Bioacoustic Survey

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Abstract Multi-frequency acoustic data were collected around the South Shetland and South Orkney Islands, Antarctica from January through March 2009. Data were collected to determine the distribution and biomass of krill and to infer the acoustic characteristics of the benthos.

- Around the South Shetland Islands in January, mean krill abundance was 25, 63, and 17 g/m² for the West, Elephant Island, and South Areas, respectively. During Leg II, krill abundance ranged from 0 to 794 g/m² per nautical mile.
- Highest densities of krill were observed around Elephant Island and northwest of the South Orkney Islands.
- More than 2,225 nautical miles of acoustic data were collected to characterize benthic properties around the South Orkney Islands.

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. The survey was also conducted to map the distribution of myctophids and to determine their relationship with water mass boundaries and zooplankton distribution. Finally, transects were completed in order to characterize krill distribution and the benthic environment around the South Orkney Islands for future analysis.

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

Cruise	Elephant Island krill length	120-38	200-120	West krill length	120-38	200-120	South 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

Methods

Acoustic data were collected using a multi-frequency echo sounder (Simrad EK60) configured with down-looking 38, 70, 120, and 200 kHz split-beam transducers mounted in the hull of the ship. System calibrations were conducted before and after the survey, using standard sphere techniques (Foote, 1989), 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 all four frequencies. 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 with Myriax's Echoview software.

During Leg I, acoustic surveys completed in the South Shetland Islands were divided into four areas (See Figure 2 in Introduction): (1) a 43,865 km^2 area centered on Elephant Island (Elephant Island Area) was sampled with seven north-south transects; (2) a 38,524 km^2 area along the north side of the southwestern portion of the South Shetland archipelago (West Area) was sampled with seven transects oriented northwest-southwest and one oriented north-south; (3) a 24,479 km^2 area in the western Bransfield Strait (South Area) was sampled with seven transects oriented northwest-southwest; and (4) an 18,151 km^2 area north of Joinville Island (Joinville Island Area) with three north-south transects. During Leg II, acoustic data were collected whenever IKMT net tows were completed to quantify krill aggregations. Acoustic data were also collected between tows to characterize benthic properties around the South Orkney Islands.

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 at night (Demer and Hewitt, 1995).

Data Analysis

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

For the purpose of delieating myctophids, a ΔS_v win-

Table 3.2. Daytime integrated krill density estimates by area and transect for Leg I of the AMLR Survey; n = 1 nautical mile.

Area	Transect	n	Krill density (g/m²)
West Area			
	Transect 1	39	38.3
	Transect 2	39	14.2
	Transect 3	42	53.7
	Transect 4	43	42.9
	Transect 5	59	44.9
	Transect 6	53	13.3
	Transect 7	102	0.4
Elephant Island Area			
	Transect 1	98	19.3
	Transect 2	65	24.2
	Transect 3	96	19.5
	Transect 4	85	73.6
	Transect 5	115	99.7
	Transect 6	35	39.9
	Transect 7	108	125.6
South Area			
	Transect 1	44	11.1
	Transect 2	40	30.8
	Transect 3	40	17.5
	Transect 4	26	0
	Transect 5	44	28.7
	Transect 6	0	n/a
	Transect 7	37	8.4

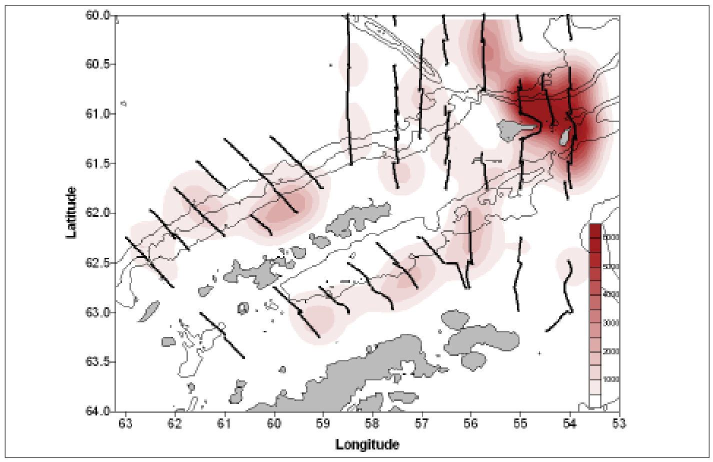

Figure 3.1. Normalized krill NASC values for Leg I at 120 kHz using daytime data (Latitude is south and longitude is west).

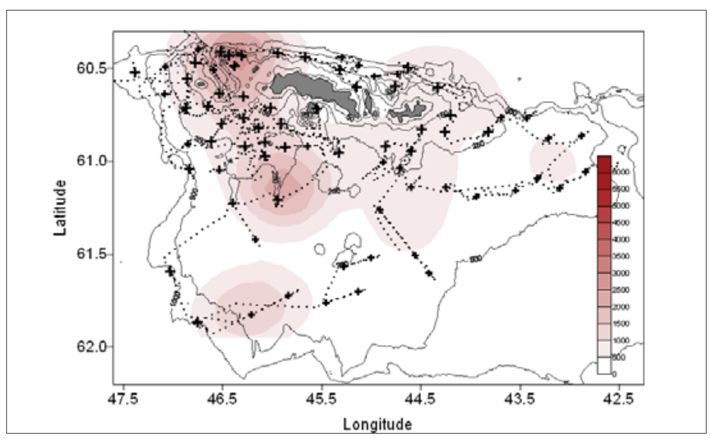

Figure 3.2. Normalized krill NASC values for Leg II at 120 kHz using daytime data. (Latitude is south and longitude is west).

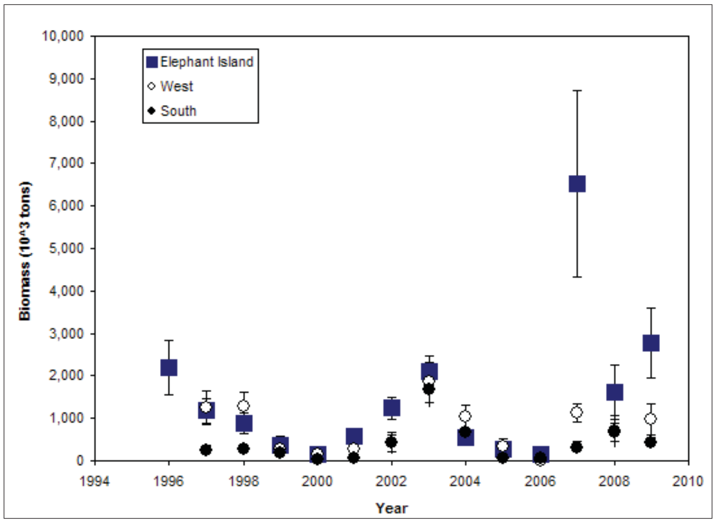

Figure 3.3. Historical (1996-2009) krill biomass (10^3 tons) values for Elephant Island, West and South Areas.

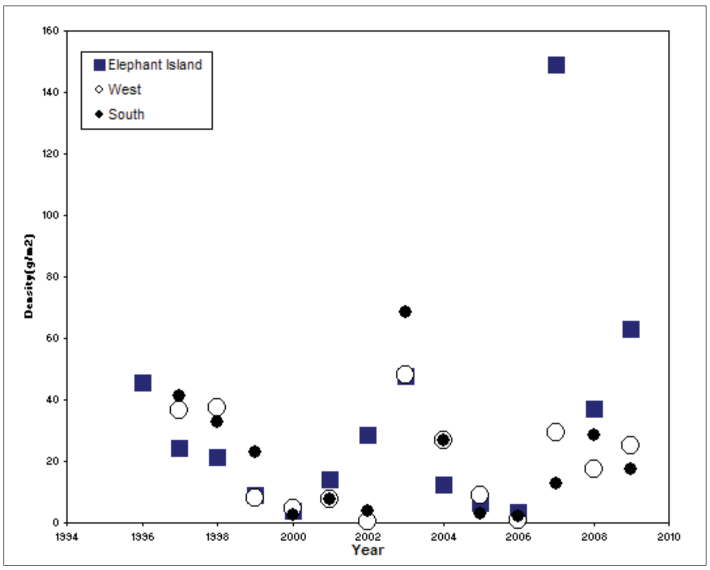

Figure 3.4. Historical (1996-2009) integrated krill density (g/m^2) values for Elephant Island, West and South Areas.

dow of -5 to 2 dB was applied using a two-frequency (38 kHz and 120 kHz) method. 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 ΔSv 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 (500 m) 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 (ρ) 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 (σ) ($\sigma = 4\pi r10^{TS/10}$ where r is the reference range of 1 m; Hewitt and Demer, 1993). The length-to-weight relationship

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

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

$$(2) \qquad \rho\ (g/m2) = \frac{\sum_{i=1}^{n} f_i W(l_i)}{\sum_{i=1}^{n} f_i \sigma(l_i)} \text{NASC}$$

where f_i equals the relative frequency of krill of standard length l_i. Krill biomass was then estimated by multiplying ρ by the area surveyed.

For each area in the 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 NASC within each area and to expand the abundance estimate for the South Shetland Islands.

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's Echoview software and then mapped across the South Shetland Islands using SURFER (Golden Software, Inc. Golden, CO). However, owing to large amounts of noise in the acoustic data this year, we did not produce a map of myctophid associated NASC.

Results

Mean integrated krill density for each transect line in each area is presented in Table 3.2; NASC values for each Leg of the AMLR Survey are in Figures 3.1 (Leg I) and 3.2 (Leg II). For comparison, historical krill biomass and mean integrated density values are presented in Figures 3.3 and

3.4, respectively. Mean integrated krill density was 25, 63, and 17 g/m^2 for the West, Elephant Island, and South Areas, respectively, during Leg I. Highest densities were seen around Elephant Island, which is consistent with historical data. Abundance estimates measured in the South Orkney Islands during Leg II ranged from 0 to 794 g/m^2 for a given nautical mile.

Additionally, more than 2,225 nautical miles of acoustic data were collected to characterize benthic properties around the South Orkney Islands. The data await analysis in the Southwest Fisheries Science Center.

Discussion

Our data indicated that krill biomass was greater than last year, and, in the Elephant Island Area, was the second greatest observed in the since 1996. In the South Shetland Islands, integrated krill density was highest around Elephant Island, which is where krill are historically distributed.

The highest integrated krill density observed in the South Orkney Islands was in the canyon northwest of Coronation Island. This is where the highest integrated density of krill was found in 2008, as well as where the krill fishery is historically located. Refining our calculation of the biomass data collected in the South Orkney Islands in 2008 and 2009 will allow more accurate analysis of the region.

Protocol Deviations

Due to high amounts of acoustic noise recorded during the survey, integration was only completed to 250 m.

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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 use approximately 10 MB. The data are available from Anthony Cossio, Southwest Fisheries Science Center, 3333 North Torrey Pines Court, La Jolla, CA 92037; phone/fax – (858) 546-5609/546-5608; e-mail: Anthony.Cossio@noaa.gov.

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AMLR ANTARCTIC MARINE LIVING RESOURCES PROGRAM

AMLR 2008/2009 FIELD SEASON REPORT

Objectives, Accomplishments and Tentative Conclusions

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The National Oceanic and Atmospheric Administration (NOAA), organized in 1970, has evolved into an agency which establishes national policies and manages and conserves our oceanic, coastal, and atmospheric resources. An organizational element within NOAA, the Office of Fisheries is responsible for fisheries policy and the direction of the National Marine Fisheries Service (NMFS).

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