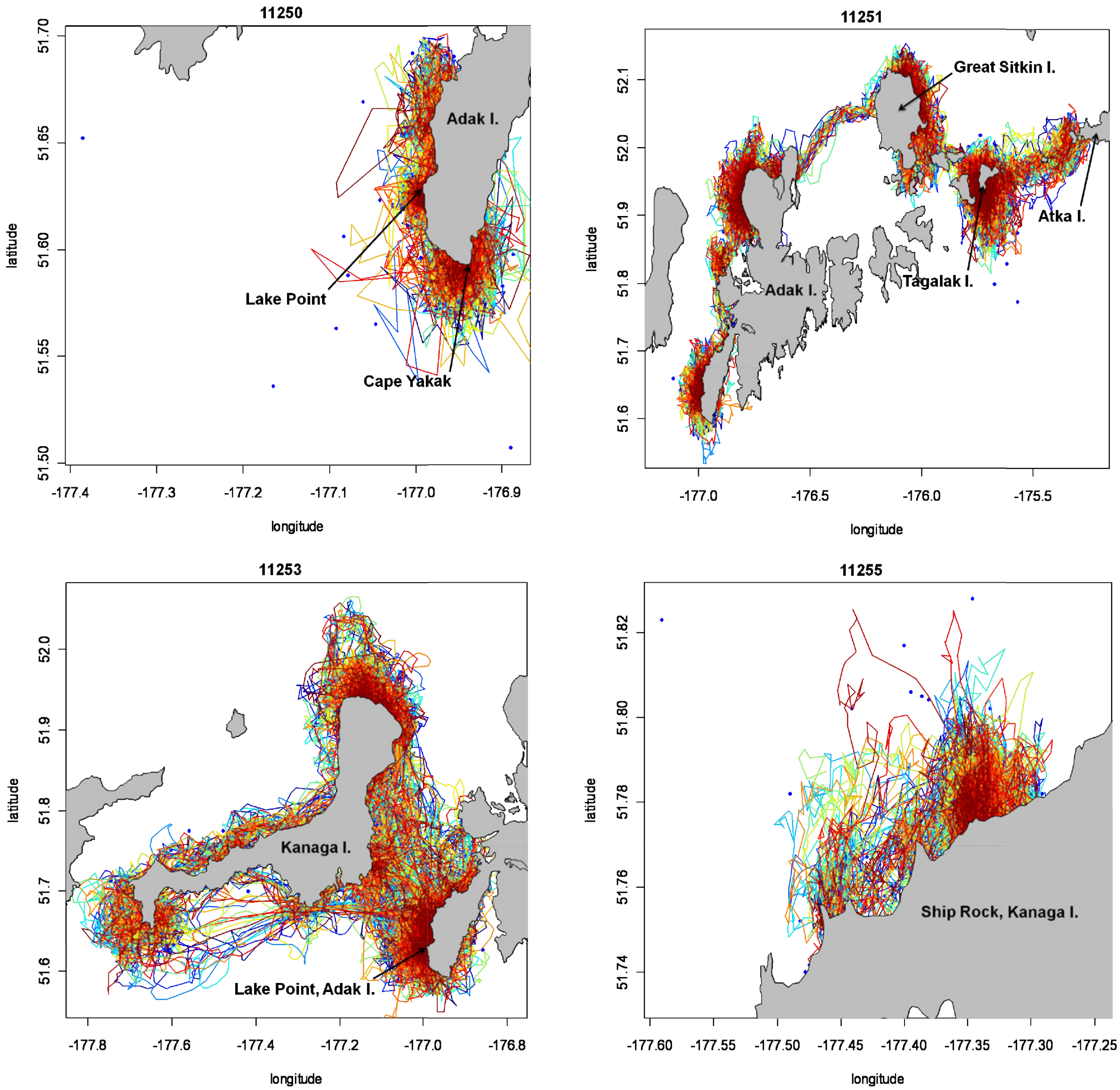


Figure 9.-- Continued.

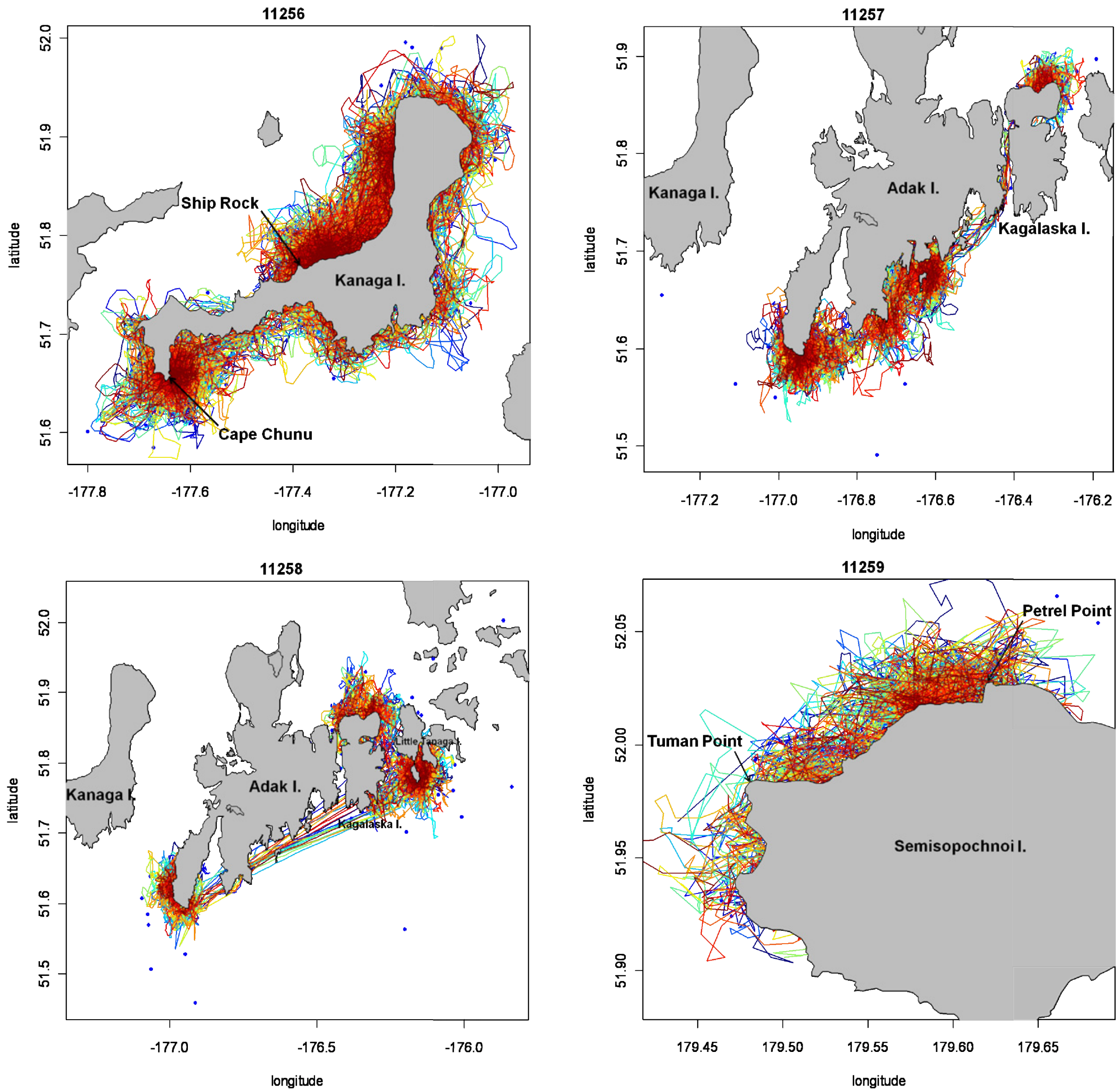


Figure 9.-- Continued.

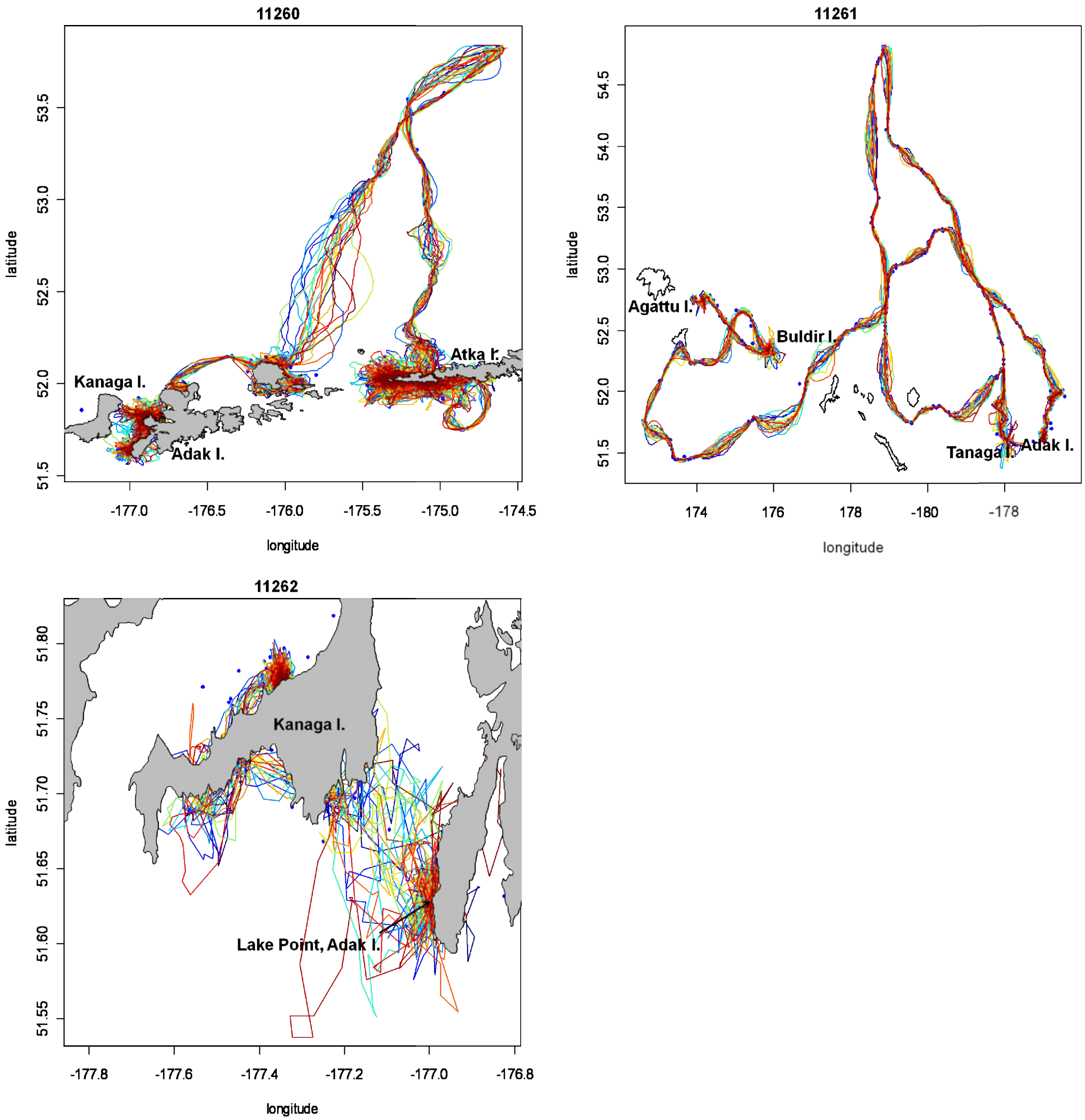


Figure 9.-- Continued.

RECENT TECHNICAL MEMORANDUMS

Copies of this and other NOAA Technical Memorandums are available from the National Technical Information Service, 5285 Port Royal Road, Springfield, VA 22167 (web site: *www.ntis.gov)*. Paper and electronic (.pdf) copies vary in price.

AFSC-

217 LAZRUS, H. M., J. A. SEPEZ, R. G. FELTHOVEN, and J. C. LEE. 2011. Post-rationalization restructuring of commercial crew member opportunities in Bering Sea and Aleutian Island crab fisheries, 62 p. NTIS number pending.

216 CHILTON, E. A., C. E. ARMISTEAD, and R. J. FOY. 2011. The 2010 eastern Bering Sea continental shelf bottom trawl survey: Results for commercial crab species, 101 p. NTIS number pending.

215 VON SZALAY, P. G., C. N. ROOPER, N. W. RARING, and M. H. MARTIN. 2011. Data Report: 2010 Aleutian Islands bottom trawl survey, 153 p. NTIS number pending.

214 LEW, D. K., J. LEE, and D. M. LARSON. 2010. Saltwater sportfishing in Alaska: A summary and description of the Alaska saltwater sportfishing economic survey, 2007, 229 p. NTIS number pending.

213 CAHALAN, J. A., B. M. LEAMAN, G. H. WILLIAMS, B. H. MASON, and W. A. KARP. 2010. Bycatch characterization in the Pacific halibut fishery: A field test of electronic monitoring technology, 66 p. NTIS number pending.

212 KELLY, B. P., J. L. BENGTSON, P. L. BOVENG, M. F. CAMERON, S. P. DAHLE, J. K. JANSEN, E. A. LOGERWELL, J. E. OVERLAND, C. L. SABINE, G. T. WARING, and J. M. WILDER 2010. Status review of the ringed seal (*Phoca hispida*), 250 p. NTIS number pending.

211 CAMERON, M. F., J. L. BENGTSON, P. L. BOVENG, J. K. JANSEN, B. P. KELLY, S. P. DAHLE, E. A. LOGERWELL, J. E. OVERLAND, C. L. SABINE, G. T. WARING, and J. M. WILDER. 2010. Status review of the bearded seal (*Erignathus barbatus*), 246 p. NTIS number pending.

210 JOHNSON, S. W., J. F. THEDINGA, A. D. NEFF, and C. A. HOFFMAN. 2010. Fish fauna in nearshore waters of a barrier island in the western Beaufort Sea, Alaska, 28 p. NTIS No. PB2011-102346. .

209 RONE, B. K., A. B. DOUGLAS, A. N. ZERBINI, L. MORSE, A. MARTINEZ, P. J. CLAPHAM, and J. CALAMBOKIDIS. 2010. Results from the April 2009 Gulf of Alaska line transect survey (GOALS) in the Navy training exercise area, 39 p. NTIS No. ADA522221.

208 VON SZALAY, P. G., N. W. RARING, F. R. SHAW, M. E. WILKINS, and M. H. MARTIN. 2010. Data Report: 2009 Gulf of Alaska bottom trawl survey, 245 p. NTIS No. PB2011102345.

207 PUNT, A. E., and P. R. WADE. 2010. Population status of the eastern North Pacific stock of gray whales in 2009, 43 p. NTIS No. PB2011102344.

206 ALLEN, B. M., and R. P. ANGLISS. 2010. Alaska marine mammal stock assessments, 2009, 276 p. NTIS No. PB2010-107408.

205 CAHALAN, J., J. MONDRAGON, and J. GASPER. 2010. Catch sampling and estimation in the Federal groundfish fisheries off Alaska, 42 p. NTIS No. PB2010-105918.

204 LAUTH, R. R. 2010. Results of the 2009 eastern Bering Sea continental shelf bottom trawl survey of groundfish and invertebrate resources, 228 p. NTIS No. PB2010-113178.

203 LAAKE, J., A. PUNT, R. HOBBS, M. FERGUSON, D. RUGH, and J. BREIWICK. 2009. Re-analysis of gray whale southbound migration surveys 1967-2006, 55 p. NTIS No. PB2010-103939.