

UNDER-ICE ZOOPLANKTON OF THE WESTERN WEDDELL SEA

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Abstract: Species composition, abundance, and seasonal dynamics of the under-ice zooplankton collected during the USA-Russia ISW-1 Expedition, from the end of February to the middle of May in 1992, in the western rim of the Weddell Sea Gyre are presented. Zooplankton were collected by a diver with plankton landing net directly from the under-ice surface (0 m layer) and at 5-m depth.

Larvae and postlarvae of *Euphausia superba* (Euphausiidae), *Oithona similis*, *Stephos longipes*, *Paralabidocera antarctica*, *Pseudocyclopina belgicae*, *Microcalanus pigmaeus* and *Ctenocalanus citer* (Copepoda) were most abundant in both layers. Differences in the stage composition and abundance of these species between two layers (0 and 5 m) were found. *E. superba*, *S. longipes*, *P. antarctica* and *P. belgicae* were numerous near the under-ice surface and scarce at 5 m. *O. similis* density was greater at 5 m than at 0 m. *M. pigmaeus* and *C. citer* were comparatively greater in number at 5 m. Seasonal changes in abundance and stage structure of euphausiids and copepods are discussed. A delay in seasonal development of *E. superba*, *S. longipes*, *P. antarctica* and *P. belgicae* comparing is shown.

1. Introduction

The primary production of sea ice flora is now believed to be one of the first trophic levels in both the Arctic and Antarctic marine ecosystems (BUNT, 1963; MEGURO *et al.*, 1967; HORNER, 1976; SULLIVAN and PALMISANO, 1981; HOSHIAI *et al.*, 1989; MELNIKOV, 1989a, b; IRWIN, 1990). The consumers of the sea ice flora, cryopelagic fauna, or fauna associated with the bottom ice surface (ANDRIJASHEV, 1967), represent the second trophic level of the food chain in the sea ice ecosystem and have been mainly studied in the Arctic (MELNIKOV and KULIKOV, 1980; GULLIKSEN, 1984; RUNGE and INGRAM, 1988). Cryopelagic organisms constitute links in transport of energy from the sea ice flora to sea birds and mammals living in high latitudes and to deep-sea plankton in the open ocean. Our knowledge of this important trophic level in the Antarctic sea ice ecosystem is based mainly on observations in coastal regions, e.g., Lützow-Holm Bay (FUKUCHI and TANIMURA, 1981; TANIMURA *et al.*, 1984; FUKUCHI *et al.*, 1985a, b; TANIMURA *et al.*, 1986); McMurdo Sound (FOSTER, 1987, 1989; WAGHORN and KNOX, 1988); Prydz Bay near Davis Station (TUCKER and BURTON, 1988, 1990) and in the Weddell Sea

near Halley Bay, where some stations have been located rather far from the shore (KURBJEWIT *et al.*, 1993). Zooplankton of the Antarctic sea ice zone have also been studied (DALY and MACAULEY, 1988; HOPKINS and TORRES, 1988; MENSHENINA, 1992; BATHMANN *et al.*, 1993; KURBJEWIT, 1993). These studies were conducted from vessels, and materials collected mainly during a short period of observations. These materials are of great biological interest for understanding the function of the Antarctic sea ice zone.

The purpose of the present study was to examine species composition and seasonal dynamics of the under-ice zooplankton in the western Weddell Sea.

2. Materials and Methods

Investigations were carried out in the perennial ice area of the western rim of the Weddell Sea Gyre where the USA-Russia Ice Station Weddell (ISW-1) drifted between 72 and 65°S latitude and 51 and 53°W longitude from February 11 to June 9, 1992 (GORDON and LUKIN, 1992) (Fig. 1).

Cryopelagic fauna were caught by a SCUBA-diver under the perennial drifting ice at midday. Dives were carried out through a separate hydrohole made in the ice floe. Some observations were carried out under the newly formed ice in leads. In all cases, samples were collected by scraping a plankton net (mesh size 180 μm) with a 40 \times 20-cm-wide flat top at the opening frame for 30 m along the under-ice surface. After the tow the plankton net was closed in the water in order to avoid sampling

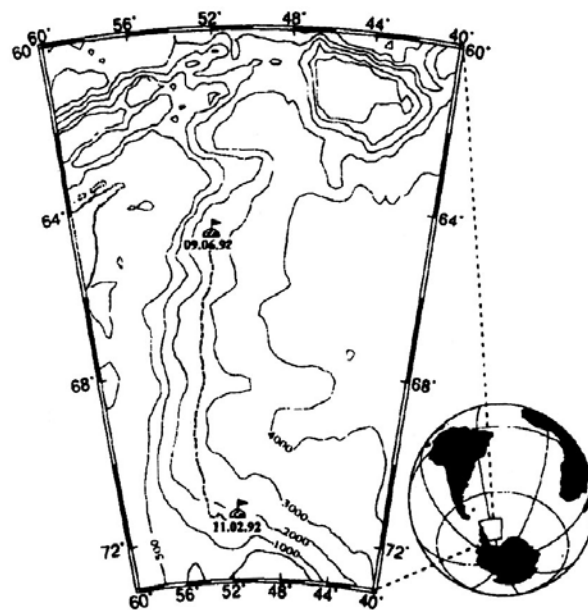


Fig. 1. Drifting course of the USA-Russia Ice Station Weddell-1 (ISW-1) from February 11 to June 9, 1992.

planktonic fauna. Planktonic fauna were also collected with horizontal tows at 5-m depth by the same plankton net. Other than the SCUBA sampling, animals were also collected in the hydrohole.

In the laboratory the samples were washed on nylon gauze (mesh size 180 μ m). The organisms were immediately fixed with 5% formaldehyde. Plankters were identified in a plankton counting tray. Depending on the abundance of organisms, all or 1/10, separated by stemple pipette, were enumerated. The numbers were not standardized per volume of water but reflected the catch per sample (per set length, i.e. 30 m).

3. Results

3.1. Occurrence of zooplankton under the ice

A total of 31 samples were analyzed, 15 from the under surface of the ice (0 m layer) and 5 from 5 m below it, and 11 from the water surface through the hydrohole in the ice (the hole).

The occurrence of 7 most numerous species from the 0 and 5 m layers and the hole are given in Table 1 (1 species of euphausiid and 6 of copepods). High abundances of *E. superba* were observed at 0 m and in the hole. At 5 m this species was distinctly less abundant. Abundance of copepods as a whole group at 0 and 5 m were roughly equal. Markedly lower numbers of copepods were caught in the hole. Among copepods at 0 m *S. longipes* predominated. At 0 m *S. longipes* appeared to be an order of magnitude greater than at 5 m and in the hole. But difference in number with a subdominant species (*O. similis*) was more marked at 0 m than in the hole. *O. similis* was a subdominant species at 0 m and in the hole. The number of *O. similis* was 4 times greater at 0 m than in the hole. At 5 m *O. similis* showed the highest abundance (5 times greater than at 0 m) and was the dominant species. *P. belgicae* was obviously present at 0 m. It was scarce at 5 m and absent in the hole. *P. antarctica* decreased in abundance at 5 m, compare with 0 m, and was almost absent in the hole. *M. pigmaeus* and *C. citer* were scarce in the sampling sites but *M. pigmaeus* showed a slight increase in abundance at 5 m.

A number of plankters were caught but they were not included in Table 1

Table 1. Mean numbers (per sample) of abundant plankton species under the ice-floe in the western Weddell Sea from late February to May 1992.

Species	Hauls from		The hole
	0 m	5 m	
<i>Euphausia superba</i>	28.80	6.60	49.27
<i>Stephos longipes</i>	47.40	4.80	6.36
<i>Paralabidocera antarctica</i>	9.07	4.40	.73
<i>Microcalanus pigmaeus</i>	1.87	5.80	1.73
<i>Ctenocalanus citer</i>	1.93	2.20	.64
<i>Oithona similis</i>	23.13	96.20	5.36
<i>Pseudocyclopina belgica</i>	13.60	2	0

because of their low abundance or because of uncertainties about identification. A large polychaeta, *Tomopteris carpeniteri* was caught three times at 0 m and once at 5 m. Chaethognaths, *Eukrohnia hamata*, *Sagitta gazellae* and *S. marri*, were usually observed at 0 m. *Euphausia crystallorophias* (up to 8 specimens per sample) was registered 5 times only at 0 m. Siphonophores were caught three times at 0 m and three times in the hole. Juvenile gammarid amphipods were mainly observed from 5 m, there were less than 5 specimens. In a single sample from 0 m 4 ostracods were found. Two specimens of appendicularia (Oicopleuridae) were registered at 0 m. Nine species of copepods never reached more than 10 specimens and never caught at 0 m. Among them *Calanus propinquus* was occurred from one to five times at all sites. *Metridia gerlachei* and *Calanoides acutus* was absent in the hole; *Spinocalanus* sp. (copepodites), *Euchaeta* sp. (copepodites), *Oithona frigida* and *Oncaea notopus* were caught only at 0 m; *O. curvata* was found everywhere but only once at each site; *O. conifera* was found in a single sample in the hole. Harpacticoids were caught mainly at 0 m in a few samples. Copepod nauplii were rare, possibly because they were small enough to pass through the mesh.

3.2. Age composition of dominant species

Age composition *E. superba*, *S. longipes*, *P. antarctica*, *C. citer* and *M. pigmaeus* distinctly differed among the catches from 0 m, 5 m layer and the hole (Fig. 2). The age composition of *P. belgicae* differed slightly between 0 and 5 m (in the hole *P. belgicae* was absent). Age composition of *O. similis* showed no differences.

E. superba was represented by furcilia V, VI and postlarvae. Furcilia V was observed only in the hole in very small number. Furcilia VI and postlarvae were numerous at all three sites. At 0 m postlarvae predominated. At 5 m the percent age of furcilia VI and postlarvae were roughly equal. In the hole furcilia VI predominated.

S. longipes was represented by all copepodite stages and adults at 0 m layer. Copepodites II, III, IV (CII, CIII, CIV) and adults were numerous while CI and CV were scarce. At 0 m and at 5 m CIII predominated and CII was subdominant. At 5 m the percent of CII was more than at 0 m. In the hole adults were numerous while all copepodite stages were scarce.

In *P. antarctica*, CIV predominated at 0 m, at 5 m CV predominated and in the hole adults were dominant. The percent age of non-dominant stages was low everywhere.

M. pigmaeus CV and adults were represent at 0 m. CV slightly predominated. At 5 m CIV, CV and adults were caught. In the hole CIII and CV, roughly equal in numbers, were present.

C. citer showed increase of share of later copepodite stages (CIV was dominant) at 5 m compared with 0 m and in the hole. At 0 m and 5 m layer CII–CV were caught while in the hole only CII and CIII were present. Adults were absent in all samples.

Age composition of *P. belgicae* was similar between 0 and 5 m. The population consisted of CIV, CV and adults. Juveniles prevailed in both layers but increased at

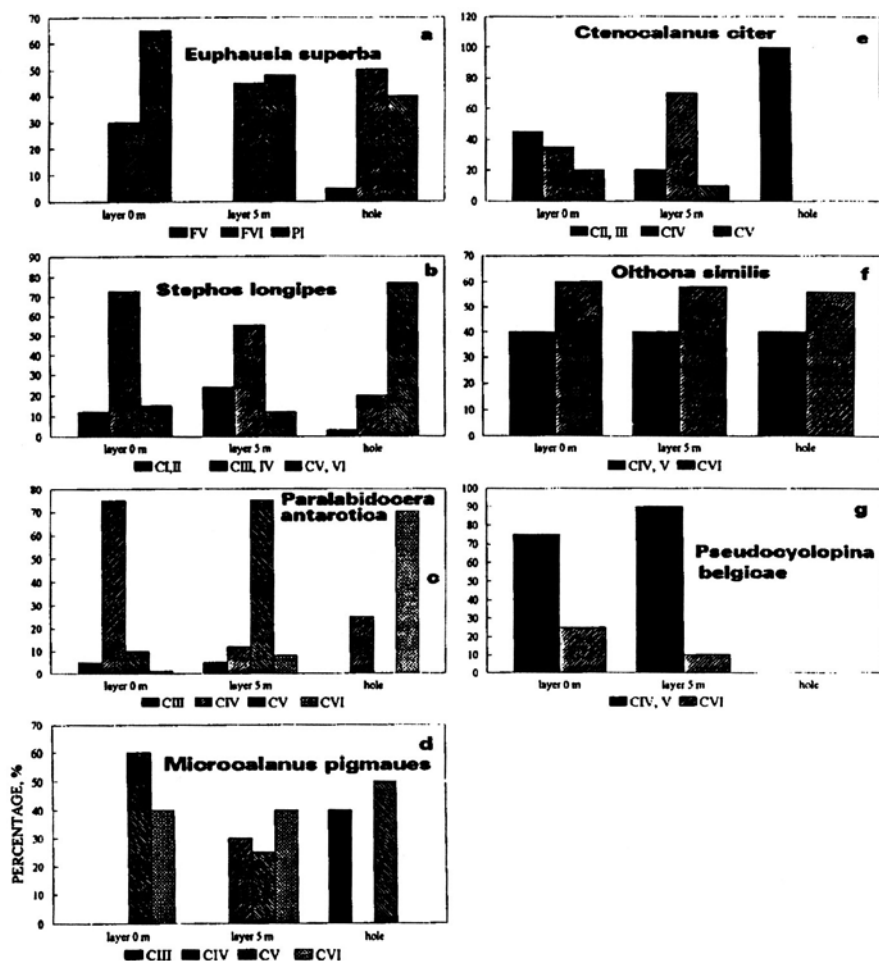


Fig. 2. Stage composition of most abundant plankton species under-surface of the ice, at 5-m depth from the bottom of the ice and in the hole in the ice.

5 m compared with 0 m.

Age composition of *O. similis* (CIV, CV and adults were caught and adults predominated) was identical at 0 and 5 m and in the hole.

3.3. Seasonal dynamics of dominant species

3.3.1. Seasonal changes of abundance

Samples collected at 0 m were used for seasonal dynamics studies mainly. At 5 m and in the hole *O. similis* (at 5 m) and *E. superba* (in the hole) were the only species to yield adequate numbers for enumeration and analysis. Despite the increase in abundance of *M. pigmaeus* and *C. citer* at 5 m compared to 0 m, their

absence in three (*M. pigmaeus*) or four (*C. citer*) samples at 5 m made it impossible to estimate temporal changes of these species there.

The abundance of *E. superba* at 0 m was highest at the end of February and the beginning of May (Fig. 3). From the middle of May to the middle of April it was comparatively low. At the end of April a rapid increase of *E. superba* abundance was registered. In the hole the greatest abundance took place at the end of May (May 19) and beginning of April (April 9) (Fig. 4). For *E. superba* distribution (even for larvae) patchiness is very characteristic (MARR, 1962). The presence of four maxima (two in the hole and two at 0 m) at different times revealed that

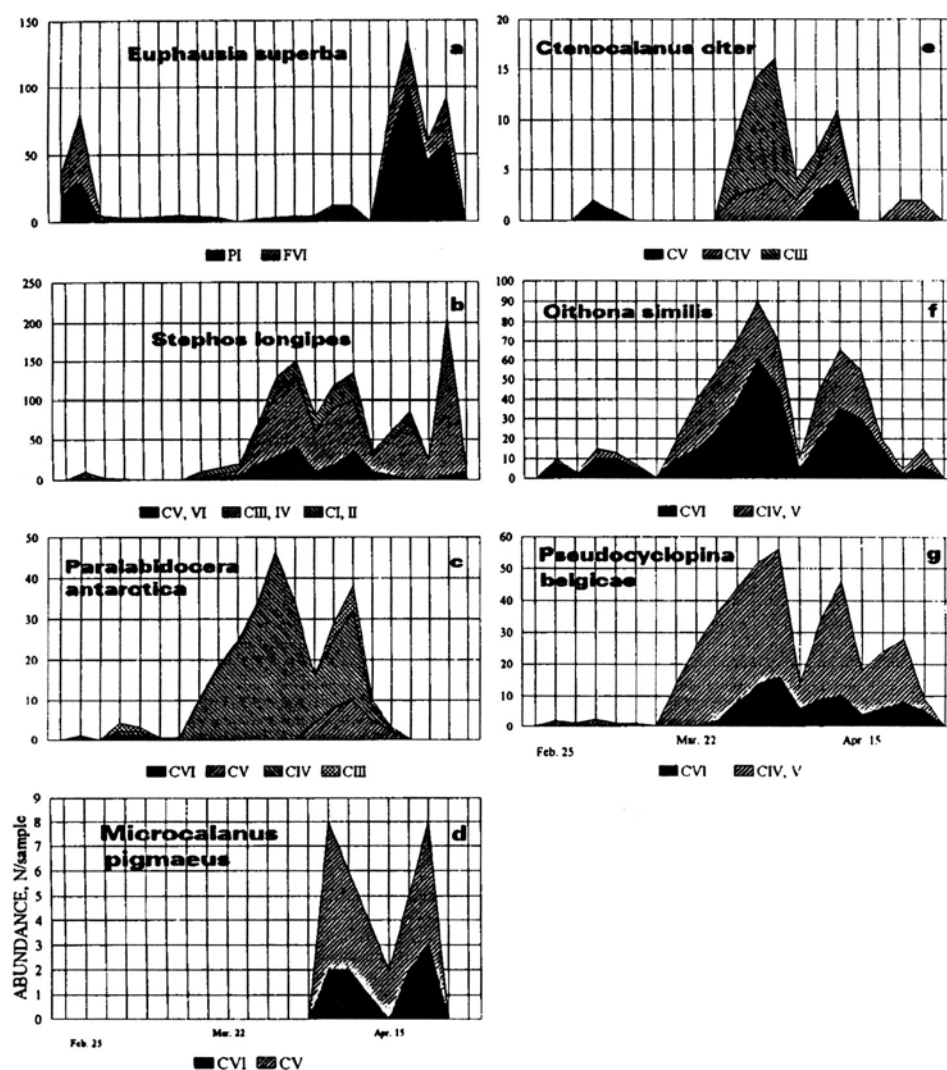


Fig. 3. Seasonal changes in abundances and stage compositions of most abundant plankton species under-surface (0 m layer) of the ice (number per sample).

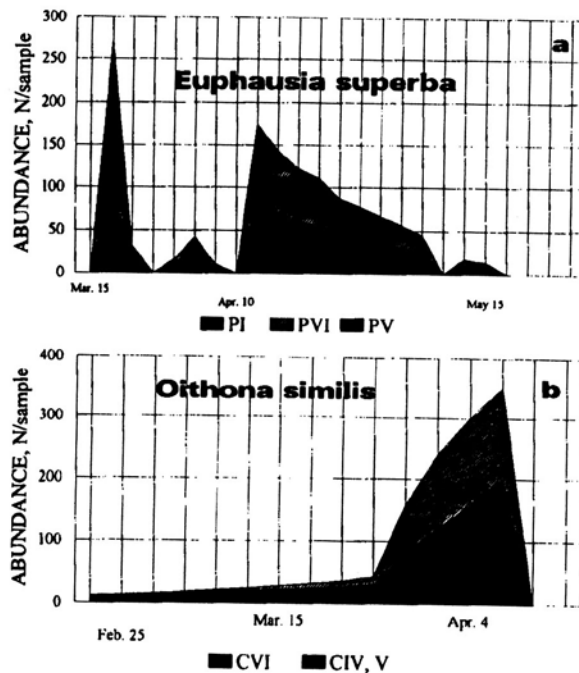


Fig. 4. Seasonal changes in abundances and stage compositions of *Euphausia superba* in the hole in the ice and *Oithona similis* at 5-m depth from the bottom of the ice.

changes in abundance of this species were accidental. Age composition of *E. superba* changed both at 0 m under the ice and in on hole. The percent composition of postlarvae increased with time. At 0 m the increasing was more noticeable (Figs. 3 and 4).

Seasonal dynamics in all the copepod species abundance was seems to be similar. All the species were absent (*M. pigmaeus*) or scarce (*C. citer*, *P. belgicae*, *S. longipes*, *P. antarctica* and *O. similis*) from the end of February to the end of March or beginning of April. At the end of March (*P. antarctica*, *O. similis*, *P. belgicae*) or beginning of April (*S. longipes*, *M. pigmaeus*, *C. citer*) a rapid increase of abundance took place (Fig. 2). *P. antarctica*, *C. citer*, *O. similis* and *P. belgicae* showed distinct decreases in abundance in late April. *S. longipes* and *M. pigmaeus* reached their highest densities at the end of April.

Temporal dynamics of *O. similis* at 5 m was seems to be similar to that at 0 m (Figs. 2 and 4). Appearance of *S. longipes* in the hole (from 18 of March to 9 of April) and at 5 m (April 6) coincided with a period of greater abundance at 0 m (Fig. 3). At 5 m (March 24 and April 6) and in the hole (March 18, 19 and 25, April 2) several specimens of *P. antarctica* were caught when the abundance of this species at the under surface of ice was the greatest (Fig. 3). The presence of *C. citer* and *M. pigmaeus* at 5 m (April 6) and in the hole (April 9) took place simultaneously with increase of these species numbers at 0 m (Fig. 3).

3.3.2. Seasonal changes of stage composition

Stage composition temporal changes were noted in all the species. They were not distinct in *M. pigmaeus*. This species was represented at 0 m by CV and adults. The percent of adults increased during April from 25% to 50% (Fig. 3). *P. belgicae* was characterized by absence of adults toward the beginning of April. Then their percentage increased and reached 67% at the end of April (Fig. 3). In *O. similis* copepodites were scarce from the end February to the middle of May. After the middle of May they reached roughly 50% and did not change their percentage. During April, *C. citer* developed gradually from earlier stage of CIII to later stages of CIV and CV. No adults of *C. citer* appeared even in the latest samples (Fig. 3).

Only early (CI and CII) copepodites of *S. longipes* were observed toward the end of March when this species was scarce. Then adults and all the other copepodite stages (CIII, CIV and a few specimens of CV) appeared at the beginning of April. CIII predominated during April. The percentage composition of adults and CI and CII gradually decreased toward the end of April. At the end of April almost all specimens of *S. longipes* were CIII.

P. antarctica was represented by CIII, CIV and adults from the end of February to the middle of May, while their abundances were low. CIII predominated. When abundance increased, adults disappeared and CIV became the dominant stage. At the beginning of April CV appeared and then CIV and CV became dominant during April.

4. Discussion

Calanoides acutus, *Calanus propinquus*, *Metridia gerlachei*, *Oithona similis*, *Oncaea curvata*, *Microcalanus pigmaeus* can be considered as oceanic (TUCKER and BURTON, 1990; KURBJEWIT, 1993). *Paralabidocera antarctica* can be classified as an inshore resident (TUCKER and BURTON, 1990) as well as *Pseudocyclopina belgicae* (WAGHORN and KNOX, 1988). *Stephos longipes* can be considered as both inshore (TUCKER and BURTON, 1990) and typical oceanic species (KURBJEWIT, 1993). *Euphausia superba* is an ice-neritic species (BECKLEMISHEV, 1958) and *E. crystallorophias* is a typical neritic species (VORONINA, 1984).

E. superba does not or poorly breeds in high-latitude waters (MAKAROV and MENSHENINA, 1989) in the region of the present investigation. Early larvae of *E. crystallorophias* were always found in the shelf waters not far from the coast (MAKAROV and MENSHENINA, 1989).

Furcilia VI and postlarvae of *E. superba* and *E. crystallorophias* obviously hatched during the previous summer according to the spawning period (MENSHENINA, 1990) and developmental rate of larvae (IKEDA, 1984; MENSHENINA and SPIRIDONOV, 1991). Hence these specimens must have been hatched not far from the coast of Queen Maud Land from where the ice-floe drifted (A. PROVORKIN, personal communication) (both species breed off Queen Maud Land (MAKAROV and MENSHENINA, 1992)). As in the water column under the ice-floe, no euphausiid larvae were caught (E. KOLOSOVA, personal communication). It may be concluded

that the present data confirm that these two species do not breed there.

Overwintering stages of *E. superba* are furciliae V and VI (DALY and MACAULAY, 1988) or even furcilia IV (MENSHENINA, 1992). Further development of overwintered larvae was observed in 1989 in the eastern part of the Weddell Sea. In October the earliest stage was furcilia VI (MENSHENINA, 1992). Supposing a common developmental rate of larvae, one could expect to find only postlarvae of *E. superba* from the end of February to the middle of May. Nevertheless, even in the middle of May furcilia VI was almost as abundant as postlarvae. Hence the notable delay of spring, a start of development of overwintered stages or slowing of development of *E. superba* larvae took place.

E. crystallophias was represented by the same stages, but sparse information on later furciliae of this species (MAKAROV *et al.*, 1990) does not permit numerical estimates.

S. longipes, *M. pigmaeus*, *M. gerlachei* and *C. propinquus* are considered to be dominant copepod species in the Weddell Sea (KURBJEWIT, 1993), as well as *O. similis*, *C. citer* and *Oncaea curvata* (FRANSZ, 1988). Among them only *S. longipes* and *O. similis* were numerous at 0 m; *M. pigmaeus* and *C. citer* were characterized with low dense and *O. curvata* and *M. gerlachei* were almost absent at 0 m. At 5 m abundances of all these species except *S. longipes* were higher than at 0 m. Among these species only *S. longipes* inhabits sea ice during its life cycle (KURBJEWIT, 1993; SCHNACK-SCHIEL and MIZDALSKI, 1994; SCHNACK *et al.*, 1985).

Comparing periods of maximum abundance and changes of stage composition of *S. longipes* with the previous studies (KURBJEWIT, 1993; KURBJEWIT *et al.*, 1993; TUCKER and BURTON, 1990) some distinctive features may be found. Highest abundances of *S. longipes* near Davis station (the Prydz Bay) were observed from February to April. Increase of abundance started in January and was rapid (TUCKER and BURTON, 1990). Rapid increase of abundance at ISW was observed at the beginning of April. At the end of April there were no signs of any decrease of *S. longipes* abundance. A preliminary picture of the life cycle of *S. longipes* was drawn by KURBJEWIT *et al.* (1993) using data collected off the east coast of the Weddell Sea. They described the life cycle as "at the end of December or beginning of January, young copepodite stages leave the brine channels inside the ice floes to feed in the upper under-ice water layer". Rapid increase in number of copepodites of this species in January described by TUCKER and BURTON (1990) agreed with their scheme. At ISW-1 appearance of numerous early copepodite stages (CII-CIII), however, took place at the beginning of April. Then, early copepodite stages develop to CIV and CV by the end of March and then migrate to greater depth as observed by KURBJEWIT *et al.* (1993). At ISW-1 at the end of March *S. longipes* in the upper water column (5 m) was still absent, appearing from the beginning of April at CII and CIII. At 0 m up to the end of April CIII distinctly predominated. Hence, the phenological state of the *S. longipes* population at ISW-1 was earlier than that presented by KURBJEWIT *et al.* (1993) for March. Differences between data on seasonal changes in number of *S. longipes* in Prydz Bay, the scheme of *S. longipes* life cycle observed at ISW-1, showed that a delay of two to three months took place

in seasonal development of *S. longipes* at ISW-1 compared with other localities.

O. similis, *M. pigmaeus* and *C. citer* abundances and stage composition changed during the period. But all of them mainly inhabit the water column (SCHNACK *et al.*, 1985; SCHNACK-SCHIEL and MIZDALSKI, 1994). Hence the sampling method used was insufficient to estimate abundances and stage compositions of these species. So it is impossible to compare the seasonal dynamics of these species with those in other localities.

P. antarctica is a species whose life cycle is completed within ice (KURBJEWIT *et al.*, 1993). It is typically observed in inshore regions and is considered to be endemic to coastal species (FUKUCHI *et al.*, 1985). It was collected under a drifting ice-floe far from a coast, but its abundance appeared to be three orders of magnitude less than in inshore regions. In Lützow-Holm Bay *P. antarctica* occurred in the highest concentration between December and February and disappeared in March (TANIMURA *et al.*, 1984). In catches of ISW-1 its highest abundance was observed from the middle of May to the middle of April. Then *P. antarctica* disappeared from catches. Similar stage composition was observed in Lützow-Holm Bay in the middle of December (TANIMURA *et al.*, 1984) and at ISW-1 in late March and early April (CIV predominated). Thus it may be suggested that a delay in seasonal development of *P. antarctica* under the ice-floes in the western part of the Weddell Sea compared with the inshore region. Seasonal changes of *P. belgicae*, typical inshore species (WAGHORN and KNOX, 1988) from November to January were described in McMurdo Sound (WAGHORN and KNOX, 1988). It was most numerous there from late November to the middle of December. In late November CII predominated. In the middle of December CIV became dominant. At ISW-1 this species was most abundant from the end of March to the middle of April. Early copepodite stages (CI-CIII) were absent. Adults were less abundant than CIV and CV up to the middle of April. Then adults prevailed. If this species really has a short spawning period and overwintering stages were late copepodites or adults (WAGHORN and KNOX, 1988), the phase of seasonal development observed in March at ISW-1 may be compared with that observed in the middle of December in McMurdo Sound. Thus the possible delay in seasonal development of this species is about three months.

Temporal changes of abundance and stage composition of *E. superba*, *S. longipes*, *P. antarctica* and *P. belgicae* were compared with those in other regions. For all the species seasonal development was delayed from two to three months. It seems that the reasons for the delay for *E. superba* may differ from that for three copepod species. Seasonal changes of *S. longipes*, *P. antarctica* and *P. belgicae* were studied earlier in the inshore regions (TANIMURA *et al.*, 1984; WAGHORN and KNOX, 1988; TUCKER and BURTON, 1990; KURBJEWIT *et al.*, 1993). In the inshore region the so-called "oasis effect" was found. In regions near a coast seasonal development of plankton community is more rapid compared with the oceanic region to the north (MAKAROV *et al.*, 1982; VLADIMIRSKAYA *et al.*, 1985; VLADIMIRSKAYA *et al.*, 1988). The ice-floe with the ISW-1 drifted during field deployment in the oceanic region. The delays in seasonal development of three

copepod species may mark slow rate of seasonal development of the whole zooplankton community in the ocean region compared with inshore regions as supposed in the "oasis effect" conception. An earlier "oasis effect" was shown for epipelagic species (MAKAROV *et al.*, 1982; VLADMIRSKAYA *et al.*, 1988). It obviously influences species closely associated with sea ice.

The beginning of development of overwintered *E. superba* larvae was studied in lower latitude regions (the northern part of the Weddell Sea) or in the eastern part of the Weddell Sea (DALY and MACAULEY, 1988; MENSHENINA, 1992) where modified waters of the Antarctic Circumpolar Current may intrude (BAGRYANTZEV and GURETZKY, 1986). In these warmer regions biological spring must begin earlier. So the delay in the development of overwintered stages of *E. superba* may mark a difficult to achieve general seasonal developmental rate in the cold waters in the western part of the Weddell Sea.

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