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Tintinnid cytoplasmic volume and biomass

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In recent years, increasing attention has been given to the role of microzooplankton in the transfer of matter and energy in antarctic food webs; studies on this subject are presently underway at selected locales of the Antarctic (Putt and Stoecker 1989). In this respect, tintinnids (planktonic ciliates provided with a chitinous shell) represent a very significant component, both in terms of numbers and in terms of biomass (Boltovskoy, Alder, and Spinelli 1989; Garrison and Gowing in press). Assessment of the trophic impact of microzooplankters requires information on the biomass (expressed as, for example, organic carbon) of the consumers. For the tintinnids, these estimates have traditionally been based on measurements of the organisms' shells and subsequent calculation of their respective volumes; protoplasmic volumes, in turn, have usually been estimated as 40–60 percent of the volume of the shell and a conversion factor of 0.11 is used to transform plasma volume (in cubic micrometers) into picograms of organic carbon (Edler 1979). This technique, however, has been criticized because plasma volumes show significant changes after fixation (Brownlee 1982), and especially because 40–60 percent cell-occupancy overestimates actual plasma volumes considerably (Gilron and Lynn 1989). To check the above assumptions, observations, measurements, and photographs were made of live specimens of 7 tintinnid species collected around Palmer Station (64°47'S 64°06'W) during March-April 1990. These taxa represent approximately 70 percent of the total recorded for the southern ocean. The table shows that, in effect, actual cell-occupancy is very significantly lower than previously assumed, varying between 12 and 54 percent, with an average of 27 percent. In consequence, protoplasmic biomass values are actually less than half of those derived on the basis of the traditionally used method. These estimates are useful when detailed biomass data are needed furnishing precise information on actual cytoplasmic biomass, yet total tintinnid carbon is partitioned between that contained in the cell and lorical (i.e., shell) carbon. Verity and Langdon (1984) carried out chemical analyses of whole tintinnid specimens finding a highly significant correlation between lorica volume and organic carbon contents. Applying their equation to our data yields the figures shown in the table (column F), which indicate that the 40–60 percent cell-occupancy figure is an adequate indicator of total tintinnid carbon (rather than cytoplasmic carbon only; the 60 percent value overestimates total carbon by just 20 percent).

In connection with the above studies, tintinnids were cultured experimentally in the lab under different conditions of feeding (37, 65, 45, and 80 micrograms of chlorophyll *a* per liter), temperature (−2, 0, and 2 °C), and illumination (300, 75, 1 microeinsteins per square centimeter per second, and total darkness). Light proved to be of great importance for the survival of the ciliates: highest light intensities were unfit for tintinnid growth, while the lowest ones and total darkness yielded high survival rates). Interestingly, these results are in agreement with previous findings (Boltovskoy et al. 1989; Alder and Boltovskoy in press),

Estimates of tintinnid volume and biomass

Tintinnid species	A	B	C	D	E	F	G
Cymatocylis vanhoeffeni	2,924,582	31.00	99,728	193,022	51.7	155,447	64:36
Cymatocylis flava	1,105,392	17.76	21,595	72,956	29.6	59,030	37:63
Cymatocylis drygalskii	1,033,278	31.20	35,462	68,196	52.0	55,208	64:36
Cymatocylis affinis/convallaria	599,806	23.57	15,551	39,587	39.3	32,234	48:52
Cymatocylis antarctica	171,050	11.76	2,213	11,289	19.6	9,510	23:77
Laackmanniella naviculaefera	147,024	33.48	5,415	9,704	55.8	8,237	66:34
Codonellopsis balechi	69,394	12.70	969	4,580	21.2	4,122	24:76
Average	864,361	23	25,848	57,048	38	46,256	47:53

Column heads are: A. Lorica volume (in cubic micrometers); B. Cell-occupancy (in percentage); C. Plasma biomass estimate based on column B (in picograms of carbon); D. Plasma biomass estimate assuming 60 percent cell occupancy (in picograms of carbon); E. Percentage difference, column C vs. column D; F. Total biomass estimate based on Verity and Lagdon (1984) (in picograms of carbon); G. Percentage relationship of plasma carbon vs. lorica carbon.

where maximum tintinnid abundances were recorded in ice-covered areas (Weddell Sea, Bransfield Strait, Bellingshausen Sea), or at approximately 60 meters below the surface (Weddell-Scotia confluence: Alder unpublished data).

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Studies on the nutrient status in sea ice and underlying platelet layer of McMurdo Sound

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Past studies of the sea-ice microbial communities (SIMCO) in the land-fast ice of McMurdo Sound, Antarctica, have concentrated on the role of light in microalgal growth in the congelation and underlying platelet ice (Bunt and Lee 1970; Palmisano et al. 1987; SooHoo et al. 1987). Due to sampling difficulties, comparatively little attention has been paid to the nutrient regime in this habitat.

In antarctic waters, concentrations of major nutrients are high compared to other oceanic regions and are, thus, generally considered to be nonlimiting for algal growth. Recent studies on sea ice, however, have indicated that the nutrient concentrations in sea ice can differ considerably from the underlying water column. One reason for this may be restricted exchange between sea ice and seawater, concomitant with enhanced biological activity.

The bottom 20 centimeters of congelation ice and the platelet layer which underlies a large portion of the fast ice of McMurdo Sound in spring and summer has been observed to harbor a SIMCO of exceptionally high biomass (Palmisano and Sullivan 1983). To improve our understanding of the development and growth of this unique microbial community, we studied the nutrient environment of the platelet ice and the upper water column.

Our main sampling site (ice falls) was located in McMurdo Sound approximately 3 kilometers north of McMurdo Station (77°49.48′S 166°41.45′E). The ice cover consisted of 2-year-old congelation ice approximately 2.5 meters thick underlaid by roughly 65 centimeters of platelet ice. Snow cover in the region ranged from 0 to 10 centimeters, although we concentrated our sampling efforts in clear ice areas. Sampling took place at 1- to 5-day intervals starting 26 September 1989 and ending 3 December 1989. All sampling holes were located within our 200-square-meter study site. We had a second sampling site approximately 5 kilometers west of ice falls located near the ice runway and a third 10 kilometers north of ice falls located west of the cinder cones between McMurdo Station and Turtle Rock. The ice runway site was characterized by 3.5 to 4 meters of multiyear congelation ice over 70 centimeters of platelet ice all covered by 40 centimeters of snow. This site was used to determine nutrient concentrations in areas of low biological activity. The cinder cones site contained 1.9 to 2.0 meters of first-year ice overlying 50 to 65 centimeters of platelet ice and covered by 0 to 50 centimeters of snow. The latter two sites will not be discussed here.

Nutrients in congelation ice were studied in melted core sections obtained by standard ice coring procedures; however, these results will not be discussed here. A new sampling device, ADONIS (Arrigo/Dieckmann Nutrient Ice Sampler, figure 1), was developed to profile at high resolution the entire platelet layer and underlying water column down to a depth of approximately 1 meter. ADONIS consists of a 4-meter length of 5.7-centimeter diameter PVC pipe through which six lengths of 0.6-centimeter diameter polyethylene tubing are fed. The tubing remain inside the pipe until the unit is inserted into a 7.5-centimeter diameter hole drilled into the ice with an ice auger. At this time, the tubing is forced out from the pipe to a distance of 25 centimeters through a series of guide holes placed at 12-centimeter intervals at the base of the pipe. The tubing is guided by additional small PVC inserts with a 90° bend glued into the interior of the pipe so that the tubing exits

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