



**UNITED STATES**  
**AMLR** ANTARCTIC MARINE **PROGRAM**  
LIVING RESOURCES

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**AMLR 2009/2010**  
**FIELD SEASON REPORT**

**Objectives, Accomplishments**  
**and Tentative Conclusions**

Edited by  
Amy M. Van Cise

**January 2011**

NOAA-TM-NMFS-SWFSC-470



**Southwest Fisheries Science Center**  
**Antarctic Ecosystem Research Division**

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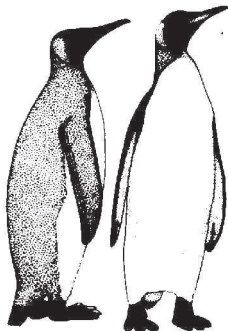
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**The U.S. Antarctic Marine Living Resources (AMLR) program provides information needed to formulate U.S. policy on the conservation and international management of resources living in the oceans surrounding Antarctica. The program advises the U.S. delegation to the Convention for the Conservation of Antarctic Marine Living Resources (CCAMLR), part of the Antarctic treaty system. The U.S. AMLR program is managed by the Antarctic Ecosystem Research Group located at the Southwest Fisheries Science Center in La Jolla.**

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### Introduction

The 2009/10 U.S. Antarctic Marine Living Resources (U.S. AMLR) field season continued a long-term series of studies of the Antarctic Peninsula ecosystem, designed to support the conservation and management of Antarctic marine fisheries by the Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR). The U.S. AMLR Program is managed and implemented by the Antarctic Ecosystem Research Division (AERD).

The field research is used to describe the Antarctic ecosystem as a function of the relationships between Antarctic krill (*Euphausia superba*), their predators and the physical and biological oceanographic conditions of the marine environment. Two working hypotheses have been proposed: 1) krill predators respond to changes in the availability of their food source, and 2) the distribution of krill is affected by both physical and biological aspects of their habitat.

Since the inception of the U.S. AMLR Program, annual field studies have been conducted in the vicinity of the South Shetland Islands (Figure 1), which are located to the north of the Antarctic Peninsula. Historically, these field studies include land-based observations of pinnipeds and seabirds at Cape Shirreff on Livingston Island and Admiralty Bay (Copacabana) on King George Island (Figure 1), and two identical surveys of the waters surrounding the South Shetland Islands (Figure 2), completed in January and again in February.

During the austral summer of 2009/10, logistical difficulties arising from the combination of a smaller ship and frequent large storms prevented the successful completion of the full AMLR Survey. Two legs were undertaken, but only 39% of the planned survey was completed. A total of 83 CTD and water samples were taken and 82 net tows completed.

All land-based activities were successfully completed during the 2009/10 AMLR field season; the camps were opened in October of 2009 and closed in March of 2010. During that time, researchers conducted studies on the foraging ecologies, breeding biologies and abundances of three penguin and four pinniped species. In addition to their routine efforts, AMLR scientists began a study on the overwinter movement patterns of these predators. A total of 61 animals were tagged for monitoring through the austral winter of 2010.

This is the 22<sup>nd</sup> issue in the series of U.S. AMLR Field Season Reports, documenting the 24<sup>th</sup> year of Antarctic research.

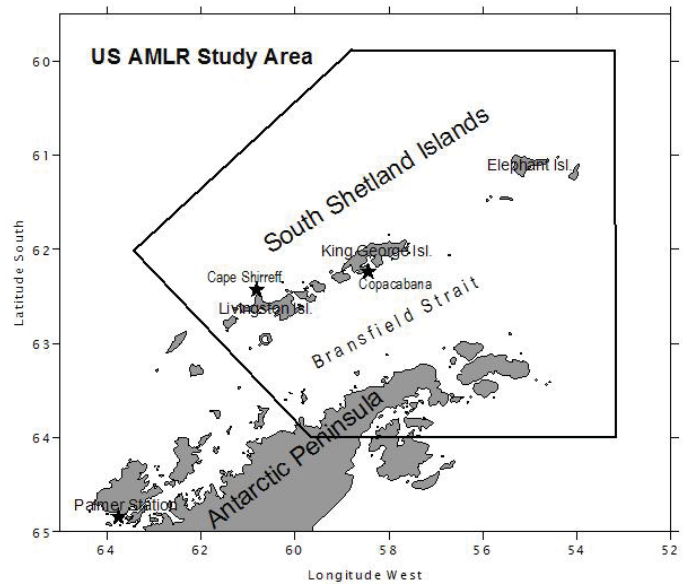


Figure 1. Location of U.S. AMLR field research: AMLR study area; Cape Shirreff, Livingston Island; Admiralty Bay (Copacabana), King George Island.

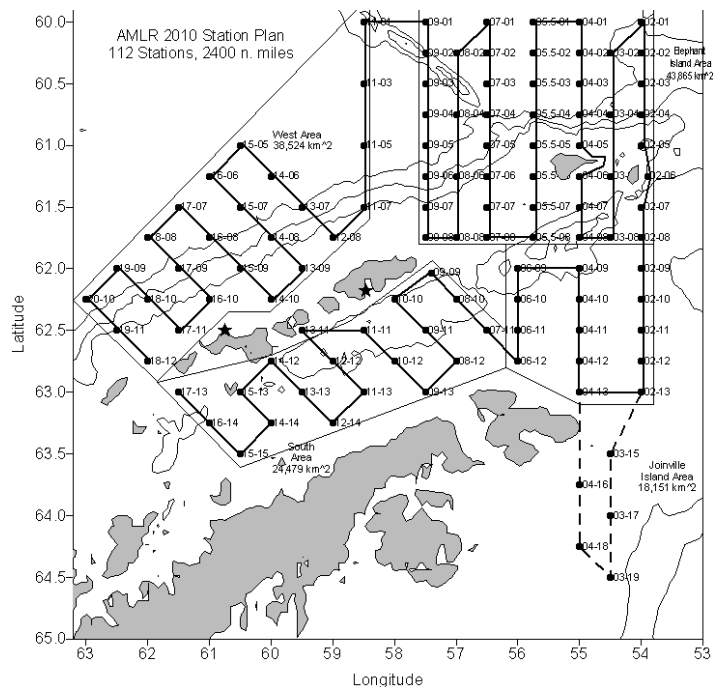


Figure 2. The survey design for AMLR 2009/10 (Survey A & D) in the vicinity of the South Shetland Islands, Elephant Island and the Antarctic Peninsula; field camp locations are indicated by a star. Survey strata are outlined by thin lines: the West Area, South Area, Joinville Island Area and Elephant Island Area. Depth contours are 500 m and 2000 m. Black dots indicate the location of planned biological/oceanographic sample stations; heavy lines indicate planned transects between stations.

## Summary of 2010 Results

Hydrographic results characterizing the waters around the South Shetland Islands indicate that several water masses converge in the area, forming a front along the shelf break north of the archipelago. This front is associated with high densities of phytoplankton and Antarctic krill, although there is great variability in the seasonal presence and reproductive success of krill, which is strongly correlated with multi-year trends in the physical environment. Predator foraging patterns and breeding success are tied to the annual variability in krill, the primary prey item in the Antarctic ecosystem.

During the 2009/10 U.S. AMLR Survey in the South Shetland Islands, acoustic estimates of krill biomass were the lowest seen since 2006; the results will be recalculated based on updated models from the 2010 CCAMLR WG-ASAM. Net-based estimates of krill abundance also decreased, for the second consecutive year, and recruitment indices were low, indicating that a weak cohort was produced the previous year. The abundance of *Salpa thompsoni* was greater this year than the last ten years. The production of penguin chicks decreased compared to the 2008/09 breeding season; gentoo penguins produced 16% fewer than the 12-year mean, while chinstrap penguins produced 41% less than the 12-year mean. Antarctic fur seals pup production decreased for the third consecutive year during the 2009/10 austral summer. Foraging trips by female fur seals decreased in length midway through the breeding season, and increased again toward the end of the season. Mortality of neonate fur seals increased compared to the prior year, and 69% of pups were lost to leopard seal predation.



### Oceanographic data

The Antarctic Circumpolar Current (ACC), characterized by warm, nutrient-poor waters, was farther north in 2010 than in 2009. Its southern boundary, characterized by the Polar Front, remained between 57°S and 59°S during the field season. Water masses were well defined this year, with clear Bransfield Strait-type water and Weddell Sea-type water present in addition to transitional water between these two local sources and the ACC.

### Phytoplankton data

Average Chl-*a* values (integrated to 100 m) were slightly lower in 2009/10 than in previous years. Stations sampled in the Bransfield Strait had the highest Chl-*a* concentrations, while stations to the north of the South Shetland Islands and off the shelf generally had lower Chl-*a* concentrations.

### Bioacoustic data

Biomass estimates of krill were the lowest since 2006, but the spatial distribution of krill was similar to historical distributions, with the largest krill biomass estimated around Elephant Island. The West Area had the least amount of krill and an intermediate biomass of krill was estimated for the Joinville Island Area.

### Zooplankton Composition data

The collection of zooplankton data was negatively impacted by logistical difficulties this year; therefore, only data collected during Leg II (February – March) were used for abundance estimates. Median krill abundance during Leg II of the 2009/10 AMLR field season was lower than the previous four years, and resembled that of 2002, 2004 and 2005. The tunicate *Salpa thompsoni* was, by far, the most abundant species, with a measured abundance greater than it had been in the last 10 years. Copepods and *Thysanoessa macrura*, the next most abundant taxonomic groups, were

similar in abundance to previous years.

### **Seabird Research data**

The penguin rookery at Cape Shirreff consisted of 19 sub-colonies of gentoo and chinstrap penguins during the 2009/10 breeding season: a total of 802 gentoo penguin nests and 4,339 chinstrap penguin nests were counted. This census continues a general trend of decline in the chinstrap penguin breeding population at Cape Shirreff.

Annual recruitment of penguins was estimated through population censuses and studies of reproductive success in each species. The gentoo chick count was 916 chicks, 9% lower than the 2008/09 count and 16% lower than the previous 12-year mean. The chinstrap chick count was 3,762 chicks, 13% lower than the 2008/09 count and 41% lower than the previous 12-year mean. Overall, breeding population counts and reproductive success of both gentoo and chinstrap were slightly lower than the previous 12-year mean for each species, which could be attributed, in part, to there being an abundance of snow early in the season.

In addition to ongoing data collection during the breeding season, the U.S. AMLR Program began an overwinter study of predator movement patterns. For this purpose, 15 chinstrap and 15 gentoo penguins were instrumented with ARGOS satellite-linked transmitters for over-winter tracking studies.

### **Pinniped Research data**

A total (live plus cumulative dead) of 1,385 Antarctic fur seal pups were estimated to have been born in 2009/10, representing an 11.7% reduction in pup production over last year. An estimated 68.3% of pups were lost to leopard seals by 24 February 2010. Krill were present in approximately 98% of all diet samples, while fewer fish were eaten than any previous year.

In addition to ongoing data collection during the breeding season, the U.S. AMLR Program began an overwinter study of predator movement patterns. For this purpose, 20 adult female Antarctic fur seals, five leopard and six Weddell seals were instrumented with ARGOS satellite-linked transmitters for over-winter tracking studies.

### **Shipboard seabird and marine mammal data**

During the 2009/10 AMLR field season, fewer seabird aggregations were observed than in previous years, and the seabird community composition contained few sub-Antarctic species. In the Bransfield Strait, humpback whales

were densely concentrated. Offshore areas to the north of the South Shetland Islands and Elephant Island were not as well sampled as in previous years.



## 2009/10 AMLR Field Season Objectives

The objectives for the 2009/10 AMLR field season, similar to previous years, are listed below.

### Shipboard Research

1. Conduct a bio-acoustic, oceanographic and net-based krill survey in the vicinity of the South Shetland Islands (Legs I and II) to map meso-scale features of water mass structure, phytoplankton biomass and productivity, zooplankton constituents, and the dispersion, biomass and population demography of krill.
2. Calibrate the shipboard hydroacoustic system in Admiralty Bay the end of Leg I and again near the end of Leg II.
3. Collect continuous measurements of the ship's position, sea-surface temperature, salinity, turbidity, fluorescence, air temperature, barometric pressure, relative humidity, and wind speed and direction.
4. Collect underway observations of seabirds and marine mammals.
5. Deploy drifter buoys.
6. Provide logistical support to the field camps at Cape Shirreff, Livingston Island and Admiralty Bay (Copacabana), King George Island, including the transfer of personnel, equipment, building materials, other supplies, and provisions.
7. Prepare fur seal milk for lipid analysis, process shore-based collections of fur seal diet samples, collect fur seal and penguin prey (krill, squid and fish) for lipid analysis and bomb calorimetry, and measure krill to validate the krill-carapace to total length relationship.
8. Deploy time-depth recorders (TDRs) on chinstrap and gentoo penguins during chick rearing for diving studies.
9. Record at-sea foraging locations for chinstrap penguins during the chick-rearing period using ARGOS satellite-linked transmitters (PTTs).
10. Instrument chinstrap and gentoo penguins with satellite tags for overwinter analysis of movement patterns.
11. Monitor female Antarctic fur seal attendance behavior.
12. Collaborate with Chilean researchers in collecting Antarctic fur seal pup mass for 100 pups every two weeks through the season.
13. Collect ten Antarctic fur seal scat samples every week for diet studies.
14. Collect a milk sample during each female Antarctic fur seal capture for fatty acid signature analysis and diet studies.
15. Record at-sea foraging locations for female Antarctic fur seals using PTT and GPS units.
16. Deploy TDRs on female Antarctic fur seals for diving studies.
17. Tag 500 Antarctic fur seal pups for future demographic studies.
18. Collect teeth from selected Antarctic fur seals for age determination and other demographic studies.
19. Deploy a weather station for continuous summer recording of wind speed, wind direction, ambient temperature, humidity, and barometric pressure.
20. Instrument Antarctic fur seals, leopard seals and Weddell seals with satellite tags for overwinter analysis of movement patterns.
21. Capture and instrument leopard seals for studies of top-down control of South Shetland Island fur seal populations.

### Land-based Research (Cape Shirreff)

1. Estimate chinstrap and gentoo penguin breeding population size.
2. Band 500 chinstrap and 200 gentoo penguin chicks for future demographic studies.
3. Determine chinstrap penguin foraging trip durations during the chick rearing stage of the reproductive cycle.
4. Determine chinstrap and gentoo penguin breeding success.
5. Determine chinstrap and gentoo penguin chick weights at fledging.
6. Determine chinstrap and gentoo penguin diet composition, meal size, and krill length-frequency distributions.
7. Determine chinstrap and gentoo penguin breeding chronologies.

## Description of Operations

1. South Shetland Survey: Leg I consisted of 39 CTD and 40 net-sampling stations, while Leg II consisted of 44 CTD and 42 net-sampling stations. During the first leg, operations were focused on the Elephant Island Area; some additional stations were sampled in the Joinville Island and South Areas. During Leg II, the South and Joinville Island Areas were surveyed (the Joinville Island Area was not completed due to ice cover), and 14 stations were sampled in the West Area.
2. A) Acoustic transects: Active acoustic data were collected continuously using Simrad ES60 echosounder and hull-mounted transducers (38, 120 and 200 kHz). B) CTD operations: CTD casts were conducted to 750 m or 10 m from the bottom at a total of 83 stations. Water samples were collected at 11 discrete target depths for analysis of Chl-*a* concentrations, nutrients, and salinity. Samples were taken to measure oxygen concentrations twice in each 24-hour period during Leg II, as the weather permitted. C) Net sampling operations: During both legs of the survey, a standard 2 m IKMT fitted with a 505 micron mesh net was used to sample zooplankton and micronekton (including krill). Primary sample processing for both legs was conducted on the ship. D) Phytoplankton operations: A deck cell for the collection of PAR was installed on the ship super structure; see also (B) E) XBT operations: A total of 71 XBT probes were deployed to collect temperature data to depths of up to 750 m, during the Drake Passage transits and at other times during the cruise. The expendable probes were launched every 15 km from the stern of the ship while underway between the South Shetland Islands and the Polar Front (58°S). A few were deployed when the CTD could

Table 1. The itinerary and schedule of events for the 2009/10 AMLR field season.

<b>VESSEL:</b>	R/V <i>Moana Wave</i>		
<b>OPERATING AREA:</b>	South Shetland Islands, Antarctica		
<b>ITINERARY</b>	Date	Sea Days	Port Days
Port call in Punta Arenas	21 Jan - 24 Jan		4
Leg I	25 Jan - 13 Feb	19	
Port call in Punta Arenas	14 Feb - 15 Feb		2
Leg II	16 Feb - 15 Mar	28	
Port call in Punta Arenas	16 Mar - 19 Mar		4
Total Days		48	10
<b>SCHEDULE OF EVENTS</b>			
<i>LEG I</i>			
Transit to South Shetland Islands	25 - 27 Jan	3	
Conduct large-area survey	28 Jan - 05 Feb	9	
Transfer personnel and trash from Cape Shirreff	06 Feb	1	
Conduct large-area survey	07 Feb - 10 Feb	3	
Transit to Punta Arenas	11 - 13 Feb	3	
Total days		19	
<i>LEG II</i>			
Transit to South Shetland Islands	16 - 18 Feb	3	
Copacabana Field Camp resupply/ personnel/calibrate	19 - 20 Feb	2	
Cape Shirreff Field Camp resupply/ personnel	21 Feb	1	
Conduct large-area survey	22 Feb - 6 Mar	14	
Calibrate in Admiralty Bay, close Copacabana field camp	7 Mar	1	
Close Cape Shirreff Field Camp	8 - 10 Mar	3	
Transit to Punta Arenas	11 - 15 Mar	5	
Total Days		29	

not be deployed due to weather conditions.

3. Acoustic system calibration: At the end of Leg II, the ship anchored in approximately 25 fathoms of water in Admiralty Bay (Ezcurra Inlet) to calibrate the acoustic system.
4. Continuous environmental data collection: During Legs I and II a meteorological instrument package was mounted on the ship's forward mast. Continuous measurements of sea-surface temperature and salinity, air temperature, barometric pressure, relative humidity, wind speed, wind direction, scalar and cosine PAR, and shortwave radiation were collected and logged on data-logging computers located in the computer room. Navigational data were taken from the ship's GPS receiver and gyro compass.
5. Deploying drifters: A total of 17 drifters were deployed from the ship during the field season. One drifter was deployed by the ship's crew after the end of the field season, as the ship returned to its home port.
6. Seabird and marine mammal observation: Seabird and marine mammal observations were made from inside the pilot house along transects between stations and during the transits to and from Punta Arenas, Chile.
7. Field camp logistical support, Legs I and II: The scientific party conducted the following operations:
  - Near the end of Leg I personnel were transferred from Cape Shirreff to Punta Arenas. Trash was recovered to the ship from both camps.
  - At the beginning of Leg II, personnel were transferred from Copacabana to Cape Shirreff and additional supplies were brought to both camps.
  - Near the end of Leg II, personnel, equipment and trash were recovered from Cape Shirreff and Copacabana to close the field camps for the season.
  - Daily radio communications were maintained between the two field camps and the ship.
8. D. Krause, J. Hinke and N. Pussini arrived at Cape Shirreff on 16 February 2010, with additional supplies and equipment.
9. Antarctic fur seal pups and female fur seals were counted at four main breeding beaches every other day from 30 October through 31 December 2009.
10. Attendance behavior of 32 lactating female Antarctic fur seals was measured using radio transmitters. Females and their pups were captured, weighed, and measured from 2-16 December 2009.
11. CCAMLR Antarctic fur seal pup growth protocols were implemented and four samples of pup weights were collected. Measurements of mass for a random sample of 100 pups were begun 30 days after the median date of pupping (7 December 2009) and continued every two weeks until 20 February 2010.
12. Information on Antarctic fur seal diet was collected using scat (random collection of 10 per week for 11 weeks) and fatty-acid signature analyses of milk (92 samples) collected during every capture of a lactating female.
13. Fifteen Antarctic fur seals were instrumented with time-depth recorders (TDRs) for studies of dive behavior.
14. Ten Antarctic fur seal females were instrumented with GPS satellite-linked TDRs for studies of at-sea foraging location and diving from 4 December 2009 to 26 February 2010.
15. A total of 499 Antarctic fur seal pups were tagged at Cape Shirreff by U.S. AMLR researchers for future demography studies. Of the 499, 11.2% (56) were pups of tagged mothers. An additional 32 new adult females were tagged.
16. Weather data recorders were set up at Cape Shirreff for wind speed, wind direction, barometric pressure, temperature, humidity, precipitation and solar radiation.
17. A single post-canine tooth was extracted from 10 adult lactating female fur seals for aging and demographic studies.
18. Five leopard seals were captured and instrumented with Mark 9 time depth recorders (TDR). Three TDRs were successfully retrieved after collecting dive and temperature data for over a month. Five additional leopard seals were instrumented with ARGOS-linked transmitters after molting (1-5 March 2010) for over-winter data collection.
19. Six hundred and eight DNA samples were collected from

### Land-based Research

1. A five-person field team (M. Goebel, R. Burner, R. Buchheit, K. Pietrzak and M. Mudge) arrived at Cape Shirreff, Livingston Island, on 18 October 2009 via the R/V *Laurence M. Gould*. Equipment and provisions were also transferred from the R/V *Laurence M. Gould* to Cape Shirreff.
2. C. Bonin, Scripps Institute of Oceanography, arrived at Cape Shirreff on 1 December 2009 aboard the Brazilian R/V *Ary Rongel*.
3. R. Vasquez del Mercado, along with supplies and equip-

- four species of pinnipeds: Antarctic fur seals, elephant seals, Weddell seal and leopard seals. All samples have been catalogued and stored in the SWFSC DNA archive.
16. Twenty adult female fur seals were instrumented in late-February with ARGOS satellite-linked instruments to record over-winter dispersal and foraging locations.
  17. Six Weddell seals were instrumented in early-March with satellite-relay data loggers that collect conductivity and temperature at depth for every dive. These data will serve to characterize the over-winter hydrography of the western Antarctic Peninsula region and record over-winter foraging locations.
  18. The annual censuses of active gentoo and chinstrap penguin nests were conducted on 5 December and 30 November 2009, respectively. Reproductive success was studied by following a sample of 100 chinstrap penguin pairs and 50 gentoo penguin pairs from egg laying to crèche formation.
  19. Radio transmitters were attached to 18 chinstrap penguins on 7 January 2010 and remained on until their chicks fledged in early March 2010. These instruments were used to determine foraging-trip duration during the chick-rearing phase. All data were received and stored by a remote receiver and logger set up at the bird observation blind.
  20. Satellite-linked transmitters were deployed on adult chinstrap and gentoo penguins 38 times for seven to ten days at a time. The first deployment coincided with the chick-guard phase, when penguin pairs alternate between attending the nest and foraging. The second deployment was made during the chick crèche phase when both parents forage simultaneously.
  21. Diet studies of chinstrap and gentoo penguins during the chick-rearing phase were initiated on 20 January 2010 and continued through 9 February 2010. Forty chinstrap and 20 gentoo adult penguins were captured upon returning from foraging trips, and their stomach contents were removed by stomach lavage.
  22. Counts of all gentoo and chinstrap penguin chicks were conducted on 10 and 8 February 2008; respectively.
  23. Fledging weights of 115 chinstrap penguin chicks were collected, and a total of 128 gentoo penguin chicks were weighed.
  24. Five hundred chinstrap penguin chicks and 200 gentoo penguin chicks were banded for future demographic studies.
  25. Reproductive studies of brown skuas and kelp gulls were conducted throughout the season at all nesting sites around Cape Shirreff.
  26. Time-depth recorders (TDRs) were deployed a total of 21 times on chinstrap and gentoo penguins for seven to ten days at a time. The first deployment coincided with the chick-guard phase, when penguin pairs alternate between attending the nest and foraging. The second deployment was made during the chick crèche phase when both parents forage simultaneously.
  27. ARGOS-linked transmitters were deployed on 15 gentoo and 15 chinstrap penguins after the molt for over-winter tracking studies.
  28. The Cape Shirreff field camp was closed for the season on 8 March 2010. All U.S. personnel, garbage and equipment were retrieved by the R/V *Moana Wave*.

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## Scientific Personnel

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Andre du Randt (Leg I)

André Hoek (Leg II)

Mike Soule (Leg II)

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**Krill and Zooplankton Sampling:**

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## Physical Oceanography and Underway Environmental Observations

Derek Needham and Andre du Randt (Leg I), and André Hoek and Mike Soule (Leg II)

### Abstract

Oceanographic data were collected at a reduced number of stations during two legs of the 2009/10 AMLR Survey. A total of 83 CTD/carousel casts were completed, and meteorological data was taken continuously throughout the survey. Results indicated that:

- Antarctic Circumpolar Current (ACC) water remained mainly offshore, and was found primarily in the western part of the South Shetland Islands.
- Waters were mixed between Elephant Island and the Shackleton Fracture Zone, giving way to the colder, saltier waters of the Bransfield Strait south of Elephant Island and around Joinville Island.

### Introduction

The objectives of this study were to 1) collect and process physical oceanographic data in order to identify hydrographic characteristics and map oceanographic frontal zones; and 2) collect and process underway environment data in order to describe sea surface and meteorological conditions experienced during the surveys. These data may be used to describe the physical circumstances associated with various biological observations as well as provide a detailed record of the ship's movements and the environmental conditions encountered.

### Methods

#### CTD/Carousel Stations

A total of 83 CTD/carousel casts were completed, 39 of these as part of Leg I and 44 as part of Leg II (Figure 2, Introduction). Additional casts were also completed during acoustic calibrations in Admiralty Bay and to test various aspects of equipment functionality.

The reduced number of CTD stations occupied on the traditional grid can be attributed to:

- time restraints due to the delayed Leg I departure date;
- the R/V *Moana Wave* having to leave the survey grid in bad weather to seek shelter;
- time lost waiting out bad weather when aft deck operations became unsafe.

Installation of the CTD winch's auxiliary components (sea-cable deadend termination, underwater connector,

sliprings and cabling to the laboratory) was successfully completed in Punta Arenas before Leg I, enabling static deck testing of the full CTD and carousel systems to be completed before the ship sailed. The CTD and carousel were set up as per Table 1.1. Assistance was also provided to the ship's staff to set up and calibrate the winch monitor system (cable load, wire out and wire speed).

Deck sheets were generated for every station and CTD data was logged and bottles triggered using Sea-Bird Seasave Win32 Version 5.30a software. CTD "mark" files (reflecting data from the cast at bottle triggering depths), were also collected. Data was processed using SBE Data Processing Version 5.30a software, averaged over 1 m bins, and saved separately as up and down traces during post processing. Downcast data was reformatted using a SAS script and then imported into Ocean Data View (ODV) format for further checking and presentation.

The CTD and its auxiliary sensors were calibrated by the manufacturers prior to the cruise and all calibration certificates have now been stored in a central filing system, along with the calibration sheets from previous AMLR cruises. The CTD, auxiliary sensors and carousel equipment functioned reliably, even though the deployment, retrieval, moving and storage operations on R/V *Moana Wave* were not ideal for sensitive equipment such as the CTD system (see Appendix A). The CTD system was stowed on the aft deck and secured to the ship's steelwork with ratchet straps during transits and between stations.

Water samples were collected at 11 discrete depths on all casts for phytoplankton analysis. For Legs I and II,

water profiles and samples were collected with the Sea-Bird SBE-911plus CTD system and Sea-Bird SBE-32 carousel water sampler equipped with ten-liter sampling bottles. A pumped Sea-Bird SBE-43 dissolved oxygen sensor, Chelsea Instruments Aquatracka III fluorometer and Wetlabs C-Star red transmissometer made up the auxiliary sensors. The above equipment was serviced and calibrated by Sea-Bird Electronics prior to the cruise. A Biospherical QCP200L PAR sensor was also mounted on the CTD frame. CTD scan rates were set at 24 scans/second during both down and up casts. Sample bottles were only triggered during the up casts. Profiles were limited to a depth of 750 m or 5 m above the sea bottom when shallower than 750 m. A Teledyne Benthos altimeter was used to stop the CTD decent 5 to 15 m from the seabed on the shallow casts. Standard bottle sampling depths were 750 m, 200 m, 100 m, 75 m, 50 m, 40 m, 30 m, 20 m, 15 m, 10 m and 5 m.

Salinity calibration samples from 113 bottles on Leg I, and 70 bottles on Leg II, were analyzed on board using a Guildline Portasal salinometer. Comparisons of dissolved oxygen levels in the carousel water samples and the levels measured during the casts (via the O<sub>2</sub> sensor) were not attempted during the survey.

#### *Underway Environmental Observations*

Environmental and vessel position data were collected, logged and displayed for a total of 46 days (18 days and 28 days during Legs I and II, respectively) via the Scientific Computer System (SCS) software package, which was run on a new Windows XP based Dell PC with an internal 8-port RS232 expander card.

Environmental data were collected via a Coastal Environmental Company

Table 1.1. SCS and CTD sensor installation summary (Legs I & II)

<b>SCS Sensor Installation Summary Leg I &amp; Leg II 2010</b>				
Sensor	Manufacturer	Model	Serial No.	Calibrated
Weather Station	Coastal Environmental Systems	WEATHERPAK-2000	797	17 Aug 2009
PAR sensor (2pi)	LI-COR	LI-2000SZ, S114	Q28168	17 Aug 2009
PAR sensor (4pi)	Biospherical Instruments, Inc.	QSR-2100	10281	19 Aug 2009
Thermosalinograph	Sea-Bird Electronics, Inc.	SBE-21	2971	06 Aug 2009
Remote TSG probe	Sea-Bird Electronics, Inc.	SBE-03-01/S	1310	13 Nov 2009
GPS navigator	Ship's GPS	-	Supplied by ship	-
Gyro compass	Furuno Marine Electronics	-	Supplied by ship	-

<b>CTD Sensor Installation Summary Leg I &amp; Leg II 2010</b>					
Sensor	Manufacturer	Model	Serial No.	Voltage Channel	Calibrated
Deck Unit	Sea-Bird Electronics, Inc.	SBE 11	11P13966-0434	-	-
U/W Unit	Sea-Bird Electronics, Inc.	SBE 9plus	09P13966-0454	-	30 Oct 09
Temperature Sensor	Sea-Bird Electronics, Inc.	SBE 3plus	3P2234	Freq 1	4 Aug 09
Conductivity Sensor	Sea-Bird Electronics, Inc.	SBE 4C	041815	Freq 2	10 Sept 09
Pressure Sensor	DigiQuartz 410K-105	Internal	64268	Freq 3	4 Aug 09
Circulation Pump	Sea-Bird Electronics, Inc.	SBE 5T	051654	-	10 Sept 09
SBE Carousel	Sea-Bird Electronics, Inc.	SBE 32	3235861-0509	-	28 Aug 08
DO Sensor	Sea-Bird Electronics, Inc.	SBE 43	430912	Voltage 0	22 Aug 09
PAR (old)	Biospherical Instruments, Inc.	QCP200L	4264	Voltage 2	19 Aug 09
Altimeter	Datasonics	PSA-900	508	Voltage 4	New pulg. Nov 2009
Fluorometer	Chelsea Instruments	Aquatraka III	05-5173-001	Voltage 6	27 Aug 09
Transmissometer	WET Labs	C-Star Red	CST-882DR	Voltage 7	29 Oct 09

Weatherpak system, a Licor quantum PAR sensor and a Biospherical 4PI QSR-2100 PAR sensor, installed on the R/V *Moana Wave's* bridge-top mast. A Sea-Bird SBE-21 thermosalinograph (TSG) with a remote sea surface temperature probe was installed in the zooplankton laboratory and fed into the SCS. A new remote temperature sensor was added to the TSG system, on the suction side of the clean seawater pump, close to the ship's hull. A new debubbler unit was also fitted, near the salinity housing, and problems with "spiking" salinity traces that were experienced during past cruises were eliminated. The relative wind data were converted to true speed and true direc-

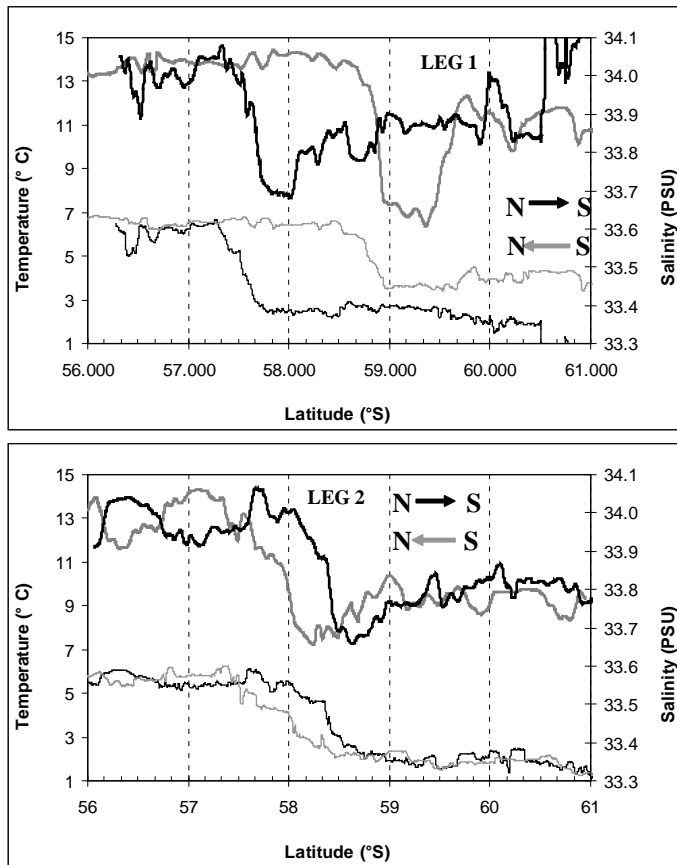


Figure 1.1. The position of the polar fronts as determined for AMLR 2010 Legs I (top) and II (bottom), from measurements of sea surface temperature and salinity for the south and north transits to and from the South Shetland Islands survey area.

tion by the internally derived functions of the SCS logging software.

Vessel position data were recorded through the ship's GPS and gyro-compass, which were also fed into the SCS system.

The R/V *Moana Wave* does not have a deep echo sounder that can be used to record bottom soundings or provide an indication of depth before deploying the CTD. In shallow waters, soundings were obtained from the EK60 system; in deeper water, soundings obtained during the 2009 survey were used.

Although the ship sailed on 25 January 2010, uninterrupted SCS data logging only commenced at 23:45 on Thursday 26th January due to having to install, cable and integrate the SCS hardware and setup the software on the new PC. Data were logged for surface environmental conditions encountered over the entire AMLR Survey for the duration of the cruise including transits to and from Punta Arenas.

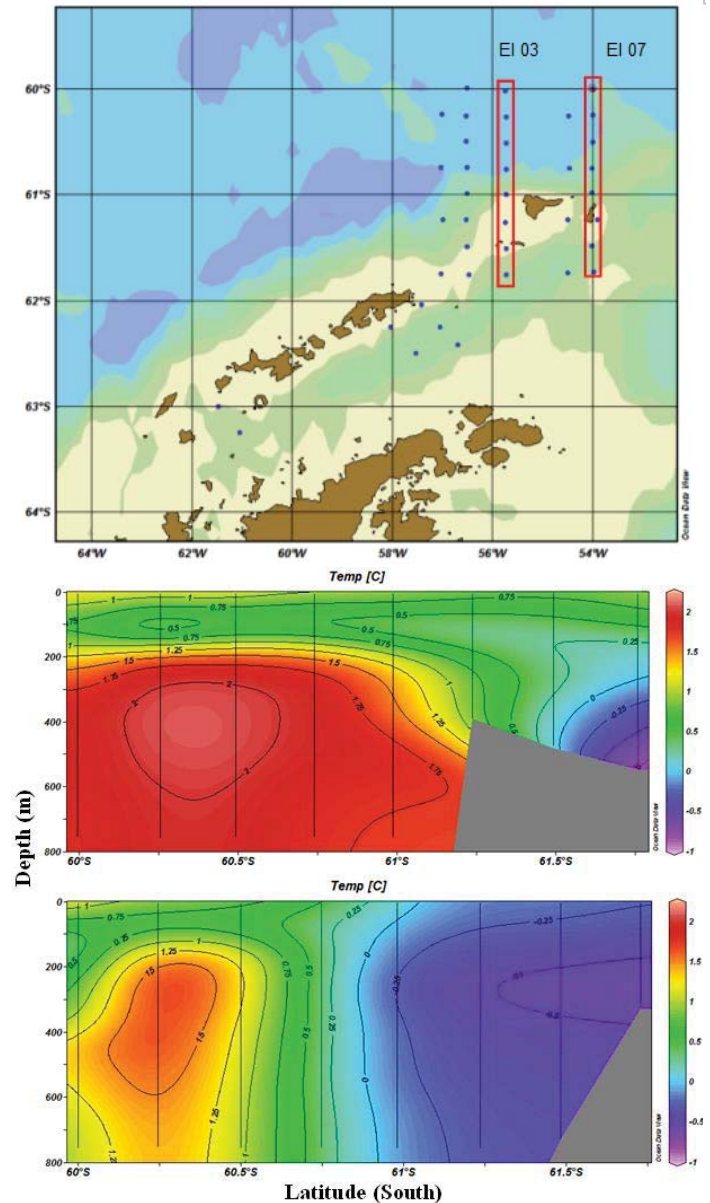


Figure 1.2. Vertical temperature profiles derived from CTD data recorded on two transects, EI03 (top) and EI07 (bottom), during Leg I of the AMLR 2010 Survey.

The underway sensors and systems were all calibrated by the manufacturers prior to the cruise and all calibration certificates have now been stored in a central filing system, along with the calibration sheets from previous AMLR cruises.

## Results

The position of the Antarctic Polar Front, identified by pronounced sea surface temperature and salinity change, was located from the logged SCS data during the four tran-



sits from and to Punta Arenas and the South Shetland Islands survey area. This frontal zone is normally situated between 57–58° S.

During the south-bound transit of Leg I, the Antarctic Polar Front was well defined between 57° 20'S and 57° 50'S, with sea surface temperature (SST) dropping from approximately 6.5°C to 2.5°C. On the northern transect the front was encountered further south and was well defined between 59° 00'S and 58° 30'S, with a change in SST from 3.7°C to 6.6°C. On the south-bound transit of Leg II the front was not as defined as on Leg I and was encountered between 58° 00' S and 58° 45' S, with the SST changing from 5.4°C to 2.1°C. On the return transit, at the end of Leg II, the front was broader and located between 58° 40' S and 57° 30' S, with the SST changing from 2.0°C to 6.2°C (Figure 1.1).

Due to the later sailing date of Leg I, it was decided to cover the Elephant Island area CTD stations first, to preserve the historic time series in this area. 37 CTD stations were successfully occupied in the Elephant Island and Joinville Island Areas. Some stations were also sampled in the South Area, when weather conditions made working north of the islands too difficult. During Leg II the effort was concentrated in the West, South and Joinville Island Areas, with no stations occupied in the Elephant Island Area.

Close agreement between CTD measured salinity and the Portasal values was obtained. The final CTD/Portasal correlation produced an  $r^2=0.9990$  ( $n=112$ ) during Leg I and  $r^2=0.9946$  ( $n=178$ ) across Leg I and II. A comparison of the Sea-Bird SBE-21 thermosalinograph (TSG) system with CTD data showed that the TSG salinity reading were on average 0.024 ppt ( $n=60$ ) lower than the CTD, while the sea temperature showed the TSG to be on average 0.099°C ( $n=60$ ) higher than the CTD 5 m temperature data.

For comparative purposes, vertical temperature profiles have been plotted for the same three station lines (W03, EI03 and EI07) each year. Figure 1.2 shows lines EI03 and EI07 for AMLR 2010 Leg I (line W03 was not done during Leg I and lines EI03 and EI07 were not repeated on Leg II).

#### Underway Data

Winds encountered across the survey area during

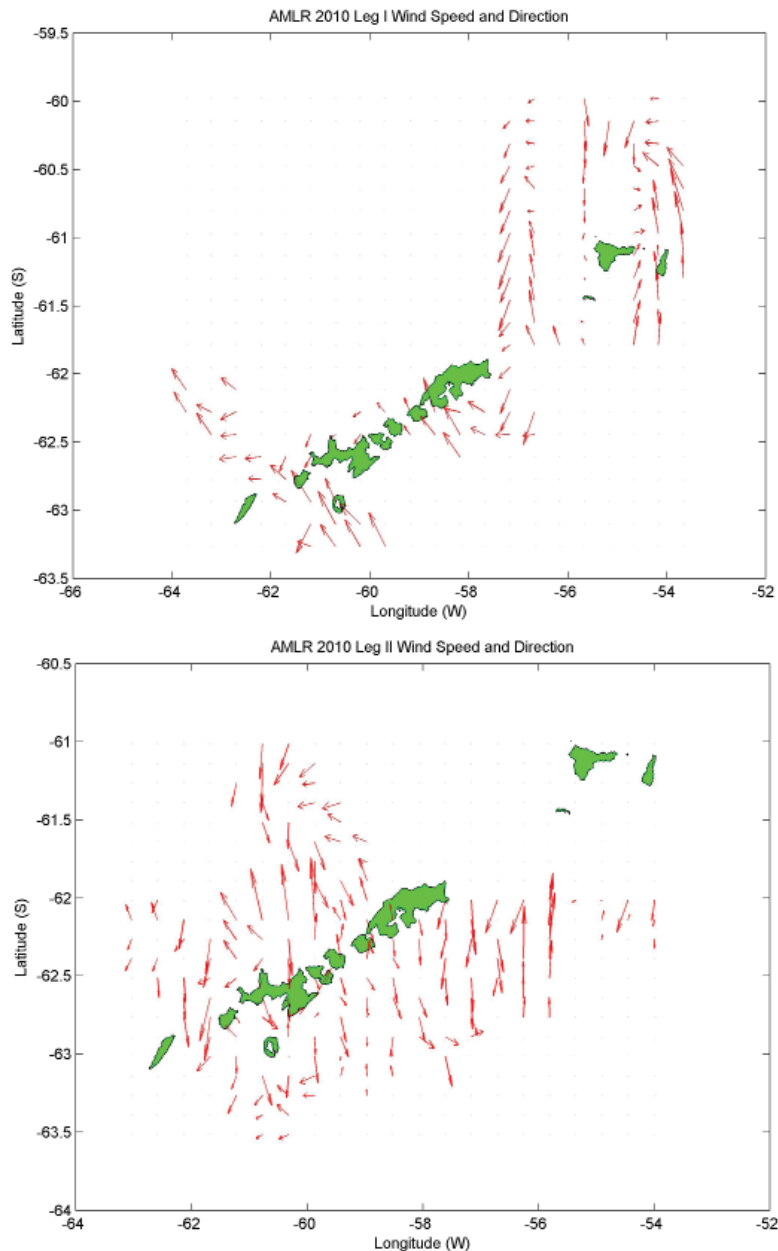


Figure 1.3. Vectors representing wind speed and direction for Legs I (top) and II (bottom), derived from data recorded by the SCS logging system during the AMLR 2010 field season (survey area only).

Leg I were predominantly northeasterly with shorter periods of Northwesterlies and Southeasterlies. The shifts from northeast to southeast produced the highest wind speeds. Leg II saw the predominately Northeasterlies of Leg I being replaced by constantly varying wind directions, with the highest wind speeds being recorded during a Southeasterly gale, increasing to above 60 knots. The ship had to frequently seek shelter in the lee of the islands during storms. Figure 1.3 shows wind speed and direction encountered during both legs.

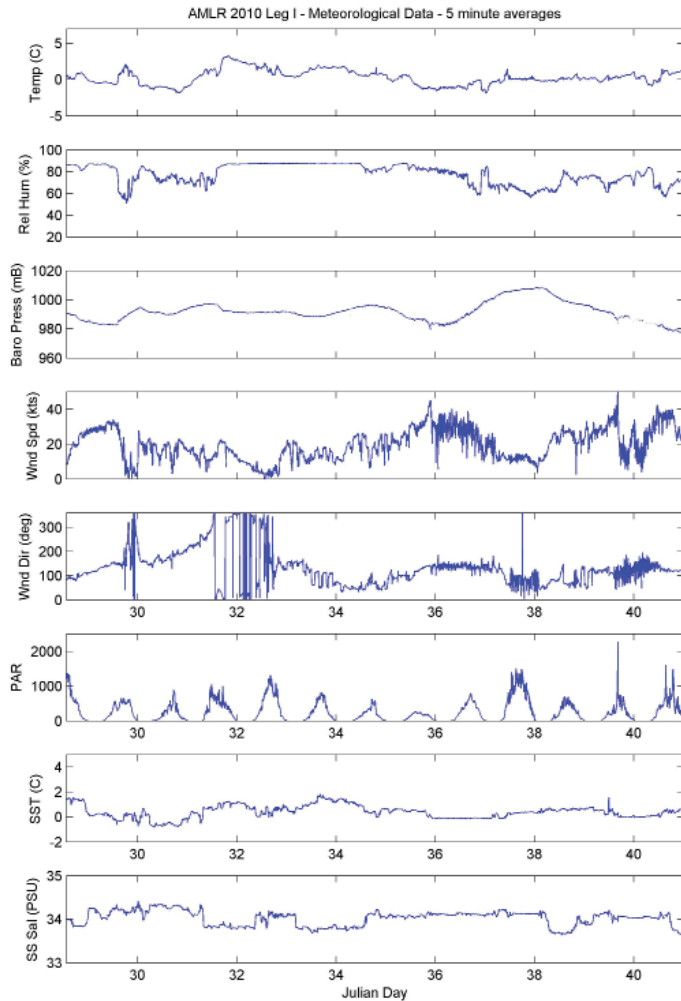


Figure 1.4. Meteorological data (five minute averages) recorded between 28 January and 9 February during Leg I of the 2009/10 AMLR Survey (PAR is photosynthetically available radiation).

Environmental data were recorded for the duration of the surveys and for the transits between Punta Arenas and the survey area. Processed data were averaged and filtered over 1-minute and 5-minute intervals. Those data can be found in Figures 1.4 and 1.5 for Legs I and II (respectively).

### Discussion

Even with the reduced number of stations, an attempt was made to group stations with similar temperature and salinity profiles into five water zones as defined in Table 1.2. The tentative water zone classifications are sometimes prone to ambiguity, particularly in the coastal regions around King George & Livingston Islands and in the south and southeast of Elephant Island. Classifications of Zone

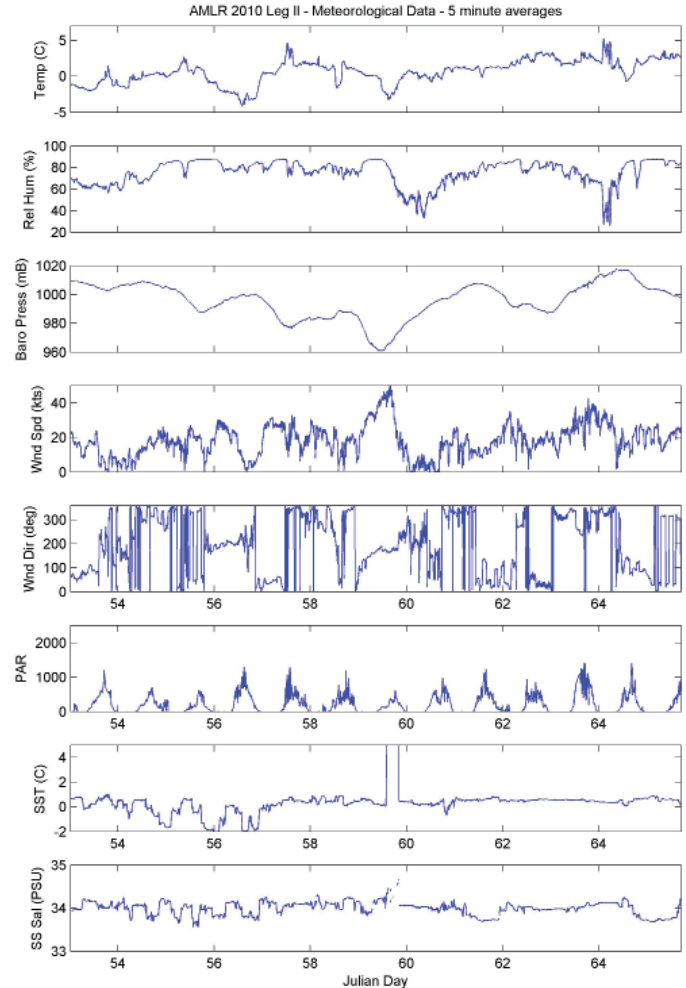


Figure 1.5 Meteorological data (five minute averages) recorded between 22 February and 6 March during Leg II of the 2009/10 AMLR Survey (PAR is photo-synthetically available radiation).

IV (Bransfield Strait) and Zone V (Weddell Sea) waters in these areas could change if other oceanographic data such as density are considered. For the purpose of this report, in which only tentative conclusions are reported, only the criteria contained in Table 1.2 were used. This was done to ensure consistency with past cruises and only serves as a “first attempt field classification”.

During Leg I (Figure 1.6) the most clearly defined Zone I (ACC) water was found near the southeast edge of the Shackleton Fracture Zone, with the furthestmost stations offshore tending towards Zone II (Transition) water. Between the Fracture Zone and Elephant Island, the stations produced a mixture of Zone I (ACC), Zone II (Transition) and Zone III (Transition), with the stations south of Elephant Island and the Joinville Island Area being pre-

Table 1.2. Water Zone definitions applied during the 2008/09 AMLR Survey.

Water Zone Definition	T/S Relationship			
	Left	Middle	Right	Typical T/S Curve (from 2002)
Water Zone I (ACC)	Pronounced V shape with V at <0 C			
Warm, low salinity water, with a strong subsurface temperature minimum, Winter Water, approx. -1°C, 34.0 ppt salinity, and a temperature maximum at the core of the CDW near 500m.	2 to >3°C at 33.7 to 34.1 ppt	<0°C at 33.3 to 34.0 ppt	1 to 2°C at 34.4 to 34.7ppt (generally >34.6 ppt)	
Water Zone II (Transition)	Broader U-shape			
Water with a temperature minimum near 0°C, isopycnal mixing below the temperature minimum and CDW evident at some locations.	1.5 to >2°C at 33.7 to 34.2 ppt	-0.5 to 1°C at 34.0 to 34.5 ppt (generally >0°C)	0.8 to 2°C at 34.6 to 34.7 ppt	
Water Zone III (Transition)	Backwards broad J-shape			
Water with little evidence of a temperature minimum, mixing with Type II transition water, no CDW and temperature at depth generally >0°C	1 to >2°C at 33.7 to 34.0 ppt	-0.5 to 0.5°C at 34.3 to 34.4 ppt	< 1°C at 34.7 ppt	
Water Zone IV (Bransfield Strait)	Elongated S-shape			
Water with deep temperature near -1°C, salinity 34.5 ppt, cooler surface temperatures.	1.5 to >2°C at 33.7 to 34.2 ppt	-0.5 to 0.5°C at 34.3 to 34.45 ppt	<0°C at 34.5 ppt (salinity <34.6ppt)	
Water Zone V (Weddell Sea)	Small fish-hook shape			
Water with little vertical structure and cold surface temperatures near or < 0°C.	Aprox. 1°C at 34.1 to 34.4 ppt	-0.5 to 0.5°C at 34.5 ppt	<0°C at 34.6ppt	

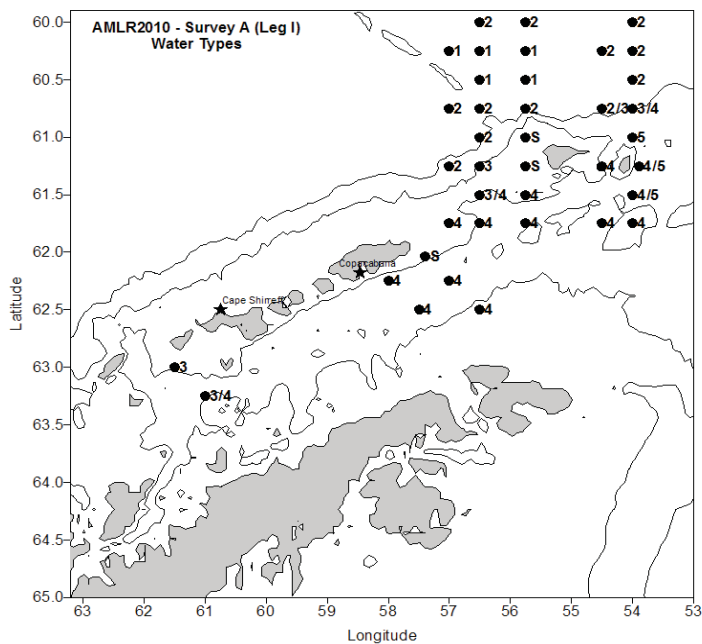


Figure 1.6. Classification of water zones for Leg I for AMLR 2009/10, as defined in Table 1.2 (Water Zone definitions). Stations marked with “S” were too shallow, and “M” too mixed, to properly classify.

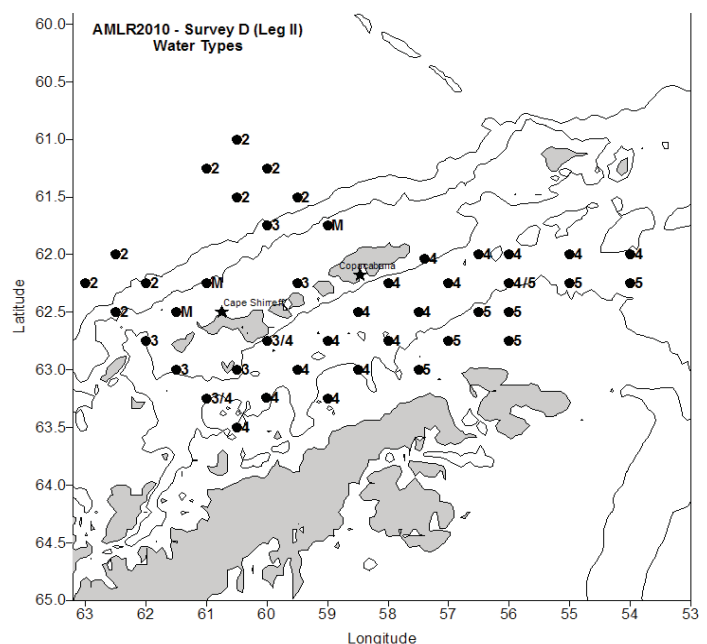


Figure 1.7. Classification of water zones for Leg II for AMLR 2009/10, as defined in Table 1.2 (Water Zone definitions). Stations marked with “S” were too shallow, and “M” too mixed, to properly classify.

dominantly Zone IV (Bransfield Strait) water. An intrusion of Water Zone V (Weddell Sea) influence was encountered east of Elephant Island. No stations were occupied in the Joinville Island and West Areas.

During Leg II (Figure 1.7) stations occupied across the South and Joinville Island Areas produced mainly Zone IV (Bransfield Strait) water, with the eastern stations and the southern Stations around the Antarctic Sound being Water Zone V (Weddell Sea). The eastern end of the Bransfield Strait, southwest and west of Livingston Island, showed and influence of Zone III (Transition) water. All stations were not occupied across the West Area, but the lines that were completed showed the predominance of Zone II (Transition) water offshore and across the shelf break. Closer to the islands Zone III (Transition) water was encountered.

### **Protocol Deviations**

Protocols followed from 2001 to 2009 were attempted on the new ship. Most protocols were achievable, except that station bottom soundings for stations deeper than 500 m were noted as the same as 2009, as the ship did not have a deep echosounder. Sea Surface Temperature was also changed to be logged from a temperature sensor closer to the hull, instead of from within the thermosalinograph, as in previous years.

A leak was experienced on the connector of the dissolved oxygen sensor on Station A02-06, resulting in no dissolved oxygen trace for this station.

### **Disposition of Data**

Data are available from Christian Reiss, Southwest Fisheries Science Center, 8604 La Jolla Shores Drive, La Jolla, CA, 92037; phone/fax (858) 546-5603/(858) 546-5608; email: christian.reiss@noaa.gov.

### **Acknowledgements**

The co-operation and assistance of the R/V *Moana Wave*'s staff was excellent. All requests for assistance were dealt with effectively and in a professional manner.

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## Phytoplankton Studies in the South Shetland Islands

Christian Reiss, Guido Bordignon, Tara Clemente and Amy Van Cise

### Abstract

Phytoplankton samples were collected in the South Shetlands Islands during January and February of 2010 to estimate chlorophyll levels. During the 2009/10 AMLR Field Season:

- A total of 87 stations were sampled, representing 39% of the planned survey.
- Average Chl-*a* concentration in the euphotic zone was 0.46 mg m<sup>-3</sup>, slightly lower than recent years.
- The Bransfield Strait had the highest Chl-*a* values, while water off the shelf was generally lower in productivity.

### Introduction

Long-term monitoring of chlorophyll in pelagic waters around the South Shetland Islands, Antarctica, has been a component of the Antarctic Marine Living Resources (AMLR) Program for 24 years. This data has been used to examine the nature of local trophic relationships and changes in productivity over intra- as well as inter-annual and decadal timescales. Ultimately, the research allows AMLR scientists to provide the scientific basis for management advice to the international Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR).

The phytoplankton studies conducted in the South Shetland Islands record the amount of primary production that occurs during the austral summer of each year and can be related to the oceanography of the area, as well as serving as a trophic link that is key to understanding the abundance and distribution of Antarctic krill, *Euphausia superba*, and other zooplankton species. This report documents the research completed during the 2009/10 field season of the AMLR Survey, and gives preliminary results of the data collected.

### Methods

#### Sample Collection

Data were collected from standard stations in four historically delineated areas in the South Shetland Islands: the West, South, Elephant Island and Joinville Island Areas (Fig. 2, Introduction).

At each station, water samples were collected for Chl-*a* measurement at discrete depths using Niskin bottles attached to a conductivity-temperature-depth (CTD) sensor carousel. The CTD was lowered to 750 m, or 10 m off the bottom, and bottles were closed on the up-cast at target depths of 200, 100, 75, 50, 40, 30, 20, 15, 10 and 5 m. A

one second binned record of the data collected by the CTD sensors was recorded as each bottle closed. As the season progressed, the loss of Niskin bottles required fewer depths to be sampled at each station.

A Profiling Reflectance Radiometer (PRR) system was deployed at local noon stations in order to analyze the underwater light profile. The PRR sensor was lowered and raised twice at each noon station, and measurements were electronically recorded.

Water samples were collected at 15 m or 10 m for the determination of macronutrient concentration in the water. A representative station was chosen for each of the five characteristic water types (Chapter 1) in the South Shetland Islands, and macronutrient samples were collected from all target depths at those stations. Samples were stored frozen in 120 mL acid-washed bottles.

Samples were collected for phytoplankton taxonomic analysis from 10 m depth and preserved with 0.5% buffered formalin. The samples were sent to J. L. Iriarte (Universidad Austral de Chile).

Additional samples were collected for pigment analysis at 10 m and 30 m. At each depth, a 2 L water sample was collected and filtered, frozen in liquid nitrogen, then returned to Scripps Institute of Oceanography for analysis with high pressure liquid chromatography (HPLC) techniques (Wright et al., 1991; Goericke and Repeta, 1993; Trees et al., 2000).

#### Data Collection

Chl-*a* fluorescence was measured using the methods developed by Holm-Hansen et al. (1965) and Holm-Hansen and Rieman (1978), using a Turner Designs Fluorometer (TD-700).

Water samples (100 mL) were filtered through glass

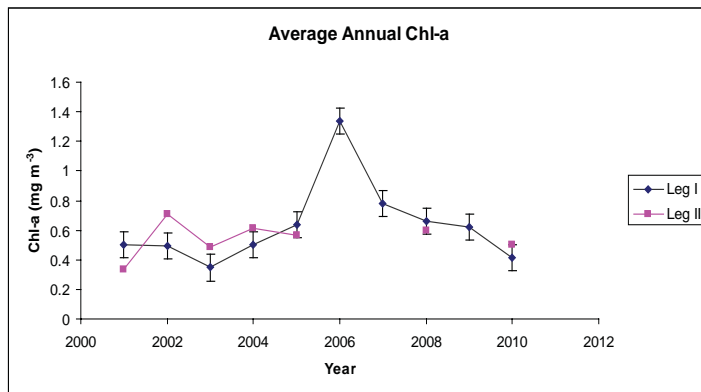


Figure 2.1. Annual Chl-*a* production ( $\text{mg m}^{-3}$ ), averaged over the upper 100 m and for all stations sampled on the historical survey grid between January and March each year during the austral summer. Samples taken during January (Leg I) are shown in blue, while samples taken during February (Leg II) are shown in pink. Missing data points are from years when a February survey was not conducted. During 2010, the January survey consisted mainly of samples from the Elephant Island Area, while the February survey consisted of samples from the South, Joinville Island and West Areas.

fiber filters (Whatman GF/F, 0.7  $\mu\text{m}$ ), and the remaining particular matter stored in 10 mL methanol at 4°C for a minimum of 12 hours to extract the photosynthetic pigments from the filter. The samples were then shaken and centrifuged. Each sample was placed in the TD-700 and a fluorescence reading (Rb) was taken; two drops of 1.0 N HCl were then added to the sample and the reading was taken again (Ra) to analyze the amount of phaeopigment in each sample.

Additionally, Chl-*a* was measured continuously in-situ using a Chelsea Aquatracka III fluorometer, mounted to the CTD carousel, with a log-voltage output. These values were compared to the data obtained from the water samples to ensure accurate data collection.

#### Data Analysis

Chl-*a* ( $\text{mg m}^{-3}$ ) is calculated for each station (*n*) as follows:

$$(1) \text{Chl-}a = Fd * t / (t-1) * (Rb-Ra) * 1000 / V_1 * V_2$$

Phaeopigment ( $\text{mg m}^{-3}$ ) at each station is calculated as follows:

$$(2) \text{Phaeo} = Fd * (t * Ra - Rb) * 1000 / V_1 * V_2$$

Where *Fd* and *t* are calibration factors for the TD-700 fluorometer,  $V_1$  is the volume of water filtered, and  $V_2$  is the volume of methanol/Chl-*a* extract measured in the

fluorometer.

The calculated Chl-*a* values at each target depth were averaged across all stations sampled during the 2009/10 field season to create a profile of Chl-*a* production in the water column. For inter-annual comparison, measured Chl-*a* values were averaged over the upper 100 m target depth samples, then averaged across all stations sampled historically during each leg. The distribution of Chl-*a* production at 10 m depth was mapped using ArcGIS.

#### Results

A total of 87 stations were sampled for primary productivity during the 2009/10 AMLR Survey: 41 stations (covering the Elephant Island Area and part of the Joinville Island Area) during Leg I, and 46 stations (covering the South, Joinville Island and part of the West Areas) during Leg II.

Overall, average Chl-*a* in the euphotic zone (<100 m), averaged over both legs, was  $0.46 \text{ mg m}^{-3}$ , which is lower than recent years (Fig. 2.1). A single station, Station 09-11 in the Bransfield Strait, had a surface (10 m) Chl-*a* value of  $3.47 \text{ mg m}^{-3}$ , more than six times the average. However, mean Chl-*a* was slightly higher at most depths during Leg II than it was during Leg I (Fig. 2.2).

Chl-*a* concentrations ( $\text{mg m}^{-3}$ ) are mapped in Figure 2.3. Higher concentrations of Chl-*a* ( $>0.5 \text{ mg m}^{-3}$ )

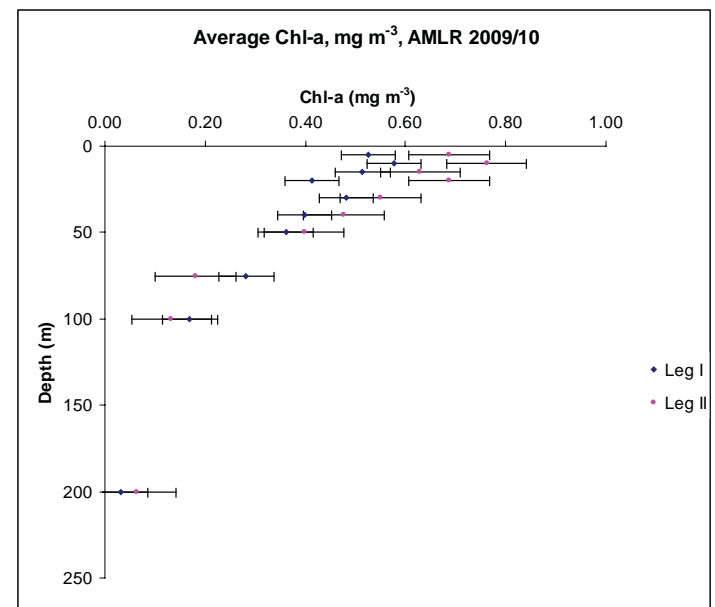


Figure 2.2. Chl-*a* ( $\text{mg m}^{-3}$ ), averaged at each target depth for all stations sampled during the AMLR 2009/10 survey. Comparison between January (Leg I) and February (Leg II) shows a slight increase in productivity through the water column.

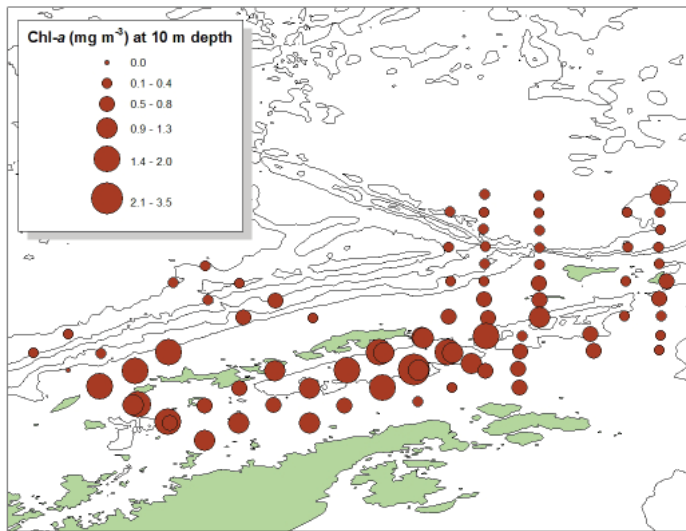


Figure 2.3. Distribution of Chl-*a* concentrations ( $\text{mg m}^{-3}$ ) measured at a target depth of 10 m throughout the sampled area. Samples were taken both in January and February; overlapping circles represent stations that were sampled twice.

were found in the Bransfield Strait, near the Weddell Sea and around Livingston Island. Stations over deeper water had predominantly low concentrations of Chl-*a* ( $<0.5 \text{ mg m}^{-3}$ ).

### Discussion

Logistical and weather difficulties that curtailed the survey period this year decreased the number of stations that were sampled: 87 of 224 planned stations (39%) were successfully sampled. It is important to consider the effects that these data gaps might have on the analysis and interpretation of primary productivity data collected during the 2009/10 AMLR field season, especially when the data are compared to previous years. For example, the survey grid was covered once during the two legs, instead of once during January and once during February, therefore some information on temporal variability throughout the austral summer has been lost. The completed stations were distributed to minimize the impact of the curtailed operation and ensure that each of the four areas was sampled.

Chlorophyll-*a* values overall were lower this year than previous years, which was probably due to changes in oceanographic patterns resulting from climatic forcing (Chapter 1), and likely affected the dynamics of the ecosystem during the 2009/2010 breeding season.

The region around Elephant Island, sampled during Leg I, has historically higher productivity farther north (e.g. Hewes et al., 2008), even extending past the shelf break and into

the pelagic ocean. The Bransfield Strait, sampled during Leg II, had primary productivity values comparable to past years. This suggests a later onset than normal of summer productivity levels, but with little overlap in the samples between legs it's hard to substantiate this hypothesis.

### Protocol Deviations

During the 2009/10 field season, a combination of logistical and weather-based obstacles prevented the completion of the full survey. A total of 39% of planned stations were successfully sampled; however, the missing data will make future time-series analysis difficult. This also results in a loss of data on temporal variability, since 78% of the survey area was covered during January and February, while in previous years this grid is covered twice.

A storm on 28 February, 2010 damaged many of the Niskin bottles used to collect water samples. Subsequently, water samples were collected from fewer depths, focusing on the euphotic zone ( $<100 \text{ m}$  depth). Because of this, some of the auxiliary sample collections (HPLC, phytoplankton taxonomy, nutrients), normally collected at 10 m, were collected at 15 m.

### Disposition of Data

All Chl-*a* and primary productivity data are available from Christian S. Reiss, NOAA Fisheries, Antarctic Ecosystem Research Division, 3333 N. Torrey Pines Court, La Jolla, CA 92037. Ph: 858-546-7127; Fax: 858-546-5608.

### Acknowledgements

We appreciate the hard work and dedication of Captain John Seville and the crew of the R/V *Moana Wave*, whose continued support was instrumental in the success of the 2009/10 AMLR field season.

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**Bioacoustic survey**

Anthony M. Cossio and Christian Reiss

**Abstract**

Multi-frequency acoustic data were collected around the South Shetland and Elephant Islands, Antarctica from January to March 2010. Data were collected to determine the distribution and biomass of krill.

- Around the South Shetland Islands in January through March, mean krill density was 1.6, 18, 7.5 and 4.3 g/m<sup>2</sup> for the West, Elephant Island, South, and Joinville Island Areas, respectively.
- Highest densities of krill were observed around Elephant Island.

**Introduction**

The primary objectives of the bioacoustic survey were to map the meso-scale dispersion of Antarctic krill (*Euphausia superba*) in the vicinity of the South Shetland Islands and to determine their association with predator foraging patterns, water mass boundaries, spatial patterns

of primary productivity, and bathymetry. In addition, efforts were made to map the distribution of myctophids and to determine their relationship with water mass boundaries and zooplankton distribution. Finally, we collected data in order to characterize the benthic environment for future analysis.

Table 3.1. Range of total lengths (TL, mm) and acoustic  $\Delta Sv$  ranges applied to assess biomass of Antarctic krill in the Elephant Island, South and West Areas of the South Shetland Islands region between 1998 and 2009, using the simplified SDWBA model (see Conti and Demer, 2005; and CCAMLR, 2005).

Cruise	Elephant Island Area			West Area			South Area		
	Krill length	120-38	200-120	Krill length	120-38	200-120	Krill length	120-38	200-120
1996A	18-59	2.5 to 14.7	-0.5 to 2.1	x	x	x	x	x	x
1996D	20-57	2.5 to 14.7	-0.5 to 2.1	x	x	x	x	x	x
1997A	19-58	2.5 to 14.7	-0.5 to 2.1	17-58	2.5 to 17.7	-0.5 to 6.8	15-52	2.5 to 17.7	-0.5 to 6.8
1998A	17-53	2.5 to 17.7	-0.5 to 6.8	15-52	2.5 to 17.7	-0.5 to 6.8	16-44	4.6 to 17.7	-0.5 to 6.8
1998D	21-52	2.5 to 14.7	-0.5 to 2.1	19-53	2.5 to 14.7	-0.5 to 2.1	19-48	4.6 to 14.7	-0.5 to 2.1
1999A	32-54	2.5 to 11.1	-0.5 to 0.4	30-54	2.5 to 11.1	-0.5 to 0.4	26-52	2.5 to 14.7	-0.5 to 2.1
1999D	35-56	2.5 to 11.1	-0.5 to 0.4	36-51	4.6 to 11.1	-0.5 to 0.4	x	x	x
2000D	39-58	2.5 to 7.7	-0.5 to -0.3	39-59	2.5 to 7.7	-0.5 to -0.3	40-55	2.5 to 7.7	-0.5 to -0.3
2001A	18-57	2.5 to 14.7	-0.5 to 2.1	40-60	2.5 to 7.7	-0.5 to -0.3	22-55	2.5 to 14.7	-0.5 to 2.1
2001D	26-60	2.5 to 14.7	-0.5 to 2.1	26-60	2.5 to 14.7	-0.5 to 2.1	28-57	2.5 to 14.7	-0.5 to 2.1
2002A	17-59	2.5 to 17.7	-0.5 to 6.8	18-60	2.5 to 17.7	-0.5 to 6.8	20-45	4.6 to 14.7	-0.5 to 2.1
2002D	21-59	2.5 to 14.7	-0.5 to 2.1	20-56	2.5 to 14.7	-0.5 to 2.1	20-49	4.6 to 14.7	-0.5 to 2.1
2003A	13-53	2.5 to 17.7	-0.5 to 6.8	13-54	2.5 to 17.7	-0.5 to 6.8	13-45	4.6 to 17.7	-0.5 to 6.8
2003D	15-53	2.5 to 17.7	-0.5 to 6.8	19-54	2.5 to 14.7	-0.5 to 2.1	16-49	4.6 to 17.7	-0.5 to 6.8
2004A	21-55	2.5 to 14.7	-0.5 to 2.1	24-57	2.5 to 14.7	-0.5 to 2.1	20-57	2.5 to 14.7	-0.5 to 2.1
2004D	29-58	2.5 to 11.1	-0.5 to 0.4	22-55	2.5 to 14.7	-0.5 to 2.1	18-56	2.5 to 17.7	-0.5 to 6.8
2005A	20-59	2.5 to 14.7	-0.5 to 2.1	21-57	2.5 to 14.7	-0.5 to 2.1	20-57	2.5 to 14.7	-0.5 to 2.1
2005D	28-57	2.5 to 14.7	-0.5 to 2.1	39-55	2.5 to 7.7	-0.5 to -0.3	19-53	2.5 to 14.7	-0.5 to 2.1
2006A	25-61	2.5 to 14.7	-0.5 to 2.1	41-60	2.5 to 7.7	-0.5 to -0.3	26-59	2.5 to 14.7	-0.5 to 2.1
2007A	16-60	2.5 to 17.7	-0.5 to 6.8	19-58	2.5 to 14.7	-0.5 to 2.1	19-55	2.5 to 14.7	-0.5 to 2.1
2008A	19-57	2.5 to 14.7	-0.5 to 2.1	19-57	2.5 to 14.7	-0.5 to 2.1	16-56	2.5 to 17.7	-0.5 to 6.8
2008D	19-58	2.5 to 14.7	-0.5 to 2.1	x	x	x	21-51	4.6 to 14.7	-0.5 to 2.1
2009A	19-58	2.5 to 14.7	-0.5 to 2.1	20-57	2.5 to 14.7	-0.5 to 2.1	14-51	4.6 to 17.7	-0.5 to 6.8
2010A	18-60	2.5 to 14.7	-0.5 to 2.1	x	x	x	x	x	x
2010D	x	x	x	30-58	2.5 to 11.1	-0.5 to 0.4	23-58	2.5 to 14.7	-0.5 to 2.1

Table 3.2. Daytime krill density estimates by area and transect for Leg I of the 2009/10 AMLR Survey.  $n = 1$  interval = 1 nautical mile. Transects are ordered from west to east in each area. Transects 2 and 7 in the South Area were completed at night, therefore no acoustic data are available for those transects.

Area	Transect	n	Krill density (g/m <sup>2</sup> )
West Area	Transect 1	20	2.4
	Transect 2	46	1.9
	Transect 5	48	1.6
	Transect 6	44	0.9
Elephant Island Area	Transect 2	62	15.3
	Transect 3	82	17.8
	Transect 4	105	15.8
	Transect 6	48	28.5
South Area	Transect 7	83	17.5
	Transect 1	66	0.02
	Transect 2	NA	NA
	Transect 3	46	11.1
	Transect 4	17	5.7
	Transect 5	28	22.1
	Transect 6	21	4.9
Transect 7	NA	NA	

## Methods

### Data Collection

Acoustic data were collected using a multi-frequency echo sounder (Simrad EK60) configured with down-looking 38, 120, and 200 kilohertz (kHz) split-beam transducers mounted in the hull of the ship. System calibrations were conducted after the survey using standard sphere techniques while the ship was at anchor in Ezcurra Inlet, King George Island. During the surveys, pulses were transmitted every two seconds at one kilowatt for one millisecond duration at 38 kHz, 120 kHz and 200 kHz. Geographic positions were logged simultaneously every two seconds. Ethernet communications were maintained between the EK60 and a Windows XP workstation. The workstation was used for primary system control, data logging, and data processing using Myriax Echoview software.

Acoustic surveys of the water surrounding the South Shetland Islands were divided into four areas (Figure 2, Introduction): (1) a 43,865 km<sup>2</sup> area centered on Elephant Island (Elephant Island Area) was sampled with five north-south transects; (2) a 29,031 km<sup>2</sup> area along the north side of the southwestern portion of the South Shetland Island archipelago (West Area) was sampled with four transects oriented northwest-southwest and one oriented north-south; (3) a 24,479 km<sup>2</sup> area in the western Bransfield Strait (South Area) was sampled with five transects oriented northwest-southwest; and (4) an 18,151 km<sup>2</sup> area

north of Joinville Island (Joinville Island Area) with three transects.

Acoustic data recorded while on biological sampling stations were discarded from analyses. Further, only daytime data were used in this analysis due to possible bias from diurnal vertical migration of krill above the transducer depths during night time (Demer and Hewitt, 1995).

### Data Analysis

Krill are delineated from other scatterers by use of a three frequency  $\Delta Sv$  method (Hewitt et al., 2003; Reiss et al., 2008). The  $\Delta Sv$  range is dynamic and is based on krill length ranges present in each survey area (CCAMLR, 2005; Table 3.1). This differs from previous work when analyses were conducted using a constant range of  $\Delta Sv$  ( $4 \leq (Sv,120 - Sv,38) \leq 16$  dB and  $-4 \leq (Sv,200 - Sv,120) \leq 2$  dB). Table 3.1 shows the ranges of krill lengths as well as the dynamic  $\Delta Sv$  ranges used between 1996 and present.

A  $\Delta MVBS$  window of -5 to 2 dB was applied to a two-frequency (38 kHz and 120 kHz) method for the purpose of delineating myctophids. This range was chosen based on observed differences in myctophid backscattering values between 38 kHz and 120 kHz.

Backscatter values were averaged over 5 m by 100 s bins. Time varied gain (TVG) noise was subtracted from the echogram and the  $\Delta Sv$  range was applied. TVG values were based on levels required to erase the rainbow effect plus 2 dB. The remaining volume backscatter classified as krill was integrated over depth (500m) and averaged over 1,852 m (1 nautical mile) distance intervals.

Integrated krill nautical area scattering coefficient (NASC) (MacLennan and Fernandes, 2000) was converted to estimates of krill abundance ( $\rho$ ) by dividing the sum of the weighted-mean masses per animal ( $W$ ; g/krill) by the sum of the backscattering cross-sectional area of krill ( $\sigma$ ;  $\sigma = 4\pi r^{10} 10^{TS/10}$  where  $r$  is the reference range of 1 m; Hewitt and Demer, 1993). The length to weight relationship

$$(1) \quad W(g) = 2.236 \cdot 10^{-3} \cdot TL^{3.314}$$

was based on net samples collected during the international krill biomass survey of the Scotia Sea conducted during January 2000 (Hewitt et al., 2004). Krill abundance was estimated according to Hewitt and Demer (1993):

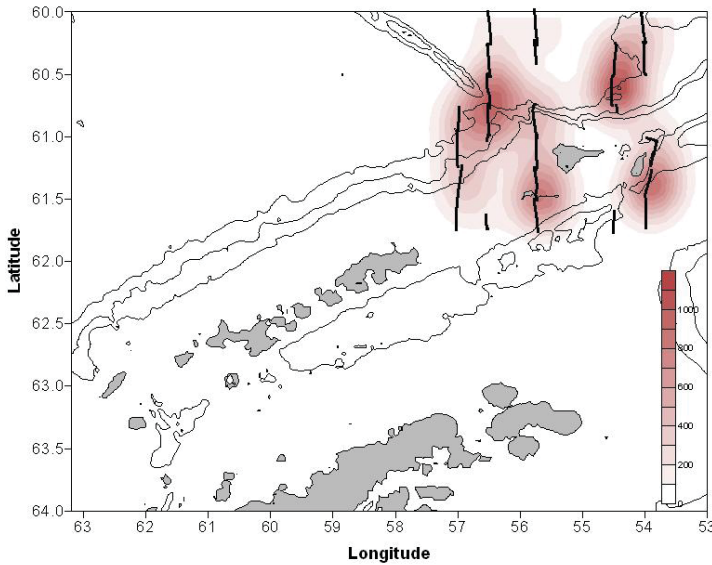


Figure 3.1. Normalized krill NASC values collected during January (Leg I) at 120 kHz, using day data (Latitude is south and longitude is west).

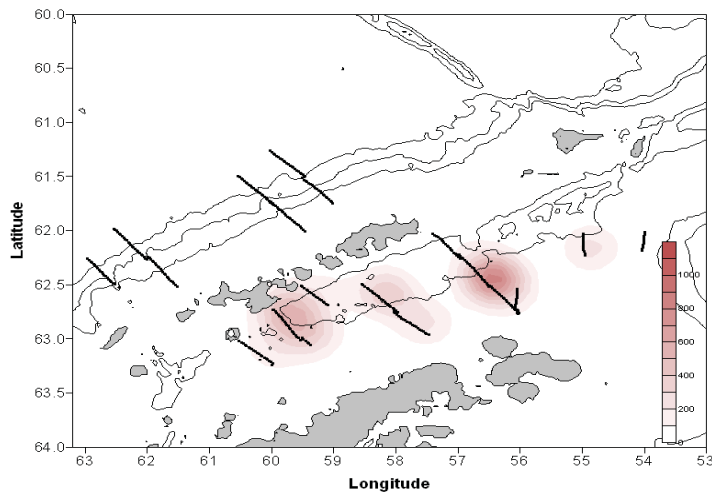


Figure 3.2. Normalized krill NASC values collected during February (Leg II) at 120 kHz, using day data (Latitude is south and longitude is west).

$$(2) \quad \rho(\text{g/m}^2) = \frac{\sum_{i=1}^n f_i W(l_i) \text{ NASC}}{\sum_{i=1}^n f_i \sigma(l_i)}$$

where  $f_i$  = the relative frequency of krill of standard length  $l_i$ . Krill biomass was then estimated by multiplying  $\rho$  by the area surveyed.

For each area in each survey, mean biomass density attributed to krill and its variance were calculated by assuming that the mean abundance along a single transect was an independent estimate of the mean abundance in the area (Jolly and Hampton, 1990). We used the cluster estimator of Williamson (1982) to calculate the variance of

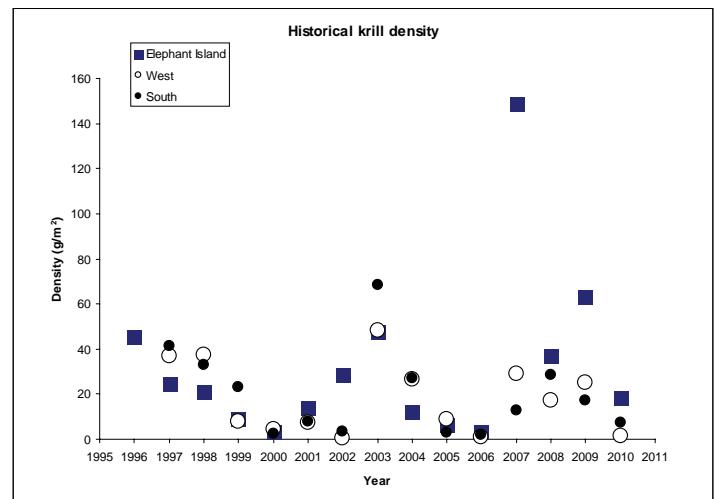
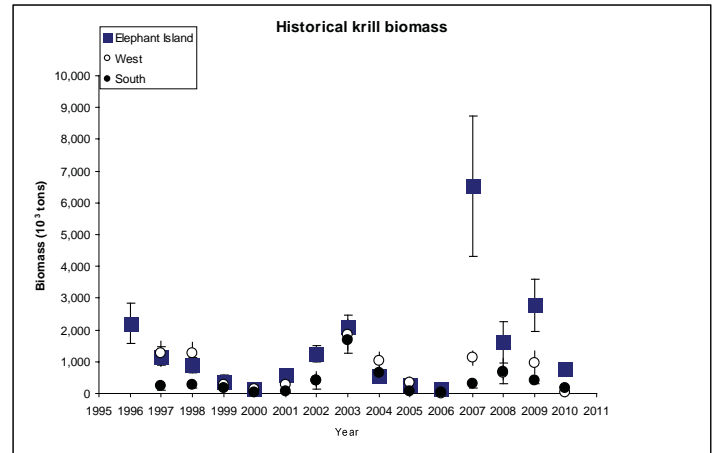


Figure 3.3. Historical (1996-2010) krill biomass ( $10^3$  tons; top) and integrated krill density ( $\text{g/m}^2$ ; bottom) values for Elephant Island, West and South Areas. Variability in historical krill biomass is represented by multiplying the CV by the biomass.

NASC within each area and to expand the abundance estimate for the South Shetlands.

No myctophid biomass estimates were made because of the lack of target strength data and length frequency distributions. Instead, the NASC attributed to myctophids was integrated using Myriax Echoview software and then mapped across the South Shetland Islands using SURFER (Golden Software, Inc. Golden, CO).

### Results

Mean krill density was 1.6, 18, 7.5, and 4.3  $\text{g/m}^2$  for the West, Elephant Island, South, and Joinville Island Areas, respectively, during Legs I and II. Highest densities were seen around Elephant Island during Leg I (Figure 3.1). Krill densities were lower in the Bransfield Strait during Leg II (Figure 3.2). The biomass estimates for this year are

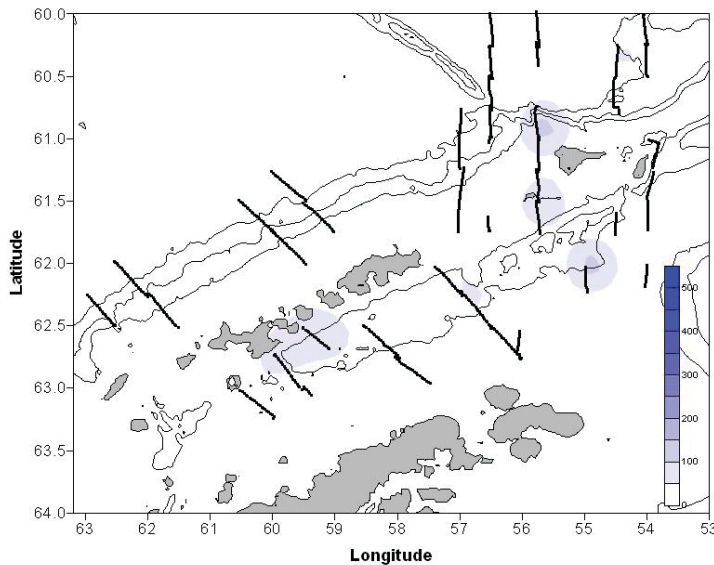


Figure 3.4. Normalized myctophid NASC values collected during January and February 2010 at 120 kHz, using day data (Latitude is south and longitude is west).

lower than the previous year, and similar to 2006 values (Figure 3.3). Myctophid NASC values are lower on average from previous years (Figure 3.4).

### Discussion

Biomass estimates are lowest since 2006. Highest krill densities were seen around Elephant Island, which has historically been a region of high krill density. Weather may be a factor in location of the krill; this year there were strong storms from the east, which may have affected their distribution.

Traditionally, acoustic transects for all survey areas are completed once during each leg of the cruise, for a total of two complete surveys. However, due to weather constraints, the acoustic transects were completed once over the two-month cruise period. Future analysis of this data should be conducted with this caveat in mind.

### Protocol Deviations

Due to logistical difficulties and curtailed operations, less than half of the planned survey effort was completed. Several transects that are historically surveyed twice during one field season were not completed this year. These include Transect 3 and 4 in the West Area, occupying the center of the area, and Transects 1 and 5 in the Elephant Island Area (transects are numbered from west to east). Additionally, Transects 2 and 7 in the South Area were not used data analysis because they were completed at night.

The remaining transects were surveyed only once during the field season.

However, due to the small ship draft, data were collected in bays and between the islands, where the survey has not historically collected data. The collected data are from areas such as the Nelson Strait, Discovery Bay, and Marion Bay.

Additionally, a meeting of acoustic experts from CCAMLR member nations is scheduled for June 2010 in Cambridge, UK. The data analysis protocol and SDWBA model will be corrected and these biomass estimates will probably change. The changes will be reflected in next year's field season report.

### Disposition of Data

All integrated acoustic data will be made available to other U.S. AMLR investigators in ASCII format files. The analyzed echo-integration data consume approximately 10 MB. The data are available from Anthony Cossio, Southwest Science Center, 3333 North Torrey Pines Court, La Jolla, CA 92037; phone/fax – (858) 546-5609/546-5608; e-mail: Anthony.Cossio@noaa.gov.

### Acknowledgements

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## Zooplankton Abundance around the South Shetland Islands, Antarctica

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### Abstract

Zooplankton abundance and Antarctic krill demography around the South Shetland Islands and Elephant Island, Antarctica is described using data collected during the 2009/10 AMLR field season, conducted in January and February of 2010. The results from this survey included:

- A total of 82 stations were sampled throughout the South Shetland Islands; krill were present at 61 of those stations.
- The average abundance of krill during austral summer 2009/10 was 198 (SD 990) krill per 1,000 m<sup>3</sup>. The high standard deviation indicates a patchy distribution.
- The tunicate *Salpa thompsoni* had the greatest average abundance (1,918 per 1,000 m<sup>3</sup>, SD 5,181) by far, nearly twice the next taxonomic group, the copepods (1,135 per 1,000 m<sup>3</sup>, SD 2,686). *Thysanoessa macrura* followed copepods with an abundance of 259 per 1,000 m<sup>3</sup> (SD 399).
- *Salpa thompsoni* was distributed throughout the South Shetland Island region, and was found in greatest numbers in the Bransfield Strait.

### Introduction

The zooplankton community plays a crucial trophic role in the Antarctic ecosystem. Most of the upper trophic level predators such as baleen whales, fur seals, penguins and other seabirds depend on Antarctic krill (*Euphausia superba*; hereafter referred to as krill) as their primary food source. Additionally, the structure of the zooplankton community is sensitive to changes in the ecosystem, and can serve as an indicator of local response to global climate change (Hays et al. 2005).

As a complement to acoustic sampling (Chapter 3), net sampling was used to estimate zooplankton abundance and assess krill demography. Krill length frequency distributions were used to refine the acoustic estimate of krill biomass in the South Shetland Islands presented by Cossio and Reiss (Chapter 3). Krill lengths and demography can also be compared to oceanographic and predator data, both spatially and temporally.

Logistical difficulties reduced the amount of time available for the survey; therefore a reduced survey was expected. However, the inability to carry out net tows in fairly typical Antarctic sea conditions was not expected and resulted in the completion of <50% of the scheduled stations (82 of 214). Zooplankton catch and krill demography from 74 unique stations are summarized in this report.

### Methods

Zooplankton were collected using an Isaacs-Kidd Midwater Trawl (IKMT) net with a 1.8 m opening and 505

µm mesh net. A General Oceanics flowmeter (Model 2030R) was mounted to the net frame to calculate the volume of water filtered during each tow. All tows were fished obliquely to 170 m depth or to approximately 20 m from the bottom, measured using a hard-wired depth sensor mounted to the net's bridle. During each tow, the ship maintained a speed of approximately two knots; the net was deployed at 40 m min<sup>-1</sup> and retrieved at 20 m min<sup>-1</sup>. Each tow was assigned a categorical time of day. Day was defined as one hour after sunrise to one hour before sunset, night as one hour after sunset to one hour before sunrise, and transition as one hour before and after sunset and sunrise.

All samples were processed on board using the following procedure:

- Post-larval krill were counted and retained separately (refrigerated or frozen) for demographic analysis. When the sample yielded fewer than 100 krill, all individuals were measured, sexed and assessed for maturity stage. When a larger number of krill were encountered, a minimum subsample of 100 krill were randomly collected and analyzed. The total length (mm) of krill was measured as the distance from the rostrum to the telson (Standard 1 as described by Mauchline, 1980). Krill were sexed and staged based on the Makarov and Denys (1981) classification system.
- Juvenile and adult fish (typically myctophids) were identified, counted, measured (standard length) and frozen for future fatty acid analysis (Chapter 6).
- Salps (*Salpa thompsoni* and *Ihleia racovitzai*) were count-

ed and measured (up to 100 individuals per sample) according to the methods presented by Foxton (1966).

- All other macrozooplankton (e.g. postlarval euphausiids, amphipods, pteropods, polychaetes) were identified and counted.
- A subsample of the remaining organisms was examined using a stereo microscope and smaller organisms (e.g. larval euphausiids, copepods) were counted and identified to the lowest taxonomic level possible. This process was repeated at least twice, and the total of the subsamples was used to estimate the total species composition for the sample.
- For larger samples, a subset of the total sample was counted and the total sample value was extrapolated based on the subset.

The processed samples were preserved in 10% buffered formalin and sent to the Southwest Fisheries Science Center for long-term storage.

### Analysis

The catch of each zooplankton species was standardized for each station by dividing the counts by volume of water filtered (No. per 1,000 m<sup>3</sup>). Leg I data is only presented qualitatively (i.e., presence/absence) in figures as the winch meter and depth sounder were improperly calibrated, therefore we are uncertain of fishing depth for the duration of Leg I. The depth sounder was calibrated again before Leg II and a Vemco Minilog-TD temperature-depth recorder (TDR) was placed on the net to verify the depth sounder accuracy. For each of the four most common species, a distribution map was created using ArcGIS (ESRI), and historical catch estimates were plotted and compared for

trends.

Average abundance ( $\bar{x}$ ) was calculated using Leg II stations only, using the following formula:

$$(1) \quad \bar{x} = \sum_1^j (T_j/V_j) \div W$$

where the total number of individuals ( $T$ ) collected at tow  $j$  is divided by the volume ( $V$ ) of water filtered (unit = 1,000 m<sup>3</sup>) at tow  $j$ , summed across all tows, and divided by the number of tows completed ( $W$ ).

Krill and salp length-frequency and krill maturity stage distributions were combined for the entire 2009/10 field season. The length-frequency distributions (LFD) of krill and salps were weighted using the following formula:

$$(2) \quad L_i = \sum_1^j ((n_{ij} * (T_j \div M_j)) * D_j) * V_j$$

where the estimated proportion of the catch ( $L$ ) at length  $i$  is equal to the number of individuals ( $n$ ) at length  $i$  for tow  $j$ , multiplied by the total number of individuals ( $T$ ) in tow  $j$  divided by the number of measured individuals ( $M$ ) in

Table 4.1. Frequency of occurrence (% tows with positive catch), mean, standard deviation, median and maximum catch (No. per 1,000 m<sup>3</sup>), percent of total catch (%Tot) and rank of total catch percent for all Leg II stations combined (n=42). Table includes zooplankton with a rank of 10 or less in at least one survey area.

Group / Species	FO(%)	Mean	StDev	Median	Max	%Tot	Rank
<b>Amphipoda</b>							
<i>Cylopus magellanicus</i>	69%	3.6	6	1.2	25.4	0.10%	12
<i>Themisto gaudichaudi</i>	76%	4.8	6.9	2	25.5	0.10%	10
<i>Vibilia antarctica</i>	90%	5.6	7	3.1	28.1	0.20%	9
<i>Amphipod, Unidentified</i>	62%	3.1	4.5	1.1	16	0.10%	13
<b>Chaetognatha</b>	88%	50.3	90.7	10.4	355.3	1.40%	6
<b>Copepoda</b>	100%	1,135.00	2,686.00	338.1	16,944.70	30.70%	2
<i>Calanoides acutus</i>	83%	44.6	87.2	20.1	520.3		
<i>Calanus propinquus</i>	86%	16.2	26.9	7.3	152.3		
<i>Metridia gerlachei</i>	86%	560.6	1,435.20	64.8	7,970.60		
<i>Paraeuchaeta spp.</i>	60%	23.9	46.6	1.2	187.5		
<i>Pleuromamma robusta</i>	14%	1.7	7.4	0	46.9		
<i>Rhincalanus gigas</i>	88%	75.2	179.8	13.3	813.9		
<i>Rhincalanus spp.</i>	45%	16.8	58.3	0	362.1		
Copepod, Unidentified	81%	330.2	1,312.90	48.4	8,533.20		
Copepod, Other	83%	65.9	149.1	13.9	884		
<b>Euphausiidae</b>							
<i>Euphausia superba</i> (Adult)	76%	197.8	989.8	1.2	6,406.40	5.30%	4
( <i>E. superba</i> excluding Stn. D11-13)		46.4	130.3	1.1	713.2		
<i>Euphausia superba</i> (Larvae)	10%	4.3	21.8	0	140.6	0.10%	11
<i>Euphausia frigida</i> (Adult)	60%	23.9	57.8	2.5	293	0.60%	7
<i>Thysanoessa macrura</i> (Adult)	100%	259.2	399.6	152.5	2,550.80	7.00%	3
<i>Thysanoessa macrura</i> (Larvae)	71%	54.2	132.1	4	656.3	1.50%	5
<b>Ostracoda</b>	48%	12.7	26.1	0	140.6	0.30%	8
<b>Tunicata</b>							
<i>Ihlea racovitzai</i>	21%	2	6.4	0	35.5	0.10%	18
<i>Salpa thompsoni</i>	93%	1,918.40	5,181.20	399.4	31,543.30	51.90%	1
( <i>S. thompsoni</i> excluding Stn. D09-11)		1,195.80	2,245.00	360.5	10,045.60		

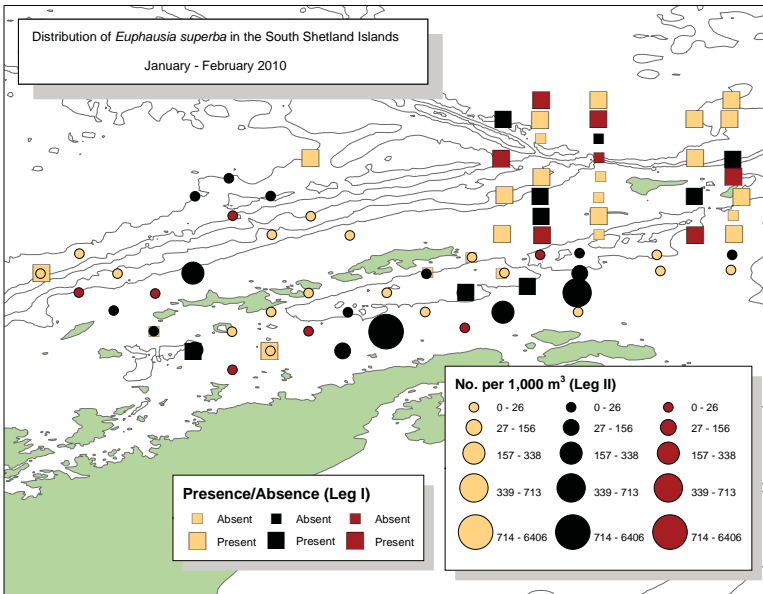


Figure 4.1. Distribution of krill based on net tows conducted around the South Shetland and Elephant Islands in 2009/2010. Only presence/absence is indicated for Leg I. Leg II catch rates from 2010 represent samples taken primarily from the South and Joinville Island Areas, as well as 14 samples from the West Area. Night samples are black, day samples are yellow and twilight samples are red.

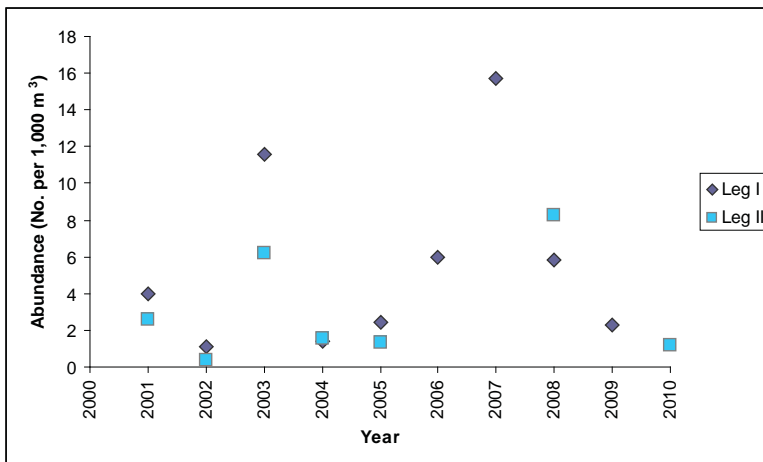


Figure 4.2. Historical median krill abundance (No. per 1,000 m<sup>3</sup>) by leg and year, 2001-2010. Leg I typically overlaps January and February and Leg II overlaps February and March. Leg II data from 2010 represents samples taken primarily from the South and Joinville Island Areas, as well as 14 samples from the West Area.

tow  $j$ , then multiplied by the depth ( $D$ ) at tow  $j$  and water volume filtered ( $V$ , unit = 1,000 m<sup>3</sup>). Leg I depths were assumed to be 170 m. For the krill distribution, only individuals that had a length, sex and maturity were included (e.g., if only gender was known, it was excluded from this calculation) which excluded 24 individuals of 2,251 in the total length frequency sample.

Relative patchiness (or index of dispersion,  $ID$ ) was estimated for stations sampled during Leg II only. The estimate is based on the mean ( $\bar{x}$ ) to variance ( $s$ ) ratio, using the following formula:

$$(3) \quad ID = s^2 \div \bar{x}$$

Recruitment indices were calculated using the number of first-year krill relative to the total number of krill, calculated according to the methods presented by Siegel et al. (2002). First-year krill were categorized by their length, based on the method used in Siegel (1987).

## Results

A total of 82 tows at 74 unique stations were sampled throughout the South Shetland Islands and more than 130 taxonomic categories were identified. Of these, the ten most abundant groups are listed in Table 4.1.

### Postlarval krill

A total of 26,354 krill were caught at 61 stations for the entire survey. Of the total, 18,012 were caught at a single station (D11-13) during Leg II. Krill catches were highest in Bransfield Strait (South Area) and around Livingston Island, with some krill near Elephant Island (Figure 4.1).

Average krill catch during Leg II was 198 (S.D. = 990) krill per 1,000 m<sup>3</sup>, with a decrease to 46 (S.D. 130) krill per 1,000 m<sup>3</sup> when D11-13 is excluded. Median krill catch was 1.2 krill per 1,000 m<sup>3</sup>. Leg II median krill catch rates were similar to Leg II rates encountered in 2002, 2004 and 2005 (Figure 4.2).

The high standard deviation in the krill catch indicates a large amount of variability in the distribution of krill during the 2009/10 field season. Relative patchiness during the 2009/10 AMLR field season was 4,952 with D11-13 (366 without D11-13), which was higher than the 2008/09 patchiness index.

Krill catch during Leg II varied widely by time of day. An average of two krill were caught per 1,000 m<sup>3</sup> for day tows, while 485 krill were caught per 1,000 m<sup>3</sup> at night.

Larger krill, representing the majority of krill caught during the 2009/10 field season, were present at most stations where krill were caught. Smaller, juvenile krill were concentrated in the Bransfield



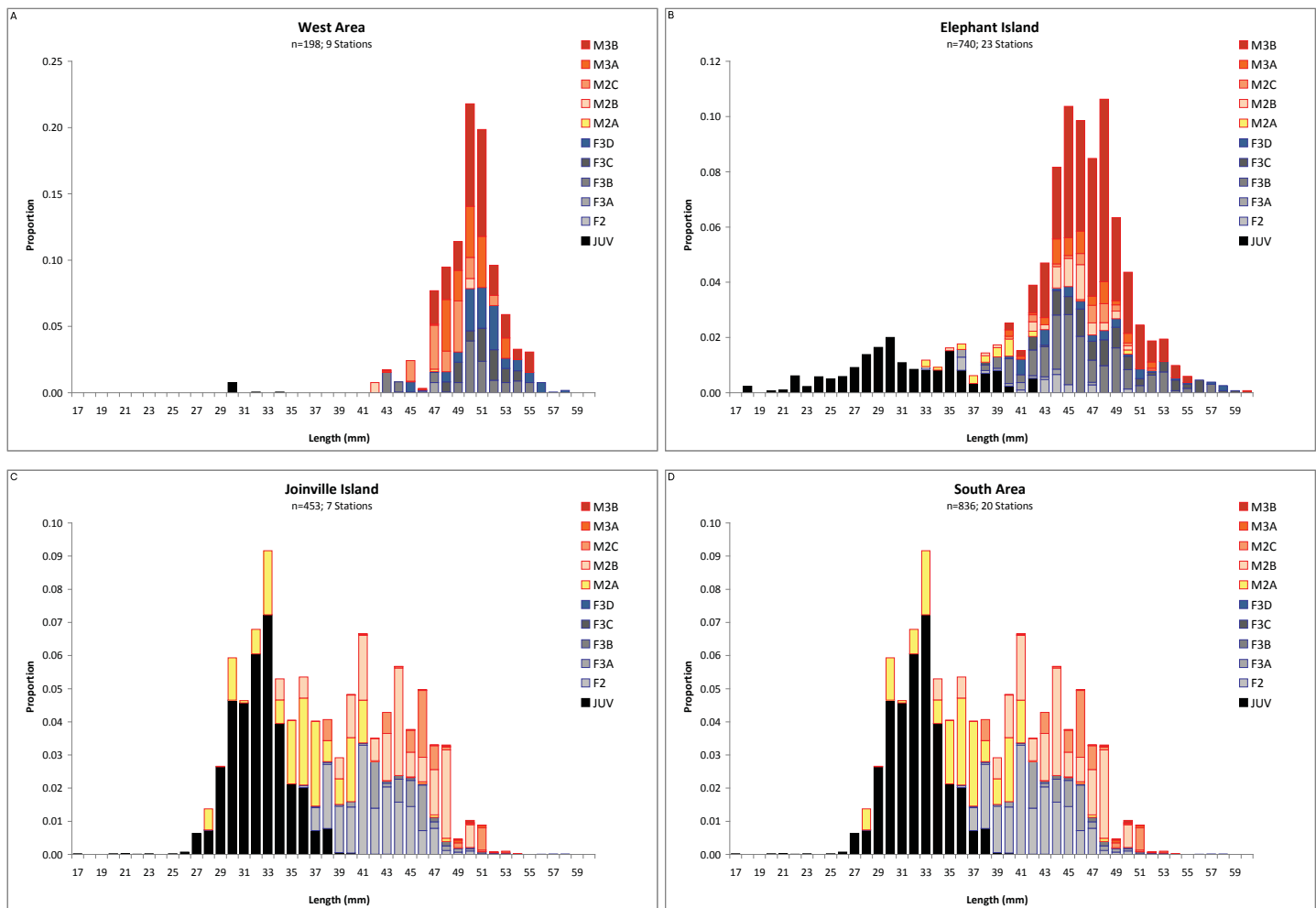


Figure 4.3. Length-frequency distribution of krill by gender, maturity stage and area. A) West Area; B) Elephant Island; C) Joinville Island; and D) South Area. M and F are Male and Female, respectively. Maturity stages according to Makarov and Denys (1981).

Strait and around Elephant Island, with a few small krill at off-shore pelagic stations. Krill demography differed by area (Figure 4.3). The West Area consisted of larger, mostly mature krill (40% F3 and 45% M3) and very few juveniles (1%). The Elephant Island area had more juveniles (17%) and 70% mature krill (30% F3 and 40% M3). The Joinville Island area had the highest proportion of juveniles (68%) and immature krill (21% F2 and M2). The South Area also had a high proportion of juveniles (31%) and immature krill (40%).

Of the total number of krill measured (2,251), 17% were under 35 mm, representing first-year class recruitment. A total of 37% were 35-45 mm (second-year class) and 45% were larger than 45 mm (third-year class and older).

#### Larval krill

Larval krill were present at only 12 stations and in very

low numbers during the 2009/10 AMLR field season. Stations where larval krill are historically caught (e.g. offshore stations north of the South Shetland Islands and to the north of Elephant Island) were not sampled this year, so data on larval krill abundance are incomplete. Those krill that were found were all at stations around Elephant Island or in the Joinville Island Area. The largest number of larval krill, 141 per 1,000 m<sup>3</sup>, was found at the eastern edge of the Bransfield Strait (Joinville Island Area). The Leg II mean catch rate was 4.3 per 1,000 m<sup>3</sup> (S.D. 22) and consisted entirely of calyptopsis stages I and II.

#### Other zooplankton

The tunicate *Salpa thompsoni* had the greatest average catch (1,918 per 1,000 m<sup>3</sup>, S.D. 5,181), nearly double the next taxonomic group, the copepods (1,135 per 1,000 m<sup>3</sup>, S.D. 2,686). *Thysanoessa macrura* had the third highest catch rate

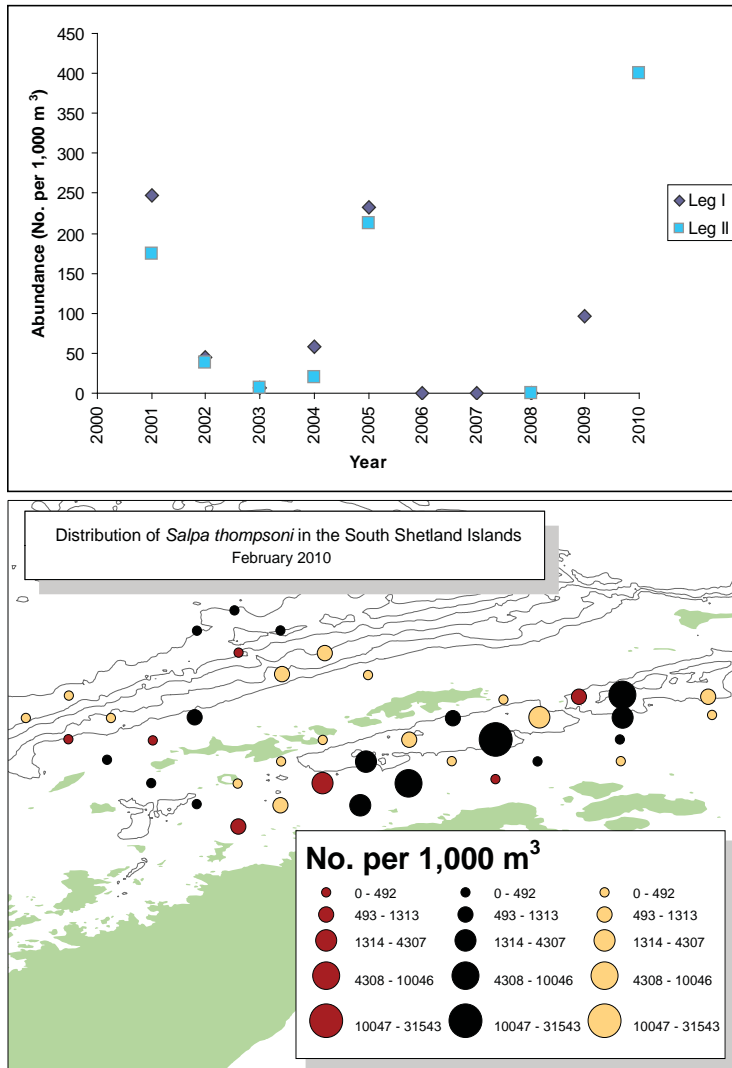


Figure 4.4. Historical median abundance (A) and February distribution (B, night samples are black, day samples are yellow and twilight samples are red) of *Salpa thompsoni*. Leg II data from 2010 represents samples taken primarily from the South and Joinville Island Areas, as well as 14 samples from the West Area.

(259 per 1,000 m<sup>3</sup>; S.D. 400). Other common species or groups included amphipods, chaetognaths, ostracods and *E. frigida* (Table 4.1).

Salps were distributed throughout the South Shetland Island region (93% of Leg II stations), and were found in greatest density in the Bransfield Strait (Figure 4.4). More than 100,000 salps were caught at station D09-11 at the northeast end of the Bransfield Strait. The mean catch rate without this outlier was 1,196 per 1,000 m<sup>3</sup> (SD 2,245). The salp catch rate was nearly an order of magnitude higher at night compared to day which may be a function of night tow location (e.g., more night and transition tows occurred in the middle of Bransfield Strait). Compared

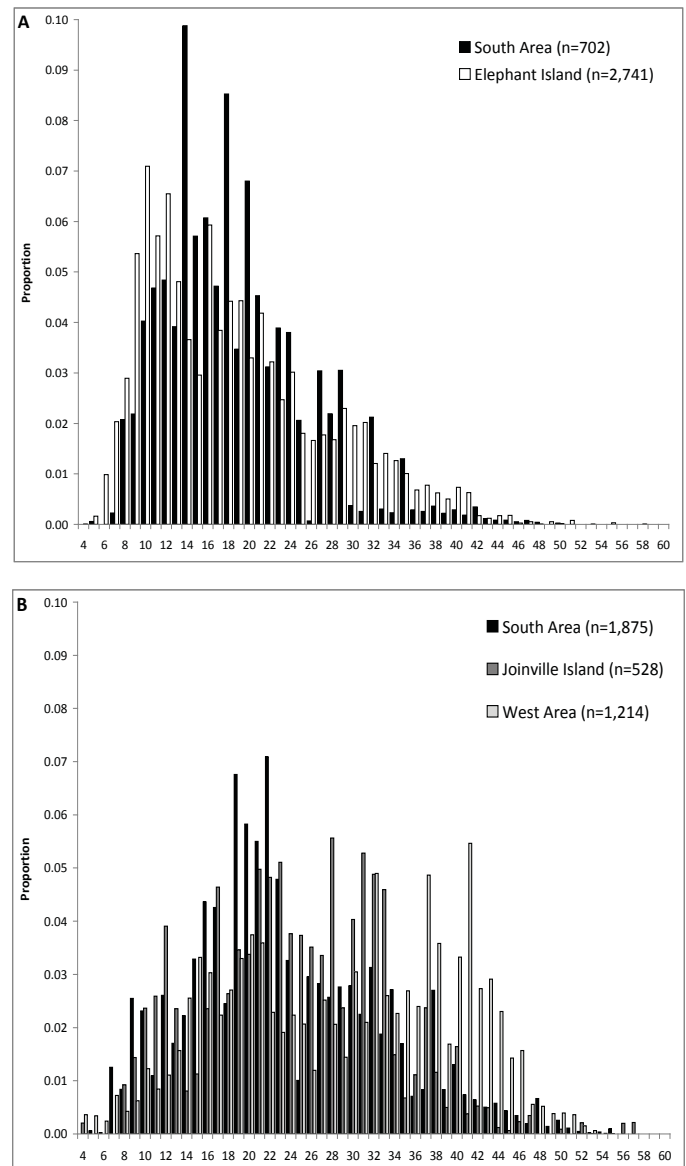


Figure 4.5. Salp length frequency distribution for Leg I (A) and Leg II (B). Distribution was cropped at 60 mm as very few salps >60 mm were encountered. Maximum length was 104 mm.

to the past, the salp catches in 2010 appear significantly higher than all other years (Figure 4.4) even when the outlier is excluded. Very few (<0.5%) solitary salps were encountered. Salps lengths were similar in the South Area and Elephant Island during Leg I and tended to be larger in the West Area during Leg II (Figure 4.5).

The most commonly identified copepods include: *Calanus propinquus*, *Calanoides acutus*, *Rhincalanus gigas*, *Metridia gerlachei*, *Paraeuchaeta spp.*, and *Pleuromama robusta* (Table 4.1). Copepods were distributed throughout the South Shetland and Elephant Island region, with an

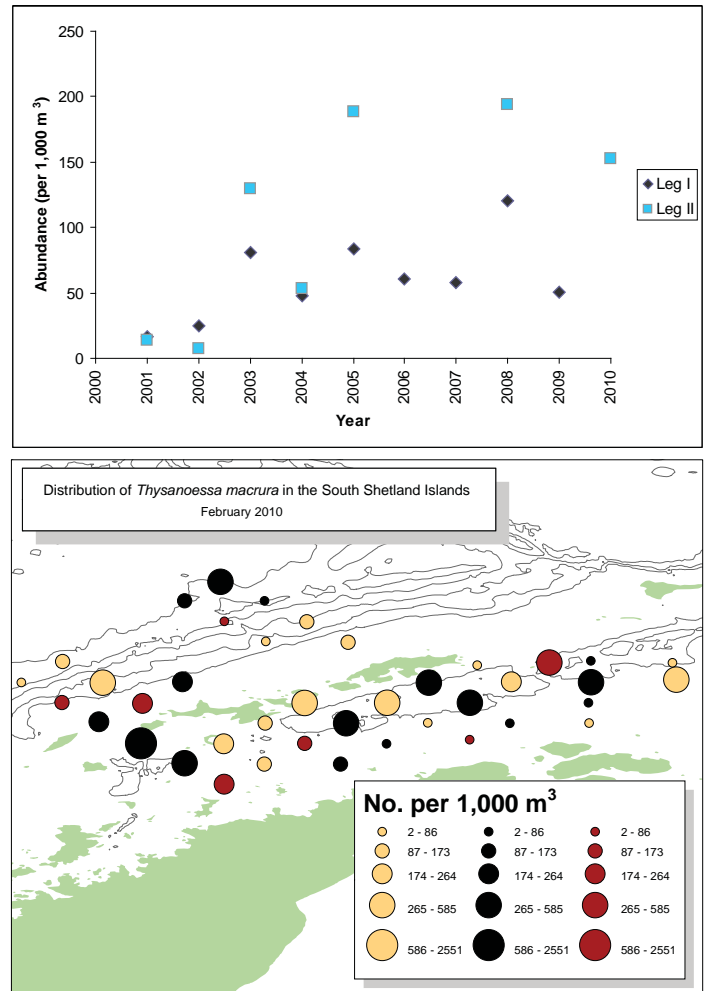
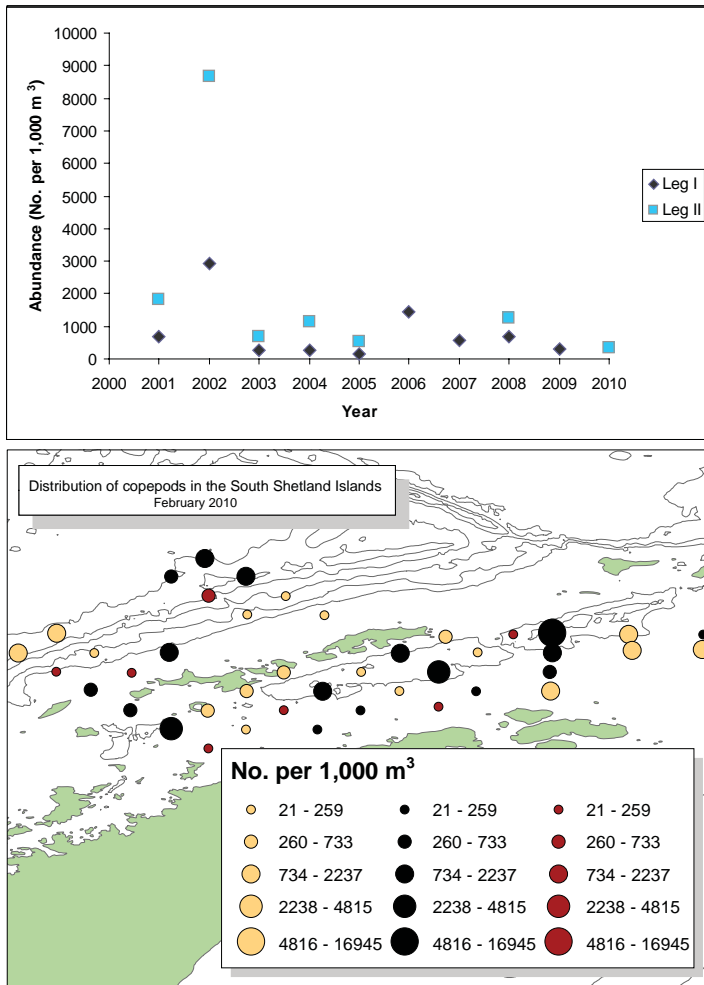


Figure 4.6. Historical median abundance (A) and February distribution (B; night samples are black, day samples are yellow and twilight samples are red) of copepods. Leg II data from 2010 represents samples taken primarily from the South and Joinville Island Areas, as well as 14 samples from the West Area.

Figure 4.7. Historical median abundance (A) and February distribution (B, night samples are black, day samples are yellow and twilight samples are red) of *Thysanoessa macrura*. Y-axis in (A) was limited to 400 in order to maintain resolution in other years; however, the full lower extent is shown. Leg II data from 2010 represents samples taken primarily from the South and Joinville Island Areas, as well as 14 samples from the West Area.

overall catch rate similar to the previous two years (Figure 4.6). Copepod catch was higher at night (2,105 per 1000 m<sup>3</sup> vs. 601 per 1000 m<sup>3</sup> during the day) which was primarily driven by differences in the catch of *M. gerlachei*.

*T. macrura* catch rates were greater in 2010 than 2009, but were similar to 2008 (Fig. 4.7). The largest catches of *T. macrura* occurred in the Bransfield Strait and around Joinville Island.

**Discussion**

During the 2009/2010 AMLR field season, logistical difficulties curtailed the sampling period (see Protocol Deviations). The survey was structured to minimize the area that was not sampled to the preserve the integrity of

the grid, however due to the loss of data, certain aspects of the analysis have been compromised, especially any analysis of intra-seasonal variability.

Zooplankton abundance was calculated using only the tows completed in February, since those completed in January are of unknown depth (data collected in January is presented as presence/absence data). In 2010, the abundance of krill in February was less than the abundance of krill in January 2009. This decrease could reflect annual rather than seasonal variability, as krill abundance typically increases throughout the breeding season. Examination of the maturity-stage and length-frequency distribution shows that larger krill were concentrated in areas with

a higher proportion of deeper, off-shore stations (i.e., West and Elephant Island Areas), while the two areas that are shallower and closer to shore (Joinville Island and South Areas) had a mixed composition of krill from all maturity stages.

Other zooplankton species also exhibited at least a slight increase in abundance over the previous year in all of the most abundant species, due to either annual or seasonal variability.

Across all species analyzed, the largest samples were caught at night. This phenomenon could be due to spatial variability (i.e. larger numbers of animals in the Bransfield Strait, where the samples were collected) or variability due to diel vertical migration. Any variability due to diel vertical migration should be considered in an analysis of temporal or spatial variability beyond this report.

### Protocol Deviations

Instead of completing the entire AMLR Survey grid (112 planned stations per leg) twice during this field season, it was only partially completed over the course of both legs (82 stations, 37%). This change will have implications on the analysis of this long term data set – for example, there will be less resolution of temporal variability, and abundance estimates for 2010 will be based on a less comprehensive data source. Additionally, the rate at which the net was raised and the ship speed during each tow were more variable this year than in previous years due to the use of a new ship and crew.

Krill demographic assessment was performed by eight different individuals rather than one as in the past. We calibrated stages among staff by staging the same krill twice; however, it is likely that there was a bias toward more juveniles at the beginning of Leg I and as our experience increased, we were able to better determine stage at the smaller lengths. A more formal plan for standardizing stages among individuals should be implemented in the future.

Station D07-09 (near Bridgeman Island) was added to the Joinville Area during Leg II. Station D07-11 was missed during Leg II due to a depth sounder malfunction.

Contractor N. Ferm identified an additional 14 copepod species which to our knowledge have not previously been identified during the AMLR survey. For summary purposes, these were included in the 'other copepod' group as the abundance of these species is biased because only one person was making identifications to this level.

Several species identifications from the past were called into question when congeneric species were encountered this year (e.g., in the past all *Rhincalanus* spp. were identi-

fied as *R. gigas* but *R. nasutus* were identified in 2010; there may also be issues with *Metridia* and *Pleuromamma* species).

Ferm also developed a dichotomous key for identifying the dominant copepod families and species, which should assist in more consistent identification in the future. We recommend further testing and development in 2011.

In order to ensure the proper use of copepod data collected as part of the AMLR Program, we suggest that all past data be summarized at least to the genus level, and that any shared data be accompanied by an explanation of the potential for copepod misidentification. Future collection of copepod identification data should be verified by allowing a copepod expert to examine a subsample of the identified animals.

### Acknowledgements

Thanks to the Captain and crew of the R/V *Moana Wave*, whose continued support throughout the season made our work possible. Thanks to the Physical Oceanography team for fixing several electrical problems with microscopes and light sources. We also thank Rosa Runcie for her assistance and expertise in the creation of the ArcGIS maps found in this report.

### Disposition of Data

Data and more detailed processing protocols are available from Christian Reiss, NOAA Fisheries, Antarctic Ecosystem Research Division, 3333 N. Torrey Pines Court, La Jolla Ca 92037. Ph: 858-546-7127, Fax: 858-546-5608.

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## Seabird Research at Cape Shirreff, Livingston Island, Antarctica

Kevin W. Pietrzak, McKenzie L. Mudge and Wayne Z. Trivelpiece

### Abstract

Land-based seabird data were collected during the Antarctic breeding season, October 18, 2009 through March 8, 2010. Results from the field season include:

- There were 916 gentoo penguin chicks, which is 9% lower than the 2008/09 count and 16% lower than the previous 12-year mean;
- There were 3,762 chinstrap penguin chicks; 13% lower than the 2008-09 count, and 41% lower than the previous 12-year mean of 6,328;
- Approximately 80% of the gentoo diet samples contained fish, and 18% of the chinstrap diet samples contained fish. This is the first time in four years that less than 100% of the gentoo diet samples have contained fish.

### Introduction

The U.S. Antarctic Marine Living Resources (AMLR) program conducted its 13th field season of land-based seabird research at the Cape Shirreff field camp on Livingston Island, Antarctica (62° 28'S, 60° 46'W), during the austral summer of 2009/10. Cape Shirreff is an Antarctic Special-ly Protected Area (No. 149) and long-term monitoring of predator populations are conducted there in support of US participation in the Convention for the Conservation of Antarctic Marine Living Resources (CCAMLR).

The objectives of the seabird research program for the AMLR 2009/10 field season were to collect the following long-term monitoring data (CCAMLR 2004):

1. To estimate chinstrap (*Pygoscelis antarctica*) and gentoo penguin (*P. papua*) breeding population size (Standard Method A3);
2. To band 500 chinstrap and 200 gentoo penguin chicks for demography studies (Std. Method A4);
3. To determine chinstrap penguin foraging trip durations during the chick rearing stage of the reproductive cycle (Std. Method A5);
4. To determine chinstrap and gentoo penguin breeding success (Std. Methods 6a,b&c);
5. To determine chinstrap and gentoo penguin chick weights at fledging (Std. Method 7c);
6. To determine chinstrap and gentoo penguin diet composition, meal size, and krill length/frequency distributions (Std. Methods 8a,b&c); and
7. To determine chinstrap and gentoo penguin breeding chronologies (Std. Method 9).

### Methods

We arrived at Cape Shirreff on October 18, 2009 via the National Science Foundation vessel R/V *Laurence M. Gould*. We conducted research until we closed camp on March 8, 2010. The AMLR-chartered vessel R/V *Moana Wave* provided logistical support and transit back to Punta Arenas, Chile, at the field season's conclusion.

#### Breeding Biology

We conducted nest censuses for gentoo penguins on December 5, 2009 and for chinstrap penguins on November 30, 2009, approximately one week after mean clutch initiation for each species. Chick censuses were conducted for gentoo penguins on February 10, 2010 and for chinstrap penguins on February 8, 2010, approximately one week after mean crèche.

Reproductive success was measured by following a sample of 50 pairs of breeding gentoo penguins and 100 pairs of breeding chinstrap penguins from clutch initiation through to crèche formation (Std. Methods 6b). Because chick mortality is typically low following crèche, these numbers are also an estimate of fledging success.

Fledging weights were collected from gentoo and chinstrap penguin chicks as a measure of chick condition. Gentoo penguin chicks are still provisioned by their parents after they begin making trips to sea, so it is not possible to obtain definitive fledging weights by catching and weighing chicks prior to departure. Alternatively, gentoo penguin chicks are weighed 85 days after their mean clutch initiation date; which is approximately the age when other *Pygoscelis* chicks fledge.

A sample of 200 gentoo and 500 chinstrap penguin chicks was banded for future demographic studies. The banded chicks that survive and return to the colony as adults will be observed for age-specific survival and reproductive success. Nests of breeding known-age penguins, banded as chicks in earlier years, were also followed until they crèched.

In addition to penguin reproductive studies, the breeding success of all skuas at Cape Shirreff and nearby Punta Oeste was followed, as well as the reproductive performance of kelp gulls (*Larus dominicanus*) nesting on Cape Shirreff.

### Foraging Ecology

Diet samples were collected from 20 gentoo and 40 chinstrap penguins between January 6 and February 9, 2010. Adults were captured at their nest sites upon returning from foraging trips, to assure they were feeding chicks, and the total stomach contents were collected using the wet-offloading technique (Wilson 1984). A subsample of 50 individual Antarctic krill from each diet sample were measured and sexed to determine length- and sex-frequency distributions of the krill selected by foraging penguins.

Radio transmitters were deployed on 18 adult chinstrap penguins during the chick rearing phase in order to determine their foraging trip durations. Colony attendance was logged between January 7, 2010 and March 2, 2010 using a remote receiver and data collection computer.

Gentoo and chinstrap penguins were instrumented with satellite transmitters (PTTs), to provide geographic data on adult foraging locations during the chick rearing period. Nineteen PTTs were deployed - ten on gentoo penguins and nine on chinstrap penguins - in mid-January, during the brooding phase for each species. Another 19 PTTs were deployed - ten on gentoo penguins and nine on chinstrap penguins - in early February, during the crèche phase for

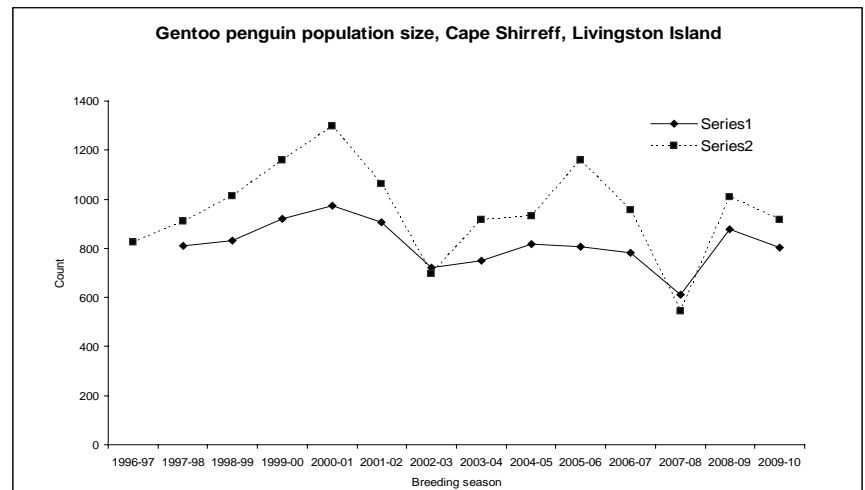


Figure 5.1. Gentoo penguin population size at Cape Shirreff, Livingston Island, Antarctica, 1996-97 to 2009-10.

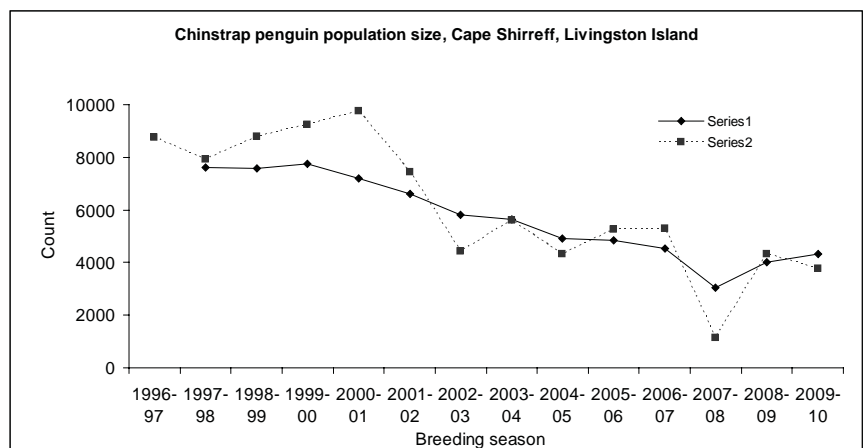


Figure 5.2. Chinstrap penguin population size at Cape Shirreff, Livingston Island, Antarctica, 1996-97 to 2009-10.

each species. Time-Depth Recorders (TDRs) were also attached to chinstrap and gentoo penguins to collect penguin diving behavior data during the chick-rearing period. Twelve TDRs were deployed - six on gentoo penguins and six on chinstrap penguins - in mid January, while these adults were brooding chicks. Another nine TDRs were deployed - four on gentoo penguins and five on chinstrap penguins - in early February, during the crèche phase when nests are unattended and both parents forage simultaneously.

## Results

### Breeding biology

The penguin rookery at Cape Shirreff consisted of 19 sub-colonies of gentoo and chinstrap penguins during the 2009/10 breeding season. A total of 802 gentoo penguin nests were counted (Figure 5.1), a 9% decrease from last year's census. This count represents a 2% decrease from the previous 12-year average of 818 nests. A total of 4,339 chinstrap

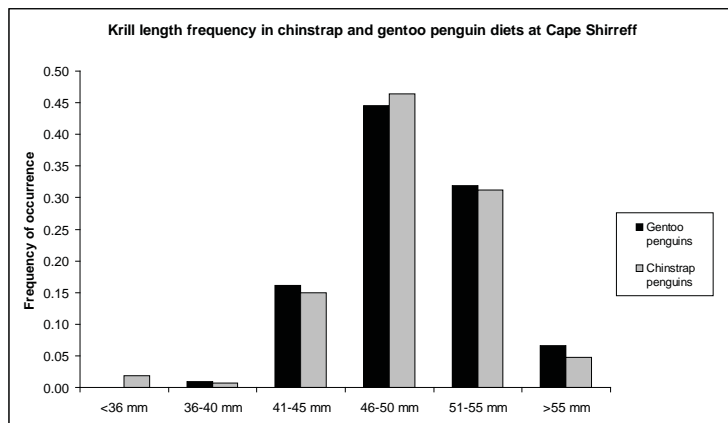


Figure 5.3. Krill length frequency distribution in gentoo and chinstrap penguin diet samples at Cape Shirreff, Livingston Island, Antarctica, 2009-10.

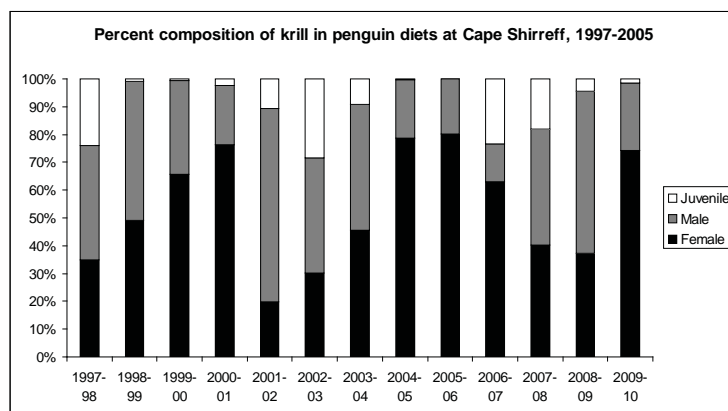


Figure 5.4. Percent composition of Antarctic krill (*Euphausia superba*) in gentoo and chinstrap penguin diet samples at Cape Shirreff, Livingston Island, Antarctica, 1997-98 to 2009-10.

penguin nests were counted. This is an 8% increase from last year's census but it is still 25% lower than the previous 12-year average of 5,797 nests. This census continues a general trend of decline in the chinstrap penguin breeding population at Cape Shirreff.

There were 916 gentoo penguin chicks, which is 9% lower than the 2008/09 count and 16% lower than the previous 12-year mean (Figure 5.1). The chinstrap penguin count was 3,762 chicks; 13% lower than the 2008-09 count, and 41% lower than the previous 12-year mean of 6,328 chicks (Figure 5.2).

Based on census data, overall gentoo penguin fledging success was 1.14 chicks/nest. This is similar to the previous 12-year mean of 1.18 chicks/nest. Overall chinstrap penguin fledging success was 0.87 chicks/nest. This is 15% lower than the previous 12-year mean of 1.02 chicks/nest. Based on data from our reproductive study, gentoo penguins fledged 1.5 chicks/nest and chinstrap penguins fledged 0.8 chicks/nest.

Twenty-six known-age gentoo penguin nests (where one member of the pair was of known age) fledged 0.73 chicks/nest. Seventy known-age chinstrap penguin nests fledged 0.69 chicks/nest.

A sample of gentoo penguin chicks was weighed on February 19, 2009 and had an average mass of 4175g ( $n = 183$ ; S.D. = 492). This is only 1% lower than the previous 12-year mean. Chinstrap penguin fledglings were caught on the beaches just before fledging between February 18 and March 3, 2009 and had an average mass of 3,129 g ( $n = 232$ ; S.D. = 359). This is about equal to (<1%) the previous 12-year mean of 3,145 g.

There were 26 skua pairs holding territories, all of which were brown skuas (*Catharacta lonnbergi*) with the exception of one pair that are likely hybrid, brown-South Polar skuas (*C. maccormicki*). Clutches were initiated by 20 pairs and overall fledging success was 0.3 fledglings/pair. This is 59% lower than the previous 12-year average of 0.74 fledglings/pair.

Forty-six kelp gulls initiated nests and overall fledging success was 0.5 fledglings/pair.

#### Foraging ecology

Antarctic krill (*Euphausia superba*) was present in all samples and comprised the majority of diet, by mass, in 88% of samples. Krill in gentoo penguin samples were slightly larger on average (50 mm) than krill in chinstrap penguin samples (49 mm) (Figure 5.3). Penguin diets were composed of 2% juvenile krill (those less than 36 mm in length), 24% males and 74% females (Figure 5.4).

Fish was the next largest component of penguin diet, and squid and other marine invertebrates represented <1% of penguin diets. In the 2009/10 season, 80% of the gentoo penguin diet samples contained evidence of fish. This is the first time in four years that less than 100% of the gentoo samples contained evidence of fish. In the previous 12 years of study an average of 77% of gentoo diet samples contained evidence of fish. Additionally, 18% of chinstrap penguin diet samples contained evidence of fish, which is lower than the previous 12-year average of 31%. However, fish represented 29% of the gentoo penguin diet by mass and ~1% of the chinstrap penguin diet by mass, which was comparable to the previous year.

The average chick meal mass for chinstrap penguins was 622 g; this is similar to the previous eleven year mean of 615 g. The ratio of fresh to digested portions in

the chinstrap penguin's diet samples was comparable to the previous twelve seasons. We only collected the fresh portion of diet samples from gentoo penguins, so chick meal mass was not evaluated.

The results from the radio transmitters show that chinstrap penguin mean foraging trip duration was 14.7 hours ( $n = 19$ ; S.D. = 3.9). Results from other satellite tag deployments are still preliminary; PTT and dive data for both gentoo and chinstrap penguins are awaiting analysis.

### Discussion

Our thirteenth season of seabird research at Cape Shirreff allowed us to assess trends in penguin population size, as well as inter-annual variation in reproductive success, diet and foraging behavior.

Breeding population counts and reproductive success of both gentoo and chinstrap were slightly lower than the previous 12-year mean for each species. This could be attributed, in part, to there being an abundance of snow early in the season. Many nests were built and clutches initiated on snow. As the snow melted and flooded the nests eggs were lost.

Overall, the chinstrap breeding population at Cape Shirreff has continued to decline. Fledging weights for chinstraps were comparable, being within 1% or less of the previous 12-year mean.

The biggest difference in diet composition for the 2009/10 season is that, for the first time in four years, some of the gentoo diets did not contain evidence of fish. We also saw the fewest number of chinstrap diets with evidence of fish in seven years. Overall the samples contained a relatively high proportion of female krill and there were very few juveniles seen this year. The interpretation of these diet patterns may be aided by analysis of foraging location and diving behavior data.

### Protocol Deviations

There were no deviations from the protocol, as described in the CCAMLR Ecosystem Monitoring Program: Standard Methods (2004).

### Disposition of Data

Land-based seabird data are available from the NOAA/NMFS Antarctic Ecosystem Research Division, 3333 N. Torrey Pines Ct., La Jolla, CA 92037. Ph: 858-546-5607, Fax: 858-546-5608

### Acknowledgements

We would like to sincerely thank Ryan Burner, Ray Buchheit, Mike Goebel, Carolina Bonin, Raul Vasquez-Del Mercado and Jefferson Hinke for their invaluable assistance and companionship in the field. We are grateful to the crew of the NSF Research Vessel *Laurence M. Gould* for our transit to Cape Shirreff and for their help with camp opening, and to the crew of the AMLR-chartered Research Vessel *Moana Wave* for their efforts in resupplying our camp and for providing transit back to Punta Arenas, Chile.

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## **Pinniped research at Cape Shirreff, Livingston Island, Antarctica**

Michael E. Goebel, Ryan Burner, Ray Buchheit, Nicola Pussini, Douglas Krause, Carolina Bonin, Raul Vasquez del Mercado and Amy Van Cise

### **Abstract**

Field personnel conducted research on Antarctic fur seals, elephant, leopard and Weddell seals at Cape Shirreff, Livingston Island between 18 October 2009 and 8 March 2010. The results of this field season include:

- The estimated number of total fur seal pups born (live plus cumulative dead) in the US AMLR study area in 2009/10 was 1,385 ( $\pm 5.0$ ). Our count this year represents an 11.7% reduction in pup production over last year;
- The mean foraging trip duration for lactating fur seals' first six trips to sea was 3.83 ( $\pm 1.49$ ) days;
- Most scats, 98.1% (106/108) of those collected, contained krill. In addition, 584 otoliths were collected from 14.8% of the scat samples. Mean krill length in fur seal diet was 46.6 mm ( $\pm 3.7$ );
- An estimated 69.6% of pups were lost to leopard seals by 24 Feb.
- Twenty adult female fur seals, five leopard and six Weddell 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, 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 status of pinnipeds throughout the summer months. The Antarctic fur seal, *Arctocephalus gazella*, 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, and reproductive success of this species. Southern elephant and Weddell seals also use Cape Shirreff for reproduction and, along with a sizable population of leopard seals, use Cape Shirreff beaches as haul-out sites.

The 2009/10 field season began with the arrival at Cape Shirreff of a five person field team via the R/V *Laurence M. Gould* on 18 October 2009. Research activities were initiated soon after and continued until closure of the camp on 8 March 2010. Our specific research objectives for the 2009/10 field season were to:

- Monitor Antarctic fur seal female attendance

behavior (time at sea foraging and time ashore attending a pup);

- Monitor pup growth collecting mass measures for a random sample of 100 fur seal pups every two weeks throughout the research period beginning 30 days after the median date of births;
- Document the phenology fur seal pup production at designated rookeries and to estimate total pup production for Cape Shirreff;
- Collect and analyze fur seal scat contents on a weekly basis to document trophic interactions and the timing and incidence of prey switching;
- 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;
- Deploy time-depth recorders on adult female fur seals for diving and at-sea foraging studies;
- Record at-sea foraging locations for adult female fur seals using GPS or ARGOS satellite-linked transmitters (whenever possible coinciding with the U.S.-AMLR Oceanographic Survey cruises);
- Tag 500 fur seal pups for future demographic studies;
- Re-sight tagged known-aged animals for population demography studies;
- Monitor over-winter survival and natality of the tagged adult female population of fur seals;
- Extract a lower post-canine tooth from tagged adult female fur seals for aging studies;

- Deploy a weather station for continuous recording of wind speed, wind direction, ambient temperature, humidity and barometric pressure during the study period;
- Opportunistically record pinnipeds carrying marine debris (i.e., entanglement);
- Record any other tagged pinnipeds observed on the Cape;
- Monitor pup production of southern elephant seals breeding at Cape Shirreff;
- Retrieve over-winter CTD-PTT tags from any returning elephant seals;
- Deploy over-winter CTD-PTT instruments on four leopard and six Weddell seals for monitoring temperature and salinity profiles of the southern ocean along migration routes and in their foraging areas and
- Deploy twenty ARGOS PTTs 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 32 lactating females from 2-16 December 2009. Thirty of these were females with a single pup and two were females suckling two pups (these two females were excluded from estimates of trip duration). 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 40 ppm). Standard Method C1.2 calls for monitoring of trip durations for the first six trips to sea. All females were instrumented 0-2 days post-partum (determined by the presence of a newborn with an umbilicus) and remained tagged 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 both an identifying bleach mark and a temporary metal flipper tag. 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 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.

Of the original 30 females instrumented, one had a VHF transmitter that failed and two lost their pups after only three trips to sea. These three females were eliminated from the sample reducing the total sample to 27 mother pup pairs.

### *Fur Seal Pup Growth*

Measures of fur seal pup growth were collected according to CCAMLR protocol (CEMP Standard Method C2.2 Procedure B) with the exception of weights being 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 were initiated 30 days after the median date of pupping (7 Dec 2009) and the last sample was taken 20 February (four bi-weekly samples; collection dates: 5 Jan, 20 Jan, 5 Feb, and 20 Feb 2010).

### *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 the Cape, 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 5-9 December pups live and dead were counted each day. Only recently dead pups are counted at each census.

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). It occurs before most leopard seal predation which begins once pups start entering the water at about one month of age (~late-December/early January). It is measured by recording the number of new pup carcasses on our 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 of pupping (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 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 predation estimate is corrected for early season on-land mortality based on dead pup surveys.

#### *Diet studies*

Information on fur seal diet was collected using three different sampling methods: collection of scats, 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 19 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 108 scats from 19 December 2009 through 1 March 2010. Diet samples that could not be processed within 24 hours of collection were frozen. All samples were processed by 9 March. Up to 25 krill carapaces were measured from each sample that contained krill. A total of 2,509 krill carapaces were measured according to Goebel et al. 2007. Discriminant equations determined sex and age class, after which independent regression equations for juvenile, male and female lengths, were applied (Goebel et al., 2007). Otoliths were sorted, dried, and identified to species. Squid beaks were counted 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 92 milk samples from 60 female fur seals. Each time a female was captured (either to instrument or to remove instruments),  $\leq 30$ mL of milk was collected by manual expression. Prior to collection of the milk sample, an intra-muscular injection of oxytocin (0.25 UI) 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 until later extraction of lipid and trans-esterification of fatty acids.

Both lipid and protein fractions of the milk are extracted. The lipid-free protein fraction is dried for stable isotope analysis. A single vibrissa from 78 fur seal females and juveniles was collected for stable isotope analysis. In addition to milk protein and vibrissae, 27 blood samples were collected from individual female fur seals for stable isotope analysis.

#### *Diving studies*

Fifteen of the 32 females outfitted with transmitters for attendance studies also received a time-depth recorder (TDR, Wildlife Computers Inc., Mark 9: 66 x 18 x 18mm, 31g, N=10; Mk-10-F: 90 x 55 x 29mm, N=5) on their first visit to shore. All females carried their TDRs for at least their first six trips to sea. In addition, five more females were captured for studies of at-sea foraging locations after their first six trips, bringing the total number of females with TDRs to 20. A total of 19 dive records for 149 trips to sea were collected from 18 females in 2009/10. Two TDRs were lost on fur seals this season. The first was on a female that failed to return after four trips to sea and the other was lost by an attachment failure.

#### *Adult female foraging locations*

We instrumented 10 females with GPS (Global Positioning System) TDRs (Mk10-F; Wildlife Computers, Inc.) with fast-loc technology. Two more females carried an ARGOS satellite-linked transmitter (SPOT5; Wildlife Computers, Inc.). A total of 52 trips to sea were recorded with GPS from 4 Dec 2009 through 26 Feb 2010. The two females carrying ARGOS instruments logged 14 trips (eight and six trips) from 10 Jan-19 Feb. GPS foraging location data were analyzed for three sampling periods (December, January, February).

#### *Demography and tagging*

We tagged 499 fur seal pups (233 females, 265 males, and one unknown) from 3 February to 7 March 2010. All tags used at Cape Shirreff were Dalton Jumbo Roto or Flexi tags with white tops and orange bottoms. The side was recorded for tag type (Flexi: 247 right, 252 left). Each pup was tagged on both fore-flippers with identical numbers. Series

numbers for 2009/10 were 6501-6999 (the sex for tag 6923 was recorded as unknown). Mother/pup tagged pairs were identified after tagging and 56 (11.2%) tagged pairs were recorded.

In addition to the 499 pups tagged, we also added 32 new tags to the adult female population (447-478).

#### *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, 5% induction, 2.5% maintenance), oxygen (2-4 L/min), and midazolam hydrochloride (5 mg). A detailed description of the procedure was presented in the 1999/00 annual report. This year we took a single post-canine tooth from 10 adult females.

#### *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 22 October 2009 to 6 March 2010. 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 zero, 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. From 8-12 February the anemometer was not recording. It was repaired at 17:30 on 12 Feb.

#### *Entangled pinnipeds*

We recorded two juvenile male fur seals with marine debris around their necks. The debris was identified, in both cases, as plastic bag. Both were removed without capture using a boat hook. In addition, a juvenile male southern elephant seal was found with a plastic band around its neck. This debris was also 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 2009/10,

we instrumented five leopard seals with time depth recorders (TDR, Wildlife Computers; Mk9, 66 x 18 x 18mm, 31 g). TDRs were attached to an Allflex tag and were deployed without capture. Three were successfully retrieved without recapture and had recorded over a month of diving behavior for each seal. In addition to the dive recorders deployed, five leopard seals were instrumented with two types of ARGOS-linked transmitters (Sirtrack 100, N=1; SMRU-CTD, N=4) from 1-5 March after they were fully molted. Vibrissae, blood, and a blubber sample were collected from each seal and mass, length, and girth recorded.

#### *Other pinnipeds: southern elephant seals*

U.S. AMLR, in collaboration with University of California-Santa Cruz researchers, instrumented 12 adult female elephant seals with ARGOS satellite-linked CTD-PTT transmitters for post-molt dispersal at sea in January 2009. One of these returned to the Cape with her instrument still attached. She was captured and the instrument recovered. Vibrissae, blood and blubber samples were collected.

A daily census for elephant seals was conducted from 19 October through 21 November of breeding areas on the Cape; thereafter a weekly census was conducted for the entire Cape.

In addition, U.S. AMLR personnel captured and weighed 21 elephant seal pups, 19 of these were weighed within 24 hours of weaning. All pups were tagged (Dalton Flexi-tag white/orange; series #: 301-322, excluding 312, which was lost).

#### *Other pinnipeds: Weddell seals*

This was the first year of focal studies of Weddell seals by the U.S. AMLR program. Our primary objective for 2009/10 was to instrument Weddell seals for over-winter studies of foraging and ocean temperature/salinity. In preparation for instrumentation after the molt in late-February and early-March we tagged 11 Weddell seals from October through December. An additional five were tagged at the time of instrumentation with CTD tags (25 Feb-5 Mar).

#### *Other pinnipeds: Weekly Phocid census*

A weekly census of the entire Cape for Phocids was conducted beginning 23 October and ending on 23 February. A total of 18 censuses were made. Age class and sex were recorded when possible, without disturbance, for each of four species observed (Southern elephant, Weddell, leopard and crabeater seals).

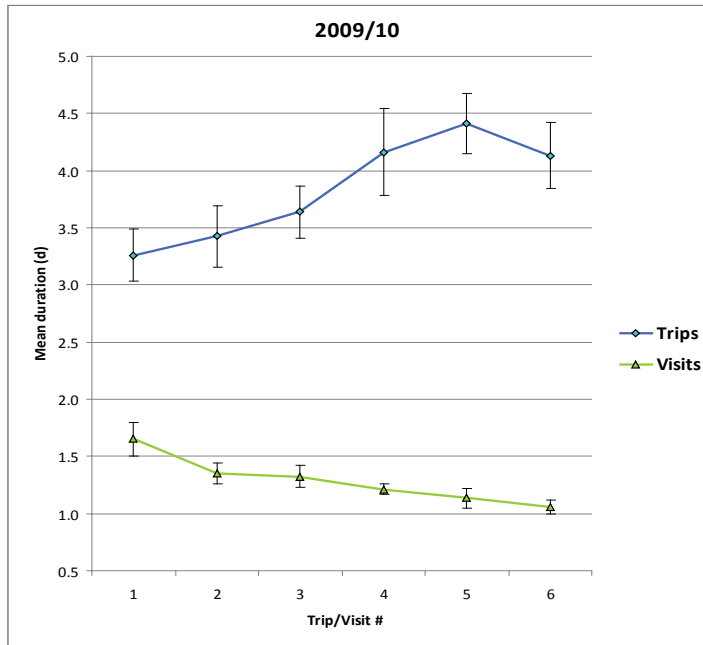


Figure 6.1. Antarctic fur seal mean trip and visit duration ( $\pm$ S.E.) for 27 females rearing pups at Cape Shirreff, Livingston Island. Data plotted are for the first six trips to sea and the first six non-perinatal visits following parturition.

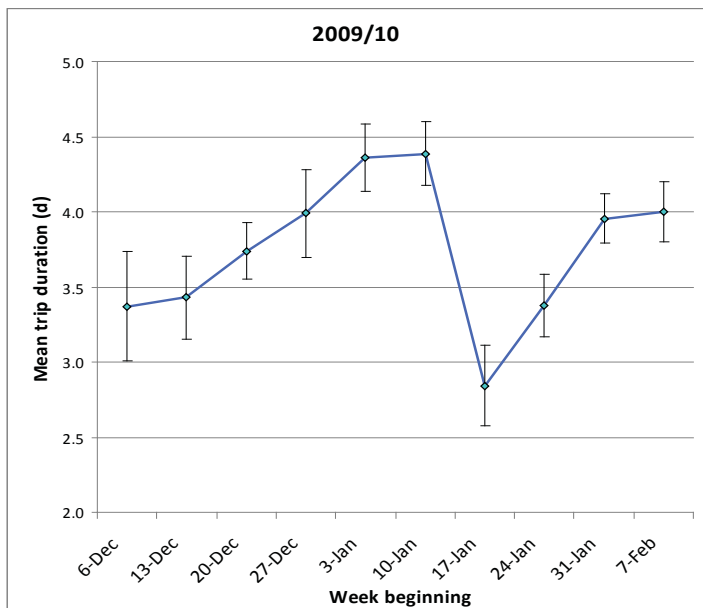


Figure 6.2. Antarctic fur seal weekly mean trip duration ( $\pm$ S.E.) for 27 females rearing pups at Cape Shirreff, Livingston Island. Data plotted are all trips to sea for each week starting 7 December 2009.

**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 27 January. Four females lost

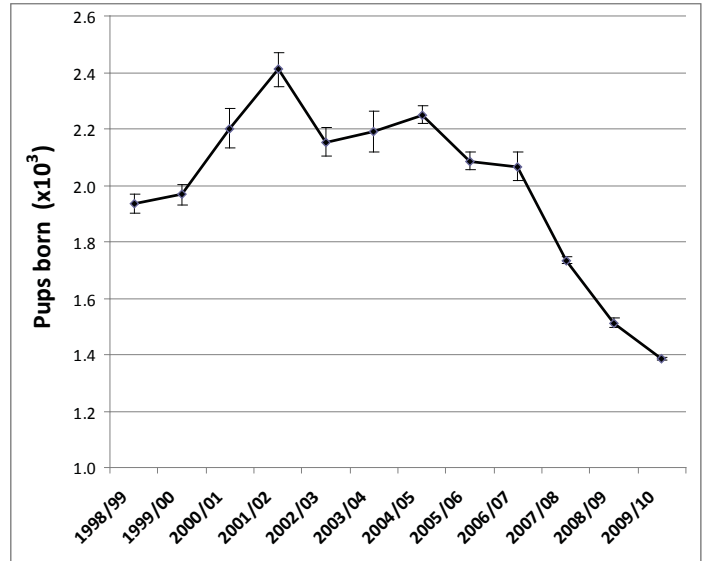


Figure 6.3. Antarctic fur seal pup production on the U.S.-AMLR study site at Cape Shirreff from 1998/99 through 2009/10. Counts are a mean of three censuses for live pups taken the last week of December with an adjustment for the cumulative daily count of newly dead pups.

their pups before completion of six trips to sea. The mean trip duration for the first six trips to sea was 3.83 days ( $\pm 0.12$ ,  $N_{\text{Females}}=27$ ,  $N_{\text{Trips}}=158$ , range: 1.19-13.15). There was a difference in duration for the first six trips with the fifth trip being significantly greater (ANOVA:  $F_{5,140}=3.65$ ,  $P=0.004$ ; Figure 6.1). We tested for the effect of carrying a TDR and found no difference (ANOVA:  $F_{2,140}=2.45$ ,  $P=0.09$ ). Interactive effects were likewise not significant (ANOVA:  $F_{10,140}=1.89$ ,  $P=0.052$ ).

The mean duration for the first six non-perinatal visits was 1.31 days ( $\pm 0.04$ ,  $N_{\text{Females}}=27$ ,  $N_{\text{Visits}}=150$ , range: 0.38-3.46; Figure 6.1).

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 17 January). Prior to that week the weekly mean trip duration was 4.4 days but thereafter the mean trip duration fell to 2.8 days. It began to increase again until it reached 4.0 days by week 10 (ANOVA:  $F_{9,270}=3.76$ ,  $P<0.001$ ; Figure 6.2).

*Pup production and phenology*

The estimated number of total pups born (live plus cumulative dead) for the combined four U.S. AMLR study beaches in 2009/10 was 1,385 ( $\pm 2.9$ ; based on three counts the last week of December). Our count this year represents an 11.3% reduction in pup production over 2008/09 (Figure 6.3). The median date of parturition based upon

daily counts of pups was 7 December (three days later than last year). The median date of parturition for our tagged female population was also 7 December (N=120 females).

*Pup growth and mortality*

Throughout the season male fur seal pups grew, on average, 132.3 g per day. Females grew 107.5 g per day (Figure 6.4). Neonate mortality was 7.6%, more than double that of last year (3.0 %). The long-term average (based on twelve years of data, 1998-2009), is 4.8% ±0.62. Only one other year had higher neonate mortality, 2002/03.

Our estimate of pup mortality due to leopard seal predation, calculated 24 February, 79 days after the median date of pupping, was based on daily tag resights of mother/pup pairs (N=120 tagged adult females with pups). By that date, 69.6% of pups were lost to leopard seals.

*Fur seal diet*

Our diet data showed that most scats were comprised of krill, 98.1% (106/108). Only 584 otoliths were collected from 14.8% of the scats (Figure 6.5). Mean total length of krill in the fur seal diet was 46.6 mm (st.dev.: ±3.70, N=2508). Juvenile krill comprised 4.9% of the sample (Figure 6.6) and the male:female sex ratio was 2.36. Most otoliths were from *Gymnoscopelus nicholsi* (89.9%, 525 otoliths). *Electrona antarctica* otoliths comprised 5.3% (N=31) of the total otoliths collected. An additional 4.8% (n=28) were eroded and unidentified otoliths. 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 6.5). Only one squid beak (preliminary ID: *Brachioteuthis picta*) was collected from one scat.

*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 2008/09. Of the 192, 152 (79.2%) returned this year. Of those 152 females, 120 (78.9%) returned pregnant and gave birth; 32 (21.1%) females did not give birth this year.

*Adult female foraging locations*

A total of 5,250 GPS-derived locations were

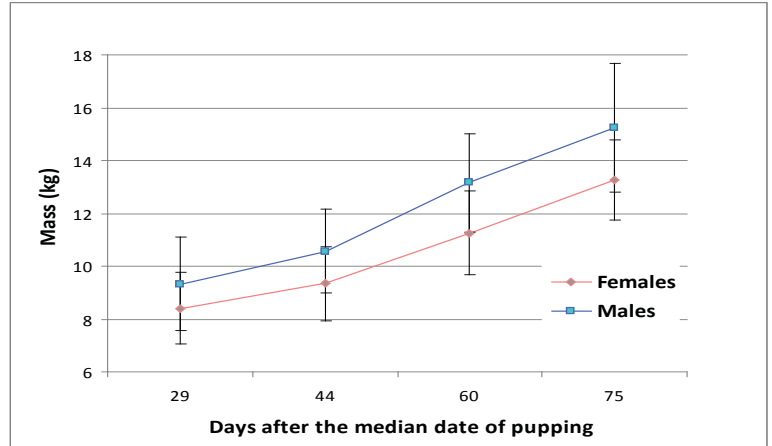


Figure 6.4. Antarctic fur seal pup growth. Four samples of pup weights were collected, every two weeks beginning 30 days after the median date of pupping (7 Dec 2009). Sample sizes ranged from 47-52 for males and from 50-53 for females.

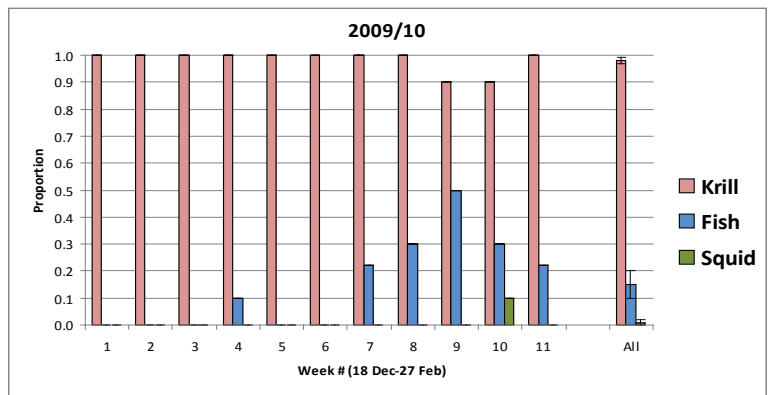


Figure 6.5. The weekly proportions of three types of prey in Antarctic fur seal diet 19 December 2009 – 1 March 2010. The last group of histogram bars is the season average plotted with standard error. Most fish otoliths (95.2%; 556/584) recovered from fur seal scats in 2009/10 were from two species of myctophid fish (*Electrona antarctica*, N=31 and *Gymnoscopelus nicholsi*, N=525). No *Electrona carlsbergi* otoliths were collected from any scats in 2009/10.

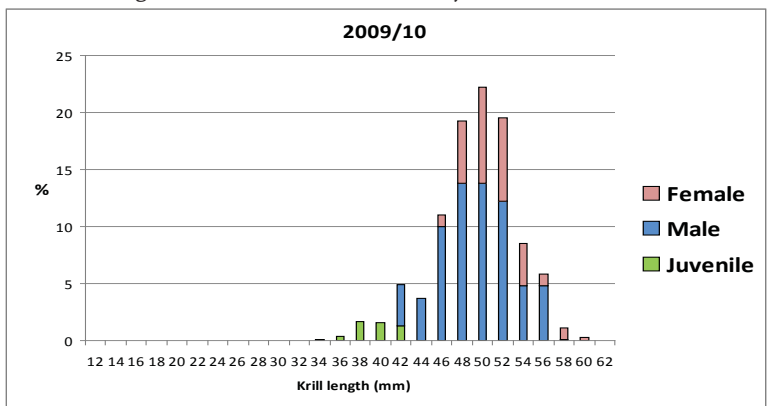


Figure 6.6. Krill length distribution in Antarctic fur seal diet from measures of 2,508 carapaces collected from fur seal scats. Data are derived by sampling 25 krill carapaces from each scat, measuring length and width, applying a discriminant function and independent regression equations for calculating total length of krill. A first order smoothing function is applied to two millimeter length bins.

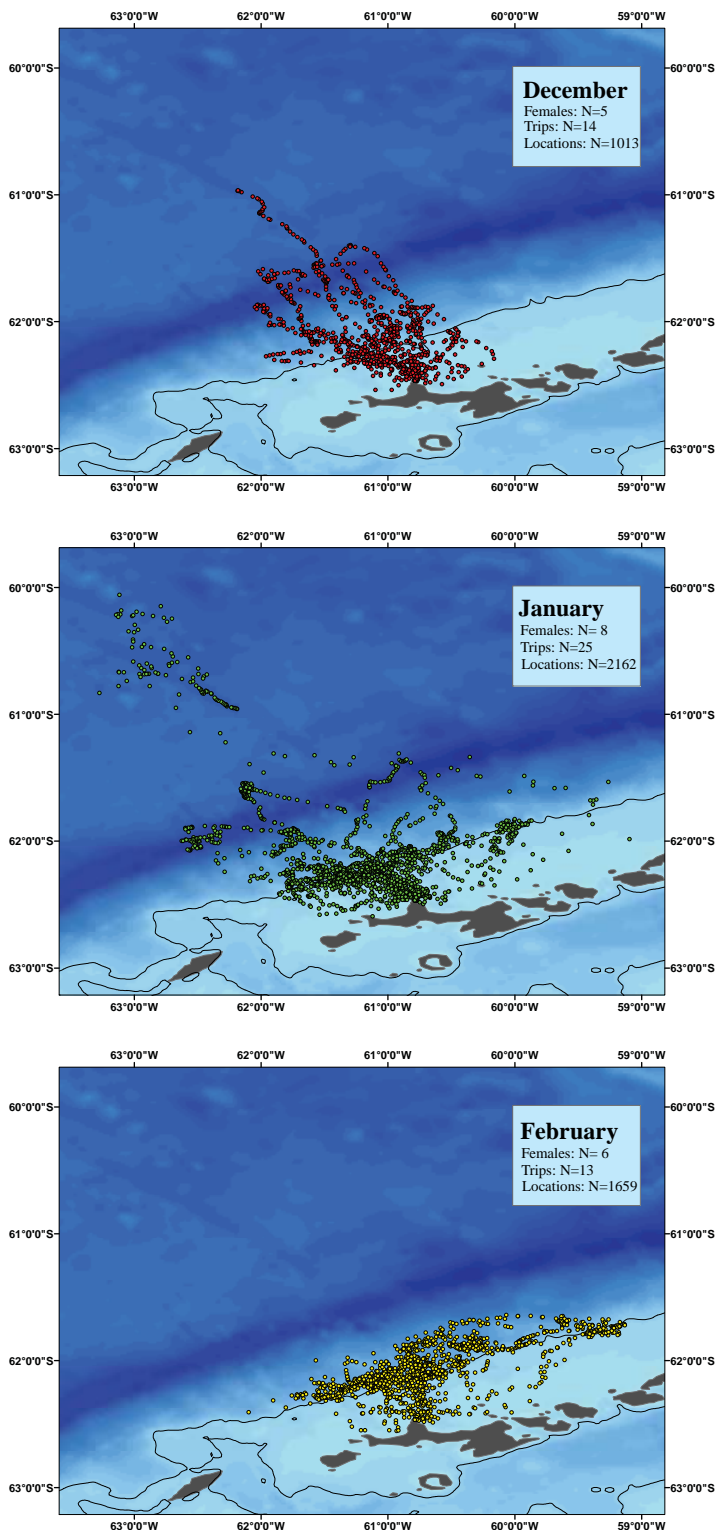


Figure 6.7. At-sea locations of lactating Antarctic fur seals carrying Mark10-F GPS time depth recorders in a) December (red), b) January (green), and c) February (yellow) foraging from Cape Shirreff, Livingston Island, South Shetland Islands, 2009/10. Sample size for the number of females, trips and GPS locations is in the inset for each plot. The 500m bathymetry is outlined to show the location of the continental shelf edge.

collected from 52 trips to sea by 10 females carrying Mark10-F time depth recorders with GPS fast-loc technology. 416 locations (7.9%) were removed from the data set before plotting; most of the outliers were from two trips by one female whose instrument 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 6.7).

*Other pinnipeds: southern elephant seals*

A total of 21 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.

The mean date of weaning was 8 November. The median was two days earlier. All pups except the last two born were weighed within 24 hours of weaning. Mean mass for female pups was 151.7 kg ( $\pm 39.8$ ) and for males was 143.4 kg ( $\pm 20.2$ ).

*Other pinnipeds: Weekly Phocid census*

The maximum number of southern elephant seals counted in the weekly census of the entire Cape was 276 recorded on 11 December. For Weddell seals the maximum count was 37, on 11 January. The maximum count of leopard seals was 22 recorded on 2 February. Crabeater seals are rarely sighted at Cape Shirreff though this year we had more sightings than usual and the maximum count in the weekly census was three.

## Discussion

Fur seal pup production in 2009/10 at U.S. AMLR study beaches showed a decline (11%) over the previous year. This is the third year of double digit decline in pup production. The decline suggests poor environmental conditions over-winter or soon after weaning in 2009 and also likely reflects a changing demography as older females from strong cohorts born in the early 90s senesce. The summer environment appeared to be one of the less favorable for female foraging and reproductive success as well. Early season neonate mortality (7.2%) was the second highest on record (after 2002/03) and well above the long-term average of 4.5%. The median date of pupping, based on pup counts, was three days later than last year. The mean foraging trip duration (3.8 days  $\pm 1.5$ ) was similar to the long-term mean (3.7 days  $\pm 1.2$ ; 1998/99-2008/09). Diet studies of fur seals indicated a high proportion of krill, especially in December and early Janu-

ary. The krill measured in fur seal diet indicated a bi-modal distribution with 4.9% juvenile krill comprising most of the first mode with a second mode at 50 mm. No *Electrona carlsbergi* were recorded in fur seal diet this year. We also recorded one of the lowest incidences of fish in the diet with only 569 otoliths collected from 108 scats. Most (92%) were from one species of myctophid fish, *Gymnoscopelus nicholsi*. In general, winter conditions were less favorable compared to previous years and indices reflecting summer conditions were average or below average resulting in less than average predator performance.

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 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 as much as half of all fur seal pups born on the Cape. This year we recorded an increase in leopard seal numbers at the Cape and by mid-lactation for fur seals (24 February) we estimated 69% 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) and penguins.

### 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.

### Acknowledgements

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## Birds and mammals at sea during the 2009/10 AMLR Survey

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### Abstract

The at-sea distribution and density of seabirds and marine mammals was determined during the 2009/10 AMLR Survey. A total of 3301 km of survey effort was conducted on the AMLR grid. This year's observations included:

- Relatively few seabird feeding aggregations compared to previous AMLR surveys.
- Seabird community composition contained few sub-Antarctic species (e.g. prions).
- First ever sighting of an emperor penguin and southern bottlenose whale cow/calf pair on an AMLR shipboard survey.
- Repeated sampling in coastal waters (e.g. Nelson Strait) resulted in improved resolution of seabird and mammal distribution in nearshore habitats.
- Dense concentrations of humpback whales throughout the Bransfield Strait and an encounter with a pod of Type B (small form) killer whales.

### Introduction

This investigation focused on the at-sea distribution and density of seabirds and marine mammals during the 2009/10 AMLR Survey. The primary objective was to map the density and distribution of seabirds and mammals at sea. The resulting data set, summarized in this report, will be used to investigate:

- a) Inter-annual spatial variability of foraging seabirds and mammals at sea.
- b) Influence of krill abundance, patchiness and demography on foraging seabirds and mammals.
- c) Community structure and habitat selection by predator groups.

### Methods

Observers collected data on predator abundance and distribution continuously during daylight hours between oceanographic/net stations along fixed transects distributed around the South Shetland Islands (Santora et al. 2009, Santora et al. 2010) (Fig. 7.1). Ship speed during transits was 10 knots (~18.6 km/hr). Sighting data were entered into a computer using real-time mapping software, and position was logged every 10 s while underway. Each record was assigned a time (to the nearest tenth of a second) and a spatial position from the ships global positioning system (GPS). Sea surface state (Beau-

fort scale) and visibility (e.g. fog, glare) were monitored and effort during unfavorable conditions (e.g. Beaufort >6, heavy fog) was excluded from the data set. Observers used hand-held binoculars and were located at a height of ~7 m above sea level.

Data on seabird distribution and abundance were collected during all four transits between the east end of the Strait of Magellan and the AMLR study area. Observations were conducted from the port side of the R/V *Moana Wave's* bridge. Counts of seabirds were made within

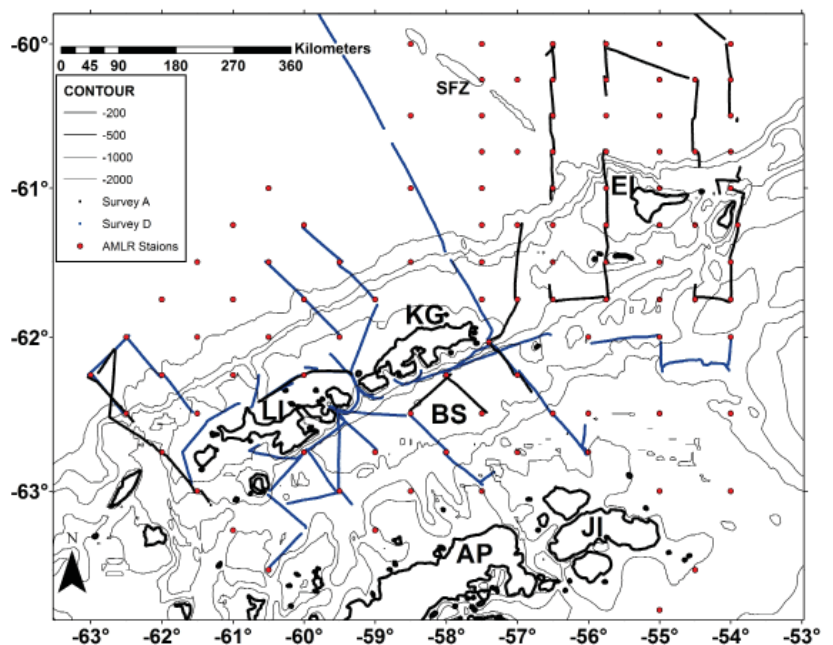


Figure 7.1: Survey trackline (daylight hours) sampled during AMLR 2010, January-March. Black trackline is Leg 1 (1572 km) and blue is Leg 2 (1667 km). Locations: AP is Antarctic Peninsula, BS is Bransfield Strait, EI is Elephant Island, KG is King George Island, LI is Livingston Island, SFZ is Shackleton Fracture Zone.

an arc of 300 m directly ahead and to one side of the ship while underway (Tasker et al., 1984). Individual birds, or flocks of birds, were assigned a behavioral code. The behaviors were: flying, sitting on water or ice, feeding, porpoising (penguins) and ship-following. Ship-following birds were recorded when first encountered and ignored thereafter. Surveys of whales were conducted using standard line transect theory by trained observers (Santora et al. 2010, Santora and Brown 2010). Weather conditions permitting, all cetacean sightings recorded were observed in a 180° arc forward of and up to 3 km away from the vessel. For each whale sighting, a best-estimate spatial position, bearing and a perpendicular distance estimate to the ship's trackline were logged. In addition, observations of seals were collected in a 180° arc forward of the vessel and included position and group size.

Photographic identification of cetaceans was conducted during transect surveys and while on oceanographic stations. The objective was to catalogue photographs of cetaceans for use in future mark-recapture studies. Images were taken using a Canon EOS XSI camera body and 55:250 mm lens. Photographic observations of cetaceans were made between 12:00 and 16:00 during Leg II, within a 180° arc forward of the ship. Photos were taken of the fluke, left dorsal and right dorsal fin when animals were close enough to obtain a clear image, generally within 400 m of the ship. Photographs were also taken whenever the photographer was alerted to the presence of cetaceans near the ship. A time stamp was assigned to each record as the photograph was taken, which was later used to geo-locate the photo.

Data on survey coverage and the abundance and distribution of seabirds and marine mammals are presented. Distribution maps were made using ArcView (ESRI 2007).

Table 7.1. Summary of seabirds observed around Elephant Island and the South Shetland Islands during Legs I-II of the 2009/10 AMLR Survey.

Species	Latin Name	Sightings	Individuals	Total/km
Emperor Penguin	<i>Aptenodytes forsteri</i>	1	1	0.0003
Adelie Penguin	<i>Pygoscelis adeliae</i>	7	11	0.0034
Gentoo Penguin	<i>Pygoscelis papua</i>	22	205	0.0633
Chinstrap Penguin	<i>Pygoscelis antarctica</i>	385	3890	1.2011
Macaroni Penguin	<i>Eudyptes chrysolohus</i>	1	1	0.0003
Wandering Albatross	<i>Diomedea exulans</i>	13	13	0.0040
Black-browed Albatross	<i>Thalassarche melanophrys</i>	184	405	0.1251
Grey-headed Albatross	<i>Thalassarche chrysostoma</i>	77	91	0.0281
Light-mantled Albatross	<i>Phoebastria palpebrata</i>	11	16	0.0049
Southern Giant Petrel	<i>Macronectes giganteus</i>	296	371	0.1146
Northern Giant Petrel	<i>Macronectes halli</i>	6	7	0.0022
Southern Fulmar	<i>Fulmarus glacialisoides</i>	617	3707	1.1446
Antarctic Petrel	<i>Thalassoica antarctica</i>	6	6	0.0019
Cape Petrel	<i>Daption capense</i>	593	3005	0.9278
White-chinned Petrel	<i>Procellaria aequinoctialis</i>	68	75	0.0232
Soft-plumaged Petrel	<i>Pterodroma mollis</i>	2	2	0.0006
Snow Petrel	<i>Pagodroma nivea</i>	9	49	0.0151
Antarctic Prion	<i>Pachyptilla desolata</i>	47	69	0.0213
Blue Petrel	<i>Halobaena caerulea</i>	10	11	0.0034
Wilson's Storm Petrel	<i>Oceanites oceanicus</i>	820	1080	0.3335
Black-bellied Storm Petrel	<i>Fregetta tropica</i>	419	462	0.1426
Brown Skua	<i>Catharacta antarctica</i>	20	20	0.0062
South Polar Skua	<i>Catharacta maccormicki</i>	110	127	0.0392
Kelp Gull	<i>Larus dominicanus</i>	5	6	0.0019
Antarctic Shag	<i>Phalacrocorax branfieldensis</i>	6	12	0.0037
Antarctic Tern	<i>Sterna vittata</i>	196	495	0.1528
Arctic Tern	<i>Sterna paradisaea</i>	17	28	0.0086
Snowy Sheathbill	<i>Chionis alba</i>	1	1	0.0003

Table 7.2. Summary of marine mammals observed around Elephant Island and the South Shetland Islands during Legs I and II of the 2009/10 AMLR Survey.

Species	Latin Name	Sightings	Individuals	Total/km
Humpback Whale	<i>Megaptera novaeangliae</i>	124	219	0.0676
Fin Whale	<i>Balaenoptera physalus</i>	36	63	0.0195
Antarctic Minke Whale	<i>Balaenoptera bonaerensis</i>	7	14	0.0043
Southern Right Whale	<i>Eubalaena australis</i>	1	1	0.0003
Un-identified Baleen Whale	<i>Balaenoptera spp.</i>	7	9	0.0028
Southern Bottlenose Whale	<i>Hyperoodon planifrons</i>	6	9	0.0028
Killer Whale	<i>Orcinus orca</i>	5	25	0.0077
Hourglass Dolphin	<i>Lagenorhynchus cruciger</i>	3	28	0.0086
Antarctic Fur Seal	<i>Arctocephalus gazella</i>	138	194	0.0599
Crabeater Seal	<i>Lobodon carcinophaga</i>	1	1	0.0003
Leopard Seal	<i>Hydrurga leptonyx</i>	2	3	0.0009
Elephant Seal	<i>Miroounga leonina</i>	2	2	0.0006

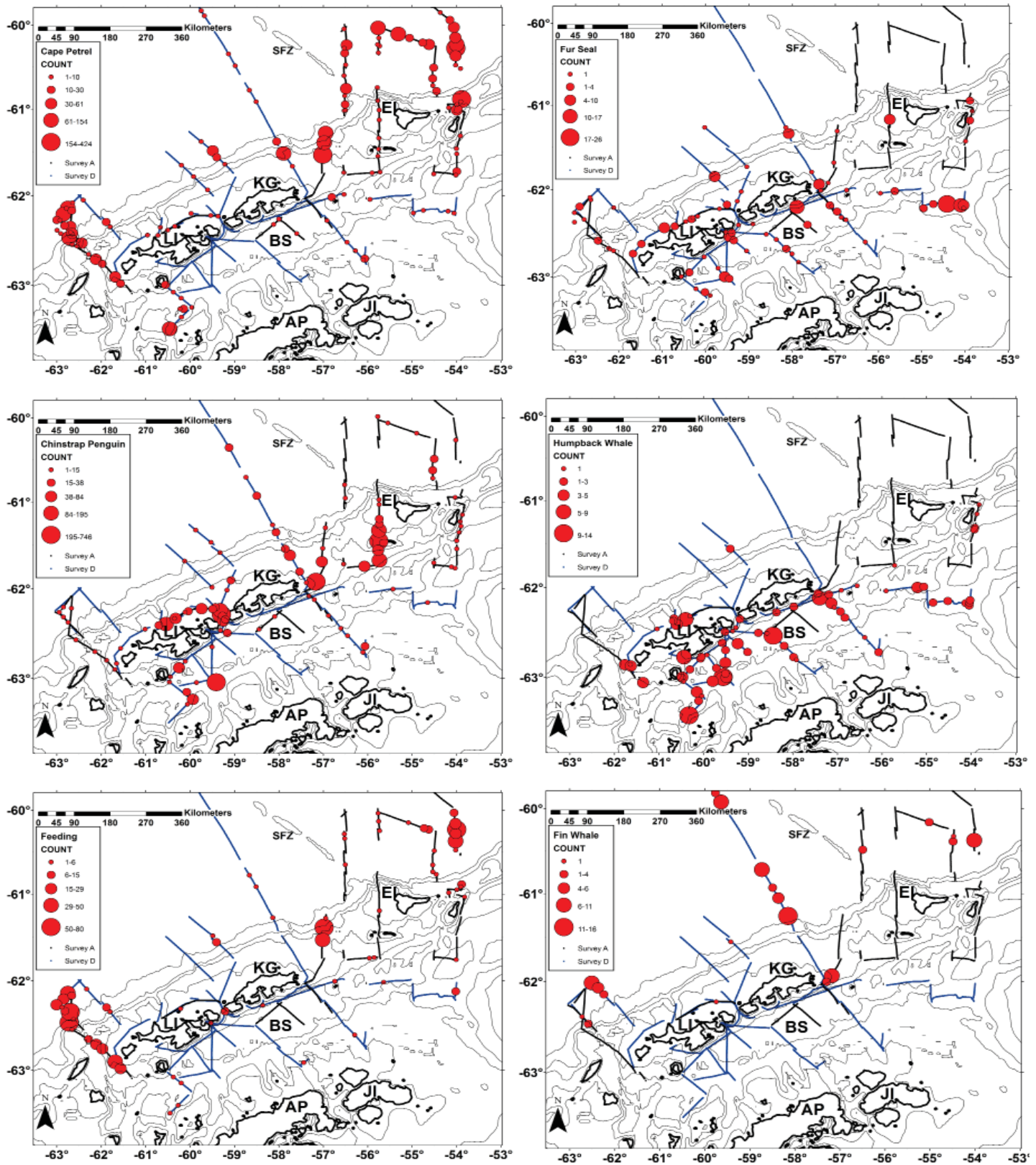


Figure 2a-f: Relative abundance ( $\# \text{ hr}^{-1}$ , or  $\sim \# 10\text{NM}^2$ ) and distribution of seabirds and marine mammals counted during Legs I and II of the 2009/10 AMLR Field Season, January through March: (a) cape petrels, (b) chinstrap penguins, (c) feeding aggregations of birds, (d) Antarctic fur seals, (e) humpback whales, and (f) fin whales.

## Results

### AMLR Survey Grid

Observations were continuously collected during daylight hours whenever the R/V *Moana Wave* was underway (e.g. between stations, to/from field camps). The combined trackline (Legs I and II) depicted in Figure 7.1 represents the spatial coverage completed by the AMLR Program in 2010. A 3,239 km trackline was sampled for 200 observation hours (95 h for Leg I, and 105 hours for Leg II). A combination of adverse weather conditions and ship logistics during Leg 1 prevented routine coverage in the waters north of the South Shetland Islands (Figure 7.1). However, adequate survey coverage was completed in the Elephant Island Area and it will be possible to make comparisons with the long-term historical data set. Weather conditions improved slightly during Leg II and we were able to survey the Bransfield Strait, coastal waters and bays around the South Shetland archipelago, but weather events (i.e. storms) prevented us from surveying the West Area completely (Figure 7.1). A summary of sightings and relative abundance of seabirds and marine mammals collected in the AMLR area is presented in Tables 7.1-7.2.

The seabird community consisted of (percentage-wise): Antarctic fulmar, chinstrap penguin, Wilson's storm petrel, Antarctic tern, cape petrel, black-bellied storm petrel, Southern giant petrel, black-browed and grey-headed albatross and snow petrel. As in past AMLR Surveys, aggregations of cape petrels were highly conspicuous along the shelf break north of the South Shetland Islands and were likely associated with the location of the southern Antarctic Circumpolar Current (Figure 7.2a). Similarly, the spatial distribution of seabird feeding aggregations (primarily composed of cape petrels) was restricted to offshore waters (Figure 7.2c). Interestingly, aggregations of cape petrels in the West Area were observed feeding and capturing salps, indicating that seabirds were responding to the numerically dominant zooplankton taxa observed during the field season (Chapter 4).

Large rafts (50-300 individuals) of chinstrap penguins were repeatedly encountered during transit through Nelson Strait, north of Livingston Island, and along the west side of Elephant Island (Figure 7.2b). These dense concentrations likely reflect the foraging distributions of penguins around their breeding locations in the South Shetland Islands (Figure 7.2b).

As in past AMLR surveys (Santora et al. 2010), humpback whales were the numerically dominant baleen whale in the Bransfield Strait, where a total of 124 sightings for 219 individuals were observed (Figure 7.2e). Fin whales were common north of the South Shetland Islands where a total of 53 sightings for 113 individuals were observed (Figure 7.2f). An aggregation of 35 humpbacks was recorded in the vicinity of station 13-13; we also observed approximately 20 killer whales pursuing a lone fin whale. Further inspection of photographs of a killer whale from that aggregation suggests that they were a small form of Type B (R. Pitman, pers. comm.). One right whale was observed in the Bransfield Strait during Leg II and a photograph of the fluke was captured. There were only six sightings of minke whales recorded in the coastal waters on the north side of Nelson Strait and two sightings in the brash ice floe in the Joinville Island Area. There were six sightings of southern bottlenose whales for a total of nine individuals. The Antarctic fur seal was the most frequently sighted pinniped (78 sightings/128 individuals) in the South Area, and in the Joinville Island Area animals were hauled out on the brash ice floes (Figure 7.2d). Other sightings of pinnipeds include southern elephant seals (2), and leopard seals (3).

For the purpose of identification, cetaceans were photographed both during the midday transect and opportunistically, totaling 17 individual humpback whales, two Southern bottlenose whales and one right whale. Figure 7.3 includes examples of individuals captured dur-



Figure 7.3. (Top) Fluke images from three distinct humpback whales, showing the variety in humpback whale fluke patterns, making these whales easily distinguishable from others. (Bottom) Dorsal images from two distinct humpback whales and a Southern bottlenose whale.

Table 7.3. Summary of survey effort and relative abundance of total birds collected during Drake Passage crossings.

	No. of Transects <sup>1</sup>	Minutes on effort	Trackline surveyed (km)	No. individuals	Birds/km	Average sea state (Beaufort)
Leg I South	64	1,814	633.4	6,398	10.1	5
Leg I North	69	2,013	743.5	752	1.0	6
Leg II South	66	1,950	772.2	3,358	4.3	5
Leg II North	49	1,423	506.6	2,450	4.8	5
Total	248	7,200	2,655.7	12,958		

<sup>1</sup>Transect defined as a 30-minute interval.

ing Leg II, including fluke and dorsal images from humpback whales and dorsal images from southern bottlenose whales. Most individuals were photographed in the Bransfield Strait, where humpback whales are known to feed. Individual cetaceans were catalogued in an Access database, and their records were geo-referenced using the ship's position log. Photographic identification of individuals in the South Shetland Islands over a number of years will allow for population abundance estimates using capture-recapture methods, as well as the detection of preferred feeding areas or groups that travel and feed together. A higher rate of identification can be achieved by carrying out observations for longer time periods during each day, as well as by increasing the focal power of the camera lens used.

#### Drake Passage Crossings

A brief summary of observation effort is presented in Table 7.3. Table 7.4 summarizes avian species totals arranged in descending order of relative abundance. Observations of marine mammals, opportunistic due to operational constraints, are summarized in Table 7.5. This summary does not take into account the various pelagic habitats surveyed during the transits. In contrast, large portions of the central Drake Passage were bereft of seabirds. In the Drake Passage, the high numbers of soft-plumaged petrels seen in the Drake Passage at the end of Leg II was remarkable and unprecedented in the 15 years data has been collected. Further analysis of the data will reveal additional spatial and temporal trends in avian abundance and distribution in the Drake Passage and on the southern Patagonian Shelf.

#### Discussion

There is no doubt that the small size of the R/V *Moana Wave* combined with adverse weather conditions restricted the sampling and spatial coverage of the AMLR vessel-based survey (e.g. acoustics, predator mapping, nets, and oceanography). The most serious effect on this year's field season is the lack of sampling in the Elephant Island and West Ar-

Table 7.4. Summary of seabird observations collected during Drake Passage surveys.

Species		Total
Sooty Shearwater	<i>Puffinus griseus</i>	6096
Black-browed Albatross	<i>Thalassarche melanophris</i>	2456
Wilson's Storm-Petrel	<i>Oceanites oceanicus</i>	803
Soft-plumaged Petrel	<i>Pterodroma mollis</i>	612
Slender-billed Prion	<i>Pachyptila belcheri</i>	383
Greater Shearwater	<i>Puffinus gravis</i>	361
unidentified prion	<i>Pachyptila sp.</i>	347
Rockhopper Penguin	<i>Eudyptes chrysolophus</i>	251
Magellanic Penguin	<i>Spheniscus magellanicus</i>	222
Southern Giant-Petrel	<i>Macronectes giganteus</i>	203
Black-bellied Storm-Petrel	<i>Fregetta tropica</i>	201
White-chinned Petrel	<i>Procellaria aequinoctialis</i>	165
Antarctic Prion	<i>Pachyptila desolata</i>	143
Manx Shearwater	<i>Puffinus puffinus</i>	121
South American Tern	<i>Sterna hirundinacea</i>	90
Cape Petrel	<i>Daption capense</i>	84
Chinstrap Penguin	<i>Pygoscelis antarctica</i>	63
Gray-headed Albatross	<i>Thalassarche chrysolophus</i>	52
Imperial Cormorant	<i>Phalacrocorax atriceps</i>	46
unidentified penguin	<i>Unknown sp.</i>	36
unidentified giant-petrel	<i>Macronectes sp.</i>	30
Royal Albatross	<i>Diomedea epomophora</i>	26
Wandering Albatross	<i>Diomedea exulans</i>	21
Westland Petrel	<i>Procellaria westlandica</i>	20
unidentified diving-petrel	<i>Pelecanoides sp.</i>	19
Blue Petrel	<i>Halobaena caerulea</i>	16
Antarctic Tern	<i>Sterna vittata</i>	15
Northern Giant-Petrel	<i>Macronectes halli</i>	13
Kelp Gull	<i>Larus dominicanus</i>	12
Common Diving-Petrel	<i>Pelecanoides urinatrix</i>	11
Magellanic Diving-Petrel	<i>Pelecanoides magellani</i>	8
unidentified Procellaria	<i>Procellaria sp.</i>	5
Southern Fulmar	<i>Fulmarus glacialis</i>	4
Kerguelen Petrel	<i>Aphrodroma brevirostris</i>	4
unidentified albatross	<i>Thalassarche/Phoebastria sp.</i>	3
Macaroni Penguin	<i>Eudyptes chrysolophus</i>	2
South Georgia Diving-Petrel	<i>Pelecanoides georgicus</i>	2
unidentified Sterna tern	<i>Sterna sp.</i>	2
Great Grebe	<i>Podiceps major</i>	1
Adelie Penguin	<i>Pygoscelis adeliae</i>	1
Shy Albatross	<i>Thalassarche cauta</i>	1
Light-mantled Albatross	<i>Phoebastria palpebrata</i>	1
Fairy Prion	<i>Pachyptila turtur</i>	1
Snowy Shearbill	<i>Chionis alba</i>	1
Arctic Tern	<i>Sterna paradisaea</i>	1
South Polar Skua	<i>Stercorarius maccormicki</i>	1
Brown (Falkland) Skua	<i>Stercorarius antarcticus</i>	1

eas. To overcome this, we combined the survey trackline from both Legs to map predator distribution (Figure 7.1), but it must be noted that in past AMLR surveys we generally complete the entire grid on each leg. However, quality data was collected in the Elephant Island Area during Leg I and in the Bransfield Strait (South Area) during Leg II. On a positive note, due to the ship's ability to sample shallow coastal waters (i.e. low draft), we successfully gathered data in regions that were not routinely sampled in previous AMLR surveys (i.e. repeated sampling of Nelson Strait and Discovery Bay). These data are valuable for understanding nearshore predator-prey interactions. In summary, the predator sighting data collected during AMLR 2009/10 are extremely valuable because this was a significant salp year and because of the unusual weather conditions. These data will be incorporated into the long-term AMLR predator sighting database. Once data are fully checked for quality control and assurance, comprehensive differences and similarities with previous surveys will be assessed and the geographic atlas of predator distribution and abundance will be updated (Santora et al., 2009, Santora et al., 2010).

### Protocol Deviations

Sampling of seabird and mammal spatial distribution occurred on a much smaller vessel compared to previous field seasons and this had obvious impacts (i.e. sampling north of the South Shetlands was reduced by the ship's inability to perform in bad weather) on all underway ship-board operations (e.g. see acoustics and oceanography sampling).

### Disposition of Data

All data are available from the NOAA/NMFS Antarctic Ecosystem Research Division, 3333 N. Torrey Pines Court, La Jolla, CA 92037. Ph: 858-546-7127; Fax: 858-546-5608.

### Acknowledgements

We would like to thank members of the AMLR scientific team who supported the underway bird and mammal effort, in particular Derek Needham and Michael Soule for providing the averaged SCS data. We especially thank the captain and crew of the R/V *Moana Wave* for their excellent support.

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## Annual Weather Report: Cape Shirreff, South Shetland Islands, Antarctica

Amy M. Van Cise and Michael E. Goebel

### Abstract

Weather data were collected continuously at two different weather stations on Cape Shirreff during the 2009/10 AMLR field season. Data from the weather station located at the camp are compared to data collected at the same station during the 2008/09 AMLR field season.

- Mean temperature in 2009/10 was 0.83°C, 1.05°C lower than in 2008/09.
- Easterly and westerly winds were dominant during the 2009/10 field season.

### Introduction

Weather data are collected as part of the long-term ecosystem monitoring Program conducted by the US AMLR Program in the South Shetland Islands, Antarctica. These data provide AMLR scientists with information about local environmental conditions that can be used in inter-annual comparisons of biological components of the ecosystem.

### Methods

Weather data, including temperature (°C), wind speed (m sec<sup>-1</sup>) and direction (degrees), barometric pressure (millibar), precipitation (mm), and solar radiation (W m<sup>-2</sup>) were collected from 18 October 2009 to ending 6 March 2010 at two sites on Cape Shirreff. The two weather stations (Davis Vantage Pro; Table 8.1) are deployed at Cape Shirreff every summer, one is located at the U.S. AMLR base camp (60°28.216'S, 62°46.261'W) and the other is at the bird blind located at the northern tip of

the Cape, approximately 2.5 km from the base camp (Figure 8.1). Both are mounted on the west-facing peak of the buildings' roofs. The sampling rate for wind speed, temperature, and humidity was every eight seconds with the averaged value for each 15-minute interval stored in memory. Barometric pressure was measured once at each 15-minute interval and stored. When wind speed was greater than 0 m sec<sup>-1</sup>, 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.

### Analysis

We calculate the average daily temperature and a seven-day running mean, as well as average barometric pressure. We average all other environmental variables, including wind speed and radiation, by week. In order to determine the predominant winds during the season, we calculate wind direction as a percentage for each week, then average

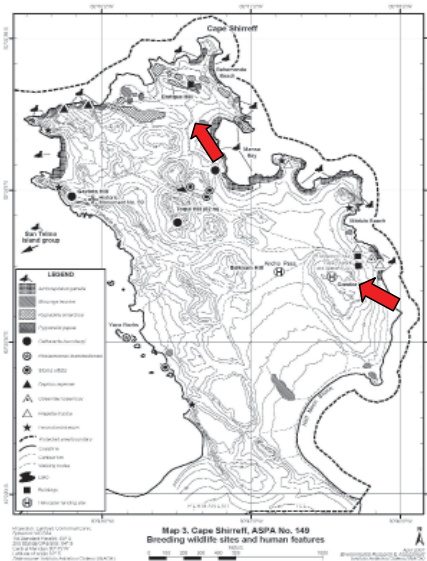


Figure 8.1 Red arrows indicate the location of Cape Shirreff weather collection stations in relation to nearby topography (map courtesy INACH).

Table 8.1. Summary of instruments installed at the Cape Shirreff weather stations.

Parameter	Instrument	Model	Manufacturer
Temperature	Weather Station	Vantage Pro	Davis
Humidity	Weather Station	Vantage Pro	Davis
Dew point	Weather Station	Vantage Pro	Davis
Wind Speed	NIST traceable Anemometer	Standard	Davis
Wind Direction	NIST traceable Anemometer	Standard	Davis
Air Pressure	NIST traceable Barometer	Standard	Davis
Precipitation	Rain Gauge	Rain Collector II	Davis
Solar radiation, 400 – 1100 nm	Solar pyranometer	Vantage Pro2	Davis

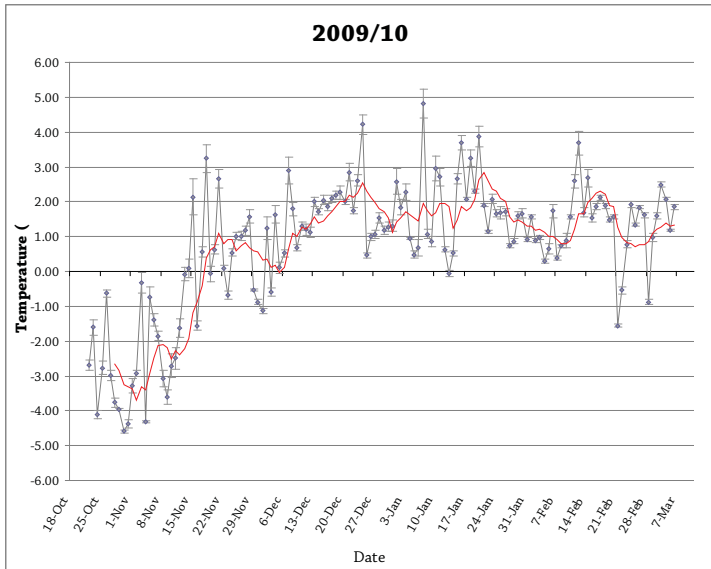


Figure 8.2. Average daily temperature ( $\pm$ SE) during the 2009/10 austral summer. The 7-day moving average is shown in red.

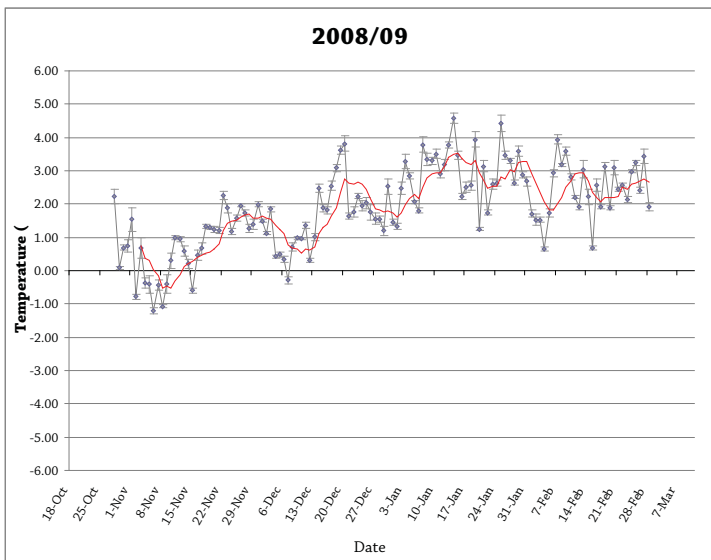


Figure 8.3. Average daily temperature ( $\pm$ SE) during the 2008/09 austral summer. The 7-day moving average is shown in red.

the weekly percentages over the study period. For comparative purposes temperature, wind speed and direction, radiation and barometric pressure for the 2008/09 season are also reported. Unless otherwise stated, all variation in the daily data are reported as standard errors.

**Results**

*Temperature*

The daily mean temperature remained below 0°C through mid November 2009. It ranged between 0°C and 2°C for most of the season, rising above 2°C only three

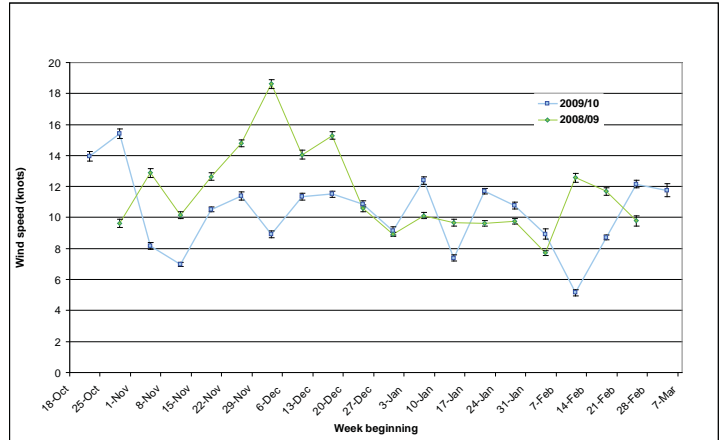


Figure 8.4 Mean weekly wind speed ( $\pm$ S.E.) during the 2008/09 and 2009/10 austral summers. Data were not collected from 13 February to 17 February due to anemometer malfunction.

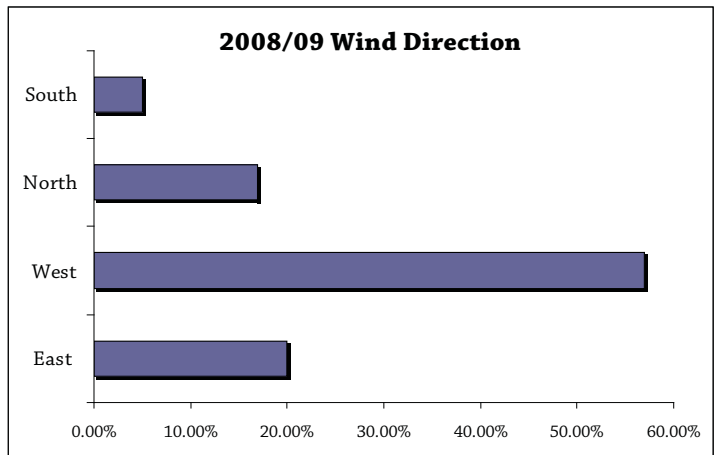
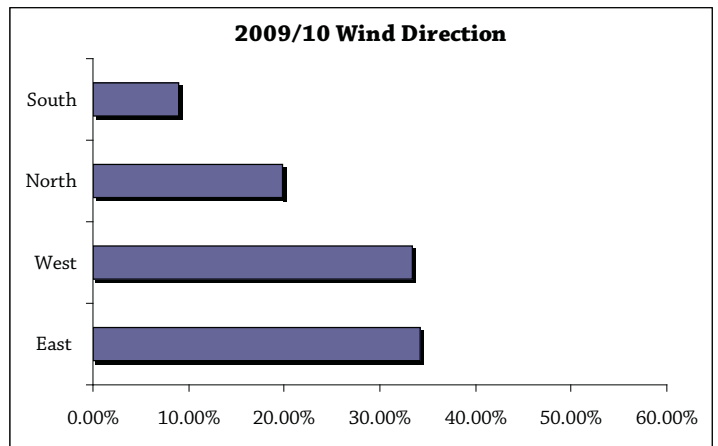


Figure 8.5 Wind direction during the 2008/09 and 2009/10 austral summers.

times (Figure 8.2). In contrast, the 2008/09 austral summer, mean daily temperature dipped below 0°C for only eight days during November. It rose to 2°C by mid-December, and remained above 2°C for the rest of the breed-



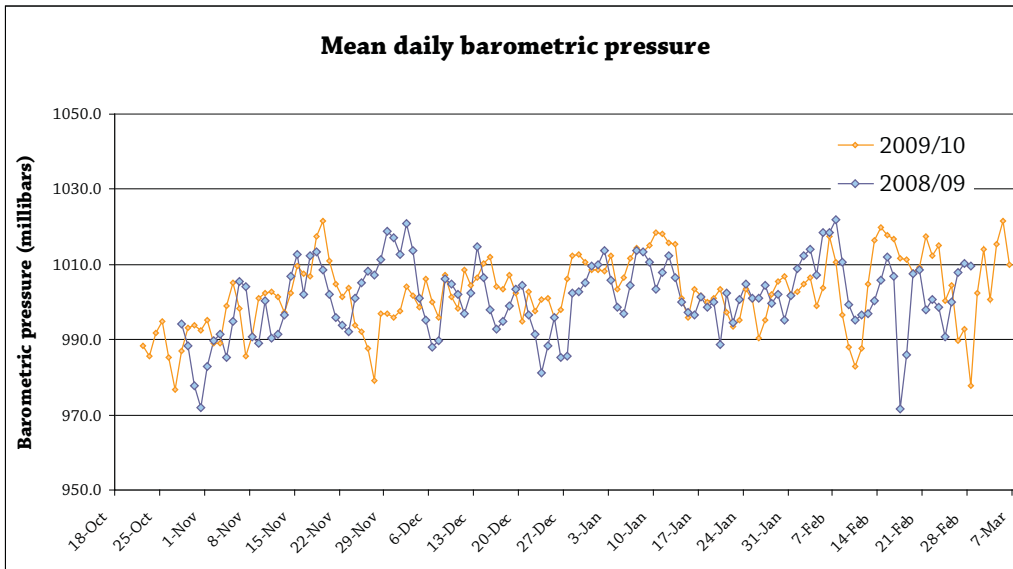


Figure 8.6 Mean daily barometric pressure during the 2008/09 and 2009/10 austral summers.

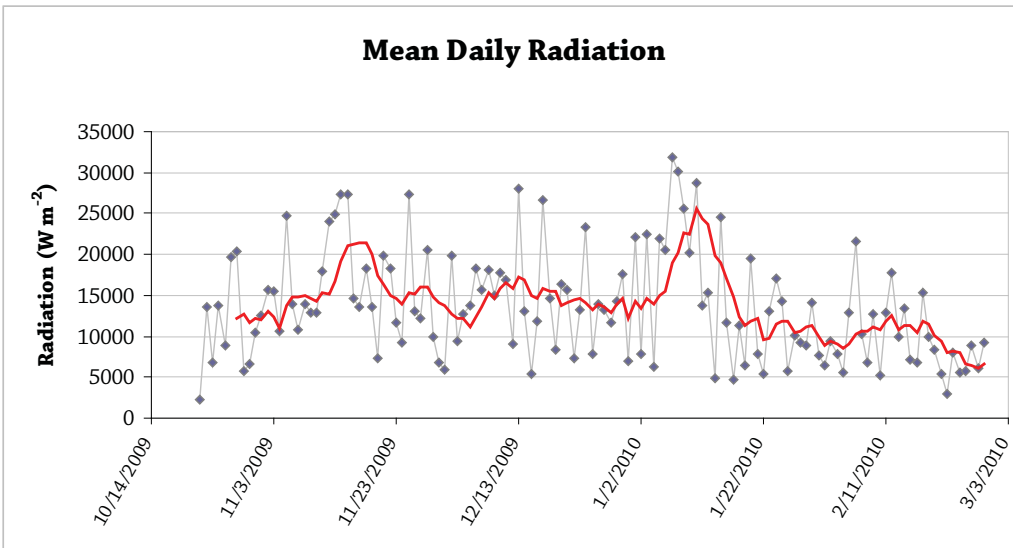


Figure 8.7 Daily cumulative solar radiation for the 2009/10 austral summer.

ing season, falling below 2°C only twice (Figure 8.3). The mean temperature for the period of 28 Oct through 28 Feb (the period for which data were collected in both years) was 1.05°C cooler in 2009/10 (2008/09: 1.88°C ±0.11°C; 2009/10: 0.83°C ±0.17°C).

*Wind Speed and Direction*

Mean weekly wind speeds were comparable between the 2008/09 and the 2009/10 (Figure 8.4), with slightly more variability in wind speed during the late season in 2009/10. The average wind direction over then entire field season changed considerably between the 2008/09 field

season and the 2009/10 field season.

The mean of the mean weekly wind speed during the 2009/10 breeding season was 5.52 (±1.13) m sec<sup>-1</sup>, and the average of the weekly maximum was 13.17 m sec<sup>-1</sup>. Winds were primarily from the east and west, with less wind coming from the north and south (Figure 8.5). The mean wind speed during the 2008/09 breeding season was 5.96 m sec<sup>-1</sup> (± 1.4) m sec<sup>-1</sup>, and the average of the weekly maximum was 14 m sec<sup>-1</sup>. Winds were primarily out of the west, with little wind coming from other directions.

*Other*

Mean daily barometric pressure was similar between 2008/09 and 2009/10 (Figure 8.6). In both years, barometric pressure increased slightly from early season to late season. As expected, because of changing day length, solar radiation increased slightly as the summer solstice approached, and decreased thereafter (Figure 8.7).

**Discussion**

Our comparison of reported weather variables (PAR, barometric pressure, wind speed and direction, temperature) showed that the most important differences between years were the change in temperature and wind direction. During the 2008/09 austral summer, winds were primarily out of the west, coming from the Pacific Ocean, whereas in 2009/10 westerly winds were diminished while easterly winds increased in strength. Also in 2009/10, the mean temperature was lower than 2008/09 by a degree, and the weekly average was also lower than the 2008/09 for most of the breeding season. Further analysis may show that these two factors are correlated with each other and with the an-

nual success of breeding animals at Cape Shirreff.

Annual variability in environmental conditions in the South Shetland Islands can be high, especially when the area is affected by the atmospheric ENSO patterns. We suggest, therefore, that an annual summary of the weather data collected throughout the South Shetland Islands (at Cape Shirreff, Copacabana, and aboard the vessel) be included in the annual AMLR Field Season Report. This permanent record will serve as an initial reference for those who are interested in annual variability in the ecosystem around the South Shetland Islands.

### **Protocol Deviations**

Data recording started earlier this year than most years, on 18 October 2009. During week 17 (7 February 2010 – 13 February 2010), the anemometer malfunctioned, therefore wind speed data are unreliable for that week. The instrument was repaired on 12 February 2010. As a result, data for the week beginning 7 February are not presented in Figure 8.4.

The solar radiation sensor lost data from 2/2/08 08:41 to 2/9/08 18:47. As a result the 2008/09 data for the week beginning 4 Feb in Figure 8.7 are not reported.

### **Disposition of Data**

All data are archived at NOAA/NMFS Antarctic Ecosystem Research Division, 3333 N. Torrey Pines Ct., La Jolla, CA 92037

### **Acknowledgements**

We thank Ryan Burner, Ray Buchheit, and Scott Freeman for their assistance in deployment, maintenance, and data summaries of the weather station and the collected data used in this report.

## Seabird Research at Admiralty Bay, King George Island, Antarctica, 2009/10

Susan G. Trivelpiece, Amy Lindsley, Alexis Will, Renee Koplan, Jefferson Hinke, and Wayne Z. Trivelpiece

### Abstract

Land-based seabird data were collected during the Antarctic breeding season, 17 October 2009 through 6 March 2010. Results from the field season include:

- There were 2,102 Adélie penguin nests at the date of the count;
- A total of 3,485 gentoo penguin nests were counted, a drop in population of nearly 1,500 nesting pairs from the previous year;
- A total of 825 chinstrap penguin nests were counted in the three colonies along the western shore of Admiralty Bay, a decline of approximately 300 breeding pairs from the prior season.

### Introduction

The U.S. Antarctic Marine Living Resources (AMLR) program conducted its 13<sup>th</sup> field season of joint NSF/AMLR land-based seabird research at the Copa field camp on King George Island, Antarctica (62° 10'S, 58° 30'W), during the austral summer of 2009/10. The western shore of Admiralty Bay is an Antarctic Special Management Area (ASMA #128) and long-term monitoring of predator populations are conducted there in support of US participation in the Convention for the Conservation of Antarctic Marine Living Resources (CCAMLR).

The objectives of the seabird research program for the 2009/10 season were to collect the following long-term monitoring data (CCAMLR 2004):

1. To estimate Adélie (*Pygoscelis adeliae*), chinstrap (*P. antarctica*) and gentoo (*P. papua*) penguin breeding population size; CCAMLR Ecosystem Monitoring Program (CEMP) Standard Method A3);
2. To band 250 Adélie and 250 gentoo penguin chicks for demography studies (CEMP Std. Method A4);
3. To determine Adélie penguin foraging trip durations during the chick rearing stage of the reproductive cycle (CEMP Std. Method A5);
4. To determine Adélie, chinstrap and gentoo penguin breeding success (CEMP Std. Methods A6a, b, & c);
5. To determine Adélie and gentoo penguin chick weights at fledging (CEMP Std. Method A7c);
6. To determine Adélie, chinstrap and gentoo penguin diet composition, meal size, and krill length/frequency distributions (CEMP Std. Methods A8a, b, & c); and

7. To determine Adélie and gentoo penguin breeding chronologies (CEMP Std. Method A9).

### Methods

We arrived at Admiralty Bay on 17 October 2009 via the National Science Foundation ARSV *Laurence M. Gould*. We conducted research until we closed camp on 6 March 2010. The AMLR-chartered R/V *Moana Wave* provided logistical support and transit back to Punta Arenas, Chile, at the field season's conclusion.

#### *Breeding biology*

We conducted nest censuses for Adélie penguins on 16 November 2009, for gentoo penguins between 6 and 12 December 2009, and for chinstrap penguins on 10 December 2009. Chick censuses were conducted for Adélie penguins on 11 January 2010, for gentoo penguins between 28 January and 12 February 2010, and for chinstrap penguins on 11 February 2010, approximately one week after mean crèche. The range of dates for the counts for gentoo penguin nests and chicks was due to the asynchrony in laying dates in different sub-colonies within the colony.

Reproductive success was also measured, by following a sample of 100 pairs of breeding Adélie and gentoo penguins from clutch initiation through to crèche formation (Std. Methods 6b). Nests of known-age penguins that initiated clutches were also followed to crèche. Because chick mortality is typically low following crèche, these numbers are also an estimate of fledging success.

A sample of 250 Adélie and 250 gentoo penguin chicks was banded for future demographic studies. The banded

chicks that survive and return to the colony as adults will be observed for age-specific survival and reproductive success.

Fledging weights were collected from Adélie and gentoo penguin chicks as a measure of chick condition. Banded Adélie penguin chicks from the demography study are captured on the beach as they are about to fledge and weighed to the nearest 25g with Pesola scales. A non-banded Adélie chick was also captured and weighed at the same location and time to increase sample sizes. Gentoo penguin chicks are provisioned by their parents after they begin making trips to sea, so it is not possible to obtain definitive fledging weights by catching and weighing chicks prior to departure. Instead, gentoo penguin chicks are weighed 85 days after their mean clutch initiation date, approximately the age when other *Pygoscelis* chicks fledge.

#### *Foraging ecology studies*

Diet samples were collected from 20 Adélie, 25 gentoo and 15 chinstrap penguins between 27 December 2009 and 15 February 2010. Adults were captured at their nest sites upon returning from foraging trips, to assure they were feeding chicks, and the stomach contents were collected using the wet-offloading technique (Wilson 1984).

Full stomach loads were collected from Adélie and chinstrap penguins. For gentoo penguins, samples were confined to the fresh portion of the stomach samples only to avoid undue stress associated with handling larger birds. A sub-sample of 50 individual Antarctic krill from each diet sample was measured and sexed to determine length and sex frequency distributions of the krill selected by foraging penguins.

Radio transmitters were deployed on 17 adult Adélie penguins during the chick-rearing phase in order to determine their foraging trip durations. Colony attendance was logged between 24 December 2009 and 18 January 2010 using a remote receiver and data collection computer.

A small sample of Adélie, gentoo, and chinstrap penguins were instrumented with satellite transmitters (PTTs), to provide geographic data on adult foraging locations during the chick-rearing period. Four PTTs were deployed on Adélie penguins in early January and three on chinstrap penguins in mid-January during their respective chick brood stages. A total of 10 PTTs were applied to gentoo penguins during two separate deployments between 24 January and 16 February; the first four during the brood stage, the remaining six during the crèche phase. PTT data are awaiting analysis.

#### *Other seabirds*

The reproductive success of brown (*Catharacta antarctica lonnbergi*), south polar (*C. maccormicki*) and hybrid skua pairs breeding along the western shore of Admiralty Bay was followed over the course of the summer season via weekly surveys and nest checks. The reproductive performance of giant petrels (*Macronectes giganteus*) was also followed throughout the season.

Diets of the at-sea foraging south polar and hybrid pairs were followed by collecting fecal samples which are later sorted for evidence of fish and other prey species. The fecal samples are collected on the breeding territories four times during the breeding season; once each during courtship and incubation and twice during the chick-rearing period. All skua reproductive data await analysis and the samples have been sent to Pomona College where they will be analyzed by N. Karnovsky as part of an ongoing collaboration.

## **Results**

#### *Breeding biology studies*

The penguin colony at Copa consists of a dozen Adélie and many loosely defined gentoo penguin sub-colonies, with a few nesting chinstrap penguins. There are additional colonies of chinstrap penguins at three other locations along the western shore of Admiralty Bay.

There were 2,102 Adélie penguin nests at the date of the count; however, the counts were difficult and are likely underestimates of the Adélie penguin population in 2009/10 as the colony was buried under four-to-six feet of snow in many areas. Adélie penguins in many sub-colonies abandoned their nests after laying eggs in snow bowls.

Gentoo penguins at Copa exhibited very asynchronous egg-laying dates, with colonies in snow-free areas laying in early November, while penguins in snowbound areas did not lay until early December, the latest laying dates ever recorded for this colony in over 30 years of study. A total of 3,485 gentoo penguin nests were counted, a drop in population of nearly 1,500 nesting pairs from the previous year. However, this decline was largely due to the lack of nesting areas that were snow free and the population is expected to rebound next season if conditions return to normal.

A total of 825 chinstrap penguin nests were counted in the three colonies along the western shore of Admiralty Bay, a decline of approximately 300 breeding pairs from the prior season. Again, the decrease in chinstrap penguin nests is most likely low due to the lack of suitable nesting

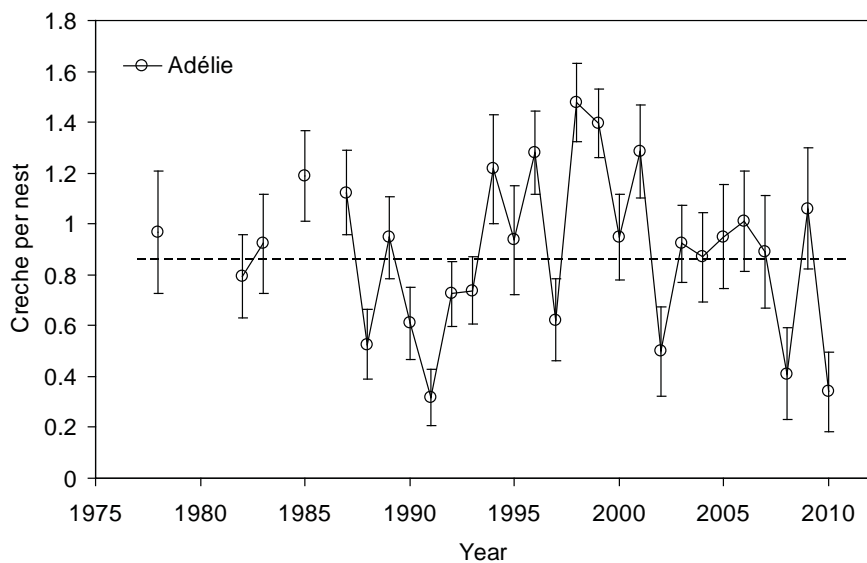


Figure 9.1. Annual mean reproductive success ( $\pm 95\%$  CI) of Adélie penguins measured during reproductive studies at Admiralty Bay, King George Island, Antarctica. The dashed line is the historical mean from 1977 through 2009.

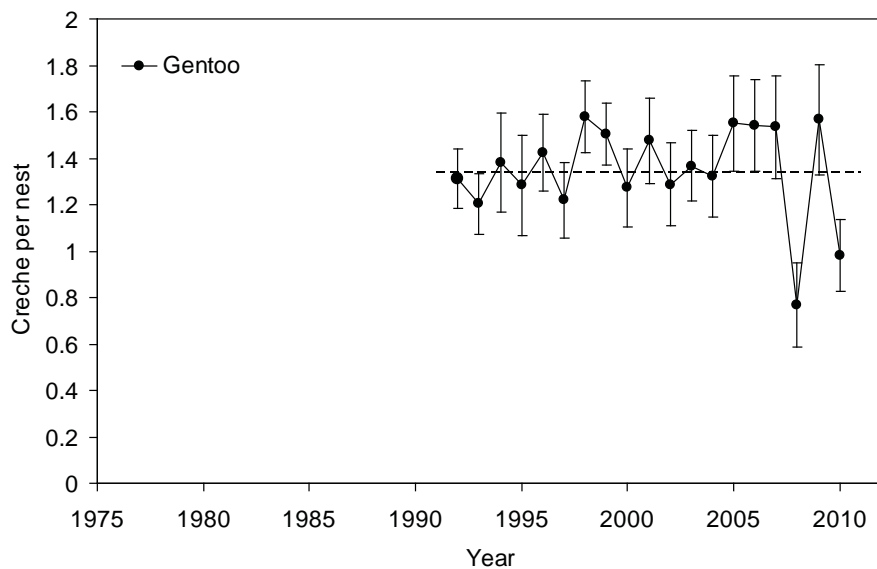


Figure 9.2. Annual mean reproductive success ( $\pm 95\%$  CI) of gentoo penguins measured during reproductive studies at Admiralty Bay, King George Island, Antarctica. The dashed line is the historical mean from 1991 through 2009.

conditions brought on by the greatest snow levels at our study site in over 30 years.

The Adélie penguin chick count was 732; the gentoo penguin chick count was 2109, and the chinstrap penguin chick count was 680. Based on census data, Adélie penguins

fledged 0.35 chicks per breeding pair, gentoo penguins fledged 0.61 chicks per pair, while chinstrap penguins had the highest fledging rate of 0.82 chicks per pair.

Based on the banded sample of nesting pair in the reproductive study, Adélie penguins fledged 0.37 chicks per pair (Figure 10.1), similar to the estimate derived from the colony count data above (0.35 chicks per pair). However, gentoo penguins in the reproductive study (Figure 10.2) fledged 0.98 chicks per pair (versus 0.61 from the census data). The higher estimate of chick production from the reproductive study may be derived from a biased selection of breeding pairs (e.g., the census data likely included nested pairs that did not reproduce because of poor nesting conditions in the breeding colony). Chinstrap penguins breed in three colonies located at distances approximately six to ten km from the primary study site. Therefore, we do not follow chinstrap penguins on a daily basis as is done for their congeners. The low reproductive success observed, relative to long-term means, for Adélie penguins (Figure 9.1) and gentoo penguins (Figure 9.2), was most likely due to high rates of egg loss during the incubation period. Chinstrap penguins normally breed a month after Adélie penguins at our site and they experienced improved nesting conditions as a result.

Twenty-three known-age Adélie penguins (3-8 years of age, with 13 first-time breeding 3 & 4 year olds) fledged only 0.17 chicks per pair, while 36 known-age gentoo penguins, two to four years of age, fledged 0.80 chicks per pair

The mean fledging mass for Adélie penguin chicks was 2881g ( $n = 88$ ; SD 448). This is the lowest recorded mean fledging mass for Adélie penguins in the last 30 years (Figure 9.3). A sample of gentoo penguin chicks was weighed on 18 February 2010 and had an average mass of 4536g ( $n = 100$ ; S.D. = 574). This is 250 grams higher than the previous 10-year mean (Figure 9.3).

### Foraging ecology studies

Adélie penguin mean stomach load mass was 475g, approximately 85g lower than the 24-year mean for this species and one of the three lowest years on record (Figure 9.4). Chinstrap penguin mean stomach mass was 568g, only slightly below the long-term mean of 590g (Figure 9.5).

Antarctic krill (*Euphausia superba*) was present in all stomach samples and comprised the majority of the diet in 59 of the 60 samples collected. Other euphausiids, including *Thysanoessa macrura* and *E. frigida*, were the next largest component of Adélie and chinstrap penguin diets, but were not seen in gentoo penguin stomach samples. Approximately 1/3 of each species' diet samples (7/20 Adélie and 5/15 chinstrap penguins) had *T. macrura* in them, most with measurable amounts. As in past years, the *T. macrura* was found in samples taken in late January and early February. *E. frigida* was also identified in three Adélie penguin stomach samples, including one sample with about 100 grams of *E. frigida* in the fresh portion of the sample. Gentoo penguins had evidence of fish in their diets (e.g., otoliths, scales, hard parts) in seven of the 25 samples; however, there was only one gentoo penguin that had fresh fish in the food load brought back to feed chicks. Other marine invertebrates, such as amphipods and tunicates, were also found in the stomach samples, but represented <0.1% of all prey items.

Krill in Adélie penguin samples were smaller (41.8 mm) than krill in gentoo (46.7 mm) or chinstrap (47.1 mm) penguin samples, which did not differ. Of the krill eaten by the three species of penguins, 70-80 % were between 41-50 mm in length, 24% of the Adélie penguin krill were less than 40 mm, and 18% of the gentoo and chinstrap penguin krill were larger than 50 mm (Figure 9.6). Krill sex ratios were approximately equal in

the 2009/10 diet samples for all three species, with 50% of the krill being males, 46% females, and 4% juveniles.

Mean Adélie foraging trip durations were 17.6 hours ( $n = 17$ ; S.D. = 6.3). This was similar to the 17.4 hour foraging trips made by Adélie penguins in 2008/09; however, the last two years have had foraging trips that were

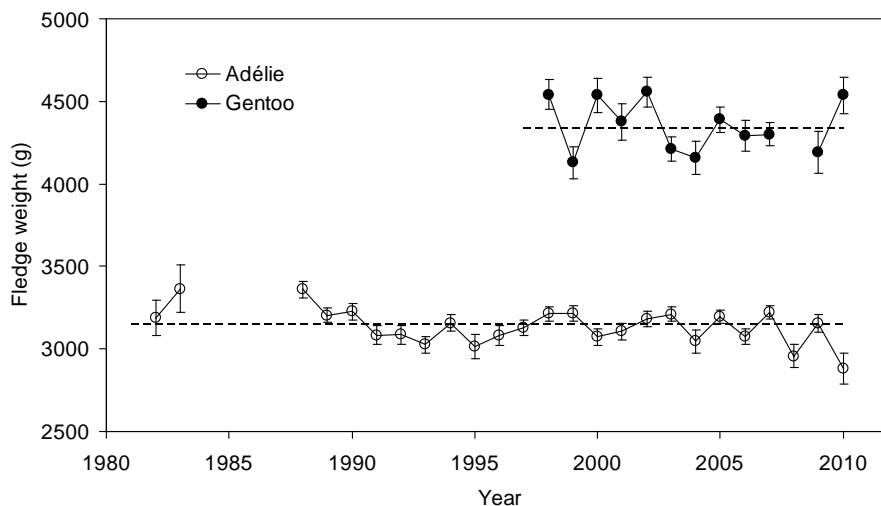


Figure 9.3. Annual mean fledgling weights ( $\pm$  95% CI) for Adélie and gentoo penguins at Admiralty Bay, King George Island, Antarctica. The dashed lines are historical means through 2009.

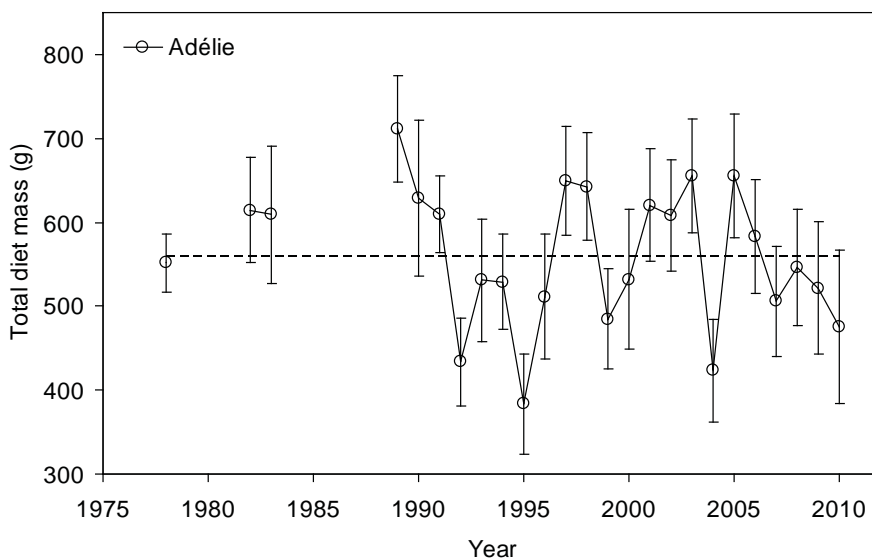


Figure 9.4. Annual diet mass ( $\pm$  95% CI) for Adélie penguins at Admiralty Bay, King George Island, Antarctica. The dashed line is the historical mean through 2009.

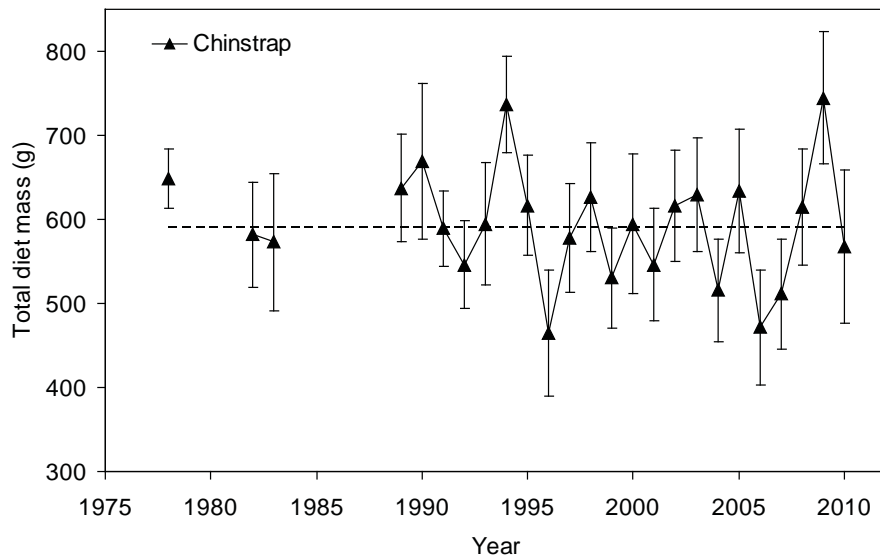


Figure 9.5. Annual diet mass ( $\pm$  95% CI) for chinstrap penguins at Admiralty Bay, King George Island, Antarctica. The dashed line is the historical mean through 2009.

at sea. All brown skua pairs that defended portions of the penguin colony as a food resource laid eggs. Several pairs re-laid after their nest was buried in a snow-storm and one pair laid four full clutches between mid-November and early January, but abandoned every attempt due to snow burying the nest. Many south polar skua pairs were not observed to lay eggs this season; however, the frequent storms and heavy snowfall could have caused extensive losses of eggs between weekly nest checks.

The giant petrel (*Marconectes giganteus*) population has been expanding of late and many known-aged birds have returned to breed in the colonies at our study site (Figure 9.7). Reproductive success was approximately 0.3 chicks fledged per pair in 2009/10, one of the two lowest success rates in the last 30 years. Loss during the incubation period, due to nest sites being buried in snow, was the primary cause of the low breeding success in 2009/10.

**Krill Length-Frequency in Adelie, Gentoo, & Chinstrap Diets at Copa**

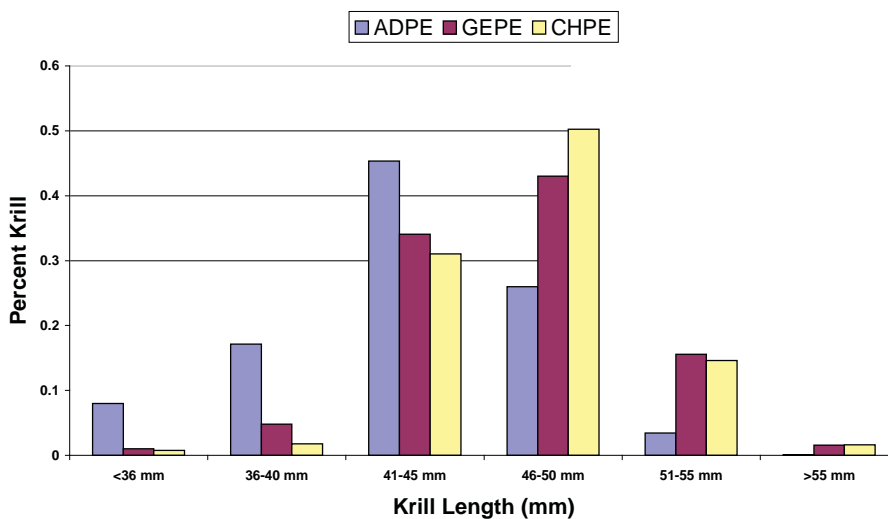


Figure 9.6. Krill length-frequency distribution from *Pygoscelis* penguin diets at Admiralty Bay, King George Island, Antarctica 2009/10.

**Discussion**

Seabird research in Admiralty Bay has continued for more than 30 years, with efforts focused at the Copacabana colony since 1984. This long-term research effort has allowed us to assess trends in penguin population size, reproductive success, diet and foraging behavior.

Breeding population counts were significantly lower for all three penguin species in 2009/10. Reproductive success for Adélie and gentoo penguins was well below their respective long term means. These results were likely driven by inclement weather during clutch initiation and incubation, including the highest snow

3 to 4 hours longer than the mean 13-14 h trips between 2005/06 and 2007/08.

*Other seabirds*

Only brown skuas defend feeding territories in the penguin colonies; south polar skuas and hybrid pairs feed

cover ever experienced at this colony in over 30 years. The snow accumulation continued throughout the summer and was often accompanied with strong winds and drifting snow in the breeding colonies, which buried occupied nests. Consequently, many adults abandoned their nests. Abandonment prior to nest censusing contributed to the low

population counts, while post-breeding abandonment may have biased the census-based estimate of reproductive success low. Fledging weights of Adélie penguin chicks were the lowest ever recorded since we began measuring this parameter in 1981.

Diet composition of all species was comparable to previous seasons, with krill accounting for the majority of prey biomass. However, Adélie penguin chicks were fed smaller krill than the krill captured by gentoo and chinstrap penguins and Adélie penguin food loads were almost 100 g below the long-term mean. Gentoo and chinstrap penguin diets were similar to past years, possibly indicating that the poor marine conditions were more pronounced in the early part of the year and may have improved for the later-breeding gentoo and chinstrap penguins. The mean foraging trip duration of Adélie penguins was slightly longer than observed in 2008/09, while adults feeding in both of the last two seasons spent 3-4 hours longer at sea in search of food than in the preceding three years. The foraging location data collected with PTTs may further assist us in interpreting the foraging trip data once it is analyzed.

### Protocol Deviations

Adélie nest censuses were conducted 16 November, more than a week later than in most seasons due to the heavy snow accumulations in the nesting areas of the birds. Due to poor reproductive success this year, only half the normal number of penguins were banded for demographic studies.

### Disposition of Data

Land-based seabird data are available from Dr. Wayne Trivelpiece, NOAA Fisheries, Antarctic Ecosystem Research Division, 3333 N. Torrey Pines Ct., La Jolla, CA 92037. Ph: 858-546-5607, Fax: 858-546-5608

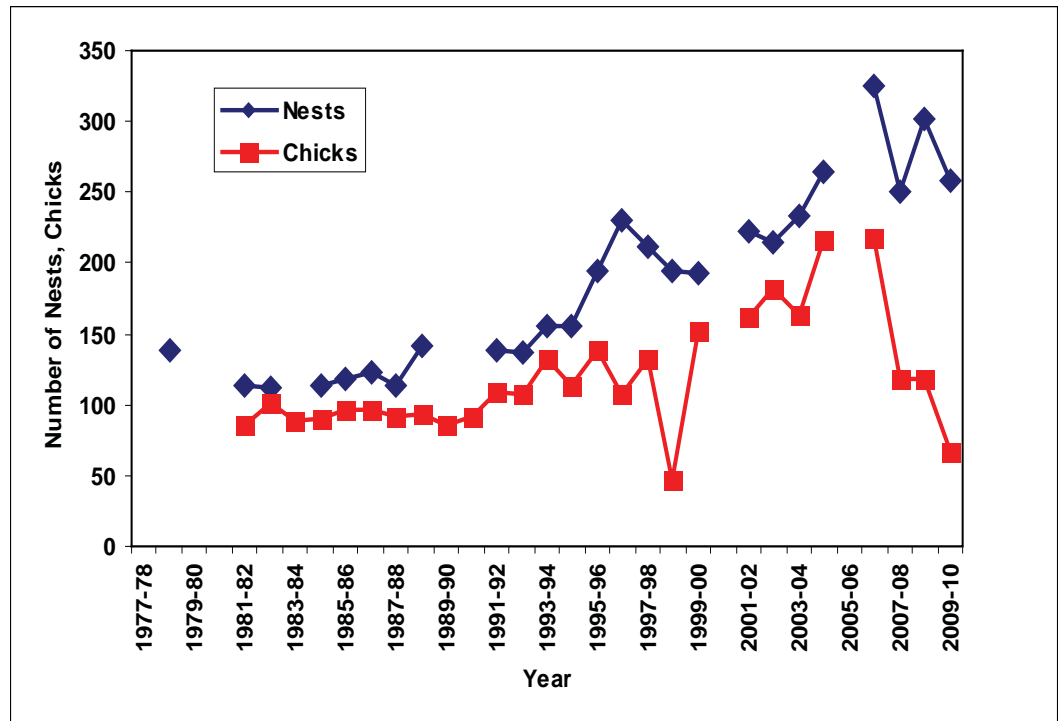


Figure 9.7. Giant petrel nest and chick count at the Copacabana colony, Admiralty Bay, King George Island, Antarctica 1978 – 2010.

### Acknowledgements

We would like to sincerely thank Dr. Andrzej Tatur, Director, Polish Department of Antarctic Biology, and members of the Polish Antarctic Expedition of 2009/10 for their assistance in the field and their hospitality. We are also grateful to the crew of the NSF Research Vessel Laurence M. Gould for our smooth transit to Admiralty Bay and for their help with camp opening, and to the crew of the AMLR-chartered Research Vessel Moana Wave for their efforts in resupplying our camp and for providing transit back to Punta Arenas, Chile.

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- Wilson RP (1984) An improved stomach pump for penguins and other seabirds. *J Field Ornithol* 55:109–112



## Appendix A: Suggestions for Improvement

*The following suggestions are made in an effort to continuously improve the nature of the AMLR Survey and the quality of data produced.*

### *Shipboard Suggestions*

- Logistical difficulties created by the curtailed sampling season and small ship's size caused less than 50% of the planned stations to be sampled during this field season. A larger ship is suggested in order to maintain the AMLR Program's ability to complete its sampling protocol each year.
- The CTD/carousel frame needed to be man-handled into a position under the A-frame, and re-stowed after every station, causing unnecessary jolting of the equipment. It also proved difficult to protect the equipment from knocking against the stern of the ship during deployments, due to the short outboard reach of the A-frame. Initial hydraulic shuddering problems with the winch added to this excessive vibration and jolting of the equipment. This, together with wave damaged while stowed on deck, caused many of the sampling bottles to break. Routine servicing of the connectors was also made difficult due to the deck wash. The CTD frame was also badly damaged at the end of Leg I, and the systems had to be rebuilt onto the spare frame. The damaged frame was repaired by welding contractors in Punta Arenas. A post cruise calibration of the SBE 9plus CTD and the auxiliary sensors is all that is required. A new set of 10 L sampling bottles and a restock of underwater leads that were used during the cruise will be required for 2011.
- This equipment will need to be serviced or replaced before the next field season.
- The operating conditions described above are risky for the deployment personnel and are not recommended when trying to maintain quality data capture with this equipment.
- Initial problems with the Guildline Portasal's clutch and suction pump were repaired and a continuous check of CTD performance was completed by frequently processing data and checking for signs of sensor drift. Close correlation was obtained between the CTD and Portasal, but it is suggested that alternative servicing agents be investigated to service the Portasal, as similar repairs had to be done on previous cruises, before work could start with the Portasal.

### *Landbased Suggestions*

- Annual variability in pinniped and seabird reproductive biology and foraging ecology is correlated with environmental factors such as wind, precipitation and temperature. In order to better record and analyze these correlations, we recommend an assessment of the existing weather stations at Cape Shirreff and Copacabana field stations. Future environmental monitoring should include measures of snow cover at the start of the reproductive season. Further, the current weather monitoring is confined to the period of human occupancy (October-February) and should be, whenever possible, be extended to year-round data collection. The existing stations should be reviewed by a meteorologist, to ensure that the data collected meets meteorological standards. Annual variability in pinniped and seabird reproductive biology and foraging ecology is likely correlated with environmental factors such as wind, precipitation and temperature. In order to better record and analyze these correlations, we recommend improving the weather stations in the South Shetland Islands. The existing stations should be replaced with equipment recommended by a meteorological representative, to ensure that the data collected meets the standards required for reliable data analysis.

## RECENT TECHNICAL MEMORANDUMS

SWFSC Technical Memorandums are accessible online at the SWFSC web site (<http://swfsc.noaa.gov>). Copies are also available from the National Technical Information Service, 5285 Port Royal Road, Springfield, VA 22161 (<http://www.ntis.gov>). Recent issues of NOAA Technical Memorandums from the NMFS Southwest Fisheries Science Center are listed below:

- NOAA-TM-NMFS-SWFSC-460 Estimates of sustainable yield for 50 data-poor stocks in the Pacific Coast groundfish fishery management plan.  
E.J. DICK, and A.D. MacCALL  
(June 2010)
- 461 Documentation of the California catch reconstruction project.  
S. RALSTON, D.E. PEARSON, J.C. FIELD, and M. KEY  
(July 2010)
- 462 Serious injury determinations for cetaceans caught in Hawaii longline fisheries during 1994-2008.  
K.A. FORNEY  
(October 2010)
- 463 Spawning biomass of Pacific sardine (*Sardinops sagax*) off the U.S. in 2010.  
N.C.H. LO, B.J. MACEWICZ, and D.A. GRIFFITH  
(October 2010)
- 464 Ecosystem survey of *Delphinus* species cruise report.  
S.J. CHIVERS, W.L. PERRYMAN, N.M. KELLAR, J.V. CARRETTA,  
F.I. ARCHER, J.V. REDFERN, A.E. HENRY, M.S. LYNN, C. HALL  
A. JACKSON, G. SERRA-VALENTE, T.J. MOORE, C. SURREY-MARSDEN,  
and L.T. BALLANCE  
(October 2010)
- 465 Oregon, California and Washington line-transect and ecosystem (ORCAWALE) 2008 cruise report.  
J. BARLOW, A.E. HENRY, J.V. REDFERN, T. YACK, A. JACKSON,  
C. HALL, E. ARCHER, and L.T. BALLANCE  
(October 2010)
- 466 A forward-looking scientific frame of reference for steelhead recovery on the south-central and southern California coast.  
D.A. BOUGHTON  
(October 2010)
- 467 Some research questions on recovery of steelhead on the south-central and southern California coast.  
D.A. BOUGHTON  
(October 2010)
- 468 Is the September 1 river return date approximation appropriate for Klamath River fall Chinook?  
M.R. O'FARRELL, M.L. PALMER-ZWAHLEN and J. SIMON  
(November 2010)
- 469 Assessment of the Pacific sardine resource in 2010 for U.S. management in 2011.  
K.T. HILL, N.C.H. LO, B.J. MACEWICZ, P.R. CRONE, and  
R. FELIX-URAGA  
(December 2010)