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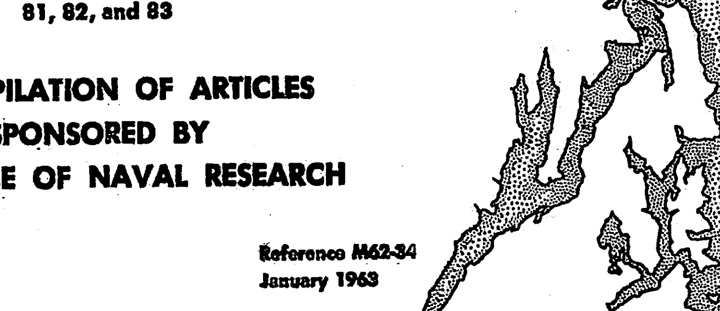

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Technical Report No. 82

NET ZOOPLANKTON AND TOTAL ZOOPLANKTON, by Karl Banse. Rapp. et Proc.-Verb., 153(36):211-215.

Technical Report No. 83

A SIMPLE SEMIAUTOMATIC REAGENT DISPENSER, by Ralph W. Riley and Francis A. Richards.

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EXTRAIT

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No. 36.
Net Zooplankton and Total Zooplankton[1])

By

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Introduction

All plankton nets tend to miss part of the plankton present. The purpose of this paper is to compare the weight of zooplankton collected by nets with the amount of zooplankton estimated chemically from small water samples. Sometimes the total biomass surpasses the No. 2 or No. 3 plankton by 15 to 30 times. The data have been taken from the literature, and apply to four areas.

Ocean Weather Station "P" (Gulf of Alaska)

Zooplankton was collected in this region by McAllister (1961), from August 1956 to January 1958, using a No. 3 vertical net (about 0·33 mm mesh aperture). Fishes and other big animals were removed before determining the wet weight of the catches. McAllister's observations would lead one to expect 10–200 mg/m³ wet weight of zooplankton in the upper 50 m of these waters during July and August. For the following discussion, 100 mg/m³, which is near the mean 24-hour surface concentration reported by McAllister, will be used. This figure is consistent with the NORPAC observations made in this area in August 1955 (Reid, 1960).

Zooplankton wet weights will be converted to dry weights from which ash weights will be subtracted to estimate the weight of dry organic matter, which can, in turn, be converted to carbon or nitrogen content. Because McAllister's method of determining the wet weight is similar to that used by Krey (1958; see also Tranter, 1960, for the conversion factor) the dry weight will be assumed to be 13 $^0/_0$ of the wet weight. The ash content of copepods will be taken as 8·5 $^0/_0$ of the dry weight (Krey, 1958). The average (Kjeldahl) nitrogen in zooplankton is approximately 10 $^0/_0$ of the dry organic matter (see Krey, 1958). Thus, the nitrogen bound to net plankton during July and August at station "P" is about 1·2 mg/m³.

Chemical analyses of particulate matter in the water are available from station "P" for July and August 1959 (McAllister *et al.*, 1959, 1960). The water was strained through a net of 0·15 mm mesh aperture in order to remove the larger metazoa, and then filtered through a Millipore filter of 0·5 μ pore diameter. It should be emphasized that the organic material was separated from the water by filtration, not by adsorption; therefore the following considerations deal with particulate matter only. The retained material was analysed for one or two amino acids in order to estimate the protein. The average protein content of the upper 50 m was found to be 130 mg/m³. The average chlorophyll content was 0·4 mg/m³; McAllister *et al.* (1960) estimated that the protein bound to plants was 14 mg/m³. The remaining approximately 115 mg of non-plant protein may be divided by 6·25 in order to estimate the nitrogen content; about 18 mg/m³ of nitrogen were bound to particulate non-plant matter. The nitrogen content of the net plankton was about 1·2 mg/m³, or 1/15 of the figure found from analysis of water samples.

The difference between total biomass and net plankton is so large that a discussion of the merits of the methods and conversion factors is not necessary. Even if the net plankton values in the upper 50 m during 1959 were 150 mg/m³ instead of 100 mg/m³, the corresponding nitrogen values would have been just 10 $^0/_0$ of the particulate nitrogen from water samples. It can be concluded that in terms of biomass, the net plankton at station "P" was unimportant during July and August 1959. A similar relation between net plankton and particulate matter can be obtained from carbon estimates from the same set of

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Table 1.
Non-plant matter at station "P" (g/m^2) during summer

Depth range	Particulate C	Particulate N	Net plankton C	Net plankton N
0– 50 m ...	6	0·9	0·30	0·06
0– 150 m ...	18	1·5	0·45	0·09
0–1000 m ...	100[1])	-	1·80	0·36

[1]) New data (Parsons, T. R., & Strickland, J. D. H., 1962. "Oceanic detritus". Science, *136*: 313–14) suggest that this figure may be 30 $^0/_0$ too high.

data. The average content in the particulate matter can be taken as 150 mg/m^3 of carbon, of which 24 mg represented plant carbon, according to the authors. As the carbon content of zooplankton is about half the weight of organic matter, the net plankton represented 6·0 mg/m^3 of carbon, about 1/20 of the particulate carbon; however, some of the particulate carbon was derived from cellulose fibres.

Values for the amount of nekton in the open Gulf of Alaska are available for July and August 1957 and 1958 (Aron, 1962). For the depth range of 20 to 60 m, the settling volumes averaged 25 ml for each minute of mid-water trawling at night. For nine of Aron's trawl samples which were made up mostly of crustaceans a mean quotient of 2·8 for settling over displacement volumes has been determined by the present author. If the specific weight of the animals is taken as 1·05, and otherwise the same conversion factors are used as above, and if it is assumed that only half of the opening area of the mid-water trawl was effective in catching (for a more detailed discussion, see Aron, *l. c.*), the nekton amounted to 2·1 mg/m^3 C, or 0·41 mg/m^3 N. The catch was much smaller during day-time. Between 20 and 30 m, 1/34 of the night-time catch was taken, and between 30 and 60 m, 1/6 of the night-time volume was collected. If the conversion factor for volume to dry weight of Bsharah (1957) is used, the nekton values should be divided by four.

The data for station "P" can also be expressed as weight under unit surface of the sea, for the depth intervals 0 to 50, 0 to 150, and 0 to 1000 m. Because only a few observations are available, the figures are approximate (Table 1). No observations of nitrogen were made below 300 m.

The ratio of carbon in non-plant particulate matter to that in net zooplankton increased with depth. It may be noted that the content of dissolved organic carbon down to 1000 m is of the order of 1 kg C/m^2 (Duursma, 1960).

Long Island Sound

In Long Island Sound, Riley (1959) found by monthly surface water sampling during 1956 and early 1957, 1·2 to 3·1 mg/l particulate organic matter, with an average near 2 mg/l. This represents about 1 g/m^3 C. The mean displacement volumes of zooplankton for the entire water column, at four stations in Long Island Sound, for 1952–1954 corresponded to about 13 mg/m^3 of carbon (Deevey, 1956; gauze No. 2, approximately 0·36 mm mesh aperture) when converted to organic matter by the factors given by Deevey (1952), and divided by two. In order to make the results comparable with the other data the figure may be increased, by perhaps 20 $^0/_0$, because the zooplankton was collected with Clarke-Bumpus samplers (Winsor and Clarke, 1940). The non-plant particulate matter will not be calculated, because with the high average chlorophyll *a* content of almost 7 mg/m^3 (Riley, 1959) a slight change in the ratio of chlorophyll to plant carbon would affect the results materially; however, it is certain that more than 0·5 g/m^3 of carbon was non-plant matter of which little more than 15 mg were retained by a coarse plankton net.

During 1954–55, Harris (1959) studied the vertical distribution of nitrogen at five stations in the Sound. The averages for each station taken from his drawings indicate ratios of zooplankton (No. 2 net ?) nitrogen to total non-plant nitrogen ranging between 1 : 7 and 1 : 13.

Fladen Ground (North Sea)

Net plankton was collected on Fladen Ground by vertical hauls from 140 m (sea bed) to the surface in July and September 1953, by Steele (1956; gauze No. 3, approximately 0·33 mm mesh aperture). After storage in ethyl alcohol, the average dry weight was 6·5 g/m^2. Using Krey's conversion factors (1958), the protein content (albumen equivalent) of the net plankton would be 2·2 g/m^2. Nanoplankton was collected from Fladen Ground in August 1953 (Hagmeier, 1960; "Gauss" station 40, 127 m depth). Six water samples were taken from the upper 50 m of which two were collected in or near the turbidity screen associated with the discontinuity layer. The samples were analysed for particulate matter, protein content (albumen equivalents), and nanoplankton; the cell counts were converted into plasma volumes (Lohmann, 1908). Hagmeier converted the volume estimate into dry weight by assuming a water content of the plasma of 75 $^0/_0$. By means of the analyses of Krey (1958), the protein content of the phytoplankton can be calculated and subtracted from the protein content of the sample which was chemically determined. Assuming a protein content of 10 $\mu g/l$ for the water below 50 m (based on neighbouring stations), the protein not bound to phytoplankton at station 40 was 2·7 g/m^2. Another station, 30 miles to the south, supports these data (station 37, 91 m depth). The values are approximately as high as the amount of plankton collected by the No. 3 net. It should be pointed out that the size ranges of plankton covered by the two approaches are not identical but overlap; small copepods retained by the net are also caught by the 4 litre Krümmel bottle used by Hagmeier (and Banse, see below). The total non-plant biomass can be assumed to have been somewhat less than the sum of the values obtained by the net and the water bottle.

Central Baltic Sea

In the low saline water of the Baltic Sea, 10 mg/m^3 albumen equivalents not bound to plants were found below the thermocline in August 1955 (Banse, 1957). One can expect about 170 mg/m^3 wet weight of net zooplankton in the 50 to 100 m layer during this season (Banse, 1957). More recently, a five-year average of 163 mg has been published by Nikolaev (1960). Applying the conversion factor given by Krey (1958), 170 mg wet weight correspond approximately to 8 mg/m^3 protein. Thus, the net catches almost reached the values for the non-plant protein found in the water samples.

Discussion

In the examples given, the organic content of zooplankton caught by nets has been compared with that of the particulate matter present in small water samples. It has been shown that nets of about 0·35 mm mesh aperture retain 1/30 to 1/1 of the non-plant biomass collected by water bottles. It can be concluded that in terms of biomass, the net plankton sometimes can be neglected; on the other hand, it is sometimes not adequate to use only water samples for estimating the total biomass present. Before discussing the kinds of losses which occur during net collections, it must be emphasized that the ratio between organic matter retained and organic matter lost is not only dependent on the mesh size of the net, but also on the kind of plankton present (Lohmann, 1908). Even in a single area there is no constant coefficient of loss, because the composition of plankton varies with the seasons.

The role of mesh size can be seen from several investigations. Deevey (1956) published displacement volumes for catches with No. 2 and No. 10 nets (0·37 and 0·16 mm mesh apertures respectively) from Long Island Sound. The mean volumes found during two years of observations were 0·29 ml/m^3 for the coarse net, and 0·95 ml/m^3 for the fine net. Because of the influence of plankton composition on the loss, the maxima and minima of the annual distribution of the volumes found by the two nets often did not coincide. Coarse nets not only miss much of the plankton, but they do not even give the trends of net plankton distribution reliably. The mean volumes for catches with a No. 2 and a No. 10 net from a one year investigation of Block Island Sound were 0·21 and 0·68 ml/m^3 respectively (Deevey, 1952).

Menzel and Ryther (1960) compared the catches of a No. 2 with a No. 8 net, and a No. 2 with a No. 20 net (0·37, 0·16, and 0·08 mm mesh apertures respectively) in the subtropical waters of the Sargasso Sea. In terms of displacement volumes, the catch ratio between the No. 8 and No. 2 net was 0·80; the ratio between the No. 20 and the No. 2 net was 1·06. In terms of dry organic matter, the ratios were 1·16 and 1·60 respectively.

From the investigations of Lohmann (1903, 1908), it can be seen that the loss by No. 3 nets, as compared with No. 20 nets, is mostly due to small metazoa; the biomass of protozoa slipping through the meshes of the net is small. In the more thorough investigation off Kiel (Lohmann, 1908), the average of 13 months of observations were 0·323 ml/m^3 animal plasma volume, of which 0·041 were unicellular animals, and 0·119 small metazoa (Rotatoria, all copepod eggs and nauplii, *Oithona similis* and lamellibranch larvae). The members of the latter fraction are mostly lost by a No. 2 or No. 3 net but are mostly retained by a No. 20 net. Lohmann (1903) reported 0·034 ml/m^3 volume of metazoa, and 0·001 ml/m^3 for protozoa for a vertical series from the Mediterranean. (In 1908, footnote on page 175, he indicated that the method used in the Mediterranean must have destroyed many protozoa; it is not possible to estimate the loss.) Almost 90 $^0/_0$ of the volume of the metazoa was retained by a No. 20 net. The dry weight of protozoa at the Fladen Ground stations (Hagmeier, 1960) was also small, of the order of 1 mg/m^3; if the dry weight of net plankton (Steele, 1956) is divided by the water depth, a mean weight of zooplankton of about 45 mg/m^3 is obtained.

With the evidence available, the protozoa cannot be supposed to constitute a considerable amount of the biomass of the zooplankton. The loss of zooplankton when using a No. 3 net is mostly due to smaller metazoa, and eventually to a great fraction of biomass which cannot be assessed at all by the routine methods so far employed in plankton counting.

The smaller metazoa are almost completely retained by a fine plankton net. In the averages given they made up 1/2 to several times the biomass of the larger zooplankton. It is apparent that the unit mass of small metazoa has a higher metabolic rate, and hence a higher grazing rate than the same mass of larger metazoa. It should be pointed out that Riley (1952) derived indirectly and with reservations, that, of the annual net production of phytoplankton in

Long Island Sound, 26 % were used by the zooplankton retained by a No. 10 net, 31 % by the benthic animals and bacteria, and 43 % by the small zooplankton and suspended bacteria. From the same set of data, Deevey (1956) had shown that the No. 10 net retained three times the amount of zooplankton collected by the No. 3 net. As in standing stock considerations, also in productivity studies the large zooplankton may be negligible. The amount of No. 3 net plankton should be used in grazing models only when it can be shown that it is locally important.

It is obvious that No. 20 or No. 25 nets can hardly be used for routine zooplankton research. If an investigation is aimed at the bulk of the metazoa, and if only one method of collection can be employed, the best estimate might be obtained from a big sample collected by a water bottle and strained through No. 25 gauze (see Steemann Nielsen, 1958). Whether a sample of 4 l or 100 l is necessary, will depend on the circumstances. In calm waters, a plankton pump is to be preferred because of its greater versatility. The point method of taking samples has the additional advantage that the vertical zooplankton distribution can be more safely related to the surrounding conditions than when nets are used. Several variables can be measured on the strained water.

It does not seem likely that the small metazoa will account for all losses in areas where the biomass found in water samples is 15 to 30 times that collected by a coarse plankton net. In annual averages, the biomass of the small developmental stages probably does not exceed that of the advanced stages and adults by a large factor. In the data of Lohmann (1908), the mean monthly plasma volumes were 0·139 ml/m^3 for adult copepods and copepodites, (of which adult *Oithona similis* accounted for 0·045 ml), and 0·056 ml/m^3 for nauplii and eggs. A definite statement about oceanic conditions cannot be made because so few data are available even for life histories of the smaller crustacea. With the evidence at hand, it must be concluded that a great part of the losses described must be due to small particles which are not measured by any of the routine counting methods used so far. They must be evaluated by chemical methods. It is not known whether the particulate protein reported represents bacteria or truly dead detritus.

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Discussion

Dr. Russell commented that nylon "silk" of 400 meshes/inch is now being made and will be useful for small nets or for filtering water samples. Dr. Yentsch said that the smaller the mesh used the more phytoplankton would be included in the sample; in the Long Island Sound data the phytoplankton was not removed in the displacement volume calculations, but the samples were not taken at a time of phytoplankton maximum. Dr. Fraser objected to the removal of "big" animals from the Gulf of Alaska net samples before calculation of the wet weight; he disagreed with Dr. Banse who thought that they would be unimportant and said that they form a substantial part of the zooplankton biomass, which is missed by small nets and water bottle samples.

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