6. Pinniped research at Cape Shirreff, Livingston Island, Antarctica, 2007/08; submitted by Michael E. Goebel, Birgitte I. McDonald, Scott Freeman, Russell G. Haner, Natalie B. Spear, and Stephanie N. Sexton.

6.1 Objectives: As upper trophic level predators, pinnipeds are a conspicuous component of the marine ecosystem around the South Shetland Islands. They respond to spatio-temporal changes in physical and biological oceanography and 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 to be an important "krill-dependent" upper trophic level predator. 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 foraging ecology of pinnipeds throughout the summer months. The Antarctic fur seal, *Arctocephalus gazella*, is the most abundant pinniped at Cape Shirreff; our studies are focused to a large degree on the foraging ecology, diving behavior, foraging range, energetics, diet, and reproductive success of this species.

The 2007/08 field season began with the arrival at Cape Shirreff of a five person field team via the R/V *Laurence M. Gould* on 7 November 2007. Research activities were initiated soon after and continued until closure of the camp on 8 March 2008. Our specific research objectives for the 2007/08 field season were to:

A. Monitor Antarctic fur seal female attendance behavior (time at sea foraging and time ashore attending a pup);
B. Monitor pup growth in cooperation with Chilean researchers by collecting mass measurements from a random sample of 100 fur seal pups every two weeks throughout the research period beginning 30 days after the median date of births;
C. Document fur seal pup production at designated rookeries on Cape Shirreff and assist, when necessary, Chilean colleagues in censuses of fur seal pups for the entire Cape and the San Telmo Islands;
D. Collect and analyze fur seal scat contents on a weekly basis for diet studies;
E. Collect a milk sample at each adult female fur seal capture for fatty acid signature analysis for diet studies;
F. Deploy time-depth recorders on adult female fur seals for diving studies;
G. 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);
H. Tag 500 fur seal pups for future demographic studies;
I. Re-sight animals tagged as pups in previous years for population demography studies;
J. Monitor survival and natality of the tagged adult female population of fur seals;
K. Extract a lower post-canine tooth from tagged adult female fur seals for aging studies;
L. Deploy a weather station for continuous recording of wind speed, wind direction, ambient temperature, humidity and barometric pressure during the study period;
M. Record any pinnipeds carrying marine debris (i.e., entanglement);
N. Record any other tagged pinnipeds observed on Cape Shirreff;
O. Capture and instrument Leopard seals for studies of top-down control of fur seal and penguin populations; and
P. Conduct an archipelago-wide census of fur seal pup production.

6.2 Methods, Accomplishments, and Results (by objective):

A. 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 28 lactating females from 3-14 December 2007. The study was conducted according to CCAMLR protocol (CCAMLR Standard Method C1.2 Procedure A) using VHF radio transmitters (Advanced Telemetry Systems, Inc., Model 7PN with a pulse rate of 40ppm). Standard Method C1.2 calls for monitoring of trip durations for the first six trips to sea. All females were instrumented 0-1 day post-partum (determined by the presence of a newborn with an umbilicus) and 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 was 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 a remote VHF receiving station with an automated data collection and storage device. 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.

The first female in our study to begin her foraging cycles did so on 9 December. All females had completed six trips to sea by 21 January. One female lost her pup before completion of six trips to sea.

The mean trip duration for the combined first six trips to sea was 3.71 days (±0.17, $N_{Females}$=27, N_{Trips}=162, range: 0.71-8.33; Figure 6.1). The mean duration for the first six non-perinatal visits was 1.35 days (±0.07, $N_{Females}$=27, N_{Visits}=159, range: 0.37-4.77) (Figure 6.1).

We use female post-partum mass as an index of condition at the start of the breeding season. The mean post-partum mass this year was 50.6kg (±1.00, N=29; Figure 6.2a). The mass-to-length ratio (arc-sin transformed), was 400.0g/cm (±6.70, N=29; Figure 6.2b).

B. Fur Seal Pup Growth: Measurement of fur seal pup growth was a collaborative effort between the U.S. research team and Chilean researchers. Pup weights and lengths were measured every two weeks beginning 30 days after the median date of pupping (6 Dec 2007) and ending 19 February (four bi-weekly samples; collection dates: 4 Jan, 19 Jan, 3 Feb, and 19 Feb). Data were collected as directed in CCAMLR Standard Method C2.2 Procedure B. The results are submitted to CCAMLR by Chilean researchers.

C. 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 compose the U.S.-AMLR study site. Censuses for live pups were conducted every day from 5-12 December 2007 and from 25-31 December 2007. Dead pups were counted once a day from 17 Nov 2007-10 Jan 2008. The estimated total pups born (live plus cumulative dead) for the combined four beaches in 2007/08 was 1809 (±6.3) (Figure 6.3). The median date of parturition was 6 December (since 1997/98, the median date of parturition has varied by five days: 6-10 Dec).

Neonate mortality was similar to last year (4.2 % vs. 4.8%). Neonate mortality is defined as pup mortality occurring from the start of the breeding season (~15 Nov) until up to one month after the median date of pupping (6 January) and before the start of Leopard seal predation (~mid-January). It is measured by recording the number of new pup carcasses on the census beaches at each count and

calculating a cumulative mortality every other day (i.e. at each census) from the start of births (17 November) until the last of pupping (~10 January). The long-term average (based on nine years of data, 1998-2007), is 4.5% ±0.60.

Our measures of neonate mortality extend only to the end of pupping (10 January). In most years neonate mortality experiences a peak during the perinatal period, or soon after females begin their trips to sea. 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. Leopard seal predation is significant and may be a factor controlling recovery of South Shetland populations of fur seals (Boveng *et al*., 1998). 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 that their disappearance was due to leopard seal predation. We included only females whose pup status could be confirmed, excluding female/pup pairs whose status was uncertain. Our estimate of pup mortality due to leopard seal predation, calculated 23 February - 79 days after the median date of pupping - was based on daily tag resights of adult females. By that date, 56.5% of pups were lost to leopard seals. Last year by 13 February 40.8% of pups were lost to predation.

D. Diet Studies: Information on fur seal diet was collected using three different sampling methods: collection of scats, enemas, and fatty acid signature analysis of milk. In addition to scats and enemas, 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. All females that are captured to remove a time-depth recorder or satellite-linked transmitter (PTT) are given an enema to collect fecal material containing dietary information. In addition to diet information from captive animals, ten scats were collected from female suckling sites every week beginning 20 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 20 December 2007-2 March 2008. Diet samples that could not be processed within 24 hours of collection were frozen. All samples were processed by 4 March. Up to 25 krill carapaces were measured from each sample that contained krill. Otoliths were sorted, dried, identified to species. The number of squid beaks were counted and preserved in 70% alcohol for later identification. A total of 2,477 krill carapaces were measured. Most scats, 97.3% (107/110) of those collected, contained krill. In addition, 2,864 otoliths were collected from 43.6% of the scats collected. Most (92.4%, 2647 otoliths) were from three species of myctophid fish (*Electrona antarctica*, n=791; *E. carlsbergi*, n=442 and *Gymnoscopelus nicholsi*, n=1414; an additional 0.3% (n=8) were eroded and unidentified otoliths. A total of 63 squid beaks (preliminary ID: *Brachioteuthis picta*) were collected from 19.1% of the scats.

E. Fatty Acid Signature Analysis of Milk: In addition to scats, we collected 65 milk samples from 36 female fur seals. Each time a female was captured (either to instrument or to remove instruments), ≤30mL of milk was collected by manual expression. Prior to collection of the milk sample, an intra-muscular injection of oxytocin (0.25mL, 10 UI/mL) was administered. Milk was returned (within several hours) to the lab where two 0.25mL aliquots were collected and each stored in a solvent-rinsed glass tube with 2mL of chloroform with 0.01% butylated hydroxytoluene (BHT, an antioxidant). Samples were flushed with nitrogen, sealed, and stored frozen for later extraction of lipid and trans-esterification of fatty acids. Of the 65 samples, 29 were collected from perinatal females and 22 were collected from females that had dive data for the foraging trip prior to milk collection.

F. Diving Studies: Twelve of 27 females outfitted with a transmitter for attendance studies also received a time-depth recorder (TDR, Wildlife Computers Inc., Mark 9s, 66 x 18 x 18mm, 31g) on their first visit to shore. All females carried their TDRs for at least their first six trips to sea. In addition, all other females captured for studies of at-sea foraging locations also received a TDR. A total of 22 dive records were collected from 17 females in 2007/08. No TDRs were lost this season.

G. Adult Female Foraging Locations: We instrumented 10 females with GPS (Global Positioning System) TDRs (Mk10-F; Wildlife Computers, Inc.) with fast-loc technology. One female carried both an Mk10-F and an ARGOS satellite-linked transmitter (SPOT5; Wildlife Computers, Inc.). The first five of these deployments occurred 20 December – 17 January. The remaining five were deployed to coincide with the U.S.-AMLR oceanographic survey in January (Leg 1). They were deployed 18 January – 3 February. An additional three females were instrumented with ARGOS PTTs (SPOT5, Wildlife Computers, Inc.) beginning 30 January. These three females were part of a study of overwinter dispersal and were not recaptured to remove their instruments. A total of 46 trips to sea were recorded with GPS and ARGOS instruments for three sampling periods (December, January, February) in 2007/08 (Figure 6.4).

H-J. Demography and Tagging: Together, Chilean and U.S. researchers tagged 496 fur seal pups (256 females, 240 males) from 9 February – 2 March 2008. All tags placed 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 2007/08 were 5501-6000 (tags 5526, 5534, 5848, and 5989 were lost or damaged and not deployed). Tag deployment distribution was different than in previous years. Usually all pups are tagged on study beaches on the east side of the Cape from Playa Marko to Ballena Norte beach. However, protocol for distribution of tags was changed by one tagging team to facilitate collection of DNA samples by the Chilean program. Approximately 50% of the tags were distributed over the entire Cape.

In addition to the 496 pups tagged, we also retagged two adult lactating females (287, 1615) and added fourteen new tags to the adult female population (413, 417-429, 431).

K. Age Determination Studies: We began an effort of tooth extraction from adult female fur seals for age determination in 1999/00. Tooth extractions are made using gas anesthesia (isoflurane, 2.5-5.0%), oxygen (4-10 liters/min), and midazolam hydrochloride (1cc). A detailed description of the procedure was presented in the 1999/00 annual report.

This year we took a single post-canine tooth from only 10 previously tagged females. The mean age of the sample was 11.5 years (± 1.11, N=10).

L. Weather at Cape Shirreff: A weather data recorder (Davis Weather Monitor II) was set up at the U.S.-AMLR field camp at Cape Shirreff from 10 November 2007 to 5 March 2008. 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.

M. Entangled pinnipeds: We recorded six fur seals, five male and one female, with marine debris around their necks. Five had net fragments or rope and one had a plastic packing band. Three of the six had their debris successfully removed.

N. Other pinnipeds: Southern elephant seals. The U.S.-AMLR program, in collaboration with University of California researchers, tagged 13 elephant seal pups (five male, eight females), 11 adult females and one adult male. The adult females and one sub-adult male were captured post-molt and were also instrumented with ARGOS satellite-linked transmitters for post-molt dispersal at sea.

O. Other pinnipeds: Leopard seals. During the summer months (Nov-Feb, the only months of human occupation of Cape Shirreff), Leopard seals are frequently observed hauling out on beaches around Cape Shirreff. Leopard seals are frequently observed preying on fur seal pups and penguins. During January and February, Leopard seals consume as much as half of all fur seal pups born on the Cape. They represent a significant top-down force influencing fur seal population growth (Boveng et al. 1998). 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 2007/08, we captured and instrumented our first Leopard seals. Four leopard seals were instrumented with ARGOS PTTs (Platform Terminal Transmitter) from 29 January – 2 February. Attachments were made after first sedating with 40-45 mL of 5mg/mL (200-225 mg) midazolam. All four instruments transmitted from initial deployment through April. Two of the four seals remained at Cape Shirreff during this period and two others moved east to Robert Island. There are no known fur seals colonies at Robert Island (Figure 6.5).

P. South Shetland Islands fur seal pup production survey. The last archipelago-wide survey of fur seal pup production was completed in February 2002. In that survey, sites were visited and particular effort focused on establishing whether fur seals had begun to re-colonize any sites on the southern shores of the South Shetland Islands in the Bransfield Strait. Although male fur seals haul out in relative abundance in those areas, no females or pups were observed. In keeping with past efforts to expand coverage at each survey, this year's survey explored more areas of the Beyer's Peninsula and Rugged Island.

The other goal for this year's survey was to accomplish as much as possible of the survey before the start of Leopard seal predation on fur seal pups, which begins when pups begin entering the water (early January).

Distribution of fur seal breeding colonies is such that >85% of all pups are born in the western part of the archipelago. Almost all of these are born on Cape Shirreff, Livingston Island and the San Telmo Islands located off the northwestern shores of Cape Shirreff. Nearby Window Island and Ray's Promontory of the Beyer's Peninsula are additional sites very close to Cape Shirreff with breeding populations of fur seals. Thus our effort prior to 17 January was focused on these islands and beaches.

Less than 15% of pup production occurs around the Elephant Island area in the northern and eastern reaches of the archipelago, with one additional colony breeding at Stigant Pt., King George Island. The Elephant Island area, because of logistics and competing research interests, was not surveyed until early February, at least two weeks after the start of Leopard seal predation.

Counts were taken using multiple counters (4-8 for any one site). Counters moved slowly along a beach counting live pups and then, once live pups are counted; a count of dead pups was made. At some sites dead pups were counted by a team of 3-4 counters counting only dead pups. Any counts 10% or more off the mean were discarded and the mean re-calculated. A total of 10 counts out of 131 individual counts (7.6%) of 31 beaches/sites were discarded. Some Seal Island sites were estimated based on prior surveys with adjustments based on relative numbers of this survey compared to the 2002 survey. Cape Lindsey was visited but weather and sea conditions prevented landings. Thus this site was also estimated in the same way as described for Seal Islands.

Total pup production was 7,602 (±103) pups, down 24.4% from the last census in 2001/02 (10,057 ±142 pups born). However, these numbers are raw counts and are not adjusted for Leopard seal predation, early season mortality (unaccounted-for mortality of washed-away or scavenged dead pups at the time of census), or natality rates (i.e. total number of females giving birth).

Sites visited for the survey and the ship track-line are presented in Figure 6.6. The 2008 Antarctic fur seal pup survey was a joint effort between U.S. AMLR and the Instituto Antartida de Chile (INACH).

6.3 Preliminary Conclusions: Fur seal pup production during 2007/08 at U.S. AMLR study beaches showed a decline (12.5%) over previous years. Early season neonate mortality (4.2%) was slightly lower than the long-term average of 4.5%. We also recorded a mid-season increase in Leopard seal predation over last year. The median date of pupping based on pup counts was one day earlier than last year. Over-winter survival for adult females decreased over last year (86.5 vs. 88.9%), and is well below the long-term mean (10 year mean: 89%). The natality rate also decreased (84.9 vs. 88.5%). The mean foraging trip duration (3.69 days ±0.17) increased by a day over last year and was slightly lower than the long-term mean (3.8 days ±0.36). Visit duration (1.35 days ±0.08) showed a similar trend and, like trip durations, were reflective of less favorable summer foraging conditions than in 2006/07. Like adult female survival, over-winter juvenile survival in 2007 was also lower than in 2006. Tag resights for the 2004/05 cohort this year confirmed, as in 2005/06 and 2006/07, a poor rate of success for that cohort. No tag returns have ever been recorded for the 2004 cohort. The 1999/00 and the 2001/02 cohorts, even with decreased survival for 2007, continued to dominate tag returns. For the first time in four years *Electrona carlsbergi* was recorded in fur seal diet. In general, both winter and summer conditions were less favorable compared to 2006/07 resulting in average performance for summer indices; and below average performance for indices reflective of winter conditions.

6.4 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.

6.5 Problems and Suggestions: The monitoring program at Cape Shirreff is confined to measuring parameters during the first three months of fur seal pup rearing. Only a few of the summer-measured parameters (e.g. adult female over-winter survival, pregnancy rates, and cohort survival) reflect ecological processes over a broader temporal spatial scale. Yet these data suggest that post-weaning environments are important for survival, recruitment, and sustainability of the Cape Shirreff fur seal population. The dominance of the 1999/00 cohort in tag return data and differential cohort strength offer one of the best examples of this. Recent technology in miniaturization and programmability of satellite-linked transmitters provide the means by which to develop an understanding of post-weaning environments, dispersal of females and pups post-weaning. These instruments not only provide information on dispersal, but they can also measure the physical environment encountered by individuals. Future studies should use this technology to measure dispersal, survival and various parameters of the physical environment in order to identify factors leading to increased survival and recruitment of juvenile pinnipeds and seabirds.

6.6 Acknowledgements: The National Science Foundation provided support and transportation to the Cape Shirreff field site for the opening camp crew. We thank the captain, crew and science staff of the November cruise of the R/V *Laurence M. Gould*. We are grateful to our Chilean colleagues: Daniel E. Torres, Susan Abuito, Veronica Villalobos, and Pilar Diaz, for their assistance in the field and for sharing their considerable knowledge and experience of Cape Shirreff. We thank Sarah Chisholm and Kevin Pietrzak for their help with pinniped studies. We are, likewise, grateful to Anthony Cossio, Christian Reiss, and all the AMLR personnel, and the Russian crew of the R/V *Yuzhmorgeologiya* for their invaluable support and assistance to the land-based AMLR personnel. All pinniped research at Cape

Shirreff was conducted under Marine Mammal Protection Act Permit No. 774-1847-02 granted by the Office of Protected Resources, National Marine Fisheries Service. Elephant seal research at Cape Shirreff in 2007/08 was supported by a National Science Foundation grant to D. Costa, University of California-Santa Cruz, D. Crocker, Sonoma State University, and M. Goebel, U.S.-AMLR Program.

6.7 References:

Boveng, P.L., Hiruki, L.M., Schwartz, M.K., and Bengtson, J.L. 1998. Population growth of Antarctic fur seals: limitation by a top predator, the leopard seal. Ecology 79 (8): 2863-2877.

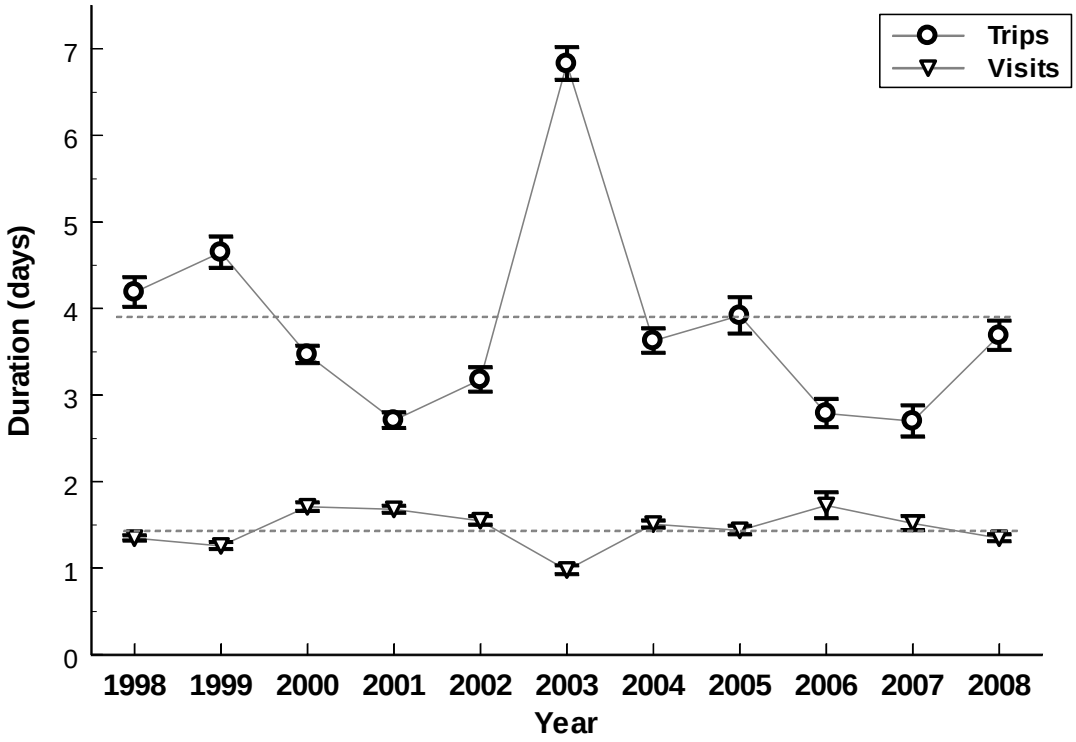

Figure 6.1. Antarctic fur seal mean trip and visit durations (with standard error) for females rearing pups at Cape Shirreff, Livingston Island. Data plotted are for the first six trips to sea and the first six non-perinatal visits following parturition. Long-term means are plotted as dashed gray lines.

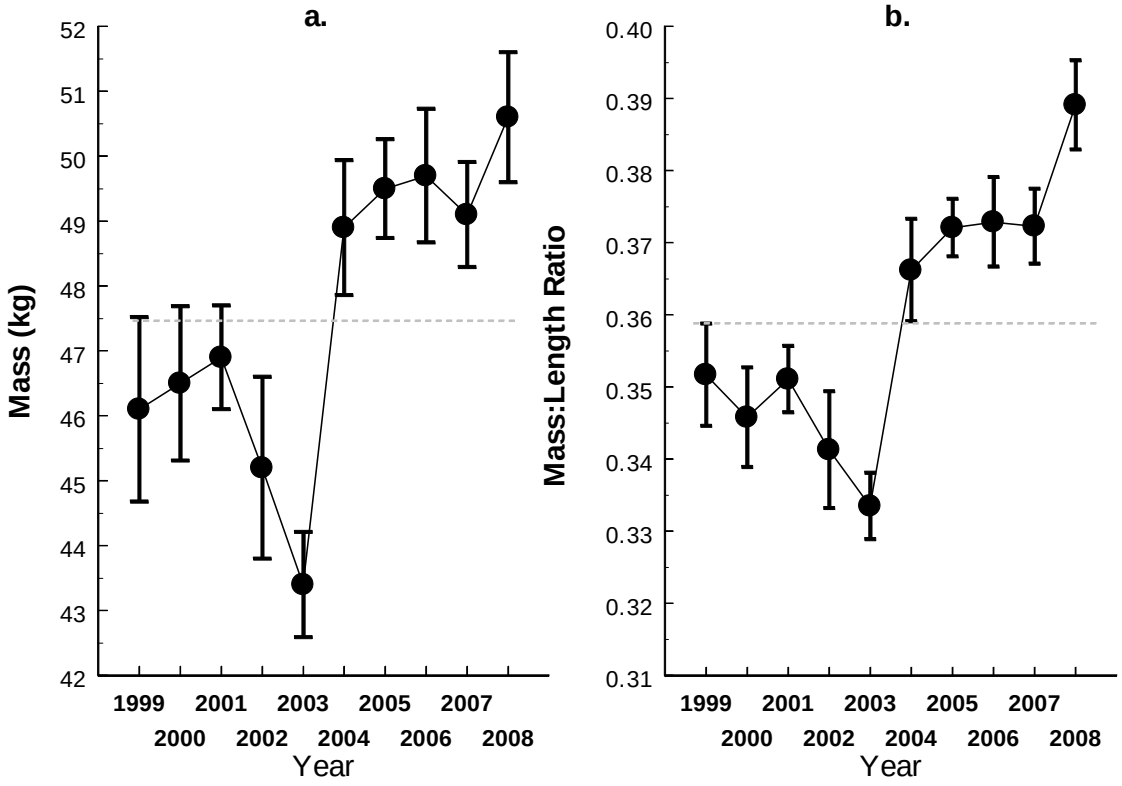

Figure 6.2. The mean mass (a.) and mass:length ratio (b.) for females at parturition, 1998/99 – 2007/08 (98/99: N=32, 99/00: N=23, 00/01, 04/05: N=29, 01/02-03/04, 05/06: N=28, 06/07: N=21, 07/08: N=29). Long-term average is plotted as a gray dashed line (mass: 47.6 ±0.73; mass:length ratio: 0.359 ±0.006).

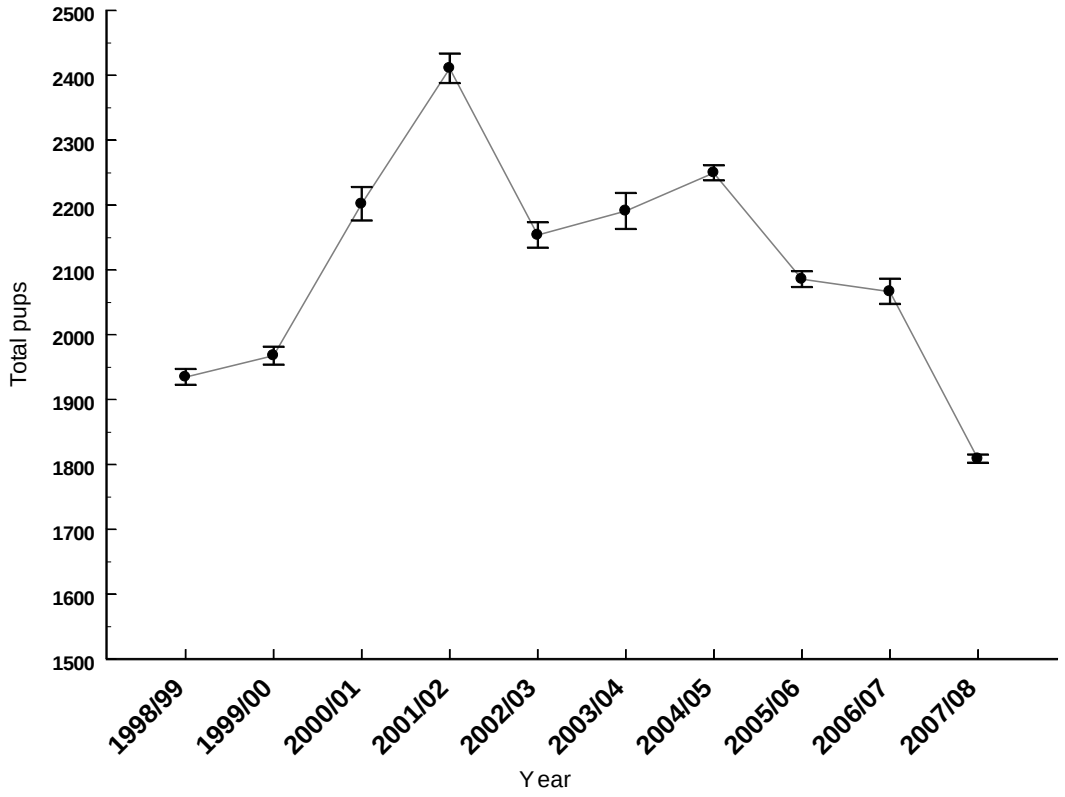

Figure 6.3. Antarctic fur seal pup production at U.S. AMLR study beaches, Cape Shirreff, Livingston Island, 1998/99-2007/08.

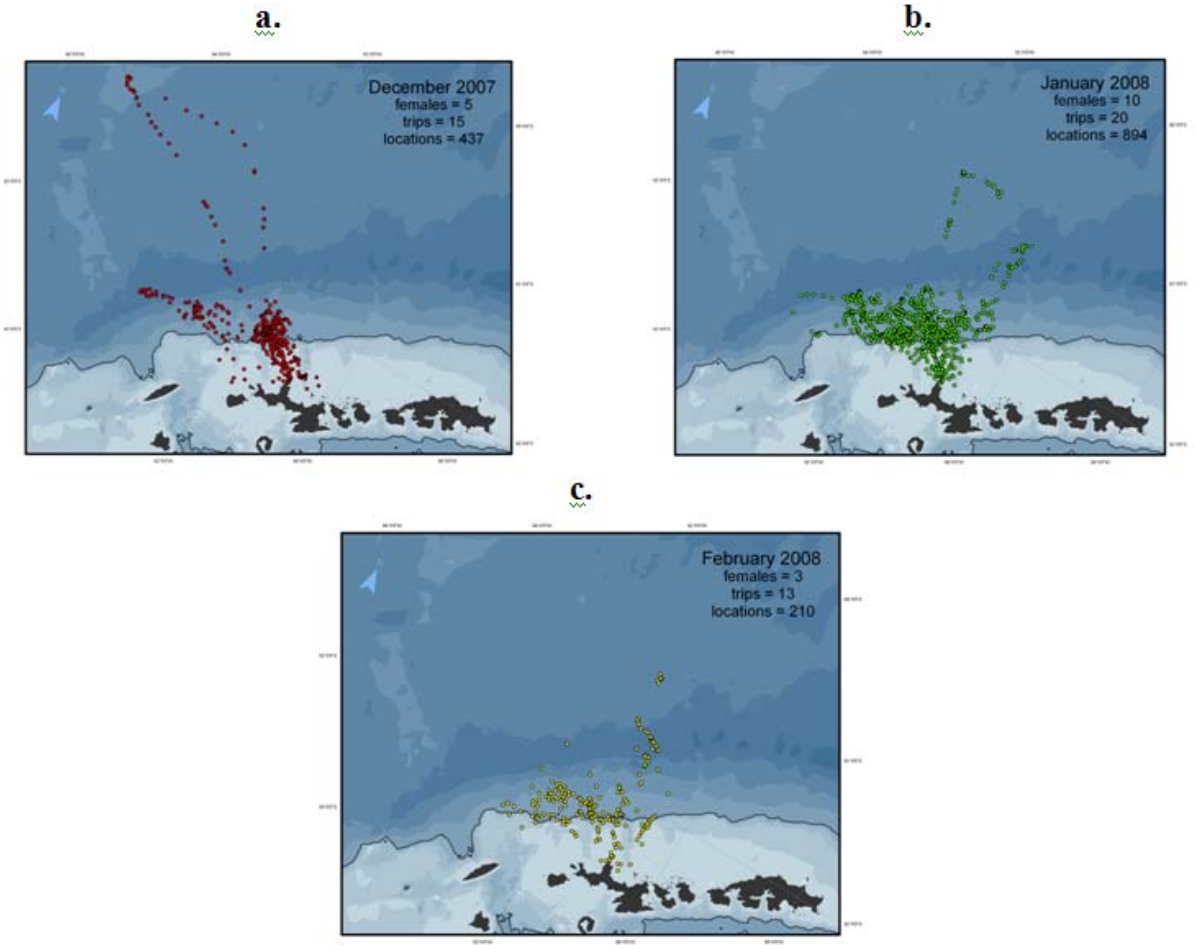

Figure. 6.4. At-sea locations of lactating Antarctic fur seals in a) December (red), b) January (green), and c) February (yellow) foraging from Cape Shirreff, Livingston Island, South Shetland Islands, 2007/08. The 500m bathymetry is outlined to show the location of the continental shelf edge.

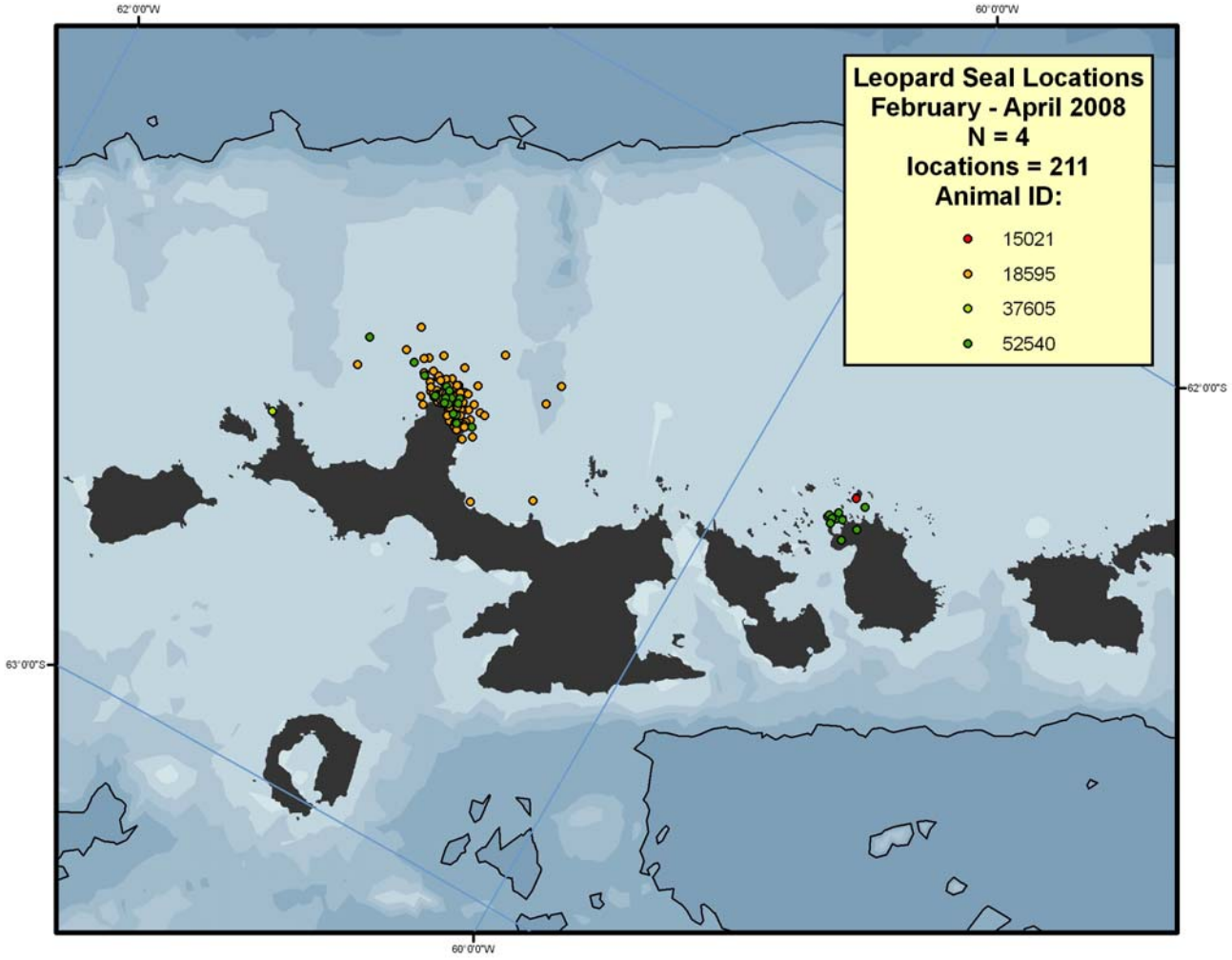

Figure 6.5. ARGOS locations for four Leopard seals from February through April, 2007/08. The largest island is Livingston Island and the 500 meter bathymetry is outlined to show the area of continental shelf.

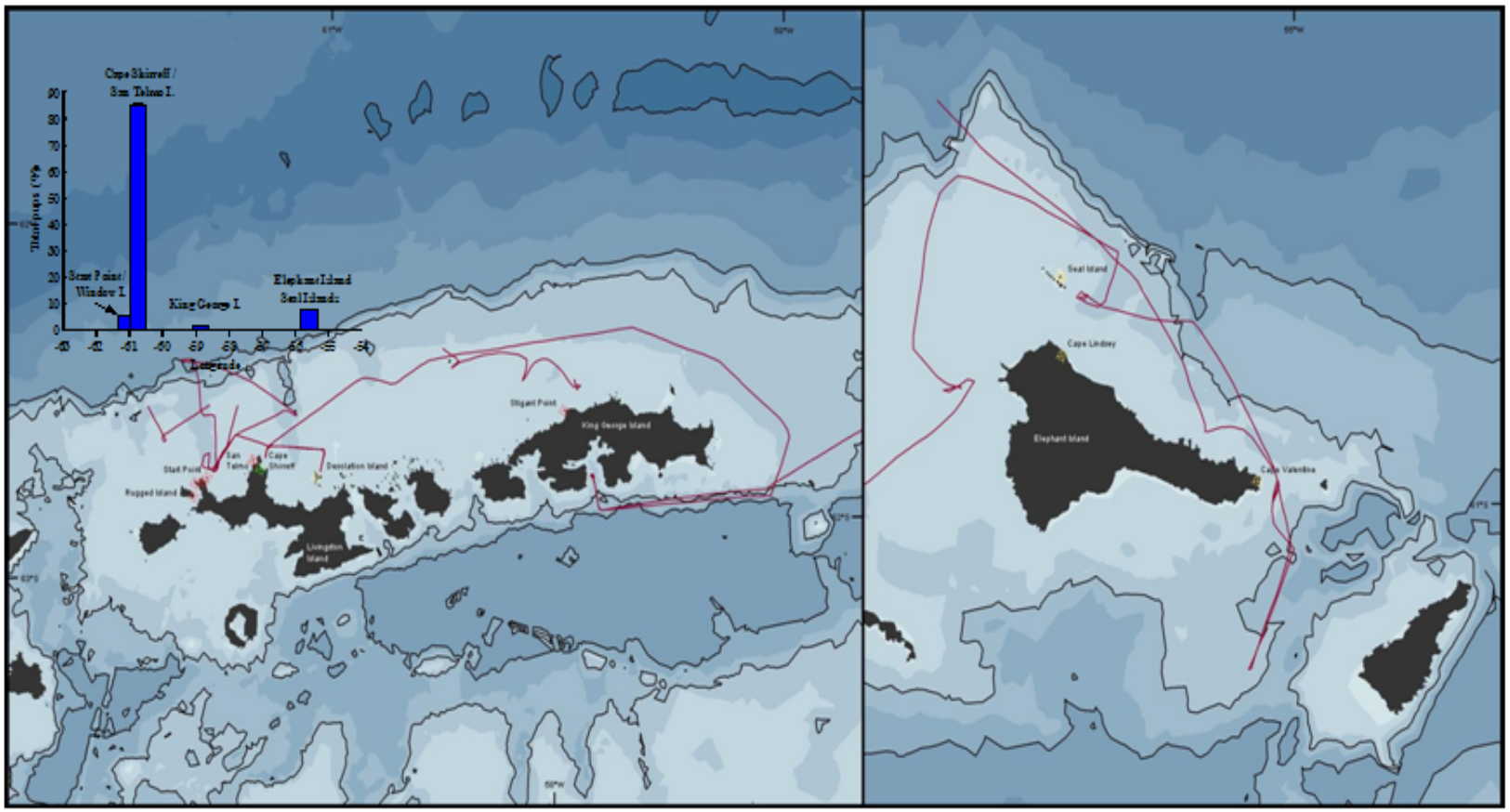

Figure 6.6. The South Shetland Islands, showing sites visited and the ship's track line for the 2008 Antarctic fur seal pup production survey. The inset shows distribution of pups born (% total) in the South Shetlands by longitude.

UNITED STATES

AMLR ANTARCTIC MARINE LIVING RESOURCES PROGRAM

AMLR 2007/2008 FIELD SEASON REPORT

Objectives, Accomplishments and Tentative Conclusions

Edited by
Amy M. Van Cise

October 2008

NOAA-TM-NMFS-SWFSC-427

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National Oceanic & Atmospheric Administration
National Marine Fisheries Service
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