

The Zooplankton Community in the Vicinity of the Ice Edge, Western Weddell Sea, March 1986

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Summary. The zooplankton community in the vicinity of the ice edge in the west central Weddell Sea was investigated in the late austral summer (March 1986). Sampling was done with two ships operating concurrently, one in the pack ice and the other in the adjacent open sea. Metazoan microzooplankton (<1 mm) was most abundant in the epipelagic zone. It consisted mostly of copepod nauplii and copepods of the genera *Oithona*, *Oncaea*, *Ctenocalanus* and *Microcalanus*. While species composition was similar in both areas, vertical patterns differed in that the microzooplankton had sparse populations in the upper 50 m under the ice. This may have been related to water temperature which in the upper 50 m under the ice was more than 1 °C cooler than in the open sea. Zooplankton in the 1–20 mm size range was dominated by the calanoid copepods *Metridia gerlachei*, *Calanus propinquus* and *Calanoides acutus* which constituted half the biomass in the upper 1000 m. Their populations had highest densities in the upper 150 m, though much of the *C. acutus* population resided below 300 m. *Metridia gerlachei* and *C. propinquus* underwent diel vertical migrations in both areas whereas *C. acutus* did not migrate. Species diversity in the epipelagic zone was moderate and the fauna was characterized by species typical of the oceanic east wind drift. Diversity increased with depth and was due primarily to the appearance of circumpolar mesopelagic copepods in Weddell Warm Deep Water. Biomass of 1–20 mm zooplankton in the 0–1000 m zone was low (1.1–1.3 gDWm⁻²) compared to other Southern Ocean areas investigated with comparable methods. It is suggested that this is related to Weddell circulation patterns and the resulting low annual primary production in the central Weddell Sea.

Introduction

The importance of ice edge dynamics in relation to primary production in polar regions has recently been

established (see Smith and Nelson 1986; Smith 1987; Nelson et al. 1987, for review). It has been estimated that ice edge blooms have a productivity 4–8 times that of open water (Smith and Nelson 1986). These blooms traverse much of the Antarctic south of the Polar Front as the ice edge retreats in spring and summer. Smith and Nelson (1986) suggested that estimates of productivity in the Southern Ocean which have not included ice edge blooms should probably be revised upwards by at least 60%. Given the significance of ice-edge production in relation to overall energy budgets for Antarctic ecosystems, it is important that higher trophic levels be examined to determine the extent of their dependence on primary production at the ice edge.

The zooplankton community at the ice edge in the west central Weddell Sea (Fig. 1) was investigated in March 1986 as a component of the U.S. National Science Foundation sponsored AMERIEZ program. Two vessels were used, one (*USCG Glacier*) sampling within the pack ice, and the other (*RV Melville*) in the adjacent open sea. This enabled a comparison of zooplankton in the two environments and produced basic data for subsequent seasonal comparisons at the ice edge. The data set fills an important gap between zooplankton community surveys made to the south in the Weddell sea (Kaczmaruk 1983; Hubold et al. 1988) and to the north in the southern Scotia Sea (see Witek et al. 1985; Zmijewska 1985, for reviews).

Methods

Zooplankton was arbitrarily defined as metazoan organisms <20 mm in body size. This excluded most individuals of high biomass species such as *Euphausia superba* and *Salpa thompsoni* which will be treated in a subsequent paper on macroplankton-micronekton. Zooplankton was collected with 30 l water bottles and collapsible 162 µ zooplankton nets 44×44 cm in mouth dimensions. The nets were suspended in the mouth of opening-closing Tucker trawls (Hopkins and Baird 1975) on the *RV Melville* and in the mouth of vertical fishing opening-closing plummet nets aboard the *USCG Glacier*. Volume filtered was estimated

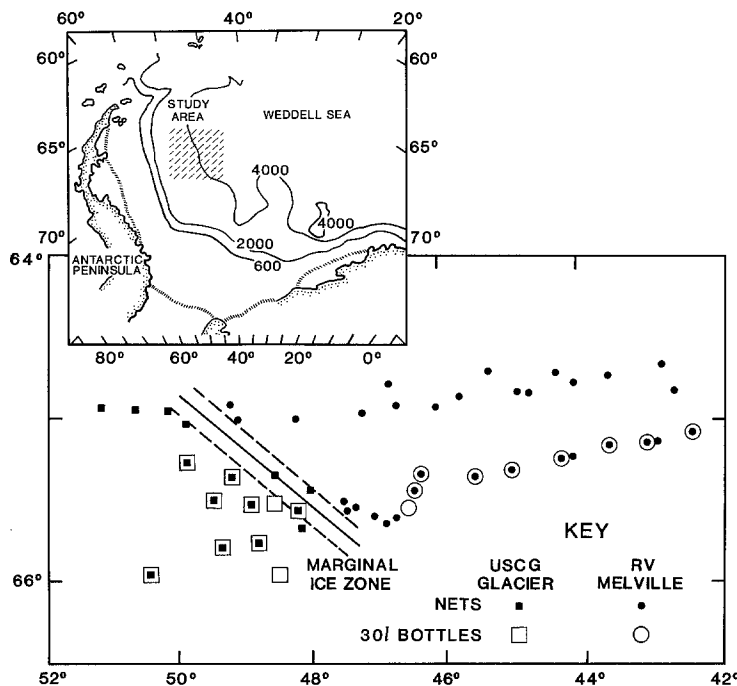


Fig. 1. Regional map showing location of zooplankton stations in the western Weddell Sea sampled from the *RV Melville* and *USCG Glacier* in March, 1986

using mechanical dial-type flowmeters mounted in the mouth of the plankton nets, with the meters recording only when the nets were open and fishing. Water from the 301 bottles was sieved through 30 μ gauze. Sampling locations are plotted in Fig. 1 and detailed station data are available in the authors' cruise report. All catches were preserved in 5%–10% v/v buffered formalin and were subsequently transferred to 50% v/v isopropanol.

Samples were analyzed by subdividing the catch using a Motoda box (Motoda 1959), then identifying, counting and measuring (± 0.1 mm) 25 individuals of each zooplankton taxon with an ocular micrometer. The biomass of each species was estimated using size-dry weight regressions established for the dominant species and for selected species which were morphologically representative of other less common forms (unpublished data). Details of the zooplankton counting protocol are available in Hopkins (1985).

Hydrographic information was from CTD casts in the vicinity of 301 bottle and plankton net collections made from both ships.

Results

Hydrography

Sampling in the western Weddell Sea was in the oceanic waters of the central gyre, well away from the influence of the continental shelf. Data from CTD casts made in the vicinity of the 301 bottle casts are summarized for the upper 150 m in the profiles shown in Fig. 2. Zooplankton collection was throughout the upper 1000 m and the water masses (Carmack and Foster 1975; Muench and Husby 1987) sampled were: surface water, which is from the surface to 25–50 m; winter (previous) water, which extends from 50 to ~100 m; and Weddell Warm Deep Water, which centers at 500 m. Between the latter two water masses is transitional water sometimes designated as Modified Deep Water; it, however, lacks clearly identifiable core properties (Carmack and Foster 1977). Differences in the profiles are apparent in that the surface water in the pack ice was both colder (-1.7 vs -0.5 °C) and less saline (33.6 vs 33.8‰) than open sea water. The ice edge showed relatively little movement during the sampling period (March 7–27), the annual summer melt having been completed and the winter freeze not yet begun.

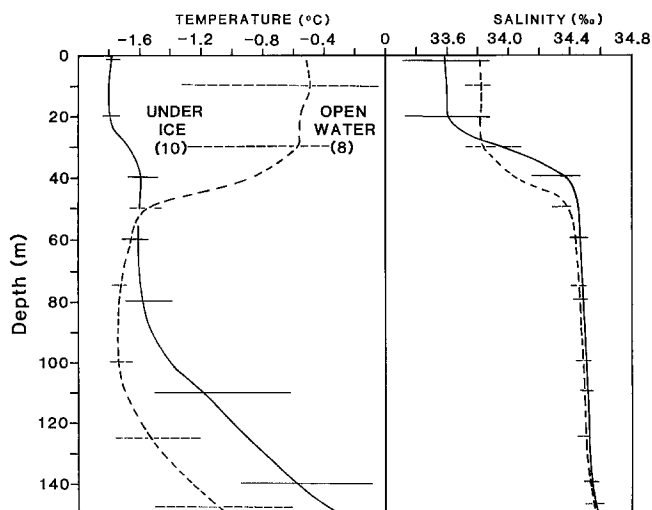


Fig. 2. Average vertical profiles for temperature and salinity based on CTD casts made in the vicinity of the 301 bottle casts (see Fig. 1 for locations). Numbers in parentheses are the numbers of CTD casts used in constructing the profiles. Ranges are indicated with horizontal bars

Biology

Water bottle collections show (Fig. 3) that in both the open sea and within the pack ice, metazoan plankton < 1 mm was most densely concentrated in the epipelagic zone, i.e., the upper 200 m. Three peaks occurred in the open sea profile, these being at 25 m, 150 m and a minor

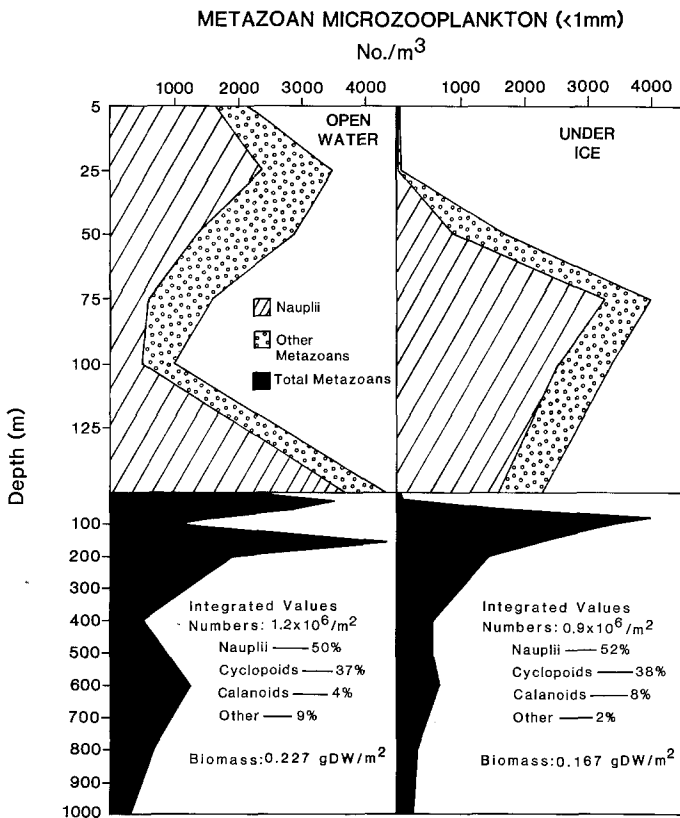


Fig. 3. Vertical distribution of metazoan microplankton (< 1 mm) in the upper 1000 m. Data based on 301 bottle casts

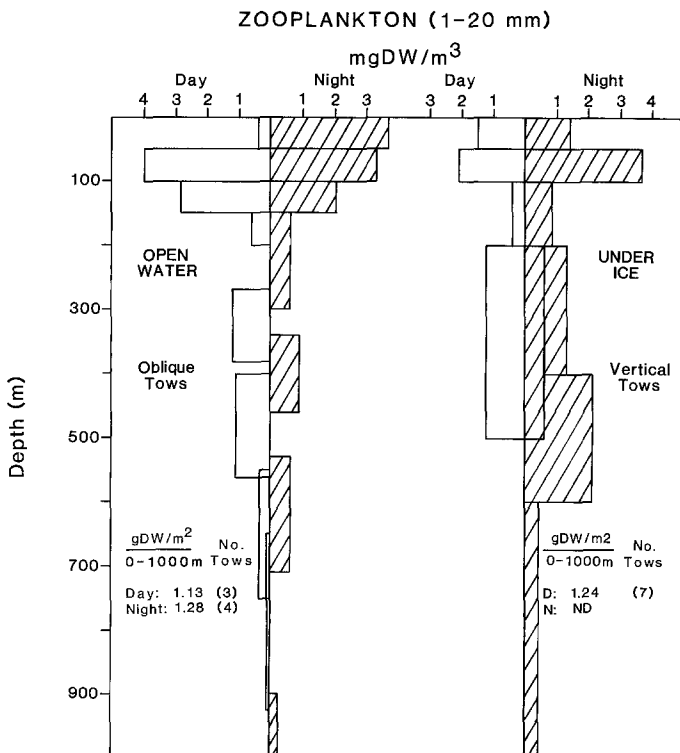


Fig. 4. Vertical distribution of the biomass of net-caught zooplankton (1-20 mm)

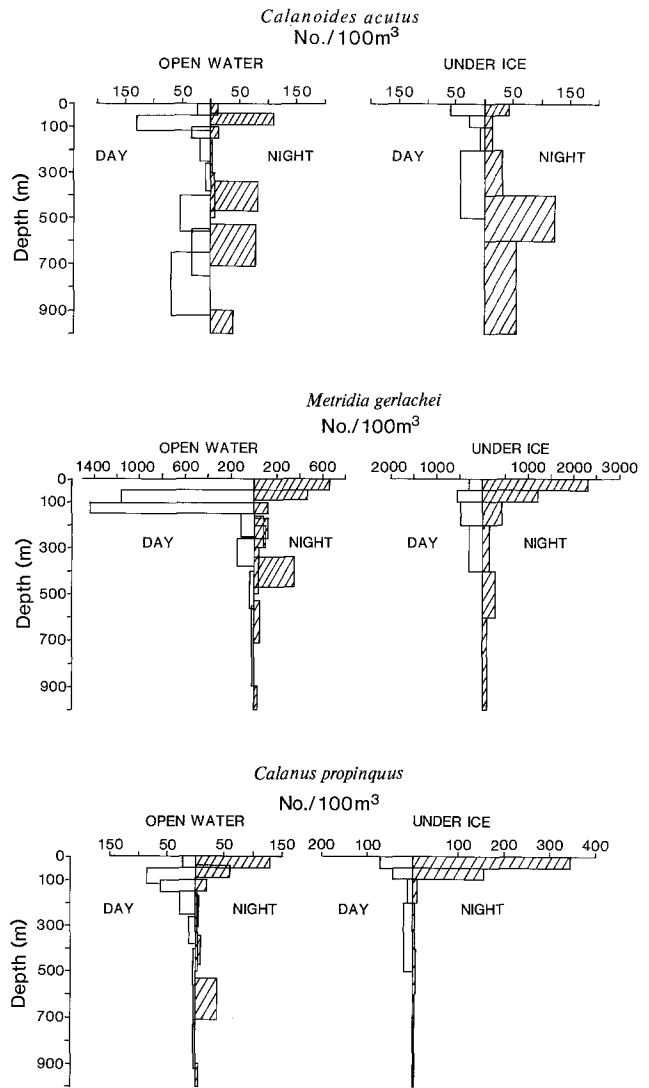


Fig. 5. Vertical distribution in the upper 1000 m of the three zooplankton biomass dominants. Adults and copepodite stages are combined

one at 600 m. Within the pack ice only two were apparent, one at 75 m and a smaller one again at 600 m. An unmistakable feature of the vertical patterns is the sparse population of microzooplankton in the upper 25 m within the pack ice. Numbers and biomass of metazoans < 1 mm integrated over 0-1000 m indicate similar standing stocks for both areas, though averages for the pack ice were smaller, particularly in the epipelagic zone (Fig. 3).

The principal taxonomic components of the microzooplankton were the same in both areas, with the dominants (Fig. 3; Table 1) being the general category of copepod nauplii, and species of Oithonidae (*O. similis*, *O. frigida*), Oncaeidae (primarily *O. antarctica*, *O. curvata*, *O. englishi* and *O. prolata*) and Pseudocalanidae (*Ctenocalanus citer*, *Microcalanus pygmaeus*). A proportional difference noted in taxonomic composition was the frequent occurrence of a representative of the harpac-

Table 1. Taxonomic list and vertical distribution of zooplankton species taken in the upper 1000 m in the vicinity of the ice edge during AMERIEZ 1986. Numbers in parenthesis represent zones of maximum density

| | Depth range (m) | | | |
|-------------------------------------|---------------------|---------------------|-----------------|---------------------|
| | Open water | | In pack-ice | |
| | Day | Night | Day | Night |
| Copepoda | | | | |
| <i>Aetideopsis minor</i> | 400–920 | 160–1000 | 200–500 | 200–1000 |
| <i>Arietellus simplex</i> | 650–920 | | | |
| <i>Augaptilus glacialis</i> | 650–920 | 300–710 | | 500–1000 |
| <i>Bathycalanus bradyi</i> | 0–1000 ^a | | | |
| <i>Calanoides acutus</i> | 0–920 | 0–1000 | 0–500 | 0–1000 |
| <i>Calanus propinquus</i> | 0–920 (50–150) | 0–1000 (0–100) | 0–500 (0–100) | 0–1000 (0–100) |
| <i>Candacia falcifera</i> | 260–920 | 300–1000 | | |
| <i>Cephalophanes frigidus</i> | 550–750 | | | |
| <i>Chiridiella subaequalis</i> | 650–920 | 900–1000 | | |
| <i>Conaea rapax</i> | | 530–710 | | |
| <i>Cornucalanus robustus</i> | 550–920 | 530–710 | | 200–500 |
| <i>Ctenocalanus citer</i> | 0–920 (50–115) | 0–1000 (0–100) | 0–500 (0–200) | 0–1000 (0–200) |
| <i>Epicalymma schmitti</i> | | | | 500–1000 |
| <i>Euauaptilus laticeps</i> | | 530–710 | | 50–1000 |
| <i>Euchaeta antarctica</i> | 0–920 (50–250) | 0–1000 (0–150) | 0–500 (50–100) | 0–1000 (0–100) |
| <i>Euchaeta austrina</i> | | 530–710 | | |
| <i>Euchaeta barbata</i> | 0–1000 ^a | | | |
| <i>Euchaeta rasa</i> | 400–920 | 300–710 | | 500–1000 |
| <i>Euchirella rostromagna</i> | 50–920 (100–250) | 0–1000 (100–150) | 50–500 | 50–1000 (50–200) |
| <i>Farrania frigida</i> | 550–920 | 530–1000 | | 500–1000 |
| <i>Gaetanus antarcticus</i> | 650–920 | 900–1000 | | 200–500 |
| <i>Gaetanus intermedius</i> | 550–920 | 530–1000 | | 500–1000 |
| <i>Gaetanus tenuispinus</i> | 100–920 (260–560) | 100–1000 (100–470) | 200–500 | 50–1000 (100–400) |
| <i>Haloptilus ocellatus</i> | 50–920 (100–380) | 40–1000 | 200–500 | 100–1000 |
| <i>Haloptilus oxycephalus</i> | 0–920 (50–560) | 100–1000 (200–470) | 100–500 | 100–1000 |
| <i>Heterorhabdus austrinus</i> | 0–920 | 0–1000 (100–260) | 200–500 | 100–1000 |
| <i>Heterorhabdus farrani</i> | 260–920 | 170–1000 | | 400–1000 |
| <i>Heterostylites major</i> | 400–560 | 200–300 | | |
| <i>Lubbockia aculeata</i> | 100–920 | 200–710 | | 100–1000 |
| <i>Lucicutia curta</i> | 650–920 | 530–1000 | | |
| <i>Lucicutia frigida</i> | 550–920 (650–1000) | 530–1000 (900–1000) | 100–500 | 500–1000 (500–1000) |
| <i>Lucicutia macrocera</i> | 550–920 | 530–1000 | | 500–1000 |
| <i>Lucicutia wolfendeni</i> | 550–920 | 530–1000 | | 500–1000 |
| <i>Metridia curticauda</i> | 400–920 | 340–1000 | | 200–1000 (400–1000) |
| <i>Metridia gerlachei</i> | 0–920 (50–150) | 0–1000 (0–1000) | 0–500 (50–100) | 0–1000 (0–100) |
| <i>Metridia princeps</i> | | 0–1000 ^a | | |
| <i>Microcalanus pygmaeus</i> | 50–920 (100–380) | 0–1000 (100–500) | 0–500 (50–500) | 50–1000 (100–600) |
| <i>Mormonilla minor</i> | 650–920 | 530–1000 | 100–200 | 500–1000 |
| <i>Oithona frigida</i> | 50–920 (260–560) | 0–1000 (100–470) | 0–400 (100–400) | 0–1000 (100–600) |
| <i>Oithona similis</i> | 0–920 (0–150) | 0–1000 (0–150) | 0–500 (0–100) | 0–1000 (0–100) |
| <i>Oncaea antarctica</i> | 0–920 (50–380) | 40–1000 | 0–400 | 0–1000 |
| <i>Oncaea convexa</i> | | | 500–1000 | 200–1000 |
| <i>Oncaea curvata</i> | 0–920 (0–115) | 0–1000 (40–260) | 0–1000 (0–100) | 50–400 (50–100) |
| <i>Oncaea englishi</i> | 0–920 | 300–1000 | 200–500 | 200–1000 |
| <i>Oncaea prolata</i> | 0–920 (260–560) | 160–1000 (160–470) | 0–500 (100–500) | 100–1000 (100–600) |
| <i>Onchocalanus magnus</i> | 550–920 | 200–1000 | | |
| <i>Onchocalanus wolfendeni</i> | | 530–710 | | 200–600 |
| <i>Pachyptilus eurygnathus</i> | 650–920 | 530–710 | | |
| <i>Pseudaugaptilus longiremis</i> | | 530–710 | | 200–1000 |
| <i>Pseudochirella elongata</i> | | 530–710 | | 500–1000 |
| <i>Pseudochirella hirsuta</i> | | 530–1000 | | |
| <i>Pseudochirella polyspina</i> | 0–1000 ^a | 0–1000 ^a | | |
| <i>Racovitzanus antarcticus</i> | 0–920 (100–380) | 100–1000 (100–300) | 50–500 | 100–400 |
| <i>Ratania atlantica</i> | 650–920 | | | |
| <i>Rhincalanus gigas</i> | 0–920 (50–560) | 0–1000 (340–470) | 0–500 | 100–1000 |
| <i>Scaphocalanus antarcticus</i> | 500–920 | 530–1000 | | 500–1000 |
| <i>Scaphocalanus farrani</i> | 260–560 | 100–710 | 200–500 | 100–400 |
| <i>Scaphocalanus parantarcticus</i> | | 0–1000 ^a | | |
| <i>Scaphocalanus vervoorti</i> | 0–920 (50–560) | 40–1000 (100–300) | 50–500 | 0–1000 (100–600) |
| <i>Scolecithricella centelis</i> | | 100–710 (170–500) | 200–500 | 100–1000 |
| <i>Scolecithricella dentipes</i> | | 0–1000 ^a | | |
| <i>Scolecithricella emarginata</i> | | 530–1000 | | |
| <i>Scolecithricella hadrosoma</i> | | 900–1000 | | |

Table 1 (continued)

| | Depth range (m) | | | |
|--|---------------------|---------------------|--------------------|--------------------|
| | Open water | | In pack-ice | |
| | Day | Night | Day | Night |
| <i>Scolecithricella minor</i> | 0–920 (50–150) | 0–1000 (0–300) | 0–500 | 0–1000 (50–200) |
| <i>Scolecithricella ovata</i> | 400–920 | | | |
| <i>Spinocalanus abyssalis</i> | 260–920 (260–560) | 170–1000 (200–470) | 200–500 | 200–1000 (200–600) |
| <i>Spinocalanus magnus</i> | 400–920 (400–560) | 340–1000 (530–1000) | | 400–1000 |
| <i>Stephos longipes</i> | 260–380 | | 0–500 | 0–600 |
| <i>Temerites brevis</i> | | 340–470 | | 200–1000 |
| <i>Teneriforma naso</i> | 650–920 | | | 500–1000 |
| Tisbidae | | 0–90 | 0–115 (0–50) | 0–600 (0–50) |
| <i>Undinella brevipes</i> | 0–1000 ^a | | | |
| Ostracoda | | | | |
| <i>Conchoecia antipoda</i> | 260–920 | 160–1000 | 200–500 | 200–1000 |
| <i>Conchoecia brachyaskos</i> | 260–750 | 200–1000 | 200–500 | 200–1000 |
| <i>conchoecia hettacra</i> | 0–920 (50–250) | 0–1000 (0–300) | 0–500 (200–500) | 0–1000 (0–400) |
| <i>Conchoecia isocheira</i> | 0–920 (50–380) | 0–1000 (0–150) | 0–500 | 50–1000 (50–400) |
| <i>Conchoecia skogsbergi</i> | 260–920 (260–750) | 100–1000 (340–470) | 200–500 | 100–1000 (200–600) |
| Euphausiacea | | | | |
| <i>Euphausia superba</i> ^d | 0–920 (0–50) | 0–1000 (0–100) | 0–500 (0–50) | 0–500 (0–50) |
| <i>Thysanoessa macrura</i> | 0–920 (260–560) | 0–1000 (100–260) | 0–500 (0–100) | 0–1000 (0–200) |
| Amphipoda | | | | |
| <i>Cylopus lucasii</i> ^d | 50–560 (50–115) | 0–150 (0–50) | 0–200 | |
| <i>Cyphocaris faueri</i> ^d | | 40–1000 | | |
| <i>Cyphocaris richardi</i> ^d | 650–920 | 340–470 | | |
| <i>Eusirus antarcticus</i> ^b | | | | |
| <i>Eusirus microps</i> ^d | 340–470 | | | |
| <i>Hyperliella dilatata</i> | 0–560 | 0–1000 (0–50) | | 100–200 |
| <i>Hyperliella macronyx</i> | 400–560 | 0–50 | | |
| <i>Hyperoche medusarum</i> | 0–1000 ^a | | | |
| Lanceolidae | 650–920 | 900–1000 | | |
| <i>Primno macropa</i> | 0–920 (0–115) | 0–1000 | 0–500 (0–100) | 0–1000 (0–400) |
| Scinidae | 260–750 | 100–1000 | | 100–200 |
| <i>Vibilia stebbingi</i> | | 0–50 | | |
| Mysidacea | | | | |
| <i>Euchaetomera zurstrasseni</i> | 500–750 | 160–710 | | |
| Coelenterata | | | | |
| <i>Calycopsis borchgrevinki</i> | 100–750 (100–150) | 0–710 (100–150) | 200–1000 | |
| <i>Dimophyes arctica</i> | 50–380 | 40–1000 (100–300) | 50–500 | 100–1000 (100–600) |
| <i>Diphyes antarctica</i> ^d | 0–920 (50–250) | 0–1000 (40–90) | 50–1000 (50–100) | 50–400 (50–100) |
| <i>Vogtia</i> sp. | 260–920 | 170–470 | | 200–500 |
| Polychaeta | | | | |
| <i>Maupasia coeca</i> | 260–380 | 160–470 | | |
| <i>Pelagobia longicirrata</i> | 50–920 (100–380) | 100–1000 (100–470) | 0–500 (50–500) | 0–1000 (100–400) |
| <i>Rhynchonereella bongraini</i> | 0–920 (50–250) | 0–1000 (0–90) | 100–500 | 0–600 (0–200) |
| <i>Tomopteris carpenteri</i> ^d | 0–115 | 0–50 | | |
| <i>Tomopteris planktonis</i> | 260–380 | 40–1000 | | 500–1000 |
| <i>Tomopteris septentrionalis</i> | 0–920 (50–150) | 0–710 (0–90) | 50–500 | 100–1000 (100–600) |
| <i>Travisioopsis coniceps</i> ^d | 0–200 | 0–200 | | |
| <i>Travisioopsis levinseni</i> | 150–920 | 160–710 | | |
| <i>Typhloscolex mülleri</i> | 150–920 | 100–1000 (100–470) | 200–500 | 100–1000 |
| <i>Vanadis antarctica</i> ^d | 0–250 (0–50) | 0–470 (40–90) | | |
| Mollusca | | | | |
| <i>Clio pyramidata</i> f. <i>sulcata</i> | | 0–50 | 200–500 | |
| <i>Clione antarctica</i> | 260–380 | 0–300 (0–50) | 200–500 | 100–1000 |
| <i>Limacina helicina</i> | 150–380 | 0–500 (0–50) | 200–500 | 600–1000 |
| <i>Spongiobranchaea australis</i> | 150–920 | 170–710 | | |
| Chaetognatha | | | | |
| <i>Eukrohnia hamata</i> | 0–920 (50–560) | 0–1000 (40–470) | 0–500 | 0–1000 (50–600) |
| <i>Sagitta gazellae</i> ^d | 0–920 (260–380) | 0–1000 (260–380) | 50–1000 | 50–1000 (50–100) |
| <i>Sagitta marri</i> | 100–920 (100–380) | 100–1000 (100–470) | 200–500 | 100–1000 (200–500) |
| Tunicata | | | | |
| <i>Doliolum intermedium</i> (?) | 100–750 | 170–710 | 200–500 | 50–600 |
| <i>Fritillaria</i> spp. | ? | ? | 100–200 | 100–400 |
| <i>Oikopleura gaussica</i> | 0–50 | 0–50 | 50–200 | 50–1000 |
| <i>Salpa thompsoni</i> ^d | 50–920 (50–115) | 0–1000 (0–50) | 100–1000 (200–500) | 0–1000 (50–100) |

^a Occurring only in 0–1000 m oblique tows; ^b Hand captured under ice with SCUBA gear; ^c Tentatively identified as *C. citer* on basis of length of first antenna (Heron and Bowman 1971); ^d Species mostly in micronekton size range (>2 cm in size)

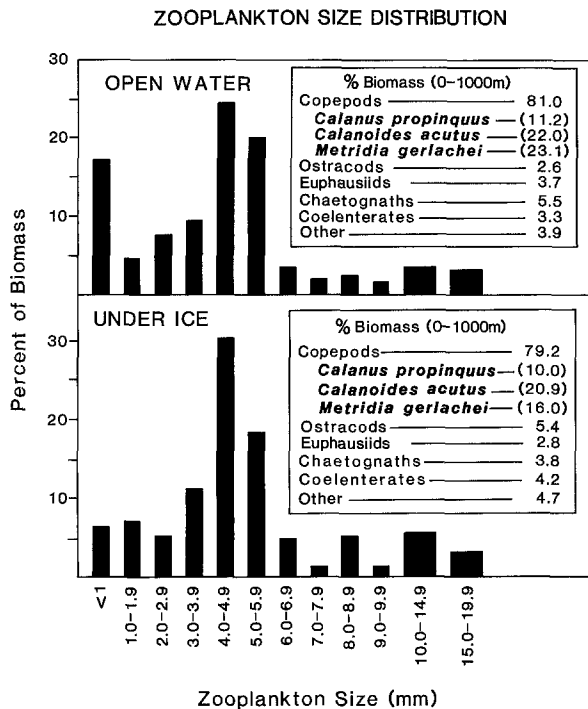


Fig. 6. Size distribution of zooplankton biomass; plankton net (1–20 mm) and 30 l water bottle (<1 mm) data combined

ticoid family Tisbidae in the water bottle samples from the upper 25 m within the pack ice. This species was uncommon in samples from the open sea.

Intermediate-to-large sized zooplankton, 1–20 mm, taken with the zooplankton nets also had highest biomass concentrations in the epipelagic zone (Fig. 4). Substantial day-night differences, especially in the upper 50 m, are suggested by the open sea data set. This diel difference is not statistically significant, however, because of the high degree of patchiness and the small number of samples available from each depth zone. The principal biomass species were the copepods *Metridia gerlachei*, *Calanus propinquus* and *Calanoides acutus*. These species had their maxima in the upper 150 m (Fig. 5), with the vertical distributions of *M. gerlachei* and *C. propinquus* indicating a marked increase in numbers in the upper 50 m at night in both areas. This was not apparent for *C. acutus* and much of its population remained below 300 m day and night in both areas. The three species combined accounted for 56% and 47%, respectively, of open sea and pack-ice net-caught and 30 l bottle biomass combined (Fig. 6). The late stage copepodites and adults of these species generate the large biomass peak seen in the 4–6 mm plankton size range in Fig. 6.

Groups other than copepods which contributed moderately (2%–6%) to biomass were ostracods, postlarval euphausiids, chaetognaths and coelenterates (Fig. 6; Table 1). The ostracods were mostly *Conchoecia hettacra*, *C. isocheira* and *C. skogsbergi*, and postlarval euphausiids were all *Thysanoessa macrura*. *Euphausia superba* was taken with our plankton nets but all in-

dividuals were larger than 20 mm, the upper size limit of zooplankton considered here. The major chaetognath was *Eukrohnia hamata*, with *Sagitta marri* being a minor contributor. *Sagitta gazellae* was seen in our sample aliquots but most individuals exceeded 20 mm in length. The principal coelenterate was the calycophoran siphonophore *Dimophyes arctica*. *Diphyes antarctica* and *Vogtia* sp. were also common as were several unidentified siphonophore species.

Other taxa which individually constituted less than 2% of the net-caught biomass were euphausiid larvae, amphipods, mysids, molluscs and tunicates. The euphausiid larvae were mostly calyptopis of *Euphausia superba* and furcilia of *Thysanoessa macrura*. While common, these contributed little to biomass. The most abundant amphipods were the hyperiids *Hyperietta dilatata* and *Primno macropa*, although the gammarid *Eusirus antarcticus* was observed in large numbers at the undersurface of the ice by SCUBA divers. The small mysid species occasionally taken was *Euchaetomera zurstrasseni* and the most numerous polychaetes were *Pelagobia longicirrata*, *Rhynchonereella bongraini* and *Tomopteris septentrionalis*. Fragments of the alciopid *Vanadis antarctica* were found in a number of our plankton collections but these were from very large individuals in excess of 20 mm. Small tunicates, primarily the larvae *Oikopleura gaussica* and *Fritillaria* spp., were common and often abundant, especially in collections from the epipelagic zone. Their biomass contribution, however, was negligible. *Salpa thompsoni* was also abundant but usually larger than 20 mm, hence not included in biomass totals.

Numerically, the most abundant taxa in both areas were copepods of the families Oithonidae, Oncaidae and Pseudocalanidae (Table 2). Species from each of these families tended to segregate by depth, even though considerable overlap in vertical distributions existed (Table 1). Among the abundant species of Oncaidae, *O. curvata* was shallowest followed in increasing depth distribution by *O. prolata* and *O. englishi*. A fourth abundant species, *O. antarctica*, co-occurred with all of these and demonstrated no apparent depth trend. In the Oithonidae, *O. similis* was shallower than *O. frigida* and in the Pseudocalanidae *Ctenocalanus citer* was centered shallower than *Microcalanus pygmaeus*. The three zooplankton biomass species, *Metridia gerlachei*, *Calanoides acutus* and *Calanus propinquus*, were numerically inconsequential in that their combined abundance in the upper 1000 m averaged only 2–4 individuals m^{-3} . Zooplankton biomass integrated over 0–1000 m was similar, 1.1–1.3 $gDWm^{-2}$, for both areas.

Discussion

During sampling in March, 1986 the ice edge was located near the position of maximum seasonal retreat noted for other years (Zwally et al. 1983). The research area was

Table 2. Average zooplankton numbers m^{-3} for 301 bottle collections, 0–150 m and 0–1000 m. Value ranges () are not included for the 0–1000 m data set due to lack of replicates from below 150 m

| | Open water | | Pack ice | |
|-----------------|------------------|----------|-----------------|----------|
| | 0–150 m | 0–1000 m | 0–150 m | 0–1000 m |
| | [n = 6 casts] | | [n = 10 casts] | |
| Oithonidae | 482 (331–756) | 120 | 257 (161–403) | 58 |
| Oncaecidae | 457 (364–562) | 319 | 269 (102–397) | 281 |
| Pseudocalanidae | 60 (39–86) | 28 | 36 (12–64) | 61 |
| Other Copepods | 14 (0–47) | 21 | 15 (0–45) | 13 |
| Copepod Nauplii | 1622 (1081–2045) | 612 | 1600 (952–2352) | 465 |
| Other Metazoa | 141 (89–228) | 17 | 27 (5–81) | 15 |

south of 64°S and well within the oceanic waters of the Weddell gyre. Taxonomic composition (Table 1) of the epipelagic waters was characteristic of the cold water Antarctic oceanic community as indicated by the presence of typical east wind drift species such as *Haloptilus ocellatus*, *Cylopus lucasii*, *Calycopsis borchgrevinki* and *Dimophyes arctica* (Mackintosh 1934; Hubold et al. 1988). Species diversity in the epipelagic zone was low which results from little apparent admixture with shelf or near-continent fauna. For example, *Euphausia crystallorophias*, larvae of *Pleuragramma antarcticum* and larvae of shallow water benthic invertebrates reported from shelf waters in the southern Weddell Sea (Hubold et al. 1988) were rare in our collections. Also rare or missing were near-continent taxa such as species of *Antarctomyxis*, the gammarid genus *Orchomene* and the ostracod *Conchoecia belgicae* (Hopkins 1985, 1987). The latter species is replaced in the western Weddell gyre by the closely related but more broadly oceanic *C. hettacra* (Deevey 1982). The study area was well south of the Weddell-Scotia confluence and warmer water species commonly taken in the Bransfield Strait-southern Scotia Sea (Mackintosh 1934; Hopkins 1985; Kittel et al. 1985) were not seen in our collections. For example, we found no *Euphausia frigida*, *Themisto gaudichaudii*, *Pleuromamma robusta* or *Calanus simillimus*, though the latter two species have been found in small numbers from the eastern Weddell Sea as far south as 69°S (Kaczmaruk 1983).

Zooplankton diversity substantially increases below the epipelagic zone. This derives from the occurrence in the deeper “warm” water of the Weddell gyre of mesopelagic species, mostly copepods, which have broad and probably circumpolar distributions (Vervoort 1957; Heron 1977; Park 1978, 1980, 1982).

Zooplankton biomass at this time of year (late summer) was still at its densest concentrations in the epipelagic zone. In open water there was an obvious increase in the upper 50 m at night (Fig. 4) which was much less apparent within the pack ice. Two of the three dominant copepod species, though, *Calanus propinquus* and *Metridia gerlachei*, were apparently undergoing diel vertical migration in both habitats (Fig. 5). *Calanoides acutus* was not actively migrating at this time, though diel

migration in summer has been reported previously for all three of these biomass species (Mackintosh 1934; Hardy and Gunther 1935; Andrews 1966). Much of the *C. acutus* population remained below 300 m throughout the diel period. This suggests that winter descent may already have been initiated for this species. Andrews (1966) data show that a greater proportion of the population of *C. acutus* was found deeper in March than in the preceding month. Voronina (1973), in comparing seasonal vertical distributions of biomass species south of the Polar Front, showed that *C. acutus* begins its winter descent before *C. propinquus* and *Rhincalanus gigas*.

While zooplankton standing stocks in the open sea and within the pack ice were roughly equivalent (Figs. 3 and 4), there were significant differences in vertical distributions. Student's *t*-test ($P < 0.001$) comparing the abundance of cyclopoid copepods and copepod nauplii, the two most abundant categories in our 301 bottle collections (Fig. 3), show that each group was far less numerous in the upper 50 m in the pack ice than in open water. As apparent in Fig. 2, the water in the upper 50 m above the thermo-pycnocline was colder, by more than 1°C, under the ice than in open water. Most of the small (<1 mm) metazoan plankton under the ice resided below this boundary. In open water a major abundance peak occurred above the thermo-pycnocline at 25 m (Fig. 3).

As would be expected most species were common to both sampling areas, though the open sea list was longer. This was probably because more water was filtered with the oblique hauls made in this zone than with the shorter vertical hauls made in the pack ice. The tishid harpacticoid copepod and the gammarid *Eusirus antarcticus*, however, were more abundant in shallow waters within the pack ice than in open water. *Eusirus antarcticus* was observed grazing at the undersurface of the ice in large numbers. Also, several interstitial samples indicated that the small calanoid *Stephos longipes* was the prevalent metazoan species in pores within the ice, whereas it was a minor constituent of the zooplankton of the water column in both areas. The tishid harpacticoid was found in pore waters as well (see also Lang 1948) but in much lower numbers than *S. longipes*.

Zooplankton (1–20 mm) biomass integrated over the upper 1000 m for the west central Weddell Sea appears to

be comparatively low in relation to other areas of the Southern Ocean where similar field and laboratory protocols have been used. Standing stocks are approximately a third to a half that reported for the open ocean in the west wind drift (Pacific sector; Hopkins 1971) and in near-continent areas such as the Gerlache Strait adjacent to the Antarctic Peninsula (Hopkins 1985) and McMurdo Sound in the Ross Sea (Hopkins 1987). The only other data for the study area are from El-Sayed and Taguchi (1981). Their values were only for the upper 200 m and were expressed as wet weight and hence not directly comparable to our results.

An explanation for the relatively low biomass may be found in the hydrography of this region. The Weddell Sea is dominated by a slow moving gyre of enormous circumference (~1700 km in diameter). Gyre-wide dynamic height calculations indicate baroclinic slow current velocities (e.g., Carmack and Foster 1977). The March, 1986 AMERIEZ (Muench and Husby 1988) data from the northwestern Weddell Sea suggest negligible baroclinic flow in the upper 1500 m. Earlier studies (Klepikov 1964; Carmack and Foster 1975; Deacon 1979) mention residence times of gyre water (deep) of at least 2 to 25 years, and despite long life cycles for the biomass dominants (1–2 generations year⁻¹; Ommaney 1936; Andrews 1966; Voronina 1978) most of the zooplankton in the Weddell Sea can probably complete their life cycles within the gyre. The size of the standing stocks, then, would be a function of the level of annual primary production within this system. Earlier midsummer data (El-Sayed 1970; El-Sayed and Taguchi 1981) and results from the late summer AMERIEZ 1986 cruise (Smith 1987; Smith and Nelson, data report) show low to moderate chlorophyll and productivity values at the ice edge in the west central Weddell Sea. Any production from blooms possibly missed in these surveys would likely persist at any location for a period of only 50–60 days (Smith and Nelson 1986). The water column would then become oligotrophic for most of the remainder of the year, especially during the long winter period. Thus, a relatively low annual production, much of it generated in a short bloom, is available to a zooplankton biomass dominated by species with long life cycles. From such conditions, a low zooplankton standing stock would be predicted.

Our data show that in the austral fall the influence of the marginal ice zone was more apparent on the vertical distribution of zooplankton than on community composition (i.e., size distribution; taxonomic components) and biomass. Marginal ice zones are transitory in relation to the water masses they overlie, and when considered with the long-lived zooplankton constituting much of the biomass, this would tend to obscure local effects of the marginal ice zone. Any changes in community structure, particularly in relation to size distribution, would most likely be linked to food availability and would be apparent through increases in newly hatched juvenile stages such as nauplii in the vicinity of a bloom. Even though phytoplankton standing crop/m² averaged 6× greater in

open water than within the pack ice, chlorophyll and primary production were generally well below bloom levels (Smith 1987; Smith and Nelson, data report). In the austral fall in the marginal ice zone of the Western Weddell Sea, the abundance of copepod nauplii in the epipelagic zone was virtually the same in both habitats (Table 2). An obvious comparison would be of the present data set with the structure of the zooplankton community in the marginal ice zone during the summer bloom period.

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