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THREE NEW ZOOPLANKTON NETS DESIGNED FOR UNDER-ICE SAMPLING; WITH PRELIMINARY RESULTS OF COLLECTIONS MADE FROM ELLIS FJORD, ANTARCTICA DURING 1985

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Abstract: Three new zooplankton nets have been designed to enable improved collection of zooplankters from ice-covered waters. These nets also enable quantitative sampling of species not adequately sampled by other methods. The first net is a vertical tow net which can be folded like an umbrella to pass through a small ice hole (10 cm). This 'Umbrella Net' takes an integrated sample of zooplankton from all sample depths. The second net is a collapsible free-fall net designed to collect mobile zooplankters capable of avoiding towed nets. This was the only net used which was capable of collecting all furcilia stages of *Euphausia crystallorophias* from Ellis Fjord, Vestfold Hills, Antarctica. The third net is a diver-operated push net designed to collect zooplankters in the top 15 cm of the under-ice water column. Because of the high standing crop of phytoplankton at and near the under-ice surface at particular times of the year, some species of zooplankton tend to congregate there. These species, particularly *Paralabidocera antarctica*, were collected in great abundance using the push net, but were rare in samples collected by other methods.

1. Introduction

Quantitative sampling of zooplankton species from ice covered waters presents a number of difficulties not usually encountered in zooplankton studies. An ice cover virtually precludes horizontal net tows and necessitates the cutting of an ice hole in order to gain access to the water. It is time consuming to cut a large hole through thick ice, so that a net which can be deployed through a small hole is of great advantage. Pumping systems have been successfully used for under-ice zooplankton studies (BAYLY, 1986), but these have severe depth limitations. A further difficulty encountered in under-ice zooplankton studies is that the under surface of the ice is extremely difficult to sample from above the ice. The three nets described in this paper were designed specifically to overcome these problems to enable a study of the geographic and seasonal variations in zooplankton populations within Ellis Fjord, Vestfold Hills, Antarctica.

Ellis Fjord is a ten kilometer long fjord located some five kilometers south of Australia's Davis Station (Fig. 1). This fjord usually maintains a year-round ice cover, with thicknesses ranging from 30 to 185 cm over the 15 month period of the present study (November 1984 to February 1986). During this period, zooplankton samples were collected each three weeks at each of seven sites along the length of Ellis Fjord using vertically towed nets. In addition to this, under-ice samples were

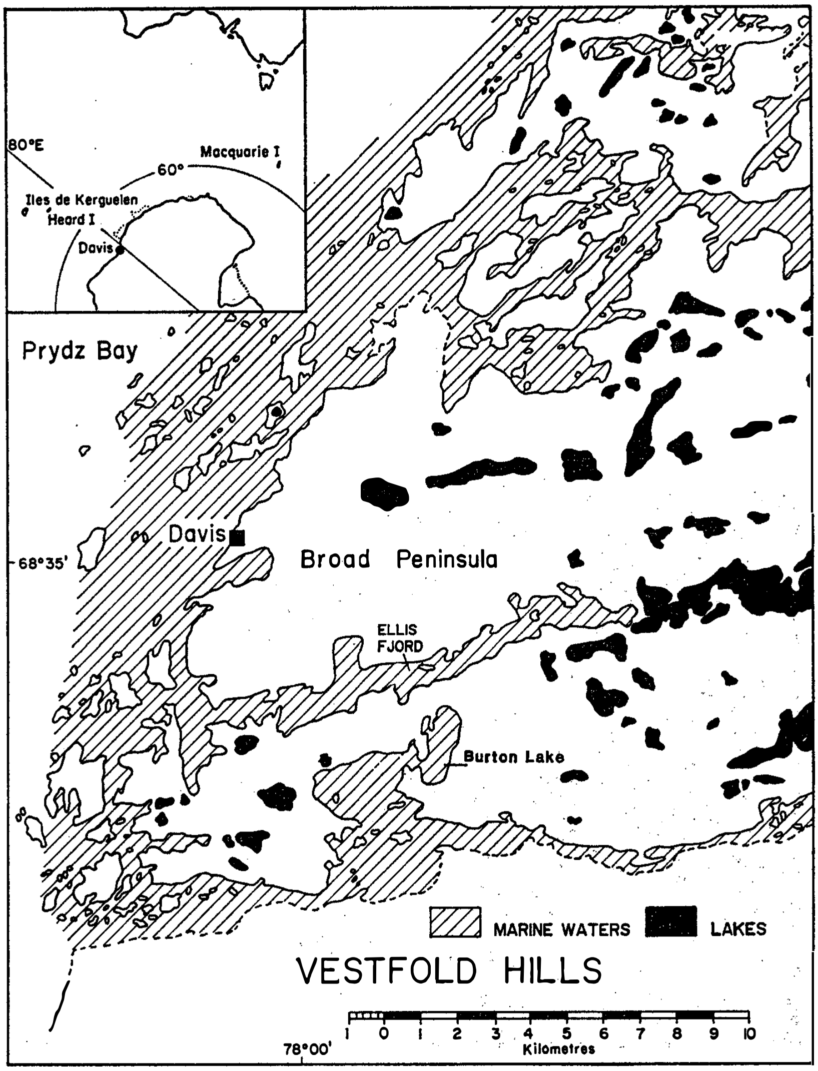

Fig. 1. Location map of Ellis Fjord in the Vestfold Hills, Antarctica.

also collected at irregular intervals using a diver operated push net. Further investigations into the zooplankton ecology of Ellis Fjord are planned for the 1987/88 Antarctic summer season.

This study of zooplankton ecology forms part of a multidisciplinary study of Ellis Fjord (coordinated by H. R. BURTON) which has included studies of water and sedimentary chemistry (P. P. DEPREZ, J. P. LIN), bathymetry and circulation (J. B. GALLAGHER), microbiology (C. BURKE, P. D. FRANZMANN), phycology (V. K. DHARGALKAR, J. L. JIANG, T. D. WALKER) and zoology (J. M. KIRKWOOD).

The present paper describes the three nets which have been employed in the Ellis Fjord zooplankton ecology study. The umbrella net has been used previously (TUCKER, 1983; BAYLY, 1986) and was only slightly modified for this study, but the other two nets are completely new designs.

2. Umbrella Net

Traditional vertically towed zooplankton nets have rigid mouths, so would require a large ice hole for deployment. Cutting suitably sized holes in the ice is time consuming and precludes the sampling of a large number of sites over a short time period. This net was designed so that it could be deployed through an ice hole of as small as 10 cm diameter (as cut by a SIPRE ice corer).

The frame of this net consists of a central metal tube to which four hinged arms are attached (Figs. 2 and 3). These hinged arms hold the net open when sampling (Fig. 2), and fold against the metal tube to hold the net closed when it is being passed through the ice or is being lowered through the water column (Fig. 3a).

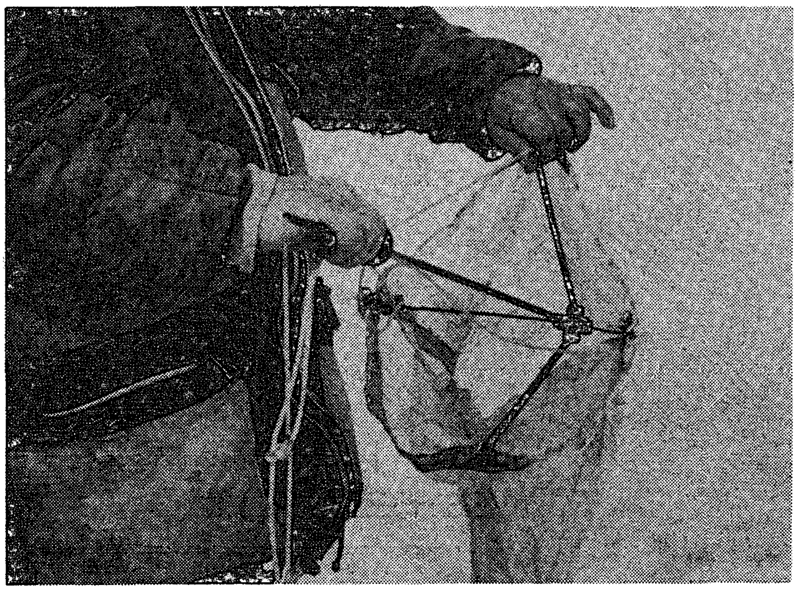

Fig. 2. Photograph of the umbrella net with the mouth open. Note the four hinged arms.

As the net is lowered to the sample depth a weighted brass cod end jar ensures that it remains in a vertical position and water pressure ensures that the net remains closed. Once the net has reached the maximum depth to be sampled (determined by a marked tow rope) lowering ceases and the net falls open (Fig. 3b). It is then hauled to the surface at a constant sampling speed either by hand or by using an electric winch. Hauling is ceased when the net reaches the under-ice surface and the net is then closed by pulling on a cord which folds the hinged arms against the central tube (Fig. 3a). The net is then retrieved through the ice hole and the sample is collected by unscrewing the cod end jar.

A 100 micron mesh net was used in this study, although other mesh sizes may be used. This net was basically conical in shape, with a square mouth of 784 cm^2 (28 × 28 cm) and was 200 cm long (Fig. 3c). It had a straight section (35 cm long) just below the mouth which caused a wave to pass down the net as it was towed through the water. This improved the filtration efficiency of the net by reducing clogging, and concentrated the sample towards the cod end. The ratio of mesh open area to mouth area was 7.00:1, which enabled the net to filter efficiently even in waters with high

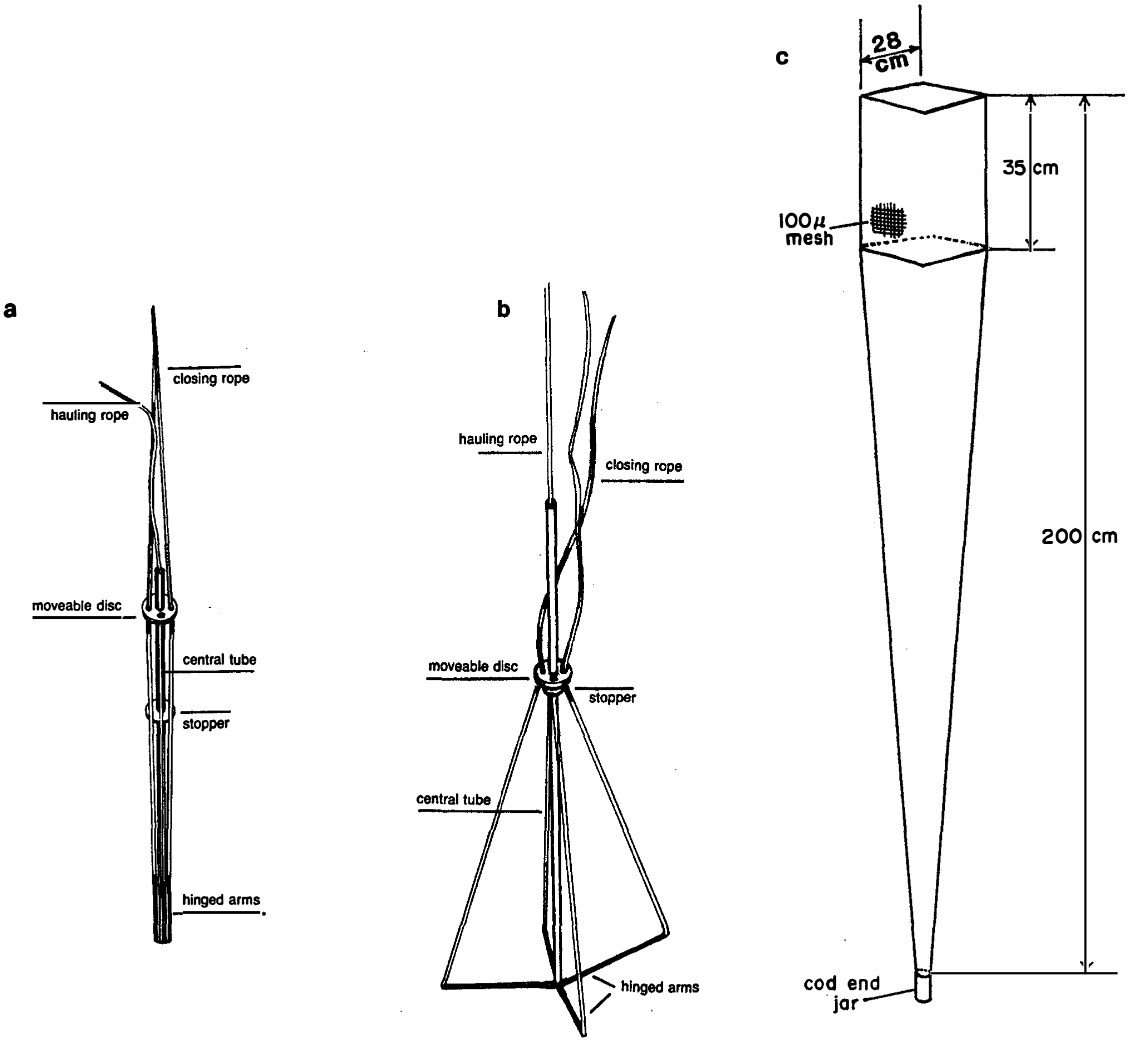

Fig. 3. Umbrella net: a. Frame in closed position for deployment or recovery.
b. Frame in open position for sampling.
c. 100 micron mesh net which is attached to frame.

phytoplankton concentrations.

Similar umbrella nets, with 200 micron mesh, have been used succesfully by TUCKER (1983) for collecting zooplankton from inshore marine sites off Davis Station and BAYLY (1986) for collecting zooplankton from nearby Burton Lake. These nets were only 100 cm long. 100 micron mesh was selected for the Ellis Fjord study to enable collection of cyclopoid copepodite and nauplii stages. The use of this finer mesh, combined with the fact that the phytoplankton concentration in Ellis Fjord reached levels far greater than at other inshore marine sites off the Vestfold Hills (T. D. WALKER, pers. commun.), meant that the filtration efficiency of the net had to be improved for this study. This was done by increasing its length and inserting the straight section, as described above.

Samples collected by this net throughout 1985 are not yet completely enumerated, but the species identified are listed in Table 1.

The advantages of this net are that it is able to be deployed through holes of as

Table 1. Zooplankton species collected from Ellis Fjord by each net. The fact that more taxa were collected with the Umbrella net than the other two is at least partially due to the fact that it was used more extensively.

Taxa	Species/Stage	Umbrella	Net Free-fall	Push-net
Protozoa	Foraminifera sp. 1	+	−	−
	Radiolaria sp. 1	+	−	−
	Ciliophora sp. 1	+	−	−
Cnidara: Hydrozoa	*Rathkea lizzioides*	+	+	−
	Hydromedusa sp. 2	+	+	−
	Hydromedusa sp. 3	+	+	−
	Siphonophora sp. 1	+	−	−
Ctenophora	Ctenophora sp. 1	+	+	+
	Ctenophora cydippid larvae	+	−	+
Nematoda	Nematoda spp.	+	−	+
Mollusca	Mollusca trochophore larvae	+	−	−
Annelida: Polychaeta	Polychaeta sp. 1	+	+	−
	Polychaeta sp. 2	+	+	−
	Polychaeta trochophore larvae	+	−	−
Copepoda: Cyclopoida	Cyclopoid nauplii	+	−	+
	Oncaea curvata	+	−	+
	Oithona similis	+	−	+
	Oithona frigida	+	−	−
	Oithona sp.	+	−	−
Copepoda: Calanoida	Calanoid nauplii	+	−	+
	Calanoides acutus	+	−	+
	Paralabidocera antarctica	+	−	+
	Euchaeta sp.	+	+	−
	Drepanopus bispinosus	+	−	−
	Calanoida sp. 1	+	−	−
	Calanoida sp. 2	+	−	−
Copepoda: Harpacticoida	Harpacticoid nauplii	+	−	+
	Harpacticus furcatus	+	−	+
	Harpacticoida spp.	+	−	+
Tanaidacea	Tanaidacea sp. 1	+	−	−
Cladocera	*Daphniopsis studeri*	+	−	−
Ostracoda	Ostracoda sp. 1	+	−	−
	Ostracoda sp. 2	+	−	−
Isopoda	Isopoda larvae	+	−	−
Amphipoda	*Paramoera walkeri*	+	+	+
	Eusirus sp.	+	−	−
	Lysianassidae sp. 1	+	−	−
	Lysianassidae sp. 2	+	−	−
Euphausiacea	*Euphausia crystallorophias*			
	Calyptopes	+	−	−
	Furcilia I-III	+	+	−
	Furcilia IV-VI	−	+	−
Decapoda	*Chorismus antarcticus* larvae	+	−	−
	Notocrangon antarcticus larvae	+	−	−
Echinodermata	larvae	+	−	−
Chordata	Ascidiacea sp. 1 eggs	+	−	−
	Ascidiacea sp. 1 larvae	+	−	−
	Oikopleuridae	+	−	−
	Pleuragramma antarcticum larvae	−	+	−

+: Collected by this net. −: Not collected by this net.

small as 10 cm diameter, it is easy to use and it provides good quantitative samples of all less mobile zooplankton in the 100 micron to 10 mm size range. The disadvantages of this net are that it cannot sample discrete depth horizons, and larger more mobile zooplankters appeared to be capable of avoiding the net.

MACAULAY and DALY (1987) have described a collapsible net (the "English umbrella net") of similar configuration to the Umbrella net described above. This English umbrella net was deployed in a similar manner to the new Umbrella net, but with the frame in the open position during deployment. The results of MACAULAY and DALY (1987) indicate that contamination of their samples by zooplankters being swirled into the open mouth of the net during deployment was either very slight or non-existent. The English umbrella net can be closed at any depth by means of a messenger activated release, thus enabling it to sample discrete depth horizons.

3. Collapsible Free-Fall Net

Early larval stages of *Euphausia crystallorophias* were present in umbrella net samples collected from Ellis Fjord (Table 1) but later furcilia stages were not present in those samples. It was suspected that these later stages were present in the water column but were avoiding the umbrella net. A different method of sampling was therefore required to collect these more mobile larval stages of *E. crystallorophias* as well as other mobile species which were able to avoid the umbrella net.

Vertical free-fall nets have the advantage that they have no tow rope or other mouth obstructions. Mouth obstructions cause vibrations or pressure waves which may disturb active zooplankters and cause them to move and so avoid the net (CLUTTER and ANRAKU, 1968). The free-fall net described here was specifically designed to overcome the problem of avoidance of the towed umbrella net by the larger and more mobile zooplankton.

Free-fall nets for fish sampling have been designed by HELLIER (1958), KAHL (1963), MOSELY and COPELAND (1969), KUSHLAN (1974), KJELSON *et al.* (1975) and HOAGMAN (1977) and for zooplankton sampling by HERON (1982). Apart from the net designed by HOAGMAN (1977) these nets all had large rigid mouths and so would require large diameter ice-holes for deployment. Although Hoagman's net had a flexible mouth opening, it still required to be deployed in the open position, so would be unsuitable for deployment through ice. In order to sample more mobile zooplankters a new free-fall net was designed which was able to be deployed through a small ice hole.

The new free-fall net has a flexible mouth opening which can be folded closed to enable the net to pass through a 25 cm diameter hole in the ice cut by a "Jiffy" drill. During sampling, the net is pulled down through the water column by six lead weights (each weighing one kilogram) evenly spaced around the net mouth. These weights also act as planes to hold the net mouth open during its descent (Fig. 4).

As with the umbrella net, maximum sample depth is determined using a marked rope. When the maximum sample depth is reached, this marked rope tightens and closes the net mouth in a strangling action. The net is then retrieved either by hand or electric winch.

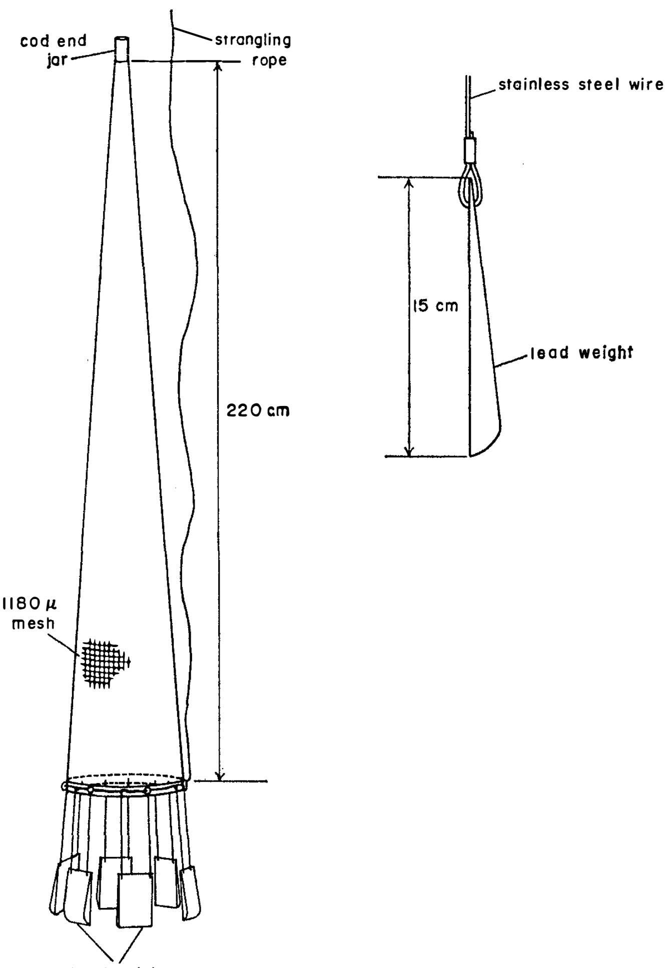

Fig. 4. Free-fall net, with detail of one of the weights.

The net used in 1985 was constructed of 1180 micron mesh and had a round mouth of 34 cm diameter, giving it a mouth area of 828 cm^2 (Fig. 4). Because of the large mesh size, clogging of the net by phytoplankton was not a problem. The length of the net was 220 cm giving it a ratio of mesh open area to mouth area of 8.67: 1. This high ratio reduced the pressure wave which preceded the net and resulted in a relatively high sampling speed of 1.2 m/s.

The free-fall net proved successful in collecting all furcilia stages of *E. crystallorophias* from Ellis Fjord. The only other specimens collected by the free-fall net but not the umbrella net were larval *Pleuragramma antarcticum* of up to 28 mm standard length.

The advantages of this net are that it is able to collect quantitative samples of larger more mobile zooplankton species, it is easy to use and it is not subject to clogging by phytoplankton. Its disadvantages are that it is not able to sample discrete depth horizons and it does not adequately sample the top few meters of the water column, as the net must commence falling through the water column before it will open. Sampling efficiency is determined by the ratio of the net open area to mouth area, the net shape, the shape and size of the lead weights, and the mesh size. Thus, in order to sample plankton smaller than 1180 microns all these parameters would have to be modified.

4. Diver Operated Push Net

Even though phytoplankton concentrations were extremely low in the Ellis Fjord water column over winter (T. D. WALKER, pers. commun.), an under-ice algal community was still present (pers. obs.). This under-ice algal community was a concentrated source of potential food for primary consumers so may be expected to attract several species of zooplankton. Previous studies have indicated that the under-ice community may be highly productive in comparison to the water column community (*e.g.* BUNT, 1963; HORNER, 1976; BRADFORD, 1978; CAREY and MONTAGNA, 1982; TUCKER, 1983), yet few quantitative comparisons have been made between the two.

The closing mechanisms of other nets used in this study meant that the water column just beneath the ice was not adequately sampled. Furthermore, the under-ice surface close to access holes was likely to be disturbed by hole cutting. It was therefore decided to construct a diver operated net which could quantitatively sample the fauna associated with the under-ice surface, and enable samples to be collected from undisturbed areas.

This net had a rectangular mouth measuring 50 cm wide by 15 cm deep, was 100 cm long and was made of 100 micron mesh. The ratio of net open area to mouth area was 2.83: 1. The net was attached to a brass frame and controlled by a handle held in front of the diver (Fig. 5). This enabled the net to be slid along the under surface of the ice ahead of any disturbance caused by the diver (Fig. 6). The cod end jar was a lightweight polycarbonate jar which could be unscrewed to collect the sample. FUKUCHI (1983) proposed a diver operated net of similar design for under-ice zooplankton collections. Fukuchi's design consisted of five nets on a single frame, arranged one above the other so that each sampled a 5 cm depth stratum from the under-ice surface to a depth of 25 cm.

The procedure used for operation of the diver operated push net was as follows. Firstly, a dive hole was cut in the ice using chainsaws. Two divers entered the water, the first holding one end of a marked cord and the second holding the net in a closed

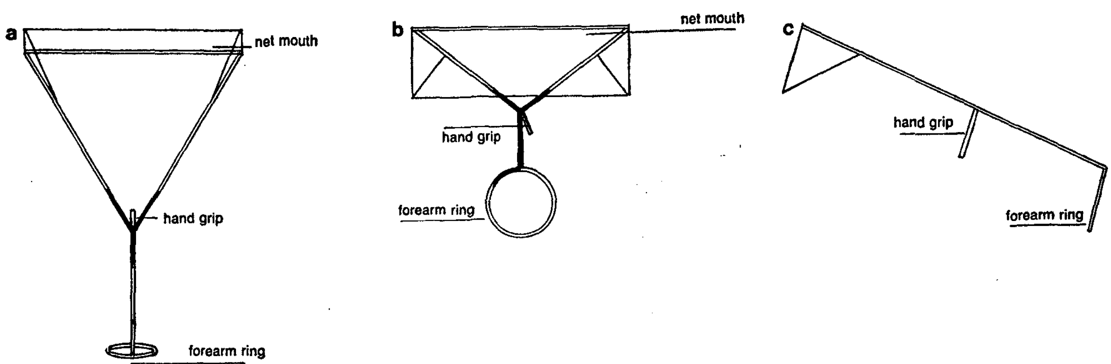

Fig. 5. Frame of diver operated under-ice push net: a. Top view. b. Rear view. c. Side view.

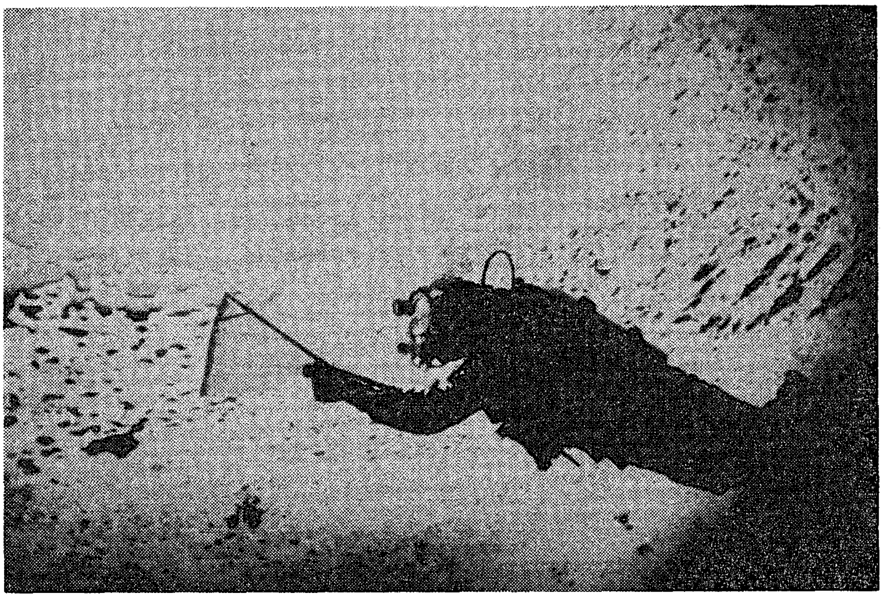

Fig. 6. Diver operating the under-ice push net.

position. The first diver swam away from the dive hole in a predetermined compass direction until he reached the end of the cord. He then ascended to the under-ice surface and held the cord tautly against the ice. The second diver then swam to a zero mark on the cord (at least two meters from the dive hole), opened the net and placed the upper edge of its mouth against the under-ice surface. He then swam parallel to the marked cord, holding the net in front of him and sliding it along the under side of the ice (Fig. 6). The usual sampling distance employed was ten meters.

After collecting a sample, the diver closed the net and returned with it to the dive hole, while the first diver repositioned the cord at 90° to its previous direction, taking care not to drag it along the under-ice surface. At the dive hole, the diver handed the net to an attendant who unscrewed the cod end jar, preserved the sample and carefully washed the net down before returning it to the diver in a closed position. In this way, four replicate samples were collected, one in each compass direction from the dive hole.

Collections made using this net did indeed show that the under-ice planktonic (or epontic) community differed from that seen in the general water column. Collections taken from June to September 1985 were similar in overall zooplankton population density to those collected by the umbrella net over the same period. However, while water column samples were dominated by the cyclopoid copepods *Oncaea curvata* and *Oithona similis*, under-ice samples were dominated by copepod eggs and nauplii of the calanoid copepods *Calanoides acutus* and *Paralabidocera antarctica*. In early October, an extremely dense one to three centimeter thick "carpet" of diatoms formed at the under-ice surface. At that time of year, phytoplankton concentrations in the water column were still very low (T. D. WALKER, pers. commun.). Under-ice zooplankton samples collected in October were dominated by *P. antarctica* nauplii. One month later (early November) this carpet of diatoms had disappeared and under-ice zooplankton samples were dominated by adult *P. antarctica*, with populations exceeding 10^4 individuals per cubic meter. *P. antarctica* was not collected in umbrella net samples over this period. TANIMURA *et al.* (1984) reported a large swarm of *P. antarctica* in a narrow layer against the ice and HOSHIAI and TANIMURA (1986) have recorded high densities of this copepod associated with the under-ice surface throughout the year, with adults appearing in early summer.

The advantages of the diver-operated push net are that it provides quantitative samples of zooplankton from a previously inaccesible habitat, it is easy to use, the depth of sampling is precisely determined and constant, the distance of sample collection can be accurately set, if clogging of the net occurs, it can be observed as it happens and the distance sampled adjusted accordingly, if net avoidance (*e.g.* by larval *Pleuragramma antarcticum*) occurs, it can be observed and recorded, there is very little disturbance in front of the net and there are no mouth obstructions. Its disadvantages are that it requires diving, so its operation is time consuming, and the net can be clogged by the dense community of diatoms which sometimes exists at the under-ice surface.

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