Pinniped Research at Cape Shirreff, Livingston Island, Antarctica

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Abstract

Field personnel conducted research on Antarctic fur seals and three species of phocid seals (elephant, leopard and Weddell) at Cape Shirreff, Livingston Island between 3 November 2010 and 9 March 2011. The results of this field season include:

- The estimated number of total fur seal pups born (live plus cumulative dead) for the U.S. AMLR study site in 2010/11 was 1,188 ± 20.1†. Our count this year represents a 14.2% reduction in pup production over last year and the fourth consecutive year of declines > 10.0 per annum;
- The mean foraging trip duration for lactating fur seals' first six trips to sea was 2.29 ± 0.93 days;
- 97.3% of the 110 fur seal scats collected contained krill. In addition, 310 otoliths were collected from 19.1% of scat samples. This represents the lowest number of otoliths collected since monitoring began in 1997/98. Mean krill length in fur seal diet was 47.7 ± 4.2 mm; and
- An estimated 57.7% of fur seal pups were lost to leopard seal predation by 22 Feb; and
- Fourteen adult female fur seals and seven leopard seals were instrumented with ARGOS satellite-linked transmitters for over-winter tracking studies.

Introduction

As upper trophic level predators, pinnipeds are a conspicuous component of the marine ecosystem of the Scotia Sea. They respond to spatio-temporal changes in physical and biological oceanography and, in the case of Antarctic fur seals (*Arctocephalus gazella*), are directly dependent upon availability of krill (*Euphausia superba*) for maintenance, growth, and reproduction during the austral summer. Because of their current numbers and their pre-exploitation biomass in the Antarctic Peninsula region and Scotia Sea, Antarctic fur seals are recognized as important "krill-dependent" upper trophic level predators. The general objectives for U.S. AMLR pinniped research at Cape Shirreff (62°28'S, 60°46'W) are to monitor population demography and trends, reproductive success, and status of pinnipeds throughout the summer months. The Antarctic fur seal is the most abundant pinniped at Cape Shirreff, and our studies are focused to a large degree on the foraging ecology, diving, foraging range, energetics, diet, reproductive success, and population dynamics of this species. Southern elephant seals (*Mirounga leonina*) and Weddell seals (*Leptonychotes weddellii*) also use Cape Shirreff for reproduction and hauling out. A growing number of leopard seals (*Hydrurga leptonyx*) also use Cape Shirreff beaches as haul-out sites.

The 2010/11 field season began with the arrival at Cape Shirreff of a five-person field team via the R/V *Laurence M. Gould* on 3 November 2010. Research activities were initiated soon after and continued until closure of the camp on 9 March 2011. Our specific research objectives for the 2010/11 field season were to:

1. Monitor Antarctic fur seal female attendance behavior (time at sea foraging and time ashore attending a pup);
2. Monitor fur seal pup growth by collecting mass measures from a random sample of 100 pups every two weeks throughout the research period, beginning 30 days after the median date of births;
3. Document the phenology of fur seal pup production at designated rookeries and estimate total pup production at Cape Shirreff;
4. Collect and analyze fur seal scat contents on a weekly basis to document trophic interactions and the timing and incidence of prey switching;
5. Collect a milk sample at each adult female fur seal capture for fatty acid signature analysis as an independent non-biased measure of trophic interactions between fur seals and their prey;
6. Deploy time-depth recorders on adult female fur seals for diving and at-sea foraging studies;
7. Record at-sea foraging locations for adult female fur seals using GPS or ARGOS satellite-linked transmitters (with most deployments coinciding with the U.S. AMLR Oceanographic Survey cruises);
8. Tag 500 fur seal pups for future demographic studies;
9. Re-sight tagged known-aged animals

for population demography studies;
10. Monitor over-winter survival and natality of the tagged adult female population of fur seals;
11. Extract a lower post-canine tooth from tagged adult female fur seals for aging studies;
12. Deploy a weather station for continuous recording of wind speed, wind direction, ambient temperature, humidity and barometric pressure during the study period;
13. Record any pinnipeds carrying marine debris (i.e., entanglement);
14. Record any other tagged pinnipeds observed at Cape Shirreff;
15. Monitor pup production of southern elephant seals breeding at Cape Shirreff;
16. Retrieve over-winter CTD-PTT tags from any returning Weddell seals;
17. Deploy over-winter ARGOS PTT instruments on leopard seals for monitoring dispersal and home range; and
18. Deploy ARGOS PTTs and geolocation light sensors on adult female fur seals for over-winter tracking studies.

Methods

Female Fur Seal Attendance Behavior

Lactation in otariid females is characterized by a cyclical series of trips to sea and visits to shore to suckle their offspring. The sequential sea/shore cycles are commonly referred to as attendance behavior. Measuring changes in attendance behavior (especially the duration of trips to sea) is one of the standard indicators of a change in the foraging environment and availability of prey resources. Generally, the shorter the duration of trips to sea, the more resources a female can deliver to her pup during the period from birth to weaning.

We instrumented 30 lactating females 0-2 days postpartum (determined by the presence of a newborn with an umbilicus) from 1-17 December 2010 using VHF radio transmitters (Advanced Telemetry Systems, Inc., Model 7PN with a pulse rate of 40 ppm) according to CCAMLR Standard Method C1.2 Procedure A. Once instrumented, females were left undisturbed for at least their first six trips to sea. Pups were captured at the same time as their mothers, and were weighed, measured, and marked with an identifying bleach mark. The general health and condition of the pups were monitored throughout the study by making daily visual observations. Presence or absence on shore was monitored for each female every 30 minutes for 30 seconds for the first six trips to sea using two remote VHF receiving stations with automated data collection and storage devices. Data were downloaded weekly. Daily visual observations of instrumented females were conducted to validate automated data collection and to confirm proper functioning of the remote system. All mother-pup pairs were successful throughout the first six trips to sea (i.e., all pups survived to their mothers' completion of six trips).

Fur Seal Pup Growth

Measures of fur seal pup growth were collected according to CCAMLR Ecosystem Monitoring Program (CEMP) Standard Method C2.2 Procedure B, with the exception that weights were sampled every 15 days instead of every 30 days. At least 50 pups of each sex were weighed for each sample. The first sample of weights was initiated 30 days after the median date of pupping (6 December 2010) and the last sample was taken 19 February (four bi-weekly samples; collection dates: 6 January, 21 January, 4 February, and 19 February 2011).

Fur Seal Pup Production

Fur seal pups (live and dead) and females were counted by U.S. researchers at four main breeding beaches on the east side of Cape Shirreff, which comprise the U.S.AMLR study site. Censuses for pups (live and dead) were conducted every other day from 30 October through 31 December. From 3-13 December, live and dead pups were counted each day. Only recently dead pups are counted at each census.

Neonate mortality is defined as pup mortality occurring between the start of the breeding season (approximately 15 November) and up to one month after the median date of pupping (6 January). It occurs before most leopard seal predation, which begins once pups start entering the water at about one month of age (approximately late December/early January). It is measured by recording the number of new pup carcasses on census beaches at each count and calculating a cumulative mortality at each census from the start of births (this year 20 November) until the last births (early January).

To estimate the extent of leopard seal predation on neonates, we calculated the loss of pups from our tagged population of females. We assumed that once pups survived to one month of age, their disappearance was due to leopard seal predation. We included only females whose pup status could be confirmed and excluded female/pup pairs whose status was uncertain.

Diet Studies

Information on fur seal diet was collected using three different sampling methods: scat collection, stable isotope analysis of milk and vibrissae, and fatty acid signature analysis of milk. In addition to scats, an occasional regurgitation is found in female suckling areas. Regurgitations often provide whole prey that is only minimally digested. Scats are collected from around suckling sites of females or from captured animals that defecate while captive. In addition to diet information from animals collected at capture, ten scats were collected opportunistically from female suckling sites every week beginning 18 December. The weekly scat samples are collected by systematically walking transects of female suckling areas and collecting any fresh scats within a short range of the observer. This method prevents any bias associated with the difference in visibility between krill laden scats, which are bright pink, and fish laden scats, which are gray to brown, and blend in with the substrate more easily.

In total, we collected and processed 110 scats from 18 December 2010 through 28 February 2011. Diet samples that could not be processed within 24 hours of collection were frozen. All samples were processed by 11 March. Up to 25 krill carapaces were measured from each sample that contained krill. A total of 2,635 krill carapaces were measured according to Goebel et al. 2007. Discriminant equations based on carapace measurements determined sex and age class of krill, after which independent regression equations for juvenile, male, and female lengths were applied (Goebel et al. 2007). Otoliths were sorted, dried, identified to species, and characterized as left or right. Squid beaks were counted, characterized as dorsal or ventral, and preserved in 70% alcohol for later identification.

Fatty Acid Signature Analysis (FASA) of Milk and Stable Isotope Analyses

In addition to scats, we collected 84 milk samples from 60 female fur seals. Each time a female was captured (either to instrument or to remove instruments), ≤ 30 mL of milk were collected by manual expression. Prior to milk collection, an intra-muscular injection of oxytocin (0.25 mL, 10 UI/mL) was administered. Milk was returned within several hours to the lab, where two 0.25 mL aliquots were each placed in solvent-rinsed glass tubes with 2 mL of chloroform with 0.01% butylated hydroxytoluene (BHT, an antioxidant). Samples were flushed with nitrogen, sealed, and stored frozen until later extraction of lipid and transesterification of fatty acids.

Once lipid is extracted from milk, the remaining protein fraction is dried for stable isotope analysis. For additional stable isotope analyses, single vibrissae (n = 102) and blood samples (n = 86) were collected from individual female fur seals.

Diving Studies

Twelve of the 30 females outfitted with transmitters for attendance studies also received a time-depth recorder (TDR, Wildlife Computers, Inc., Mark 9: 66 x 18 x 18 mm, 31 g, n = 6; Mk-10-F: 90 x 55 x 29 mm, n = 6) on their first visit to shore. All females carried their TDRs for at least their first six trips to sea. Additionally, five more females were captured for studies of at-sea foraging locations after their first six trips, for a total of 17 females with TDRs. A total of 17 dive records for 120 trips to sea were collected from females in 2010/11. One TDR was lost this season.

Adult Female Foraging Locations

Of the 17 TDRs deployed, 11 were GPS (Global Positioning System) TDRs (Mk10-F; Wildlife Computers, Inc.) with fast-loc technology. A total of 76 trips to sea were recorded with GPS from 8 December 2010 through 23 February 2011. GPS foraging location data were analyzed for three sampling periods (December, January, and February).

Demography and Tagging

We tagged 500 fur seal pups (294 females, 201 males, and five unknown) from 4 February to 6 March 2011. All tags used at Cape Shirreff were Dalton Jumbo Roto tags with white tops and orange bottoms. Each pup was tagged on both fore-flippers with identical numbers. Series numbers for 2010/11 were 7000-7499 (the sex for tags 7150, 7284, 7301, 7462, and 7494 were recorded as unknown). Mother/pup tagged pairs were identified after tagging and 72 (14.4%) tagged pairs were recorded.

In addition to the 500 pups tagged, we also added 23 new tags to the adult female population (479-496; A00-A04).

Age Determination Studies

We began an effort of tooth extraction from adult female fur seals for age determination in 1999/2000. Tooth extractions are made using gas anesthesia (isoflurane, 2.5-5.0%), oxygen (4-10 liters/min), and midazolam hydrochloride (1 cc). A detailed description of the procedure was presented in the 1999/2000 U.S. AMLR Field Season Report. This year we did not take any teeth.

Weather at Cape Shirreff

A weather data recorder (Davis Weather Monitor II) was set up at the Cape Shirreff field camp from 6 November 2010 to 5 March 2011. The recorder archived wind speed and direction, barometric pressure, temperature, humidity, and rainfall at 15-minute intervals. The sampling rate for wind speed, temperature, and humidity was every eight seconds; the averaged value for each 15-minute interval was stored in memory. Barometric pressure was measured once at each 15-minute interval and stored. When wind speed was greater than 0, the wind direction for each 8-second interval was stored in one of 16 bins corresponding to the 16 compass points. At the end of the 15-minute archive interval, the most frequent wind direction was stored in memory.

Entangled Pinnipeds

We recorded one adult male fur seal with marine debris around its neck. The debris was identified as rope. The debris was successfully removed without capture using a boat hook.

Other Pinnipeds: Leopard Seals

To better understand the role of leopard seals within the region and their influence on krill-dependent predators, we began a study of foraging range and dispersal. In 2010/11, we instrumented three leopard seals with time depth recorders (TDR, Wildlife Computers; Mk9, 66 x 18 x 18 mm, 31 g). TDRs were attached to an Allflex tag and were deployed without capture. Two were successfully retrieved without recapture and had recorded 29.6 and 31.7 days of dive and haul out behavior. In addition to the dive recorders deployed, seven leopard seals were captured and instrumented with ARGOS-linked transmitters from 17-28 February for over-winter distribution and tracking studies. Vibrissae, nail clippings, blood, and a blubber sample were collected from each seal and mass and standard lengths were recorded.

Other Pinnipeds: Southern Elephant Seals

A daily census of elephant seals at breeding areas on Cape Shirreff was conducted from 7-25 November; thereafter a weekly census was conducted for the entire Cape. In addition, U.S. AMLR personnel captured and weighed 10 of 31 elephant seal pups born at Cape Shirreff. All pups were tagged (Dalton Jumbo Roto tag white/orange; series #: 323-353).

Other Pinnipeds: Weddell Seals

This was the second year of focal studies of Weddell seals by the U.S. AMLR program. Our primary objective for 2010/11 was to retrieve over-winter CTD-PTT instruments deployed on Weddell seals in March 2010. We captured two Weddell seals to retrieve instruments and recovered a third instrument on a beach at Cape Shirreff. A fourth instrument was retrieved from a beach by personnel at King Sejong base on the Barton Peninsula of King George Island.

Twenty-one Weddell seals were tagged without capture at Cape Shirreff in 2010/11 (seven adult females, six adult males, three juvenile males, three male pups and two female pups). All tags were Jumbo roto tags with white tops and yellow bottoms. Only one tag was placed on each animal. Tag series were 018-020, 022-030, and 034-042.

Other Pinnipeds: Weekly Phocid Census

A weekly census of the entire Cape for phocids was conducted beginning 10 November and ended on 15 January. A total of eight censuses were made (a census was not conducted the second and fourth weeks of December). Age class and sex were recorded when possible, without disturbance, for each of four species observed (Southern elephant, Weddell, leopard, and crabeater seals (*Lobodon carcinophagus*)).

†Except where noted, variation is reported as standard deviation.

Results

Female Fur Seal Attendance Behavior

The first female in our attendance study to depart to sea began her foraging cycles on 6 December. All females had completed six trips to sea by 20 January. Only one female lost her pup before completion of six trips to sea. The mean trip duration for the first six trips to sea was 2.29 ± 0.07 days ($n_{females}$ = 30, n_{trips} = 180, range: 0.35-5.94 days). There was no difference among females in duration for the first six trips (ANOVA: $F_{5,162}$ = 1.395, p = 0.004; Figure 8.1). We tested for the effect of carrying a TDR and found no difference (ANOVA: $F_{5,162}$ = 0.29, p = 0.917). Interactive effects were likewise not significant (ANOVA: $F_{10,162}$ = 0.58, p = 0.830).

The mean duration for the first six non-perinatal visits was 1.52 ± 0.12 days ($n_{females}$ = 30, n_{visits} = 150, range: 0.17-3.469 days; Figure 8.1).

An intra-seasonal comparison of foraging trip duration indicated a change in trip duration week seven after the median date of pupping (i.e., the week beginning 16 January). Prior to that week, the weekly mean trip duration was 2.7 ± 0.14 days, but thereafter the mean trip duration increased to 3.5 ± 0.13 days. Trip durations remained on average a day longer after mid-January (ANOVA: $F_{9,300}$ = 10.71, p < 0.001; Figure 8.2).

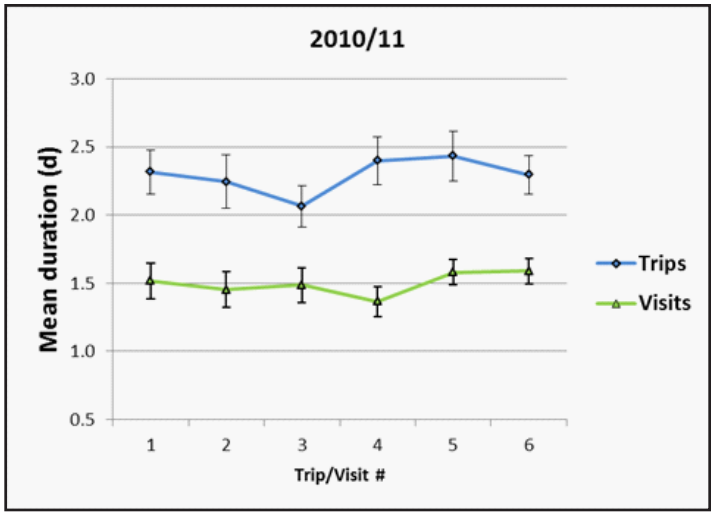

Figure 8.1. Antarctic fur seal mean trip and visit duration (with standard error) for 30 females rearing pups at Cape Shirreff, Livingston Island. Data plotted are for the first six trips to sea and the first six, non-perinatal visits following parturition.

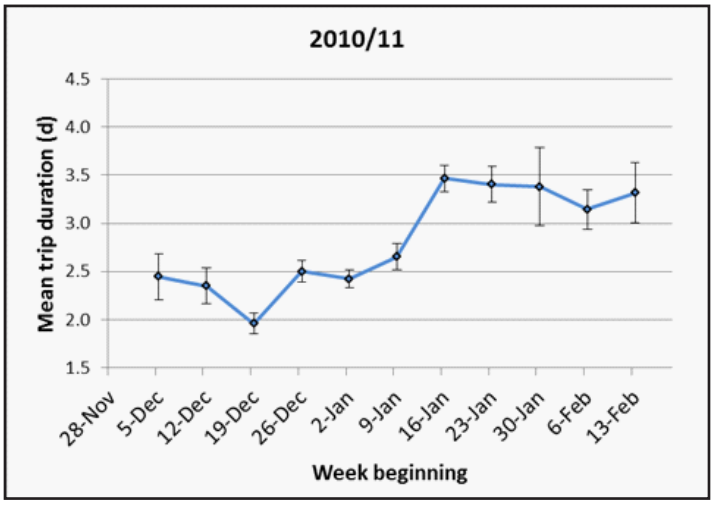

Figure 8.2. Antarctic fur seal weekly mean trip duration (with standard error) for 30 females rearing pups at Cape Shirreff, Livingston Island. Data plotted are all trips to sea for each week starting 7 December 2010.

Pup Production and Phenology

The estimated number of pups born (live plus cumulative dead) for the combined four U.S. AMLR study beaches in 2010/11 was 1,188 ± 11.6, based on three counts the last week of December. Our count this year represents a 14.2% reduction in pup production over 2009/10 (Figure 8.3). The average rate of decline since 2006-07 is 12.9% per year. The median date of parturition based upon daily counts of pups was 6 December. The median date of parturition for our tagged female population was 4 December (n = 153).

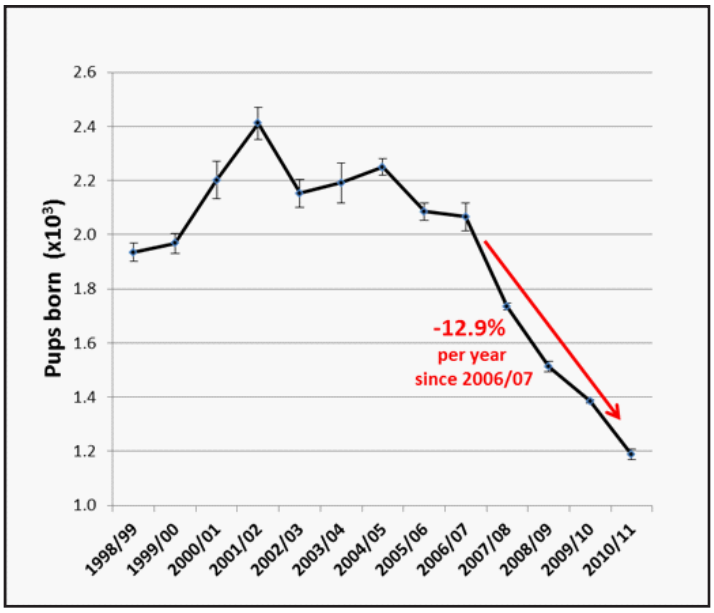

Figure 8.3. Antarctic fur seal pup production on the U.S. AMLR study site at Cape Shirreff from 1998/99 through 2010/11. Counts are a mean of three censuses for live pups taken the last week of December with an adjustment for the cumulative daily count of newly dead pups.

Pup Growth and Mortality

Throughout the season male fur seal pups grew, on average, 104.7 g per day. Females grew 95.1 g per day (Figure 8.4). Neonate mortality was 3.3%, less than half that of last year (7.6 %). The long-term average (based on thirteen years of data, 1998-2010), is 4.4 ± 0.62%.

Our estimate of pup mortality due to leopard seal predation, calculated 22 February (78 days after the median date of pupping), was based on daily tag resights of mother/pup pairs (n = 147 tagged adult females with pups). By that date, 54.4% of pups were lost to leopard seals.

Fur Seal Diet

Of the 110 scats collected this season, 97.1% contained krill. Only 310 otoliths were collected from 19.1% of scats (Figure 8.5). Mean total length of krill in the diet, calculated from carapace measurements, was 47.7 ± 4.2 mm (n = 2635). Of all krill measured in scat, 4.4% were juveniles (Figure 8.5) and the male:female sex ratio was 2.35. Most otoliths were from *Gymnoscopelus nicholsi* (87.7%, n = 272). *Electrona antarctica* otoliths comprised 2.6% (n = 8), and *Electrona carlsbergi* otoliths comprised 7.1% (n = 22) of the total otoliths collected. An additional 2.6% of otoliths (n = 8) were eroded and unidentified. As in previous years, the incidence of fish in fur seal diet increased over the 10-week sampling period from 19 December to 1 March (Figure 8.6). Only one squid beak was collected (preliminary ID: *Brachioteuthis picta*).

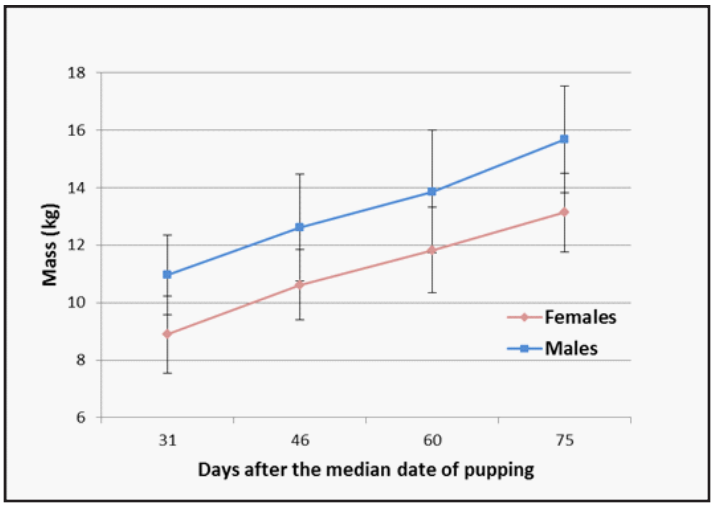

Figure 8.4. Antarctic fur seal pup growth. Four samples of pup weights were collected, every two weeks beginning 30 days after the median date of pupping (6 December 2010).

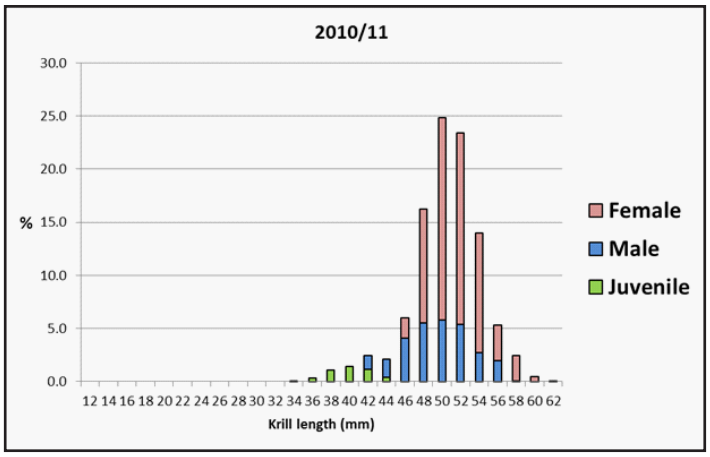

Figure 8.5. Krill length distribution in Antarctic fur seal diet from measures of 2,508 carapaces collected from fur seal scats. Data are derived by sampling 25 krill carapaces from each scat, measuring length and width, applying a discriminant function and independent regression equations for calculating total length of krill. A first order smoothing function is applied to two millimeter length bins.

Adult Female Fur Seal Over-Winter Survival and Natality

There were 192 adult tagged females with parturition sites on the U.S. AMLR study site in 2009/10. Of the 192, 156 (81.3%) returned this year. Of those 156 females, 125 (80.1%) returned pregnant and gave birth; 31 females (19.8%) did not give birth this year.

Adult Female Foraging Locations

A total of 5,039 GPS-derived locations were collected from 76 trips to sea by 11 females carrying Mark10-F TDRs with GPS fast-loc technology. Outliers and bad positions were filtered from the dataset prior to plotting, eliminating 1,399 locations (27.8%). Most of the outliers and bad

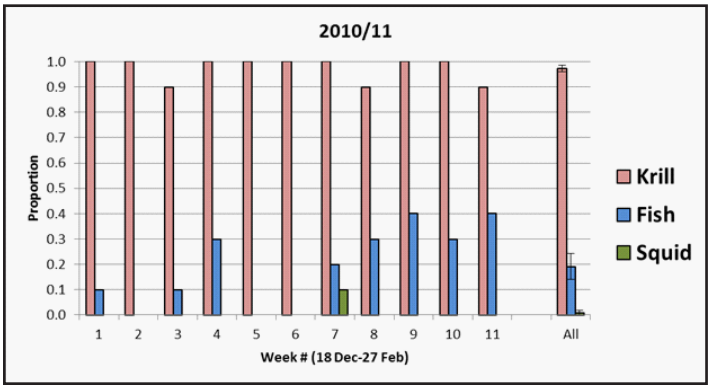

Figure 8.6. The weekly proportions of three types of prey in Antarctic fur seal diet 18 December 2010 – 28 February 2011. The last group of histogram bars is the season average plotted with standard error. Most fish otoliths (94.2%; 292/310) recovered from fur seal scats in 2010-11 were from three species of myctophid fish (*Electrona antarctica*, n = 8; *Electrona carlsbergi*, n = 22; and *Gymnoscopelus nicholsi*, n = 272).

positions were from six of the 11 female whose instruments appeared to develop problems mid-deployment. Foraging range changed from December through February with females foraging closer to the Cape in the continental shelf region as the season progressed (Figure 8.7).

Other Pinnipeds: Southern Elephant Seals

A total of 31 pups were born on Cape Shirreff (no mortalities were recorded) and no pups were born on the small sandy point between Cape Shirreff and Punta Oeste, where in past years some pup production has occurred All but two of the pups were born on Half Moon Bay above the beach. The other two were born on Marko Beach. Sixteen of the pups had already weaned at the time of the first census on 7 November.

Other Pinnipeds: Weekly Phocid Census

The maximum number of southern elephant seals counted in the weekly census of the entire Cape was 221, recorded on 28 December. For Weddell seals the maximum count was 48 on 24 November. The maximum count of leopard seals was 19 recorded on 7 January. Crabeater seals are rarely sighted at Cape Shirreff and the maximum counted at one census was only two.

Discussion

Fur seal pup production in 2010/11 at U.S. AMLR study beaches showed a decline (14%) over the previous year. This is the fourth year of double-digit decline in pup production. The decline suggests poor environmental conditions over-winter or soon after weaning in 2010, but also reflects changing demography as older females

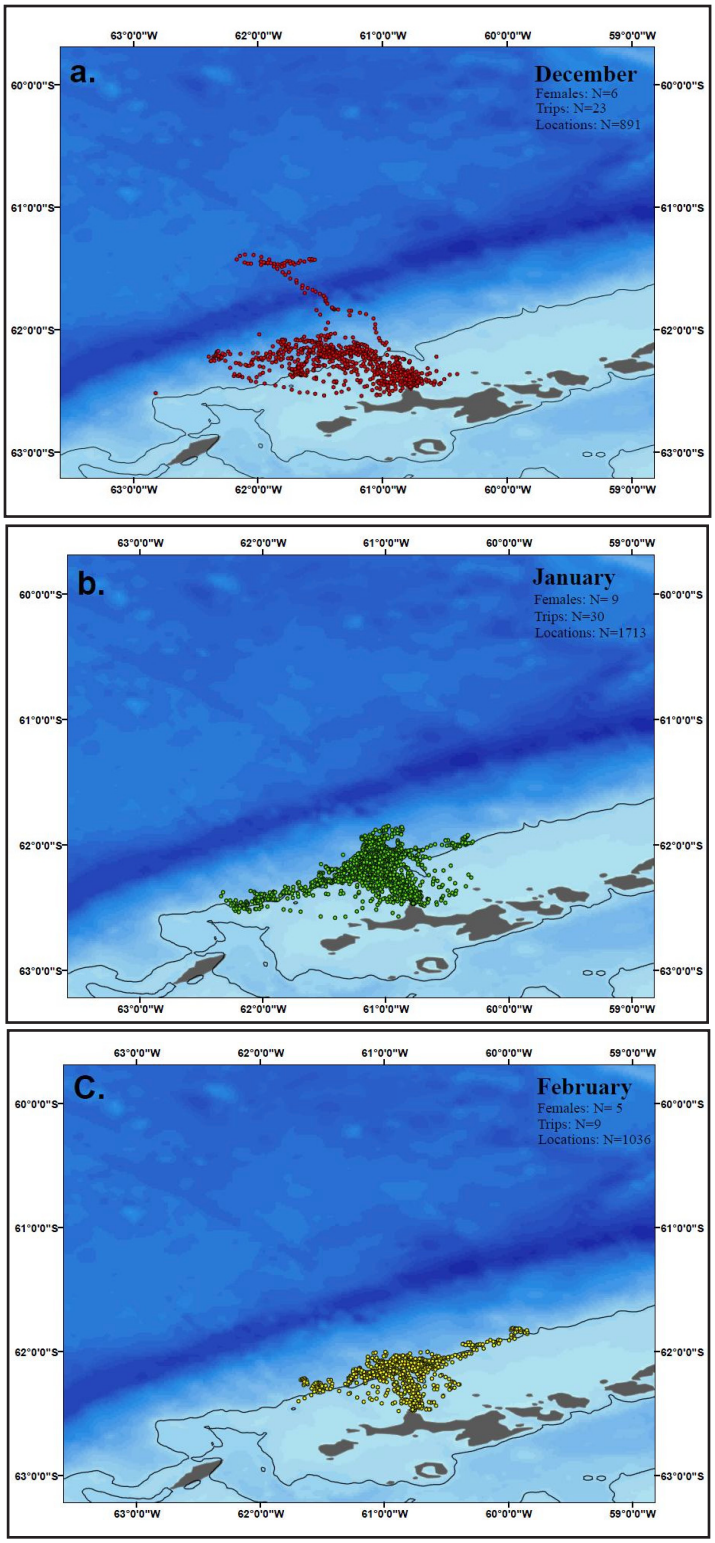

Figure 8.7. At-sea locations of lactating Antarctic fur seals carrying Mark10-F GPS time depth recorders in a) December (red); b) January (green); and c) February (yellow) foraging from Cape Shirreff, Livingston Island, South Shetland Islands, 2010/11. Sample size for the number of females, trips and GPS locations is in the inset for each plot. The 500 m bathymetry is outlined to show the location of the continental shelf edge.

from strong cohorts born in the early 90s senesce, have lower reproductive rates, and high mortality due to age. The summer environment, however, appeared to be one of the most favorable for female foraging, with mean trip duration for the first six trips being the lowest on record since our studies began at Cape Shirreff in 1997/98. Early season neonate mortality (3.3%) was lower than the long-term average of 4.5%. The median date of pupping, based on pup counts, was only one day earlier than last year. The mean foraging trip duration (2.9 ± 0.9 days) was similar to the long-term mean (3.7 ± 1.2 days; 1998/99 to 2009/10).

Diet studies of fur seals indicated a high proportion of krill, especially in December and early January. The krill measured in fur seal diet indicated a bi-modal distribution, with juvenile krill comprising most of the first mode and a second mode at 50 mm. We also recorded the lowest incidence of fish in the diet since 1997/98, with only 310 otoliths collected from 110 scats. Most (87.7%) were from one species of myctophid fish, *Gymnoscopelus nicholsi*. *Electrona carlsbergi* were recorded in fur seal diet this year for the first time since 2007/08.

In general, over-winter survival and natality were less favorable compared to previous years, but indices reflecting summer conditions were above average, resulting in better than average predator performance. Gains in performance and reproductive success were, however, offset by high leopard seal predation rates on fur seal pups.

During the summer months (November - February, the only months of human occupation of Cape Shirreff), leopard seals are frequently observed hauling out on beaches around Cape Shirreff and preying on fur seal pups and penguins. Our measures of fur seal neonate mortality extend only to the end of pupping (early January). In most years, neonate mortality experiences a peak during the perinatal period or soon after females begin their trips to sea. However, another peak in pup mortality occurs later, when young, inexperienced pups enter the water for the first time around one month of age and become vulnerable to leopard seal predation. Since remains are rare, evidence of this type of mortality is more difficult to quantify. However, we estimate that during January and February, leopard seals consume half or more of all fur seal pups born at Cape Shirreff. This year we recorded an increase in leopard seal numbers at the Cape and by mid-lactation for fur seals (22 February), we estimated 54% of all pups born were consumed by leopard seals. Leopard seal predation is a significant top-down factor controlling recovery of South Shetland populations of fur seals (Boveng et al. 1998).

Protocol deviations

Measures of fur seal pup mass were collected according to CCAMLR protocol (CEMP Standard Method C2.2 Procedure B) with the exception of weights being sampled at 15 day intervals instead of the suggested 30 days.

Disposition of Data

All raw and summarized data are archived by the Antarctic Ecosystem Research Division of the National Marine Fisheries Service, Southwest Fisheries Science Center, La Jolla, CA 92037.

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References

Boveng, P.L., L.M. Hiruki, M.K. Schwartz, and J.L. Bengtson. 1998. Population growth of Antarctic fur seals: limitation by a top predator, the leopard seal. Ecology 79: 2863-2877.

Goebel, M.E., J.D. Lipsky, C.S. Reiss, and V.J. Loeb. 2007. Using carapace measurements to determine the sex of Antarctic krill, *Euphausia superba*. Polar Biology 30: 307-315.

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AMLR 2010-2011 FIELD SEASON REPORT

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