3. Bioacoustic survey; submitted by Anthony M. Cossio and Christian Reiss

3.1 Objectives: 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.

3.2 Methods and Accomplishments: Acoustic data were collected using a multi-frequency echo sounder (Simrad EK60), configured with down-looking 38, 70, 120, and 200 kilohertz (kHz) split-beam transducers, mounted in the hull of the ship. System calibrations were conducted before and 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 2 seconds at 1 kilowatt for 1 millisecond duration at 38 kHz, 70 kHz, 120 kHz, and 200 kHz. Geographic positions were logged simultaneously every 2 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.

Acoustic surveys of the water surrounding 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 six 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; (4) and an 18,151 km^2 area north of Joinville Island (Joinville Island Area). During the second leg of the cruise, the Elephant Island Area and the South Area were re-surveyed with only 6 transects in the Elephant Island Area. The West Area was not re-surveyed because of time limits. The area surrounding the South Orkney Islands was also sampled during the second leg and split into two different areas. The northern and southern sections of the South Orkney Islands were divided at 60.5° South. The northern section consisted of five north-south transects that covered an area of 10,841 km^2 and the southern section consisted of five north-south transects that covered an area of 21,190 km^2.

Data collected while at biological sampling stations were discarded. Only daytime data were used in analysis due to possible bias from diurnal vertical migration (Demer and Hewitt, 1995).

3.2.1 Krill Delineation: 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 survey area (CCAMLR, 2005). This differs from previous work when analyses were conducted using a constant range of ΔS_v ($4 \leq (S_{v,120} - S_{v,38}) \leq 16$ 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.

3.2.2 Myctophid Delineation: A ΔMVBS window of -5 to 2dB 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.

3.2.3 Abundance Estimation and Map Generation: Backscatter values were averaged over 5m by 100s bins. Time varied gain (TVG) noise was subtracted from the echogram and the ΔS_v range was applied. TVG values were based on levels required to erase the rainbow effect plus 2dB. The remaining volume backscatter classified as krill was integrated over depth (500m) and averaged over 1,852m (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) ($\sigma = 4\pi r 10^{TS/10}$ where r is the reference range of 1m; Hewitt and Demer, 1993). The length to weight relationship

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

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):

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

where f_i = 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 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 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 SonarData Echoview software and then mapped across the South Shetland Islands using SURFER (Golden Software, Inc. Golden, CO).

3.3 Tentative Conclusions:

3.3.1 : Mean krill abundance for each transect line in each area is presented in Tables 3.2 and 3.3. Mean krill abundance was 17, 41, and 42 g/m² for the West, Elephant Island, and South Areas, respectively, during Leg 1. For Leg 2, abundance estimates were 33, 15, 129, and 61 g/m² for the Elephant Island, South Area and South Orkney Islands northern and southern sections, respectively (Table 3.4). Krill distributions were highest around Elephant Island and to the northwest of the South Orkney Islands (Figures 3.1 and 3.3).

The distribution of mean NASC of myctophids was mapped and was highest along the 2000m isobath (Figures 3.2 and 3.4). This is similar to previous years' patterns.

3.4 Protocol Changes:

There were no protocol changes or problems that arose during the acoustic survey.

3.5 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, 8604 La Jolla Shores Dr, La Jolla, CA 92037; phone/fax – (858) 546-5609/546-5608; e-mail: Anthony.Cossio@noaa.gov.

3.5 References:

CCAMLR, 2005. Report of the first meeting of the subgroup on acoustic survey and analysis methods. SC-CAMLR-XXIV/BG/3.

Conti, S. G., and Demer, D. A. 2006. Improved parameterization of the SDWBA for estimating krill target strength. *ICES Journal of Marine Science* 63: 928-935.

Demer, D. A. and Conti, S. G. 2005. New target-strength model indicates more krill in the Southern Ocean. *ICES Journal of Marine Science* 62: 25-32.

Demer, D.A. and Hewitt, R.P. 1995. Bias in acoustic biomass estimates of Euphausia superba due to diel vertical migration. *Deep Sea Research I* 42: 455-475.

Greene, C. H., Wiebe, P. H., and McClatchie, S. 1991. Acoustic estimates of krill. *Nature* 349: 110.

Hewitt, R.P. and Demer, D.A. 1993. Dispersion and abundance of Antarctic krill in the vicinity of Elephant Island in the 1992 austral summer. *Marine Ecology Progress Series* 99:29-39.

Hewitt, R.P., Demer, D.A., and Emery J.H. 2003. An eight year cycle in krill biomass density inferred from acoustic surveys conducted in the vicinity of the South Shetland Islands during the austral summers of 1991/92 through 2001/02. *Aquatic Living Resources* 16(3): 205-213.

Hewitt, R. P, Watkins, J, Naganobu, M, Sushin, V, Brierley, A. S, Demer, D. A., Kasatkina, S., Takao, Y., Goss, C., Malyshko, A., Brandon, M. A., Kawaguchi, S., Siegel, V., Trathan, P. H., Emery, J., Everson, I., and Miller, D. 2004. Biomass of Antarctic krill in the Scotia Sea in January/February 2000 and its use in revising an estimate of precautionary yield. *Deep Sea Research II* 51: 1215-1236.

Jolly, G.M. and Hampton, I. 1990. A stratified random transect design for acoustic surveys of fish stocks. *Can. J. Fish. Aquat. Sci*. 47:1282-1291.

Maclennan, H. and Fernandes, P. Definitions, units and symbols in fisheries acoustics. Draft 03/04/00. Contr FAST Working Group Meeting, Haarlem, April 2000. 6p.

Reiss, C.S., Cossio, A.M., Loeb, V. and Demer, D.A. 2008. Variations in the biomass of Antarctic krill (*Euphausia superba*) around the South Shetland Islands, 1996-2006. *ICES Journal of Marine Science* 65:497-508.

Williamson, N. 1982. Cluster sampling estimation of the variance of abundance estimates derived from quantitative echo sounder surveys. *Can. J. Fish. Aquat. Sci*. 39:229-231.

Table 3.1. Range of total lengths (TL, mm) and acoustic ΔS_v 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 2008, using the simplified SDWBA model (see Conti and Demer, 2005; and CCAMLR, 2005).

Cruise	Elephant Island Krill length	120-38 kHz	200-120 kHz	West Krill length	120-38 kHz	200-120 kHz	South Krill length	120-38 kHz	200-120 kHz
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

Table 3.2. Daytime krill abundance estimates by Area and transect for Leg I and Leg II of the survey. n = 1 interval = 1 nautical mile.

Area	Transect	n	Krill abundance (g/m^2)
West Area			
	Transect 1	35	38.9
	Transect 2	50	35.3
	Transect 3	14	49.5
	Transect 4	70	19.6
	Transect 5	39	4
	Transect 6	46	0.1
	Transect 7	112	8.7
Elephant Island Area			
	Transect 1	97	70.4
	Transect 2	95	53.7
	Transect 3	104	84.9
	Transect 4	115	4.2
	Transect 5	106	11.3
	Transect 6	94	6.3
	Transect 7	74	70.4
South Area			
	Transect 1	31	5.9
	Transect 2	44	107.3
	Transect 3	42	0.04
	Transect 4	46	34.1
	Transect 5	42	90.2
	Transect 6	0	n/a
	Transect 7	40	0.5
Elephant Island Area			
	Transect 1	69	19.2
	Transect 2	n/a	n/a
	Transect 3	63	0.04
	Transect 4	68	17.3
	Transect 5	89	84.1
	Transect 6	101	0.4
	Transect 7	85	63.7
South Area			
	Transect 1	16	0.002
	Transect 2	41	35.3
	Transect 3	0	n/a
	Transect 4	41	0.2
	Transect 5	11	4
	Transect 6	13	67.5
	Transect 7	39	0.8

Table 3.3. Range of TL (mm) and acoustic ΔS_v ranges applied to assess biomass of Antarctic krill in the South Orkney Islands Area. Daytime krill abundance estimates by area and transect for the South Orkney Islands Area. n = 1 interval = 1 nautical mile.

Area	Krill Length	120-38 kHz	200-120 kHz
South Orkney Islands - North	22-49	4.6 to 14.7	-0.5 to 2.1
South Orkneys Islands - South	22-49	4.6 to 14.7	-0.5 to 2.1

Area	Transect	n	Krill abundance (g/m^2)
South Orkney Islands - North			
	Transect 1	31	48.8
	Transect 2	31	325.6
	Transect 3	29	104.7
	Transect 4	31	63.2
	Transect 5	28	98.5
South Orkneys Islands - South			
	Transect 1	54	117.5
	Transect 2	16	116.2
	Transect 3	66	50.6
	Transect 4	16	6.6
	Transect 5	66	25

Table 3.4. Mean krill biomass for surveys conducted from 1996 to 2008. Coefficients of variation (CV) are calculated by the methods described in Jolly and Hampton, 1990, and describe measurement imprecision due to the survey design. Only one survey was conducted in 1997; 1999 South Area D values are not available due to lack of data. See Figure 2 in the Introduction Section for description of each survey.

Survey	Area	Area (km^2)	Mean Density (g/m^2)	Biomass (10^3 tons)	CV %
1996 A (late January)	Elephant Island	41,673	55.27	2,666	28.5
D (early March)	Elephant Island	41,673	35.66	1,720	29.3
1997 A (late January)	Elephant Island	41,673	24.43	1,178	23.8
	West	34,149	36.8	1,257	31.3
	South	8,102	41.38	236	51.2
1998 A (late January)	Elephant Island	41,673	31.76	1,324	25.5
	West	34,149	56.4	1,927	25.9
	South	8,102	41.1	333	23
D (late February)	Elephant Island	41,673	10.83	451	29.4
	West	34,149	18.3	625	27.2
	South	8,102	24.75	200	38.5
1999 A (late January)	Elephant Island	41,673	7.19	300	47.3
	West	34,149	8.89	304	33.8
	South	8,102	23	186	18.3
D (late February)	Elephant Island	41,673	10.7	446	68.1
	West	34,149	6.88	235	41.8
2000 D (late February)	West	34,149	4.51	154	32.2
	Elephant Island	41,673	3.67	153	36.3
	South	8,102	2.51	20	0.5
2001 A (late January)	West	34,149	0.13	4	51.1
	Elephant Island	41,673	13.44	560	21.6
	South	8,102	9.83	80	29.9
D (late February)	West	34,149	15.12	516	60.5
	Elephant Island	41,673	14.44	602	11.4
	South	8,102	5.61	45	51.5
2002 A (late January)	West	38,524	21..02	810	44.6
	Elephant Island	43,865	51.92	2,277	14.9
	South	24,479	4.28	105	48.2
D (late February)	West	38,524	0.41	16	46.4
	Elephant Island	43,865	4.73	208	26.5
	South	24,479	2.97	726	79.9
2003 A (late January)	West	38,524	54.28	2,091	21.8
	Elephant Island	43,865	57.79	2,535	13.4
	South	24,479	57.19	1,400	29.9
D (late February)	West	38,524	41.82	1,611	29.5
	Elephant Island	43,865	37.86	1,661	21.2
	South	24,479	80.02	1,959	20.4
2004 A (late January)	West	38,524	34.37	1,324	8.9
	Elephant Island	43,865	21.41	939	17.4
	South	24,479	7.22	177	48

D (late February)	West	38,524	18.87	727	44
	Elephant Island	43,865	3.51	154	42.1
	South		46.59	1,141	51.4
2005 A (late January)	West	38,524	17.11	659	26.6
	Elephant Island	43,865	11.93	523	55
	South	24,479	3.93	96	55.7
D (Late February)	West	38,524	0.37	17	85.2
	Elephant Island	43,865	0.75	33	37.1
	South	24,479	1.97	48	21.4
2006 (Late January)	West	38,524	0.81	3	45.9
	Elephant Island	43,865	3.46	152	38.9
	South	24,479	1.95	48	49.3
2007 (Late January)	West	38,524	29.23	1,126	19.7
	Elephant Island	43,865	148.87	6,530	33.7
	South	24,479	12.89	315	40.9
2008 A (Late January)	West	38,524	17.31	667	31.6
	Elephant Island	43,865	41.24	1,809	32.8
	South	24,479	41.96	1,027	47.2
SO (Late February)	South Orkneys North	10,841	129.09	1,399	40.3
	South Orkneys South	21,190	61.0	1,2934	34.6
D (Early March)	Elephant Island	43,865	32.53	1,427	47.4
	South	24,479	14.96	366	62.8

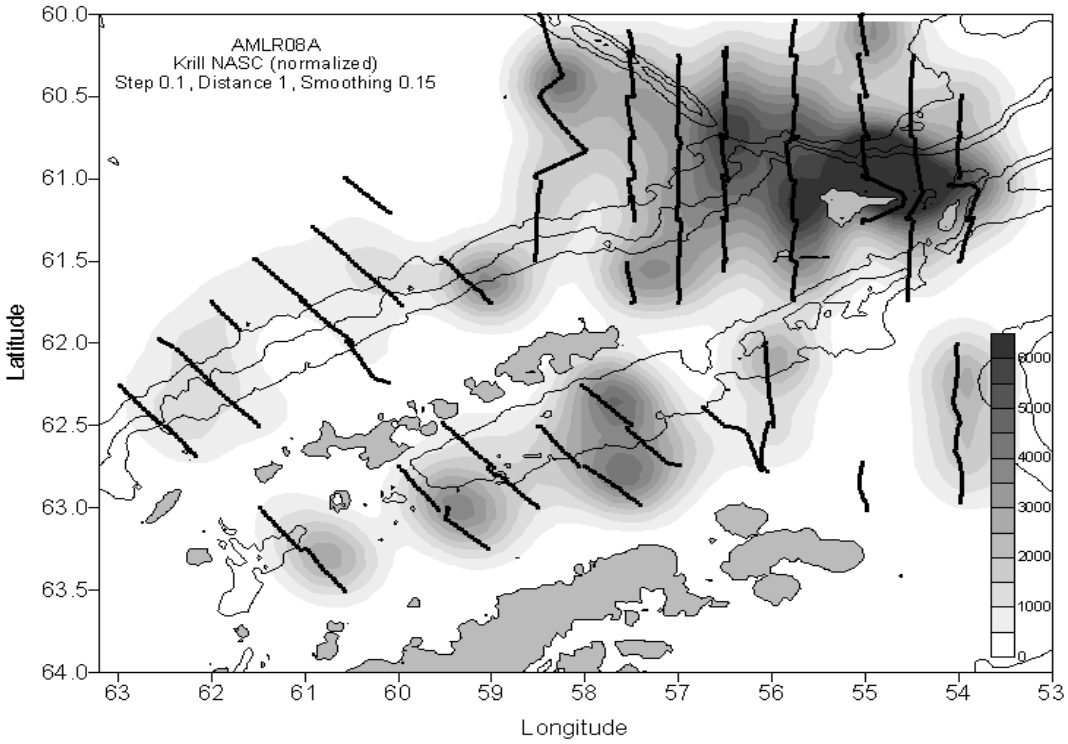

Figure 3.1. Normalized krill NASC values for Survey A (South Shetland Islands) at 120 kHz using day data. (Latitude is south and longitude is west).

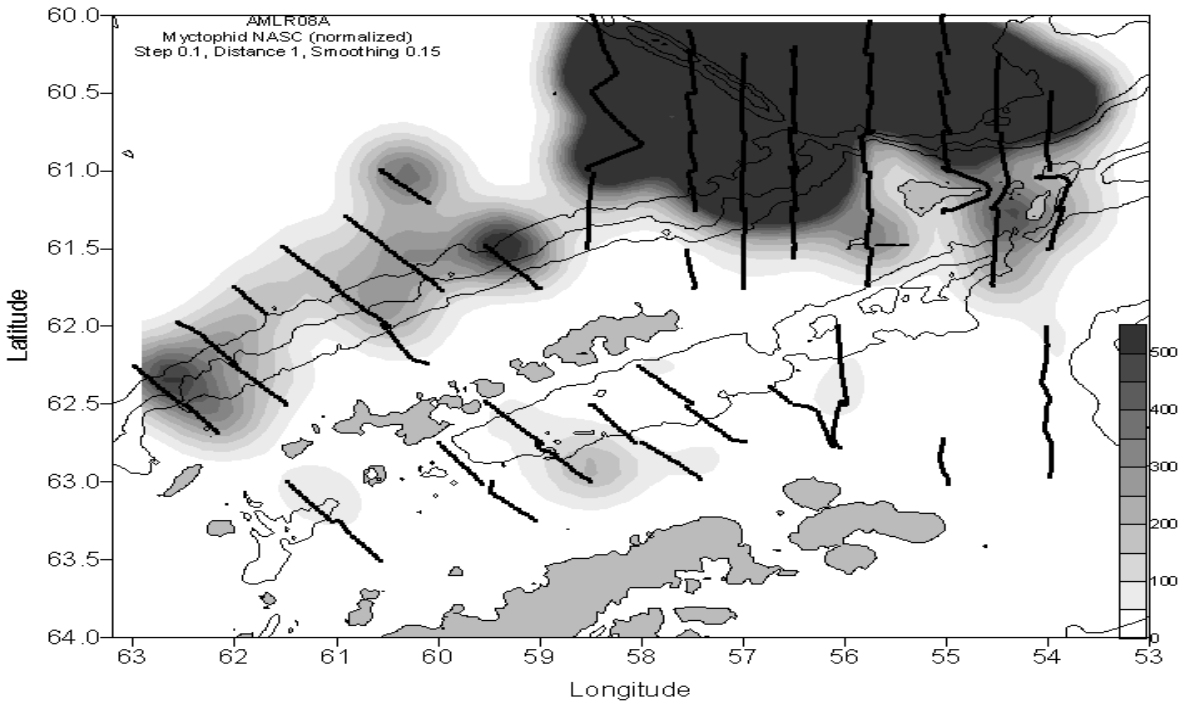

Figure 3.2. Normalized myctophid NASC values for Survey A (South Shetland Islands) at 120 kHz using day data. (Latitude is south and longitude is west).

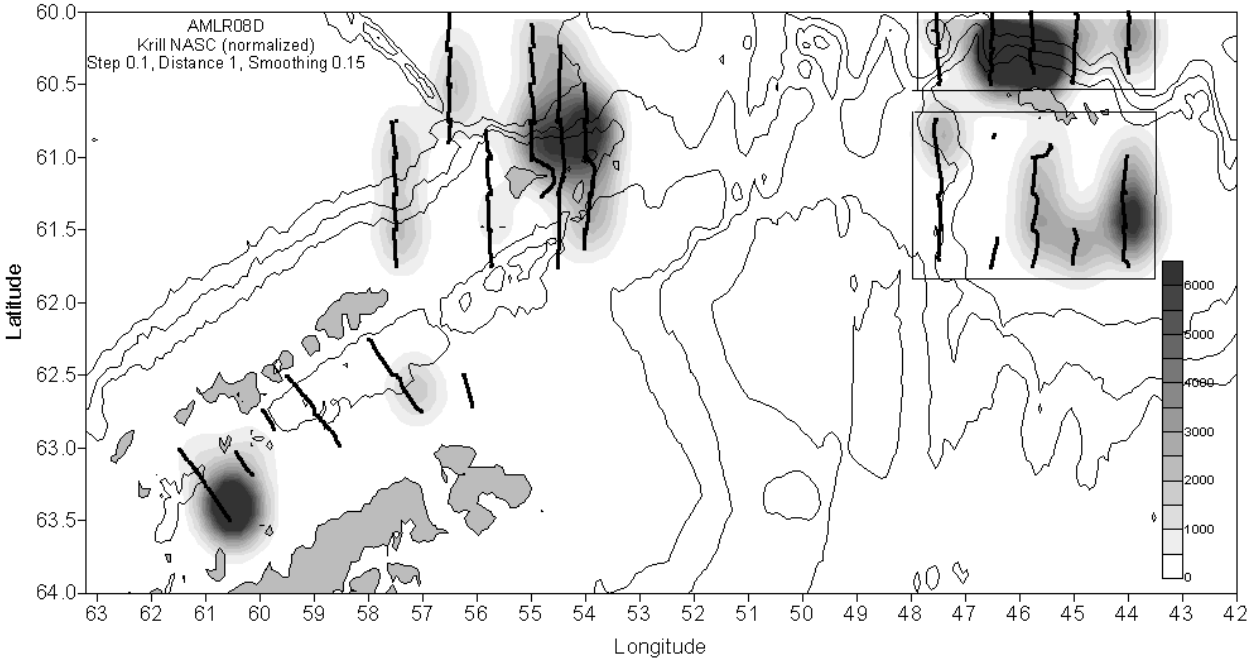

Figure 3.3. Normalized krill NASC values for Survey D (South Shetland and South Orkney Islands) at 120 kHz using day data. (Latitude is south and longitude is west).

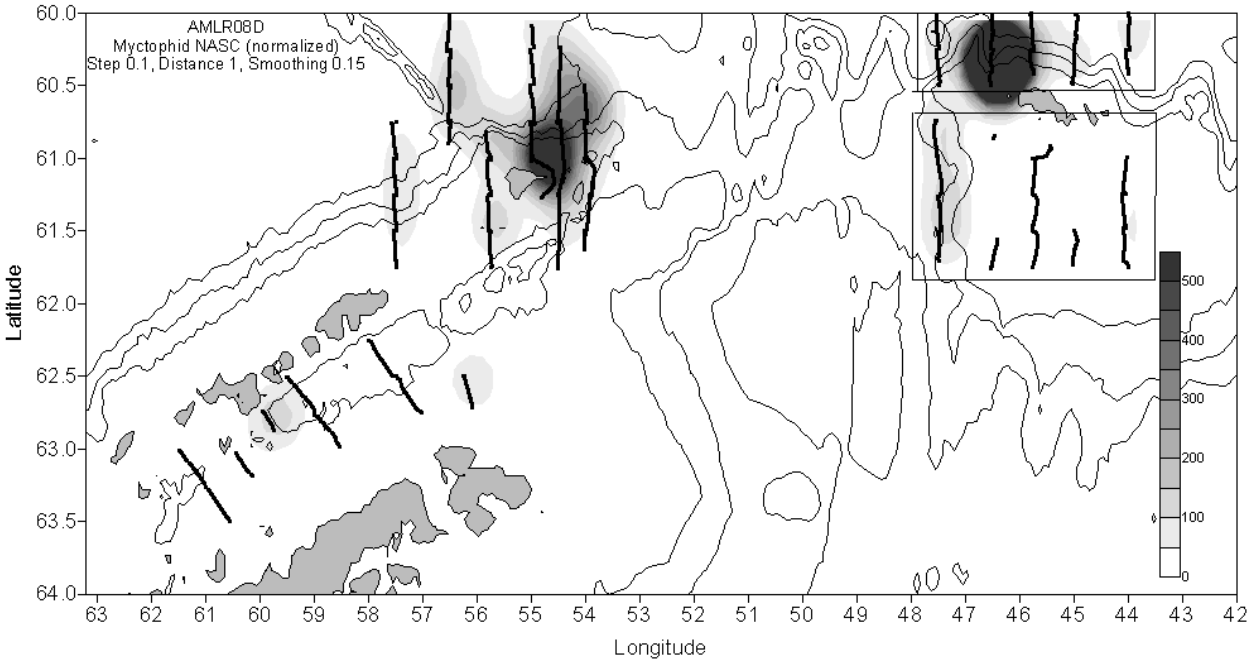

Figure 3.4. Normalized myctophid NASC values for Survey D (South Shetland and South Orkney Islands) at 120 kHz using day data. (Latitude is south and longitude is west).

UNITED STATES

AMLR ANTARCTIC MARINE LIVING RESOURCES PROGRAM

AMLR 2007/2008 FIELD SEASON REPORT

Objectives, Accomplishments and Tentative Conclusions

Edited by
Amy M. Van Cise

October 2008

NOAA-TM-NMFS-SWFSC-427

U.S Department of Commerce
National Oceanic & Atmospheric Administration
National Marine Fisheries Service
Southwest Fisheries Science Center
Antarctic Ecosystem Research Division
8604 La Jolla Shores Drive
La Jolla, California, U.S.A. 92037

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).

In addition to its formal publications, the NMFS uses the NOAA Technical Memorandum series to issue informal scientific and technical publications when complete formal review and editorial processing are not appropriate or feasible. Documents within this series, however, reflect sound professional work and may be referenced in the formal scientific and technical literature.

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.

Inquiries should be addressed to:

Antarctic Ecosystem Research Group
Southwest Fisheries Science Center
8604 La Jolla Shores Drive
La Jolla, California, USA 92037

Telephone Number: (858) 546-5600
E-mail: Amy.VanCise@noaa.gov