Distribution and Abundance of Zooplankton

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Abstract The results presented here are based on analysis of zooplankton and nekton taxa collected by 101 net samples in the South Shetland Island and Bransfield Strait region, January 2009.

- *Salpa thompsoni* outnumbered copepods in the Elephant Island Area, with mean concentrations of 883 and 809 individuals per 1,000 m^3, respectively.
- *Salpa thompsoni* dominance was less extreme and copepods represented larger proportions than previous salp dominated years, reflecting a greater influence by the Antarctic Circumpolar Current.
- A salp catch of 18,490 per 1,000 m^3 surpassed previous records but preponderance of small individuals due to a seasonally lagged bloom period minimized salp catch volume and carbon biomass.
- Zooplankton assemblages demonstrated mixed distribution patterns suggesting greater than normal hydrographic complexity across the region.

Introduction

Here we provide information on the abundance and distribution of zooplankton and nekton taxa in the vicinity of the South Shetland Islands (Livingston, King George, and Elephant Islands) and southeast Bransfield Strait (Joinville Island) during January, 2009. We describe the zooplankton assemblages present across the entire survey region as well as those within the four areas. Information useful for determining the relationship between zooplankton distribution patterns and the environment was derived from net samples taken at established CTD/phytoplankton stations.

Biomass-dominant copepod species, *Salpa thompsoni* and *Ihlea racovitzai* receive special attention because the inter-annual abundance variations of these relatively short-lived taxa reveal underlying hydrographic processes influencing the Antarctic Peninsula ecosystem. Results from Leg I are compared to those from previous AMLR Surveys to assess inter-annual differences in zooplankton composition and abundance over the 1992-2009 period. While postlarval and larval stages of Antarctic krill (*Euphausia superba*) are considered here as part of the overall zooplankton-nekton assemblage, specifics on their distribution, abundance and demography are treated separately in a companion report (Chapter 4).

Methods

Zooplankton and nekton were obtained from a 1.8 m Isaacs-Kidd Midwater Trawl (IKMT) fitted with a 505 µm mesh plankton net. Flow volumes were measured using a calibrated General Oceanics (model 2030R) flow meter mounted on the frame in front of the net. All tows were fished obliquely to a depth of 170 m, or 10 m above bottom in shallower waters. Real-time tow depths were derived from a depth recorder mounted on the trawl bridle. Tow speeds were two knots with flow volumes averaging 5,005 (+/- 755) m^3 based on a calibration factor of 0.0752, which was calculated from the nets' fishing dimensions.

All samples were processed on board. Large taxa, primarily postlarval krill and salps, were removed prior to processing the other zooplankton components. For larger samples the numbers of salps in one to two liter subsamples were used to estimate total abundance. For samples with <100 salps the two life stages (aggregate/sexual and solitary/asexual) were enumerated and internal body length (Foxton, 1966) measured to the nearest mm. Representative subsamples of >100 individuals were analyzed in the same manner for larger catches. All adult myctophids were identified, measured to the nearest mm (Standard Length, SL), and frozen. The remaining zooplankton fraction was then analyzed. All of the larger organisms (e.g., other postlarval euphausiids, amphipods, pteropods, polychaete worms) were sorted, identified to species if possible, and enumerated. Following this aliquots of the sample were enumerated and smaller zooplankton (e.g., copepods, chaetognaths, euphausiid larvae) identified to species, if possible, under maginfication. After analysis the zooplankton samples (without adult fish, postlarval krill, and most of the salps) were preserved in 10% buffered formalin for long-term storage. Specimens of pteropods belonging to genera with calcareous shells, *Limacina sp*. and *Clio sp.*, were preserved separately in buffered 95% ethanol for use in ocean acidification studies.

Abundance estimates are generally expressed as numbers per 1,000 m^3 water filtered; however, salp length-frequency plots are based on total numbers per m^2 sea surface area. For diurnal considerations, twilight samples are defined as those collected one hour before to one hour after local sunrise and sunset.

Statistical Analyses

Data from the total survey region and four component areas are analyzed here for inter- and intra-annual comparisons. Zooplankton species abundances are related to hydrography using Water Zones, as described by Needham et al. (Chapter 1). These Water Zones, numbered I to V, represent a variety of mixtures between Antarctic Circumpolar Current (ACC) (I), ACC-derived (II and III), Bransfield Strait (IV) and high latitude Weddell Sea shelf water (V).

Analyses include a variety of parametric and nonparametric techniques: Analysis of Variance (ANOVA) with Post-Hoc comparison of means (Tukey Honest Significant Difference) to establish abundance differences at the 95% probability level; Kolmogorov-Smirnov D_{MAX} values to indicate similar length-frequency distributions; Kendall's Tau (T) correlation coefficients to identify the joint variation of environmental parameters over time; Percent Similarity Indices (PSI) to indicate similarity in proportions of zooplankton taxa between regions or years; and Cluster Analysis to define distribution patterns based on aggregate salp lengths and zooplankton species assemblages. Salp cluster analysis is based on the proportional length-frequency distributions in each net sample containing at least 80 individuals while zooplankton clusters are based on log-transformed sample abundance data (N+1) for taxa present in at least 18 samples. Both analyses use Euclidean distance and Ward's linkage method with significant groupings (clusters) distinguished by a distance of 0.30 to 0.70. Statistical analyses were performed using Statistica (StatSoft) and NCSS software.

Results

Overall Composition and Abundance

A total of 117 taxonomic categories, including 10 copepod species, were identified from the 101 samples (Table 5.1). Copepods, present in all samples, comprised the most frequent taxon. The largest catch (75,400 individuals, 13,370 per 1,000 m^3), almost entirely *Metridia gerlachei*, was located over the eastern Bransfield Strait basin (Figures 5.1A; 5.2C). Other relatively large concentrations (2,200-7,900 per 1,000 m^3) were located in the eastern Bransfield Strait and offshore west of the Shackleton Fracture Zone. The most frequent and abundant constituents were small unidentified species ("other" copepods), which accounted for nearly half of the individuals enumerated. *Calanoides acutus* and *Calanus propinquus* were also widespread (94-97% of samples) but with smaller mean numbers than the less-common *M. gerlachei* due to the patchy distribution of this more "coastal" species.

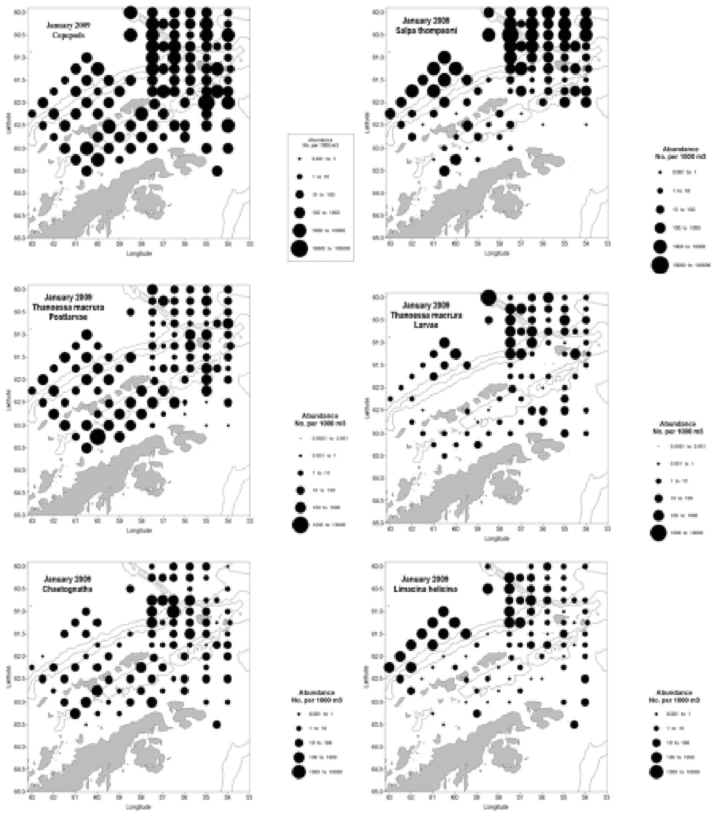

Figure 5.1. Distribution and abundance of (A) copepods, (B) *Salpa thompsoni*, (C) postlarval *Thysanoessa macrura*, (D) larval *T. macrura*, (E) chaetognaths and (F) *Limacina helicina*, January 2009.

While *Salpa thompsoni* was less frequent than copepods (88% of samples) its overall mean abundance was greater (883 vs. 809 per 1,000 m^3) due to exceptionally large concentrations at 15 stations. The largest catch, adjacent to the Shackleton Fracture Zone, contained an estimated 100,500 individuals with a concentration of 18,486 per 1,000 m^3. Other large catches (11,725-32,190 individuals, 2,180-6,615 per 1,000 m^3) primarily occurred offshore of the island shelf region (Figure 5.1B). Overall salps comprised 42% of total mean abundance compared to 38% for copepods. Postlarvae of the euphausiid *Thysanoessa macrura* (97% of samples, 116 per 1,000 m^3 mean) followed copepods in frequency and mean abundance. The largest *T. macrura* catches were in the western Bransfield Strait (Figure 5.2C). Other frequent and relatively abundant taxa included chaetognaths, pteropod *Limacina helicina* and larval

Table 5.1. Frequently occurring zooplankton and nekton taxa in the South Shetland Islands, January 2009. Taxa present in at least 11 of the total 101 samples are listed. F(%) is frequency of occurrence. N(%) is percent of total mean abundance represented by each taxon. (L) denotes larval stages.

	F(%)	Mean	STD	Median	Maximum	N(%)
Copepods	100.0	808.8	1613.5	313.6	13368.3	38.4
"Other" copepods	99.0	324.0	511.1	129.8	2818.1	15.4
Calanus propinquus	97.0	57.2	78.5	28.4	465.6	2.7
Calanoides acutus	94.1	106.0	406.1	27.9	3932.4	5.0
Rhincalanus gigas	77.2	36.2	84.8	10.5	657.2	1.7
Metridia gerlachei	72.3	256.3	1288.7	6.5	12645.0	12.2
Pareuchaeta spp.	55.4	22.9	44.3	1.7	253.7	1.1
Haloptilus ocellatus	13.9	1.2	6.4	0.0	58.6	0.1
Pleuromama robusta	12.9	2.3	11.0	0.0	81.2	0.1
Pareuchaeta antarctica	10.9	0.3	1.8	0.0	18.3	0.0
Thysanoessa macrura	97.0	116.2	218.6	49.7	1827.0	5.5
Chaetognaths	91.1	53.2	143.9	13.4	1301.7	2.5
Limacina helicina	90.1	42.3	86.8	3.1	595.4	2.0
Salpa thompsoni	88.1	883.2	2178.0	96.6	18485.7	42.0
Vibilia antarctica	87.1	7.9	11.6	4.5	88.3	0.4
Euphausia superba	84.2	22.6	78.6	2.3	561.8	1.1
Themisto gaudichaudii	84.2	15.7	27.6	4.9	173.0	0.7
Thysanoessa macrura (L)	82.2	66.5	168.3	6.3	1203.1	3.2
Spongiobranchaea australis	74.3	1.5	2.8	0.6	17.9	0.1
Primno macropa	72.3	3.3	5.6	1.6	46.5	0.2
Tomopteris spp.	61.4	2.0	4.4	0.4	36.1	0.1
Euphausia frigida	58.4	8.1	18.7	0.6	118.7	0.4
Clione limacina	56.4	1.5	3.9	0.2	23.1	0.1
Ostracods	47.5	6.4	14.1	0.0	95.8	0.3
Cyllopus magellanicus	41.6	2.1	6.1	0.0	44.2	0.1
Lepidonotothen larseni (L)	39.6	1.3	5.4	0.0	50.2	0.1
Euphausia superba (L)	37.6	8.6	29.6	0.0	225.6	0.4
Radiolaria	36.6	14.3	133.9	0.0	1353.2	0.7
Cyllopus lucasii	33.7	0.2	0.5	0.0	2.5	0.0
Electrona spp. (L)	23.8	0.3	0.6	0.0	3.6	0.0
Diphyes antarctica	23.8	0.1	0.3	0.0	2.3	0.0
Barnacle (L)	17.8	1.5	4.4	0.0	22.2	0.1
Acanthophyra pelagica	17.8	0.1	0.3	0.0	1.5	0.0
Lepidonotothen kempi (L)	15.8	0.2	0.6	0.0	5.3	0.0
Euphausia frigida (L)	12.9	0.8	3.0	0.0	21.6	0.0
Clio pyramidata spp?	12.9	0.2	1.4	0.0	14.1	0.0
Rhynchonereelia bongraini	12.9	0.2	0.8	0.0	6.0	0.0
Notolepis coatsi (L)	11.9	0.1	0.2	0.0	1.0	0.0
Hyperiella dilatata	11.9	0.0	0.2	0.0	1.5	0.0
Euphausia crystallorophias	10.9	1.0	7.2	0.0	71.7	0.0
Total		2105.1	3012.1	796.3	20588.8	
Taxa	117	21	5	22	34	

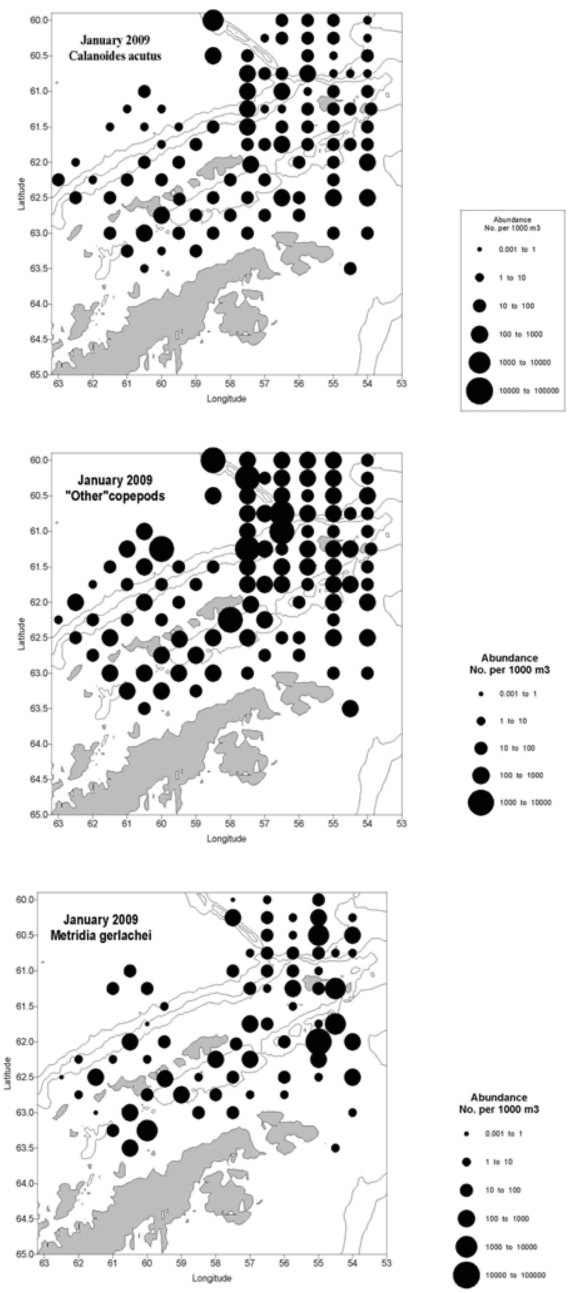

Figure 5.2. Distribution and abundance of (A) *Calanoides acutus*, (B) small unidentified "other" copepod species and (C) *Metridia gerlachei*, January 2009.

T. macrura. Greatest concentrations of *L. helicina* and larval *T. macrura* were offshore of the island shelves while those of chaetognaths were primarily west of the Shackleton Fracture Zone and in the western Bransfield Strait (Figure 5.1D-F). Postlarval krill (*Euphausia superba*) was also relatively abundant (Chapter 4). It was present in 84% of samples and contributed 1% to total mean abundance, ranking as the seventh most abundant taxon overall. The salp *Ihlea racovitzai*, an indicator species for high latitude Weddell Sea shelf water (Loeb et al., 2009), was represented by a total of eight individuals from two stations.

Spatial and Temporal Considerations

Although the four survey areas had relatively similar overall concentrations of zooplankton and nekton (means 1,175-2,478 per 1,000 m^3) they differed greatly in their taxonomic composition and abundance relationships (Table 5.2). *Salpa thompsoni* numerically dominated in the West and Elephant Island Areas, where it constituted 49% and 54% of total mean abundance, respectively. In each area copepod mean abundance was half that of salps and made up an additional 27% and 32%, respectively. In the West Area postlarval *T. macrura* and *L. helicina* followed copepods and salps in mean abundance (together 11%); their counterparts in the Elephant Island Area were larval *T. macrura* and chaetognaths (7%).

In contrast, copepods numerically dominated in the Joinville Island and South Areas, where salps accounted for <4% of total mean abundance. In the Joinville Island Area copepods constituted 83% of total mean abundance (largely due to the extremely large catch of *M. gerlachei*) while *Euphausia crystallorophias* ("ice krill"), *S. thompsoni* and postlarval *T. macrura* constituted another 15%. Postlarval *T. macrura* was present in all South Area samples, ranked second to copepods in mean abundance and constituted 25% of the total while chaetognaths and postlarval krill together contributed another 9%.

Four taxa demonstrated significantly greater abundance in one area than the others: greatest concentrations of *Limacina helicina* and amphipod *Themisto gaudichaudii* were in the West Area (ANOVA, P<0.01) while barnacle larvae and sipunculids were most abundant in the Joinville Island Area (P<0.001 and P<0.05, respectively), reflecting their higher latitude sources.

Concentrations of postlarval *T. macrura* in the South Area were greater than in the Elephant Island and Joinville Island Areas (P<0.05). As typical, the larval and postlarval stages of *T. macrura* were distributed with the larvae centered in offshore regions (T=-0.20, P<0.01; Figure 5.2C,D). Additionally, larval *E. superba* were more abundant in the Joinville Island Area vs. the West and South Areas (P<0.05).

In terms of overall taxonomic composition, the West and Elephant Island Area assemblages were most similar (PSI=86) and the South and Joinville Island Area assemblages most different (PSI=9). PSI values from other comparisons are also low (37-44), indicating a high degree of

Table 5.2. The 10 most frequent and/or abundant zooplankton and nekton taxasample in the South Shetland Islands, January 2009. R is rank of mean abundance as numbers per 1,000 m^3. F(%) is frequency of occurrence in (N) samples from each area. N(%) is percent of total mean abundance contributed by each taxon. (L) denotes larval stages.

	West Area (N=23)					Elephant Island Area (N=47)					Joinville Island Area (N=11)					South Area (N=20)				
Taxon	R	F(%)	Mean	STD	N(%)	R	F(%)	Mean	STD	N(%)	R	F(%)	Mean	STD	N(%)	R	F(%)	Mean	STD	N(%)
Copepods	2	100	594.4	1424.3	27.0	2	100	785.6	1000.0	31.7	1	100	1654.3	3740.1	82.9	1	100	644.7	544.3	54.9
"Other" Copepods		100	308.1	605.3			100	400.2	573.7			100	164.5	170.8			95.0	250.7	273.2	
Calanus propinquus		91.3	44.5	63.8			100	78.4	98.8			90.9	17.6	9.4			100	43.7	33.7	
Calanoides acutus		87.0	189.6	798.6			93.6	72.2	150.8			100	138.1	235.6			100	71.6	52.1	
Metridia gerlachei		56.5	24.1	56.0			68.1	152.6	441.6			90.9	1266.6	3605.3			90.0	211.3	353.0	
Rhincalanus gigas		47.8	15.9	42.4			83.0	55.3	116.4			90.9	17.3	16.0			90.0	24.9	25.1	
Pareuchaeta spp.		21.7	8.9	23.6			48.9	20.7	46.4			100	49.6	61.9			85.0	29.4	37.7	
Pleuromama robusta		13.0	0.5	1.7			10.6	4.2	15.7			9.1	0.1	0.4			20.0	0.9	2.9	
Heterorhabdus sp.		8.7	0.3	1.2			4.3	0.2	1.5			0.0	0.0	0.0			5.0	0.3	1.4	
Pareuchaeta antarctica		8.7	0.1	0.5			2.1	0.4	2.6			36.4	0.1	0.2			20.0	0.2	0.6	
Haloptilus ocellatus		4.3	2.5	12.0			14.9	1.2	3.9			18.2	0.3	0.6			20.0	0.2	0.5	
Copepodites		0.0	0.0	0.0			0.0	0.0	0.0			0.0	0.0	0.0			5.0	11.5	50.2	
Themisto gaudichaudii	7	100	41.2	32.1	1.9		93.6	7.3	9.1	0.3		27.3	0.2	0.4	0.0	6	75.0	14.5	37.7	1.2
Vibilia antarctica	10	100	10.7	9.1	0.5	8	93.6	10.7	14.4	0.4		54.5	1.9	3.1	0.1		75.0	1.5	1.5	0.1
Salpa thompsoni	1	95.7	1077.1	1511.1	48.8	1	100	1334.5	2897.4	53.9	3	45.5	72.4	137.6	3.6	5	75.0	46.0	84.9	3.9
Thysanoessa macrura	3	95.7	129.3	139.7	5.9	5	97.9	50.2	50.6	2.0	4	90.9	57.2	86.8	2.9	2	100	288.5	408.3	24.6
Limacina helicina	4	95.7	121.7	139.9	5.5	6	93.6	28.9	48.1	1.2		81.8	5.6	6.6	0.3		80.0	2.7	6.4	0.2
Chaetognaths	8	82.6	20.8	22.6	0.9	4	89.4	76.4	201.8	3.1	6	100	17.7	13.0	0.9	3	100	55.6	71.0	4.7
Euphausia superba		78.3	5.6	6.8	0.3	7	91.5	23.2	74.1	0.9		81.8	1.3	2.2	0.1	4	75.0	52.4	129.4	4.5
Primno macropa		78.3	2.9	4.1	0.1		74.5	4.1	7.4	0.2		36.4	0.6	1.2	0.0		80.0	3.4	2.8	0.3
Tomopteris spp.		78.3	1.6	2.5	0.1		46.8	2.2	5.8	0.1		63.6	2.2	3.3	0.1		75.0	2.1	2.1	0.2
Spongiobranchaea australis		78.3	1.2	1.3	0.1		78.7	2.2	3.7	0.1		72.7	0.7	0.8	0.0		60.0	0.7	1.4	0.1
Thysanoessa macrura (L)	5	65.2	89.5	252.7	4.1	3	87.2	94.0	162.1	3.8	7	81.8	10.8	8.0	0.5	8	90.0	6.1	5.9	0.5
Clione limacina		65.2	3.7	6.1	0.2		46.8	1.2	3.3	0.0		72.7	0.3	0.3	0.0		60.0	0.4	0.5	0.0
Euphausia frigida		56.5	10.2	20.8	0.5		55.3	8.4	20.3	0.3	8	36.4	9.6	20.1	0.5		80.0	4.0	6.7	0.3
Radiolaria	6	43.5	59.7	275.8	2.7		31.9	1.1	2.5	0.0		72.7	1.4	2.0	0.1		20.0	0.0	0.1	0.0
Euphausia spp. (L)	9	43.5	13.4	25.3	0.6	10	48.9	9.9	21.9	0.4		54.5	5.4	8.5	0.3		20.0	0.6	1.3	0.0
Ostracods		30.4	4.1	8.6	0.2		40.4	5.7	15.5	0.2	10	54.5	7.7	12.7	0.4	7	80.0	10.0	15.8	0.8
Lepidonotothen larseni (L)		13.0	2.4	10.2	0.1		25.5	0.5	1.9	0.0		72.7	2.9	4.1	0.1		85.0	1.1	1.8	0.1
Siphonophora (unid)		8.7	0.5	2.4	0.0		23.4	2.1	6.2	0.1		45.5	1.5	2.2	0.1	9	65.0	5.8	7.6	0.5
Euphausia superba (L)		8.7	0.4	1.4	0.0	9	40.4	10.4	27.9	0.4	5	81.8	31.7	62.5	1.6		40.0	1.2	1.9	0.1
Barnacle *(L)*		4.3	0.0	0.2	0.0		8.5	0.3	1.6	0.0	9	72.7	9.5	7.7	0.5		25.0	1.5	4.4	0.1
Limacina spp.		0.0	0.0	0.0	0.0		0.0	0.0	0.0	0.0		27.3	3.1	5.1	0.2	10	30.0	5.0	9.5	0.4
Euphausia crystallorophias (L)		0.0	0.0	0.0	0.0		0.0	0.0	0.0	0.0	2	63.6	79.1	120.2	4.0		15.0	0.6	1.5	0.1
Total			2205.4	2528.5				2477.8	3453.6				1994.4	3894.4				1174.6	939.5	
Taxa			19.0	4.8				19.3	2.9				26.6	4.1				23.1	5.6	

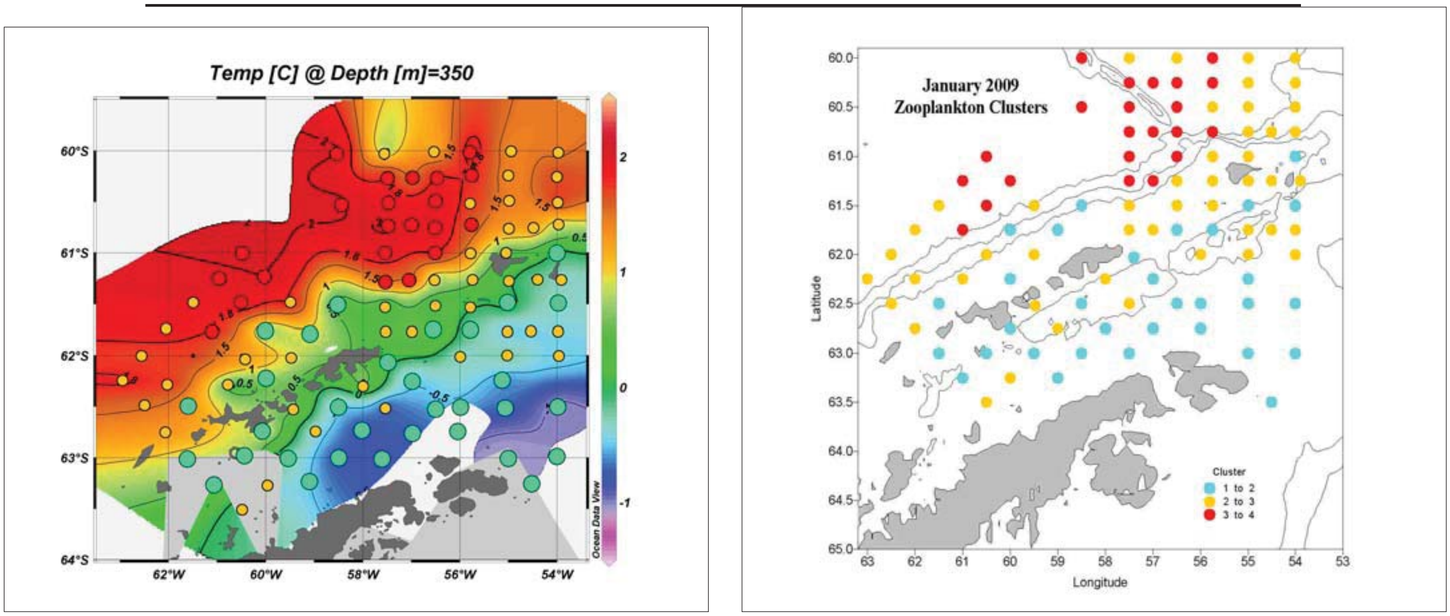

Figure 5.3. Distribution of three zooplankton clusters in relation to hydrography, January 2009. Temperature at 350 m depth indicates the major hydrographic features of this region: the 2°C isotherm denotes core waters of the ACC, 1.8°C isotherm is the southern front of the ACC and 0°C isotherm is the ACC southern boundary.

heterogeneity across most of the region. With respect to copepod taxa, the composition in the Elephant Island Area was most similar to the South and West Areas (PSI=81 and 76, respectively) reflecting shared numerical dominance by "other" species (Table 5.2). Copepods in the Joinville Island Area differed from the rest (PSI=26-56) due to the large catch of *M. gerlachei*.

Despite generally widespread distributions and apparently well-mixed hydrographic conditions, various zooplankton taxa had significantly greater concentrations within certain Water Zones. Concentrations of larval *T. macrura*, *C. acutus*, "other" copepod species, *Hyperiella dilitata*, *Beroe cucumis* and radiolaria at two of the three offshore stations represented by Water Zone I were significantly greater than in all other water types (ANOVA, $P<0.01$). Larval *T. macrura*, *C. propinquus*, *S. thompsoni*, *Vibilia antarctica* and *L. helicina* concentrations in Water Zone II were significantly greater than in Water Zones III-V (i.e., Transition I, Transition II and Weddell Sea waters; $P<0.05$). Barnacle larvae and juvenile *Pleurogramma antarcticum* were more abundant in Weddell Sea shelf water vs. other waters ($P<0.05$).

Diel catch size differences of some species resulted from their vertical migrations into the upper 170 m from greater depths at night. Significantly greater night vs. day concentrations occurred for *Euphausia frigida* and *M. gerlachei* while *S. thompsoni* catches during twilight were greater than during day ($P<0.05$).

Zooplankton Assemblages

Cluster analysis applied to 23 zooplankton taxa yielded three groupings with spatially coherent distributions. As typical, these clusters generally corresponded to coastal, offshore and intermediate environments (Figure 5.3).

Cluster 1, the more coastal group, occurred at 32 stations within the Bransfield Strait and over the South Shetland Island northern shelves. This was a fairly depauperate assemblage with total mean abundance almost an order of magnitude less than Cluster 3. Copepods dominated, representing 61% of the total. Postlarval *T. macrura* ranked second (20%), followed by chaetognaths and *Themisto gaudichaudii* (9%). The relative abun-

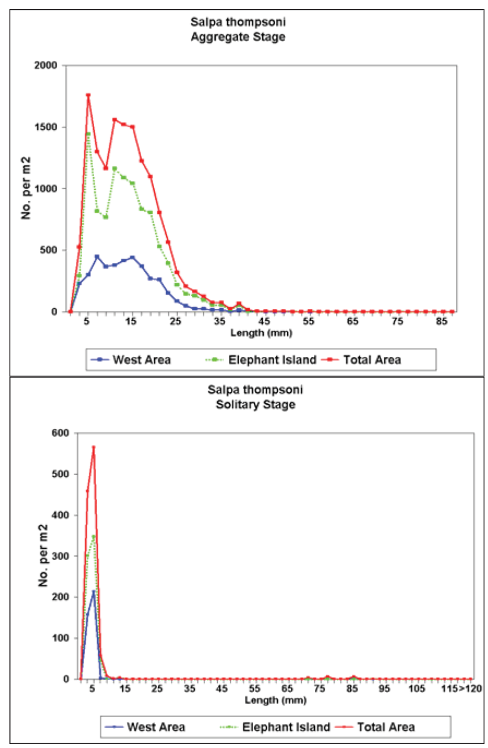

Figure 5.4. Length -frequency distributions of aggregate and solitary stages of *Salpa thompsoni* in the West Area, Elephant Island Area and total survey area, January 2009.

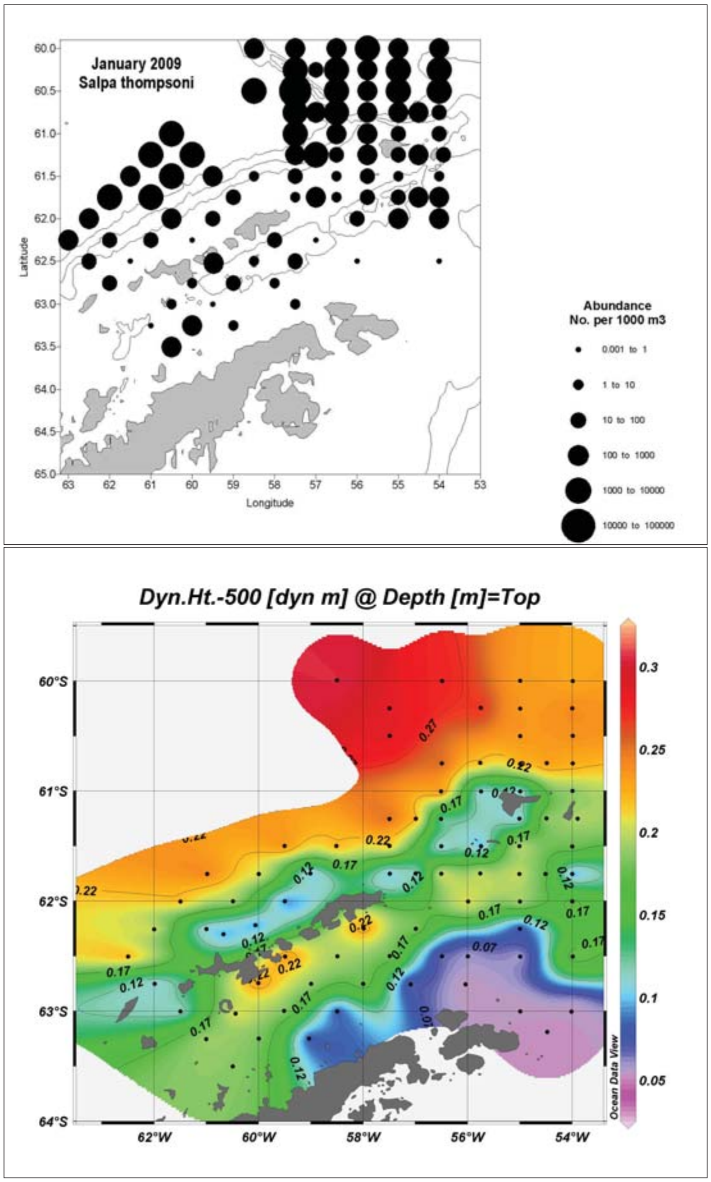

Figure 5.5. Distribution and abundance of *Salpa thompsoni* in relation to implied flow (dynamic height at 500 m relative to the surface) across the survey region. Dynamic height indicates generally northeast flow through the central Bransfield Strait and the Drake Passage, and counter-clockwise flow where the ACC is deflected northward by the Shackleton Fracture Zone.

dance of these latter two taxa suggests an oceanic water influence. Barnacle larvae were significantly more abundant here than in the other clusters reflecting a Weddell Sea shelf water source.

Cluster 2 was the most widespread group, present at 47 stations generally located between Clusters 1 and 3. However, it was also represented in offshore waters to the west and east of Cluster 3 and in a pocket surrounded by Cluster 1 in the eastern Bransfield Strait. Its overall mean abundance values were around twice those of Cluster 1. Copepods dominated and constituted 51% of total mean abundance. Although mean abundance of *S. thompsoni* was an order of magnitude less than in Cluster 3, it was second most abundant, contributing 30% to the total mean abundance. Postlarval *T. macrura* and krill were highly concentrated within this group and followed *S. thompsoni* in abundance. Larval krill were equally represented in Clusters 1 and 2. PSI values were relatively high between Clusters 1 and 2 (68) and 2 and 3 (64) due to overlapping distributions of their component taxa, but the dichotomy between composition of the coastal and offshore groups was indicated by a low PSI of 36.

Cluster 3, represented at 22 predominantly offshore stations, had by far the largest zooplankton concentrations. This was numerically dominated by *S. thompsoni* (58% total mean abundance) and copepods (28%). Larval *T. macrura*, chaetognaths and *L. helicina* were also relatively abundant (10%). With the exception of copepods, the concentrations of these taxa, along with amphipod *Cyllopus magellanicus* and pteropods *Clione limacina* and *Spongiobranchaea australis*, were significantly greater than in the other two clusters (ANOVA, $P<0.05$).

The sexual aggregate (chain) stage comprised 93% of total *S. thompsoni* individuals collected. These ranged from 4-60 mm, but the majority (94%) were immature lengths, <25 mm (Foxton, 1966), and the median length was 14 mm. Given an estimated growth rate of ca. 0.44 mm per day, the length-frequency distribution (Figure 5.4) suggests an onset of seasonal chain production in early October, with major output starting in mid- to late-November and over half of the chains released within the past month (i.e., mid-December) which is unusually late.

Solitary individuals were 4-113 mm, but 98% were < 9 mm resulting from recent release of embryos by sexually reproductive aggregates. The overall stage composition and length-frequency distributions were similar in the West and Elephant Island Areas, where the vast majority of salps occurred. In the Bransfield Strait, where fewer salps were found, there was less evidence of recent chain production. In the Joinville Island Area, 20% of the aggregates were reproductive size, >25 mm, and 14% of total salps were recently released solitary forms. In the South Area, nearly half of the solitaries were large reproductive forms, >75 mm in length, and 22% of the aggregates had been produced nearly two months earlier.

These results suggest that bloom conditions (i.e., explosive budding of aggregate chains by large overwintering solitary forms) were restricted to offshore waters and/or that the bloom would occur even later inshore. In contrast to most years, cluster analysis did not yield any spatially coherent aggregate size groups. Similar to zooplankton distribution, this is likely due to the unusually complex hydrographic conditions.

As noted above, the distribution of *S. thompsoni* was linked to the ACC; highest salp concentrations were found in Type III (Transition) water. The dynamic height plot in Figure 5.5, indicating implied flow at 500 m relative to the surface, shows a correlation between the northeasterly water flow and the off-shore distribution of salps, as well as an association between large salp concentrations and current deflection over the Shackleton Fracture Zone. Northeastward flow also explains the relatively homogeneous salp size and stage composition across the West and Elephant Island Areas.

Discussion

The overall taxonomic composition of zooplankton and nekton sampled during January 2009 was typical for the region and reflected overlapping distributions of taxa affiliated with oceanic and coastal environments. As usual, the absolute and relative abundance of taxa differed greatly from other years due to interannual variability in abundance of taxa resulting from hydrographic and atmospheric processes (Loeb et al., 2009). The most notable feature was numerical dominance of *S. thompsoni*, which has been relatively scarce since 2005. Mean abundance of *S. thompsoni* in the Elephant Island Area was three times greater than the long-term mean (Figure 5.6). This marks a dramatic abundance shift from extremely low concentrations observed in 2008.

Copepod abundance, like most other years, was significantly lower than the peaks observed in January 2002 and (lacking an earlier survey) February 2000. However, the Elephant Island Area concentrations were similar to those from the previous two years, only slightly below the long-term mean and substantially larger than prior years of high salp abudance.

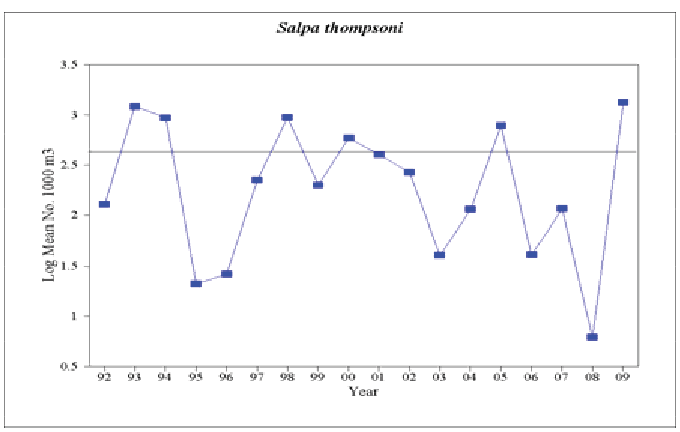

Figure 5.6. Inter-annual abundance of zooplankton *S. thompsoni*, 1992-2009.

Among other typically abundant taxa, the concentrations of *Euphausia frigida*, postlarval and larval *T. macrura*, and chaetognaths were close to their long-term means. *L. helicina* abundance in 2009 was about average, but it is important to note that this species experiences high interannual variability. In contrast to previous years of high salp productivity, *I. racovitzai* was essentially absent. The total mean zooplankton abundance in the Elephant Island Area (2,478 per 1,000 m^3) was slightly above the long term average (2,238 per 1,000 m^3) and considerably higher than average concentrations recorded during 1993-1999 surveys.

Cluster analysis of AMLR zooplankton data typically yields three more-or-less spatially coherent groups conforming to coastal, offshore and intermediate assemblages. The messy pattern observed during January 2009 was unusual and suggests greater than normal hydrographic complexity. A similarly mixed zooplankton distribution was observed during the January 1998 survey (Loeb et al., 1998). Hydrographic conditions then were reported to be more variable and with less distinct zonation than usual (Amos et al., 1998). While the 1998 period, as well as the 1994 and 2005 salp-dominated years, were marked by El Niño events and negative Southern Oscillation Index (SOI) values (Loeb et al., 2009) the 2008-2009 period was characterized by weak La Niña conditions and positive SOI values suggesting a different atmospheric-hydrographic process underlying the 2009 salp-dominated year. The fact that record numbers of small *S. thompsoni* were also reported from the West Antarctic Peninsula (Doug Martinson and Debbie Steinberg, pers. comm.) and dense salp concentrations were observed downstream in the Scotia Sea (Angus Atkinson, pers. comm.) during January-March 2009 indicates that this was not a localized phenomenon. One feature that stands out is that strong northwest winds prevailed off the Antarctic Peninsula for much of 2008, as indicated by an average speed of 4.84 ±2.37 m/s, well above the annual mean of 3.65±0.87 m/s for 1997-2008. The hydrographic complexity noted this year may well have resulted from enhanced wind-driven mixing throughout the preceding year; this somehow proved favorable for chain production by *S. thompsoni*.

Despite the huge reproductive output by the *S. thompsoni* solitary stage, the relatively narrow length range and preponderance of small recently budded aggregates observed in January 2009 suggest a seasonally lagged production period compared to other years (Figure 5.7). The

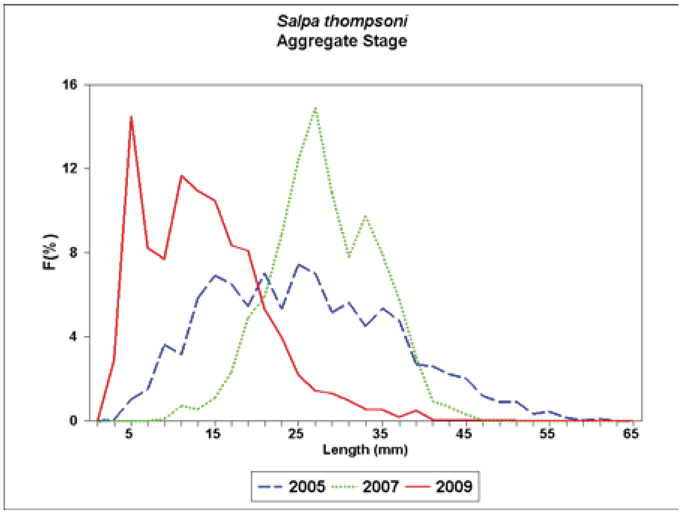

Figure 5.7. Length-frequency distributions of *S. thompsoni* aggregates during January 2005, 2007 and 2009, to demonstrate interannual variability in seasonal production by the overwintering solitary stage. During the 2005 year of high salp abudance, production started in early to mid-September with elevated production between early November and late December. Elevated chain production began almost a month later in spring 2008.

small body size minimized salp catch volume and carbon biomass associated with elevated abundance compared to other years of high salp production.

Like the overall zooplankton assemblage, the component taxa making up the copepod assemblage exhibit a great deal of interannual variability. During January 2009 the numerical dominance by small unidentified copepods differed from the previous eight years. *Metridia gerlachei* typically is the most abundant copepod in the Elephant Island Area in terms of mean concentrations due to its patchy distribution and extremely large numbers in a few samples. However, its mean value this year ranked second while its median value rivaled the lows observed during 2003 and 2005 AMLR Surveys. The widespread distribution of moderate concentrations of *C. acutus*, *C. propinquus* and *R. gigas* in 2009 reflects the ACC influence and mixing of ACC-derived waters in the Elephant Island Area.

Protocol Deviations

There were no changes to standard sampling and analytical techniques used during AMLR fieldwork.

Disposition of Data

Data and samples are available from Christian Reiss, NOAA Fisheries, Antarctic Ecosystem Research Division, 3333 Torrey Pines Court, Room 412, La Jolla, CA 92037. Ph: 858-546-7127, FAX: 858-546-5608

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UNITED STATES
AMLR ANTARCTIC MARINE LIVING RESOURCES PROGRAM

AMLR 2008/2009 FIELD SEASON REPORT

Objectives, Accomplishments and Tentative Conclusions

Edited by
Amy M. Van Cise

May 2009

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