TECHNICAL

THE SIZE DISTRIBUTION OF PARTICULATES AND PHYTOPLANKTON IN THE DAMARISCOTTA RIVER ESTUARY, LINCOLN COUNTY, MAINE

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ABSTRACT

From May to October of 1978 the size spectrum of particles from 2-100 μm diameter in the near-surface waters of the middle and upper estuarine regions of the Damariscotta River was investigated; plankton samples were subjected to Coulter Counter and microscope examinations. Generally, more than 50% of the total particle volume was incorporated in particles smaller than 20 μm diameter (range = 35-87%). Particles smaller than 10 μm constituted from 10-68% of total seston volume. Particles larger than 40 μm were comparatively uncommon (numerically) except in the upper estuary during a five-week period in July and August. During this period, large dinoflagellates (a Gonyaulax sp. and a Gymnodinium-like sp.) were abundant. Large detrital complexes and "flake-like" particulates contributed to the observed shift toward larger particles during this period.

Particle concentrations varied over the sampling period, but did not differ substantially between sites on any one sampling date. Total particle concentrations ranged from a high of 5.2×10^5 ml^{-1} in July to a low of 6.6×10^4 ml^{-1} in October. A substantial, but temporary, decrease in particle concentrations also occurred in early September.

Throughout the early summer, nanoplankton (≤20 μm) contributed generally more than 50% to the total amount of chlorophyll present in near-surface waters, and frequently constituted 90-100% of this value. The majority of these cells were 3-5 μm diameter. In the upper estuary, large microalgae (predominantly dinoflagellates) were important during middle and late summer. May and September phytoplankton blooms were dominated by large cells (microalgae) at all sampling locations.

Tidal variations in the above parameters were comparatively small during most of the study period. In the upper estuary, however, chlorophyll fluctuations were large during the period of high phytoplankton standing crop. These may have been due to the action of tidal fronts in the river. Temperature and salinity data for the near-surface waters of this estuary are presented.

INTRODUCTION

In conjunction with studies conducted on the growth and survival of experimentally-rafted mussels, Mytilus edulis, the size distribution of phytoplankton and particulates in the near-surface waters of the Damariscotta River were examined from May 10 to October 10, 1978. Salinity and water temperatures were also measured. These studies were conducted to examine relationships between potential food particles, environmental temperatures, and the survival and growth of rafted mussels; these relationships will be the subject of other publications. It is the purpose of this report to provide information on (1) the distribution of total volume of material in the seston with respect to particle sizes, (2) total particle concentrations in near-surface waters, (3) the relative contribution of different size fractions of phytoplankton to total summer phytoplankton standing crop, and (4) surface water temperatures and salinities observed during these studies in a north-temperate estuary.

This information is provided for use by other investigators working on this river; for future comparisons with similar studies on other Maine or New England estuaries; and for specific data on size relationships of phytoplankton and other components of the seston, an area of general ecological investigation worldwide.

STUDY AREA

The Damariscotta River occupies a narrow, drowned valley along the central coast of Maine, U.S.A. (60° 35' W. Long., 43° 50' N. Lat.). Most of its 29-km length may be characterized as a Type B (Pritchard, 1967) or partially mixed estuary, with relatively low freshwater input and a tidal range of approximately 3 meters. The morphometry, hydrology, sedimentology, and nutrient chemistry of this estuary have been reviewed by McAlice (1977). At present, industrial, domestic, and agricultural impacts are negligible and sedimentation rates are apparently low. The seven sites for which data are presented are located at approximate 1.5-km intervals 13-25 km from the open sea (Fig. 1).

MATERIALS AND METHODS

Water samples were collected at each site at one-week intervals from May 10 to October 10. A 4-liter whole-water sample was taken at each site from a depth of 0.5 m, and from this a 1-liter volume was filtered through a 200 μm synthetic net sieve and stored in an opaque plastic bottle held in an ambient-temperature water bath. Surface water temperature and salinity were recorded at the time of each collection, and the stage of tide was noted. Whenever possible, samples were collected between 8 and 10 a.m., and processing began within 3 hours after collection. Additional surface water temperature and salinity data were collected each week.

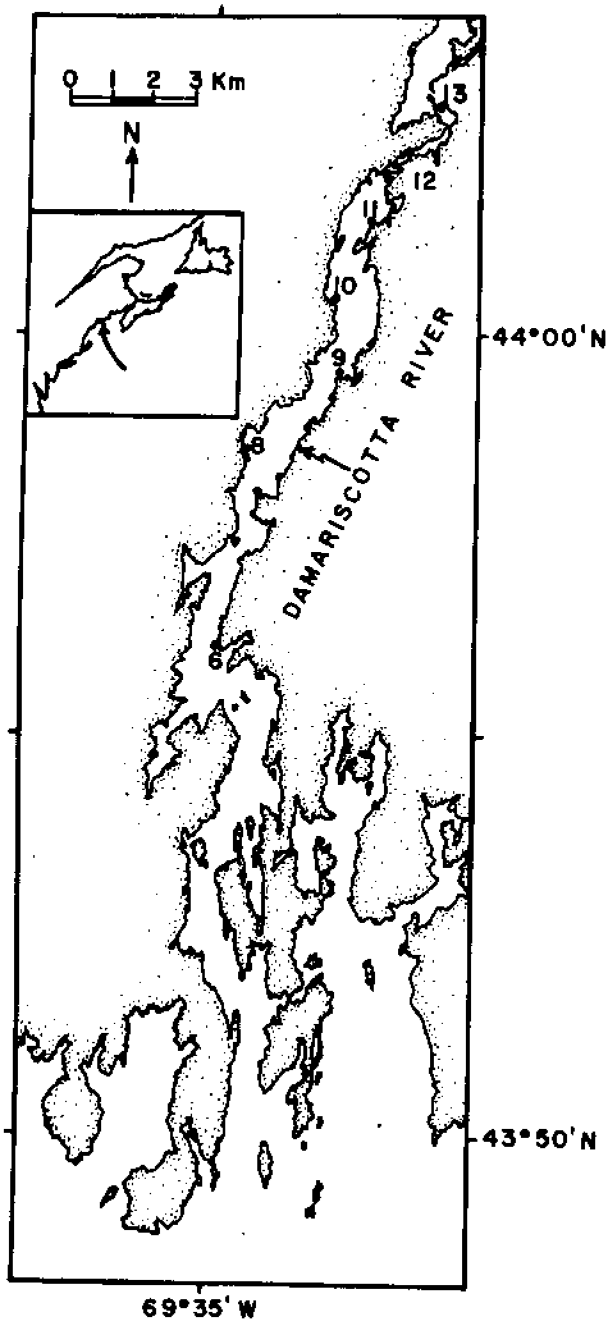

FIGURE 1. Damariscotta River, showing locations of sample sites 6-13. Inset shows location of this river in the Gulf of Maine, northwest Atlantic Ocean.

The size, abundance, and nature of available particles in the near-surface waters (depth = 0.5 m) at each site were examined in three ways. (1) Two chlorophyll measurements (Strickland and Parsons, 1968) were made from each sample. One measurement was made of total chlorophyll using a 10 ml subsample, and a second was made on particles which had passed through a 20 μm mesh, the latter being defined as nanoplankton in this study. No pressure or vacuum was applied when filtering water through the 20 μm mesh. (2) A qualitative and quantitative analysis of particle size distribution from 2-50 μm was made using a Model A Coulter electronic particle counter (Coulter Electronics, Inc.) fitted with a 100 μm aperture (Sheldon and Parsons, 1967). (3) Slides were prepared for microscopic examination of particles using a modification of the methods outlined by McNabb (1960) and Moore (1963). Steps two and three were completed within two days after collection.

Preparation of microscope slides differed from the procedures of McNabb (1960) and Moore (1963) as follows: fifteen milliliters of fixed sample (McNabb, 1960) were drawn into a 100-ml syringe with a 2 mm opening and discharged under hand pressure through a 15 mm diameter triacetate membrane filter housed in a Gelman filter holder. Twenty milliliters of 0.05% WAYFOS (Hunt Chemical Corporation, East Providence, Rhode Island) solution was then drawn into the syringe and similarly passed through the filter. The second solution was necessary in order to remove the salts which otherwise would have interfered with microscopic examination of the slide (Moore, 1963). The WAYFOS detergent was a helpful additive because it decreased water surface tension so that the filter did not contain pools of water when the filter holder was opened. Such pools tended to redistribute particulate material on the surface of the filter. However, this detergent may have added to the difficulty of getting the finished slide to cure properly.

Filters were examined by eye to determine relative uniformity of particle distribution. If the material on the filter appeared to be evenly distributed, the filter was transferred to a clean microscope slide and the procedure of McNabb (1960) followed for enumeration of particles. Approximately 200-300 particles (usually 3 or 4 microscope fields) from each slide were counted and placed in categories according to size (<10 μm, 10-20 μm, >20 μm) and nature (living cell, non-living cell, particulate). These results were used to assist in the interpretation ot results obtained by chlorophyll measurements and Coulter Counter. Results using this technique were compared initially to results obtained using 20 ml settling chambers and an inverted microscope (Ütermohl, 1958).

At first, more frequent monitoring of chlorophyll and particle size spectra was done to test the adequacy of the longer (one week) sampling interval. Tidally-induced variations in particle size spectra and concentration, chlorophyll concentration, and temperature and salinity were studied at each site.

RESULTS AND DISCUSSION

Temperature and Salinity

Surface-water temperature and salinity data are summarized in Tables I and II. The stage of tide at the time of each collection is listed in Table III. Mean temperatures were estimated from these data and were used in the construction of the temperature curves shown in Figure 2. Ranges of temperature due to tidal and climatic effects are shown by range bars (Fig. 2). Maximum observed surface water temperature at these sites was 25°C at site 13.

Salinity varied from 14‰ (May 10) to 32‰ (August 23) at the uppermost site (13), and from 28-32‰ at site 6 (mid-estuary) during this same period. Mean monthly salinities and variations due to tidal and climatic effects at these two sites are shown in Figure 3. Salinity measurements at the other sites in the estuarine gradient ranged sequentially between those reported for site 6 and those reported for site 13 (see Table II). Salinities increased gradually at all sites throughout the early summer and remained greater than or equal to 28‰ from mid-July through September. Temperature and salinity data obtained in this study show trends and values similar to those reported in an earlier study by Incze *et al.* (1978)

Chlorophyll

Data for total and nanoplankton (≤20 μm) chlorophyll *a* collected at the experimental mussel raft (XMR) sites from May to October 1978 are shown in Figure 2. Within the sampling period, three periods of peak chlorophyll values can be defined: (1) a peak in June observed at all XMR sites; (2) a late July-early August peak confined primarily to the upper estuarine sites and characterized by dense populations of Gonyaulax excavata (= tamarensis) and a Gymnodinium-like sp., with a great deal of apparent variability at each site; and (3) a late September bloom of Asterionella japonica, principally in the lower part of the experimental gradient. A fourth (lower) peak observed in May was not defined at all sites, but apparently extended along the full gradient.

In the May through September samples, nanoplankton contributed generally more than 50% to the total amount of chlorophyll present in near-surface waters, and frequently constituted 90-100% of this value. Microscopic examination indicated that the majority of these cells were 3-5 μm diameter and far outnumbered the larger ones. The dominance of these very small cells in the nanoplankton suggests that the size criterion for distinguishing nanoplankton from larger microplankton should be smaller than the 20 μm size criteria employed in this study and in most published studies to date.

Investigators in the past have used the term nanoplankton to refer to those algae which were not retained as "net plankton." Hence, these have assumed a wide variety of upper size limits: 65 μm (Yentsch and Ryther, 1959), 56 μm (Gilmartin, 1964), 22 μm (Malone, 1971a, b, c, 1977) and 20 μm (Dussart, 1965; Durbin *et al.*, 1975;

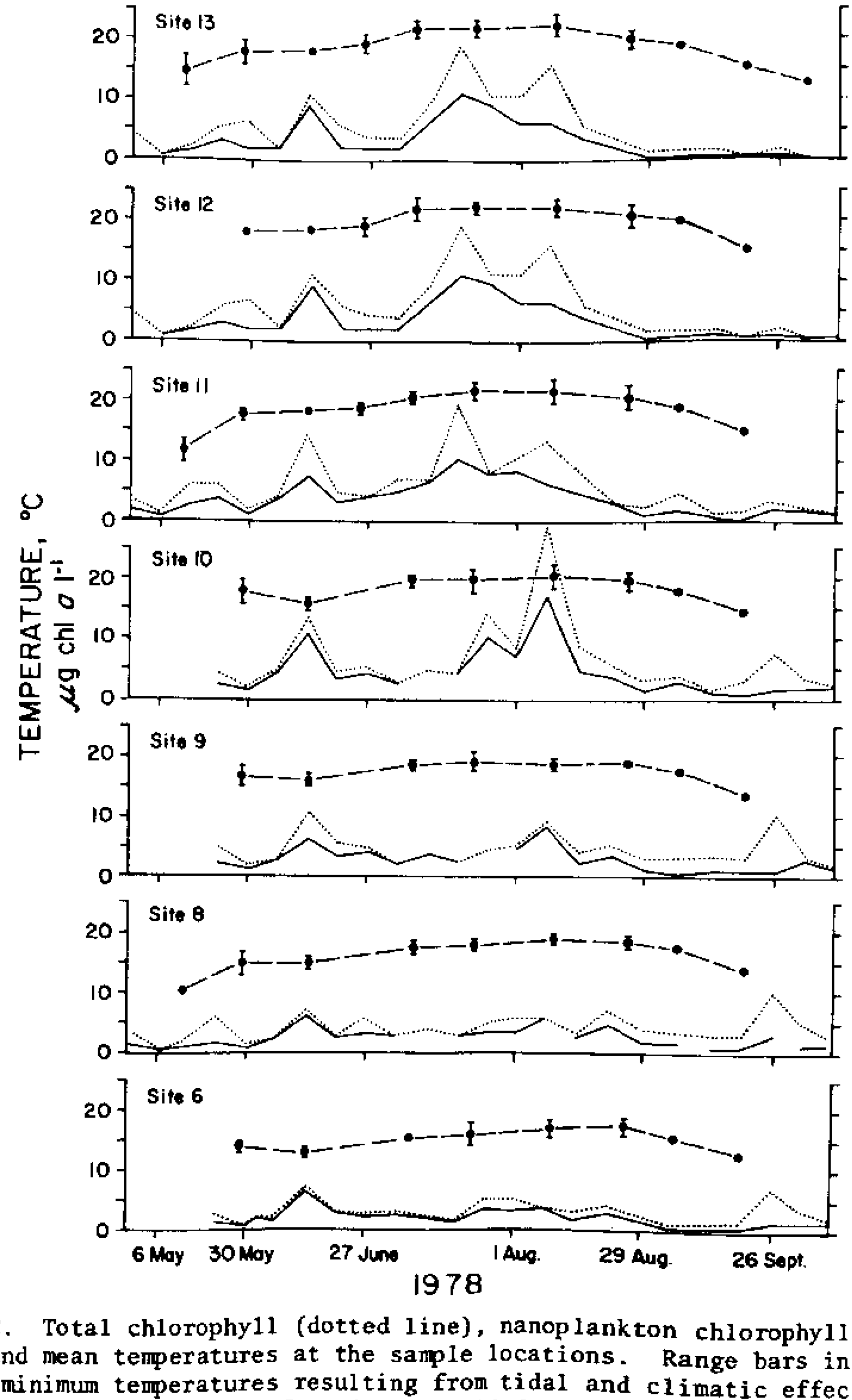

FIGURE 2. Total chlorophyll (dotted line), nanoplankton chlorophyll (solid line), and mean temperatures at the sample locations. Range bars indicate maximum and minimum temperatures resulting from tidal and climatic effects. Mean temperatures were estimated from data provided in Table I and from the stage of the tide at the time of sample collection (Table III).

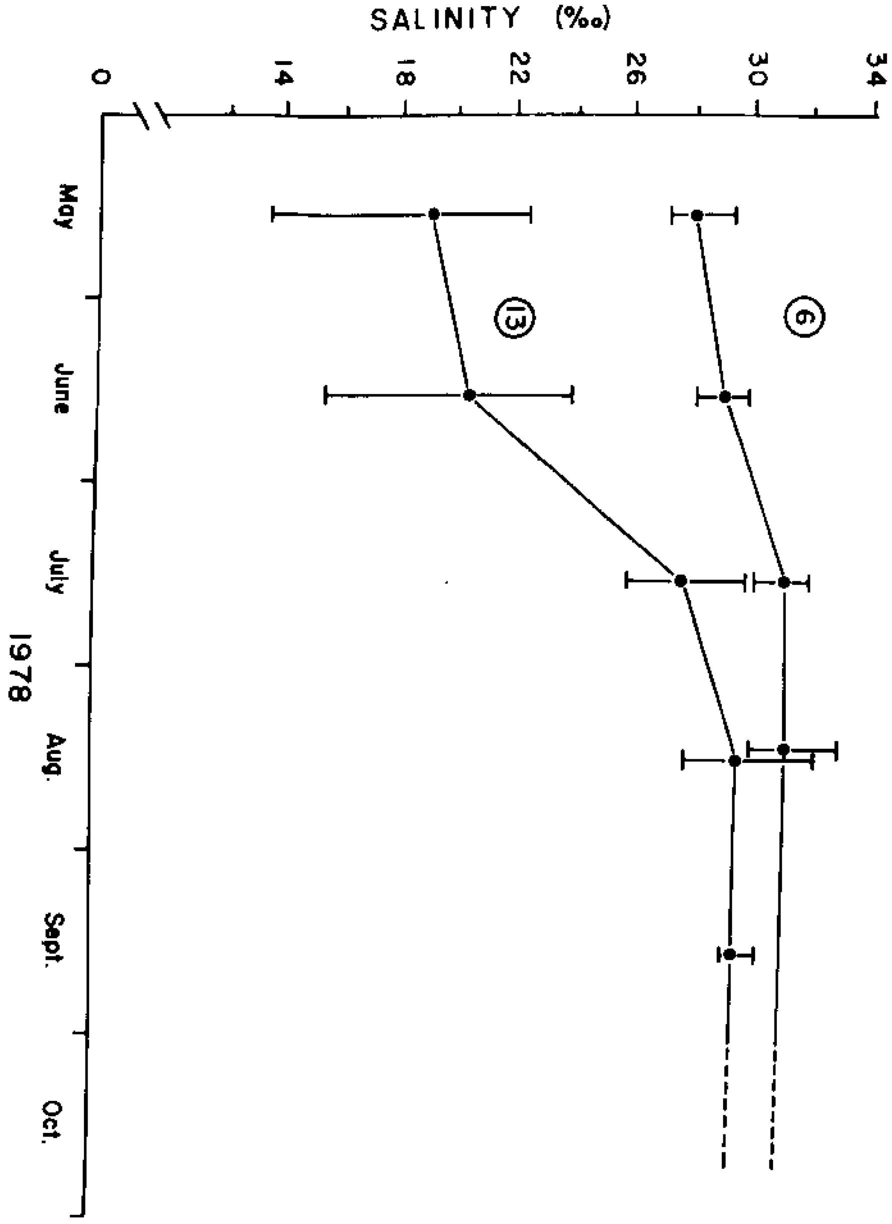

FIGURE 3. Mean monthly salinities at sites 6 and 13, showing ranges due to tidal and climatic effects (see text and Table II for details of these and other sites).

TABLE I.

Surface water temperatures (°C) at sites 6-13 (depth = 0.5 m).

	May						June					July				
Site	10	12	16	19	24	30	6	13	20	23	28	5	11	13	18	25
6	----	----	----	10.0	13.0	15.5	13.0	14.0	12.0	----	14.3	15.0	16.5	16.0	14.0	18.0
8	10.0	11.0	10.5	12.0	13.0	17.5	14.0	16.0	14.0	----	17.0	16.5	18.8	19.0	17.0	19.0
9	----	----	----	12.0	15.5	19.0	15.5	17.5	14.5	----	19.0	18.0	20.0	20.0	18.0	21.0
10	----	----	----	13.5	16.0	20.0	15.0	17.5	15.0	----	20.0	19.0	22.0	20.5	18.5	22.0
11	11.0	15.0	11.0	14.0	17.0	19.0	18.0	19.0	18.0	----	20.0	20.0	23.0	23.0	20.5	23.2
12	----	----	----	13.0	16.0	20.0	18.0	19.0	17.5	17.5	20.0	20.0	24.0	23.5	21.0	23.5
13	12.0	17.0	12.0	13.0	16.0	20.5	18.0	19.0	18.0	17.5	21.0	20.5	23.5	24.0	21.0	23.0

	August					September				October	
Site	1	8	15	23	29	6	12	19	26	4	10
6	15.5	15.5	18.5	19.0	16.0	15.8	15.0	13.0	14.0	12.4	11.8
8	18.0	18.5	20.5	19.8	17.8	17.8	15.0	14.0	14.0	13.0	11.8
9	18.0	19.0	20.5	21.0	18.0	18.0	15.5	14.0	14.0	13.0	11.8
10	19.0	20.5	23.0	21.5	18.5	18.4	16.0	15.0	14.5	13.5	11.8
11	20.0	21.0	24.0	22.8	18.9	19.3	16.0	15.0	14.5	13.5	11.0
12	21.0	23.0	24.0	22.8	19.0	19.8	16.0	15.0	15.0	13.5	11.2
13	21.0	23.0	25.0	22.0	19.0	19.2	16.0	15.5	15.0	13.0	11.2

TABLE II.

Surface water salinities (ppt) at sites 6-13 (depth = 0.5 m).

	May						June					July				
Site	10	12	16	19	24	30	6	13	20	23	28	5	11	13	18	25
6	----	----	----	26.5	27.5	30.0	30.5	28.0	28.5	----	30.0	31.0	30.0	32.0	32.0	31.5
8	24.5	28.0	25.0	24.0	27.5	28.5	30.0	26.5	26.0	----	29.0	30.0	30.0	31.5	31.0	31.5
9	----	----	----	24.0	26.0	26.0	29.0	25.0	26.0	----	27.5	30.0	30.0	31.5	30.5	31.0
10	----	----	----	22.0	26.0	25.0	28.0	23.0	25.0	----	26.0	29.0	28.0	31.0	30.5	30.0
11	18.0	23.0	24.0	21.0	22.0	24.0	24.0	21.5	18.5	----	25.5	27.0	28.0	30.0	30.5	30.0
12	----	----	----	21.0	23.5	22.0	23.0	19.0	20.0	25.0	24.0	26.5	26.5	30.5	28.5	30.0
13	14.0	18.0	19.0	21.0	23.0	20.0	22.0	16.0	18.5	24.0	24.0	26.0	27.5	28.0	28.0	29.5

	August					September				October	
Site	1	8	15	23	29	6	12	19	26	4	10
6	30.0	31.0	32.0	33.0	31.0	32.0	30.0	32.0			29.0
8	30.0	30.5	32.0	33.0	30.0	30.0	30.0	31.0			29.0
9	30.0	30.0	32.0	32.0	30.0	30.0	30.0	30.5			29.0
10	30.0	30.0	32.0	32.0	30.0	30.0	30.0	30.5			28.0
11	29.0	30.0	31.5	32.0	30.0	30.0	29.0	30.5			28.0
12	29.0	28.0	32.0	32.0	30.0	30.0	29.5	30.0			29.0
13	29.0	28.0	32.0	32.0	30.0	30.0	29.5	30.5			30.0

TABLE III.

Stage of tide at time of temperature/salinity measurements and collection of water samples for determination of chlorophyll concentrations, particle concentrations, and particle size spectra. Stages of tide (1/4, 1/2, 3/4) are indicated with respect to MHW.

May	10	MLW
	12	MLW
	16	3/4; ebbing
	19	MHW
	24	MHW
	30	1/2; ebbing
Jun	6	1/2; flooding
	13	1/2; ebbing
	20	3/4; flooding
	23	MHW
	28	3/4; ebbing
Jul	5	1/4; flooding
	11	1/4; ebbing
	13	1/4; flooding
	18	3/4; flooding
	25	1/2; ebbing
Aug	1	3/4; ebbing
	8	1/4; flooding
	15	1/2; ebbing
	23	1/2; ebbing
	29	3/4; flooding
Sep	6	MHW
	12	3/4; ebbing
	19	1/2; flooding
	26	MHW
Oct	4	3/4; flooding
	10	MHW

present study). The abundance of phytoplankton less than 10 μm in diameter (especially from 3-5 μm) and the relative dearth of phytoplankton between 10-20 μm (present study and McCarthy *et al.*, 1974) suggest that a more functional division might be at 10, 12, or 15 μm. The finding of McCarthy *et al.* (1974) that a large percentage of naked dinoflagellates passed unharmed through sieves considerably smaller than the phytoplankton cells provides further justification for this change. In this study "nanoplankton" chlorophyll increased in the upper estuary during the dinoflagellate blooms, yet microscopic examination of the plankton did not indicate such an increase in smaller cells (Incze, 1979).

Since the original data were not collected with this specific issue in mind, the question of some enhancement of nanoplankton cell numbers remains open. Nevertheless, the magnitude of the increase in nanoplankton chlorophyll measurements in the upper estuary during the summer months suggests that the naked Gymnodinium-like dinoflagellate encountered in these studies also passed through the sieve, thus biasing the nanoplankton chlorophyll measurements during the dinoflagellate blooms.

The high nanoplankton chlorophyll concentration (relative to total chlorophyll) downriver of site 9 and the high productivity of these small cells reported by other investigators* indicates that this size fraction is extremely important in the primary production of these northern coastal waters (notwithstanding the dominance of larger cells during peak chlorophyll production periods). Its greatest importance may be in providing a basal phytoplankton standing crop. The importance of nanoplankton to primary production in other northeast United States estuaries has been examined by McCarthy *et al.* (1974, Chesapeake Bay). and Durbin *et al.* (1975, Narragansett Bay).

In the upper estuary of the Damariscotta River, large microalgae were important during middle summer. The May and September blooms were dominated by microalgae at all sites.

Particle Types, Concentrations, Size Spectra, and Volume Distributions

Considerable interest has developed during the past fifteen years in the size spectrum and nature of available particles in natural waters (Parsons and Strickland, 1962; Parsons, 1963; Riley, 1963; Mullin, 1965; Sheldon *et al.*, 1967 and 1972; Nemoto and Ishikawa, 1969; Gordon, 1970; Zeitschel, 1970; Gieskes, 1972; Eisma and Gieskes, 1977; Lenz, 1977) and in the ecological significance of this size diversity (Brooks and Dodson, 1965; Hall *et al.*, 1976; Lehman, 1976; Poulet, 1976). Aside from identifiable fragments (diatom frustules, spicules, loricae, etc.) which were comparatively rare and are not considered in this paper, types of particulate material encountered in this investigation conformed in appearance and range of sizes to those described by Gordon (1970), namely: unidentifiable particulates (less than 10 μm); flakes (generally greater than 10 μm); fragments (of a variety of sizes); and loosely-connected aggregates (5-500 μm).** Unidentified particulates were the most numerous of all particles and were common to all samples; aggregates were common to nearly all samples, but were numerically much less common than the smaller particles. These two particle types were extremely important components of the small and large size-fractions of the seston, respectively, comprising 50% or more of the total particle counts in most samples.

The striking similarity of the aggregates encountered in this study to those described by Riley (1963) and Gordon (1970) suggests that they existed as true aggregates in the water column and did not result from superimposition on the filters during preparation of the microscope slides. This was confirmed by the use

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* See McCarthy *et al.*, 1974 for review.

**Primarily 5-100 μm in this study. Filtering through the 200 μm mesh was apparently not responsible for this size range being smaller than that reported by Gordon (1970): subsequent studies using settling chambers and no pre-filter also showed few aggregates larger than 100 μm (Incze and Yentsch, unpubl.).

TABLE IV.

Total particle concentrations in near-surface waters (depth = 0.5 m) determined by Coulter Counter analysis.

Date	Site	Total Particle Concentration (number of particles per ml)
Jun 13	13	4.4 X 10^5
	10	4.6 X 10^5
	6	4.6 X 10^5
Jul 5	13	4.5 X 10^5
	10	4.4 X 10^5
	6	4.6 X 10^5
Jul 11	13	4.7 X 10^5
	10	4.3 X 10^5
	8	4.0 X 10^5
	6	3.2 X 10^5
Jul 18	13	5.2 X 10^5
	12	4.4 X 10^5
	11	5.0 X 10^5
Aug 1	13	4.3 X 10^5
	10	4.4 X 10^5
	6	3.2 X 10^5
Aug 23	13	3.0 X 10^5
	10	2.7 X 10^5
	9	2.5 X 10^5
	6	2.1 X 10^5
Aug 29	13	3.8 X 10^5
	12	2.3 X 10^5
	10	2.8 X 10^5
	8	2.1 X 10^5
	6	2.0 X 10^5
Sep 6	13	1.4 X 10^5
	11	1.0 X 10^5
	10	1.7 X 10^5
	9	1.4 X 10^5
	8	1.8 X 10^5
	6	1.6 X 10^5
Sep 12	13	4.3 X 10^5
	12	3.6 X 10^5
	11	4.6 X 10^5
	10	4.7 X 10^5
	9	3.2 X 10^5
	8	2.5 X 10^5
	6	3.1 X 10^5
Sep 19	13	2.0 X 10^5
	12	2.0 X 10^5
	11	2.4 X 10^5
	10	2.6 X 10^5
	9	5.4 X 10^5
	8	3.5 X 10^5
	6	2.6 X 10^5
Sep 26	13	2.5 X 10^5
	12	2.0 X 10^5
	11	2.6 X 10^5
	10	2.7 X 10^5
	9	2.0 X 10^5
	8	1.5 X 10^5
	6	9.0 X 10^4
Oct 4	13	1.2 X 10^5
	12	1.5 X 10^5
	11	1.7 X 10^5
	10	2.0 X 10^5
	9	1.2 X 10^5
	8	1.9 X 10^5
	6	6.6 X 10^4
Oct 10	13	7.5 X 10^4
	12	7.5 X 10^4
	11	1.6 X 10^5
	10	1.9 X 10^5
	9	1.9 X 10^5
	8	2.1 X 10^5
	6	1.6 X 10^5

of settling chambers (Ütermohl, 1958) during studies on this estuary in 1979 (Incze and Yentsch, unpubl.). Riley (1963), Barber (1966), and Batoosingh *et al.* (1969) have shown how these complexes may be formed under laboratory conditions, and Riley (1963), Riley *et al.* (1964, 1965), Kane (1967), and Gordon (1970) have documented their abundance in natural seawater, particularly near the surface. Aggregates in this study appeared to contain more nanoplankton cells than the surrounding field, an observation made also by Riley (1963). It is not known whether this resulted from "scavenging" or from a more nutritive microenvironment associated with the aggregates.

The distribution of total particle volume with respect to particle sizes throughout most of this study indicated that, generally, more than 50% of the total particle volume was incorporated in particles smaller than 20 µm diameter (Range = 35-87%; see Appendix). Particles smaller than 10 µm constituted from 10-68% of total seston volume. During most of the study period, the size-distribution and concentration of particles (and thus the distribution of seston volume) did not change significantly. However, from July 18 through August 29 in the upper estuary (sites 10-13), particles greater than 20 µm increased dramatically, and the effect of this increase on the distribution of total particle volume was pronounced (Appendix). The shift to larger particles appeared to be due to both living dinoflagellates and to an increase in particulate material resembling the "organic aggregates" and, to a lesser extent, the "flake-like particles" described by Gordon (1970).

Particle concentrations (Table IV) remained at approximately 4.4-5.2 x 10^5 ml^{-1} from June through July at all sites, but decreased gradually in August and early September to less than half this concentration. Monitoring of particle concentrations through a full tidal cycle in early September confirmed that this decrease occurred throughout the middle and upper estuary. Particle concentrations returned to higher levels in late September but remained generally below summer seasonal values. Unfortunately, the data collected did not permit determination of total seston concentration (ppm) at all sites throughout the study, data which would be useful for comparison with the results of other investigators (see Zeitzschel, 1970). Microscope examinations indicated, however, that the increase in particle sizes compensated for the decrease in total particle numbers, at least through August, so that total seston volume did not decrease from early summer values. The shift toward larger particles and particles of different nature, however, may be ecologically significant for some consumers (Incze, 1979; Incze *et al.*, 1980). Mid-July (1979) seston concentrations in this estuary (¾ tide, ebbing) were 10-11 mg/l between sites 11 and 12 (just downriver of the Damariscotta-Newcastle bridge, Fig. 1); 10 mg/l at site 10; and 8-10 mg/l mid-channel off Wentworth Point at site 6.

Tidal Variations

Tidally-induced variations in chlorophyll concentration, particle concentration, relative contribution of nanoplankton to total chlorophyll, and particle size distribution were comparatively minor during most of the study period. During the tidal variation studies, data collected for each site at half tide (either flooding or ebbing) generally yielded values which were approximate means of the observed tidal variations of the above parameters (Incze, 1979). However, during the period of high phytoplankton standing crop (July 15-August 15) in the upper region of the estuary (sites 10-13), chlorophyll values varied widely, apparently as a result of tidal movements. A marine frontal zone created by the contiguity of well-stratified waters (upriver) with well-mixed waters (downriver) and an associated patch of dinoflagellates has been postulated (Incze, 1979) to account for the abrupt change in phytoplankton standing crop in this region of the river and the dominance of dinoflagellates, a phenomenon observed in an earlier study by Yentsch *et al.* (1977). The comparative stability of the stratified waters appears to be due to thermal and salinity-induced effects, the relative importance of the two factors varying over the course of the summer (McAlice, 1977; Incze, 1979). The apparent variability in phytoplankton standing crop at sites 10-13 during this period may be caused by tidal migrations of the frontal zone and associated phytoplankton patch(es), or by tidally-induced variations in the stability of the water column in this region, which would affect the degree to which the dinoflagellates became concentrated near the surface in such well-defined zones. (The results of subsequent studies on this system, conducted by L. Incze and C.M. Yentsch, are in preparation.) Tidal variations in particle volume distributions were not studied in this region of the estuary during the period of high phytoplankton standing crop.

APPENDIX

RELATIVE VOLUMES OF MATERIAL PRESENT IN DIFFERENT SIZE RANGES OF PARTICLES IN THE DAMARISCOTTA RIVER, EXPRESSED AS A PERCENTAGE OF TOTAL SESTON VOLUME MEASURED FOR PARTICLES OF 2-100 μm SPHERICAL EQUIVALENT DIAMETER

Size Categories	Site						
	13	12	11	10	9	8	6
Jun 13							
2- 5 μm	3.4	6.6	4.1	5.1	61.8	56.2	42.4
5-10	6.9	6.6	18.3	17.2	7.1	3.2	4.8
10-20	48.7	45.2	44.6	42.9	15.9	25.9	25.3
20-40	21.5	17.6	15.2	17.3	1.3	2.2	9.6
≤5	3.4	6.6	4.1	5.1	61.8	56.2	42.4
≤10	10.3	13.2	22.4	22.3	68.9	59.4	47.2
≤20	59.0	58.4	67.0	65.2	84.8	85.3	72.5
≤40	80.5	76.0	82.2	82.5	86.1	87.5	82.1
>40	19.5	24.0	17.8	17.8	13.9	11.5	17.9
Jun 20							
2- 5	16.2	27.2	26.1	26.1	12.2	24.1	23.1
5-10	29.7	24.4	33.1	29.9	17.8	21.6	19.7
10-20	31.9	25.6	22.9	22.9	36.1	24.5	26.0
20-40	11.2	11.9	7.9	9.6	24.2	20.5	17.7
≤5	16.2	27.2	26.1	26.1	12.2	24.1	23.1
≤10	45.9	51.6	59.2	56.0	30.0	45.7	42.8
≤20	77.8	77.2	82.1	78.9	66.1	70.2	68.8
≤40	89.0	89.1	90.0	88.5	90.3	90.7	86.5
>40	11.0	10.9	10.0	11.5	9.7	9.3	13.5
Jun 28							
2- 5	38.6	11.6	16.5	13.7	11.0	47.1	41.6
5-10	20.8	16.4	18.4	14.6	14.5	7.5	7.0
10-20	21.9	35.9	30.6	36.6	39.2	16.7	17.8
20-40	6.7	21.5	16.6	17.7	18.6	13.2	13.0
≤5	38.6	11.6	16.5	13.7	11.0	47.1	41.6
≤10	59.4	28.0	34.9	28.3	25.5	54.6	48.6
≤20	81.3	63.9	65.5	64.9	64.7	71.3	66.4
≤40	88.0	85.4	82.1	82.6	83.3	84.5	79.4
>40	12.0	14.6	17.9	17.4	16.7	15.5	20.6

Size Categories	Site						
	13	12	11	10	9	8	6
Jul 5			b				
2- 5 µm	22.7	32.6	25.9	13.6	21.8	22.5	27.7
5-10	8.9	14.7	8.9	11.3	14.8	15.9	11.7
10-20	37.8	20.5	27.5	33.1	22.4	19.6	20.8
20-40	9.3	18.2	23.1	26.1	20.6	16.2	21.7
≤5	22.7	32.6	25.9	13.6	21.8	22.5	27.7
≤10	31.6	47.3	34.8	24.9	36.6	38.4	39.4
≤20	69.4	67.8	62.3	58.0	59.0	58.0	60.2
≤40	78.7	86.0	85.4	84.1	79.6	74.2	81.9
>40	21.3	14.0	14.6	15.9	20.4	25.8	18.1
Jul 11							
2- 5	31.7	25.8	17.5	19.4	39.2	18.2	7.5
5-10	12.1	11.7	17.2	18.5	15.8	18.4	9.8
10-20	27.1	30.0	33.5	28.2	22.1	29.9	31.8
20-40	22.9	23.3	22.4	24.0	9.3	23.3	38.9
≤5	31.7	25.8	17.5	19.4	39.2	18.2	7.5
≤10	43.8	37.5	34.7	37.9	55.0	36.6	17.3
≤20	70.9	67.5	68.2	66.1	77.1	66.5	49.1
≤40	93.8	90.8	90.6	90.1	86.4	89.8	88.0
>40	6.2	9.2	9.4	9.9	13.6	10.2	12.0
Jul 18							
2- 5	28.9	24.7	14.1	28.4	28.6	21.9	27.9
5-10	4.8	8.3	7.2	25.4	28.6	25.5	28.8
10-20	15.9	14.1	15.2	23.4	24.7	26.7	25.8
20-40	25.1	29.3	27.6	17.3	13.8	17.9	10.7
≤5	28.9	24.7	14.1	28.4	28.6	21.9	27.9
≤10	33.7	33.0	21.3	53.8	57.2	47.4	56.7
≤20	49.6	47.1	36.5	77.2	81.9	74.1	82.5
≤40	74.7	76.4	64.1	94.5	95.7	92.0	93.2
>40	25.3	23.6	35.9	5.4	4.3	8.0	6.8
Jul 25							
2- 5	15.2	15.6	23.0	11.9	18.0	14.9	21.5
5-10	14.2	11.1	20.1	15.2	25.3	21.1	24.8
10-20	24.0	21.1	27.3	19.6	29.9	33.4	36.1
20-40	35.6	36.5	17.4	22.6	15.0	20.8	13.4
≤5	15.2	15.6	23.0	11.9	18.0	14.9	21.5
≤10	29.4	26.7	43.1	27.1	43.3	36.0	46.3
≤20	53.4	47.8	70.4	46.7	73.2	69.4	82.4
≤40	89.0	84.3	87.8	69.3	88.2	90.2	95.8
>40	11.0	15.8	12.2	30.7	11.8	9.8	4.2

Size Categories	Site						
	13	12	11	10	9	8	6
Aug 1							
2- 5 μm	11.8	15.7	12.8	17.3	22.8	27.3	26.1
5-10	9.5	11.7	9.2	16.8	19.3	11.5	13.9
10-20	13.7	12.0	16.8	27.1	24.7	33.6	25.4
20-40	27.5	23.3	29.6	28.3	18.1	26.0	28.1
≤5	11.8	15.7	12.8	17.3	22.8	27.3	26.1
≤10	21.3	27.4	22.0	34.1	42.1	38.8	40.0
≤20	35.0	39.4	38.8	61.2	66.8	72.4	65.4
≤40	62.5	62.7	68.4	89.5	84.9	98.4	93.5
>40	37.5	37.3	31.6	10.5	15.1	1.6	6.5
Aug 8							
2- 5	19.8	14.0	18.0	12.3	20.9	18.5	28.7
5-10	10.9	9.7	16.9	13.1	24.9	20.2	24.5
10-20	11.9	14.3	19.4	16.0	27.5	28.6	21.8
20-40	11.9	19.5	22.3	20.7	17.8	26.6	16.7
≤5	19.8	14.0	18.0	12.3	20.9	18.5	28.7
≤10	30.7	23.7	34.9	25.4	45.8	38.7	53.2
≤20	42.6	38.0	54.3	41.4	73.3	67.3	75.0
≤40	54.5	57.5	76.6	62.1	91.1	93.9	91.7
>40	45.5	42.5	23.4	37.9	8.9	6.1	8.3
Aug 15							
2- 5	29.9	26.5	37.1	28.5	21.5	27.4	21.2
5-10	16.4	13.6	23.8	28.5	26.2	33.6	29.3
10-20	17.7	13.0	16.3	20.5	26.8	26.0	32.5
20-40	23.1	14.6	10.0	13.5	14.1	7.9	11.2
≤5	29.9	26.5	37.1	28.5	21.5	27.4	21.2
≤10	46.3	40.1	60.9	57.0	47.7	61.0	50.5
≤20	64.0	53.1	77.2	77.5	74.5	87.0	83.0
≤40	87.1	67.7	87.2	91.0	88.6	94.9	94.2
>40	12.9	32.3	12.8	9.0	11.4	5.1	5.8
Aug 23							
2- 5	45.0	28.4	41.4	29.9	37.3	35.9	29.3
5-10	10.6	10.1	17.5	21.3	24.3	27.0	20.1
10-20	13.4	11.0	14.6	21.7	19.9	21.9	24.6
20-40	21.1	17.3	11.8	15.6	11.5	11.4	14.8
≤5	45.0	28.4	41.4	29.9	37.3	35.9	29.3
≤10	55.6	38.5	58.9	51.2	61.6	62.9	49.4
≤20	69.0	49.5	73.5	72.9	81.5	84.8	74.0
≤40	90.1	66.8	85.3	88.5	93.0	96.2	88.8
>40	9.9	33.2	14.7	11.5	7.0	7.8	11.2

Size Categories	Site 13	12	11	10	9	8	6
Aug 29							
2- 5 μm	18.3	27.5		23.3		21.5	24.3
5-10	8.4	13.1		16.0		18.6	16.6
10-20	18.9	16.2		21.2		27.4	23.1
20-40	38.1	24.1		21.3		18.3	18.8
≤5	18.3	27.5		23.3		21.5	24.3
≤10	26.7	40.6		39.3		40.1	40.9
≤20	45.6	56.8		60.5		67.5	64.0
≤40	83.7	80.9		81.8		85.8	82.8
>40	16.3	19.1		18.2		14.2	17.2
Sep 6							
2- 5	20.9		17.7	8.0	11.5	23.4	48.5
5-10	16.5		16.1	10.4	15.2	18.8	15.2
10-20	27.0		31.9	30.7	36.8	29.1	21.3
20-40	21.6		29.1	37.5	25.7	23.2	13.6
≤5	20.9		17.7	8.0	11.5	23.4	48.5
≤10	37.4		33.8	18.4	26.7	42.2	63.7
≤20	64.4		65.7	49.1	63.5	71.3	85.0
≤40	86.0		94.8	86.6	89.2	94.5	98.6
>40	14.0		5.2	13.4	10.8	5.5	1.4
Sep 12							
2- 5	33.9	23.3	33.6	28.1	23.2	20.4	42.7
5-10	11.9	7.9	25.7	16.6	22.9	17.4	15.7
10-20	24.5	16.7	23.9	24.5	28.0	23.8	20.2
20-40	23.9	30.6	12.9	20.6	16.6	17.5	19.3
≤5	33.9	23.3	33.6	28.1	23.2	20.4	42.7
≤10	45.8	31.2	59.3	44.7	46.1	37.8	58.4
≤20	70.3	47.9	83.2	69.2	74.1	61.6	78.6
≤40	94.2	78.5	96.1	89.8	90.7	79.1	97.9
>40	5.8	21.5	3.9	10.2	9.3	20.9	2.1
Sep 19							
2- 5	21.6	19.9	17.5	18.4	67.5	39.1	48.6
5-10	16.2	8.5	15.9	19.3	8.2	13.2	8.4
10-20	24.1	16.9	28.4	26.2	11.2	26.2	12.7
20-40	23.5	37.5	28.3	25.4	6.4	15.0	13.1
≤5	21.6	19.9	17.5	18.4	67.5	39.1	48.6
≤10	37.8	28.4	33.4	37.7	75.7	52.3	57.0
≤20	61.9	45.3	61.8	63.9	86.9	78.5	69.7
≤40	85.4	82.8	90.1	89.3	93.3	93.5	82.8
>40	14.6	17.2	9.9	10.7	6.7	6.5	17.2

Size Categories	Site						
	13	12	11	10	9	8	6
Sep 26							
2- 5 μm	49.2	47.7	34.4	24.4	16.2	14.2	14.1
5-10	8.5	9.2	21.9	13.4	18.2	14.6	12.4
10-20	16.8	14.3	24.1	30.7	37.7	34.3	30.5
20-40	17.6	18.6	12.4	20.3	19.6	26.8	29.6
≤5	49.2	47.7	34.4	24.4	16.2	14.2	14.1
≤10	57.7	56.9	56.3	37.8	34.4	28.8	26.5
≤20	74.5	71.2	80.4	68.5	72.1	63.1	57.0
≤40	92.1	89.8	92.8	88.8	91.7	89.9	86.6
>40	7.9	10.2	7.2	11.2	8.3	10.1	13.4
Oct 4							
2- 5	23.6	26.1	18.7	19.7	20.7	18.1	28.2
5-10	14.3	16.6	23.3	21.9	12.4	17.5	12.2
10-20	27.8	22.1	31.9	25.7	30.2	26.9	24.2
20-40	29.6	16.6	21.6	21.9	29.2	25.2	27.4
≤5	23.6	26.1	18.7	19.7	20.7	18.1	28.2
≤10	37.9	42.7	42.0	41.6	33.1	35.6	40.4
≤20	65.7	64.8	73.9	67.3	63.3	62.5	64.6
≤40	95.3	81.4	95.5	89.2	92.5	87.7	92.0
>40	4.7	18.6	4.5	10.8	7.5	12.3	8.0
Oct 10							
2- 5	27.8	25.5	30.4	47.7	56.1	48.7	42.2
5-10	6.5	7.1	16.3	10.4	13.7	11.2	10.5
10-20	15.6	19.0	27.5	20.1	11.4	14.8	11.7
20-40	32.7	36.0	21.1	23.0	11.8	25.0	16.1
≤5	27.8	25.5	30.4	47.7	56.1	48.7	42.2
≤10	34.3	32.6	46.7	58.1	69.8	59.9	52.7
≤20	49.9	51.6	74.2	78.2	81.2	74.7	64.4
≤40	82.6	87.6	95.3	100.0	93.0	99.7	80.5
>40	17.4	12.4	4.7		7.0	.3	19.5

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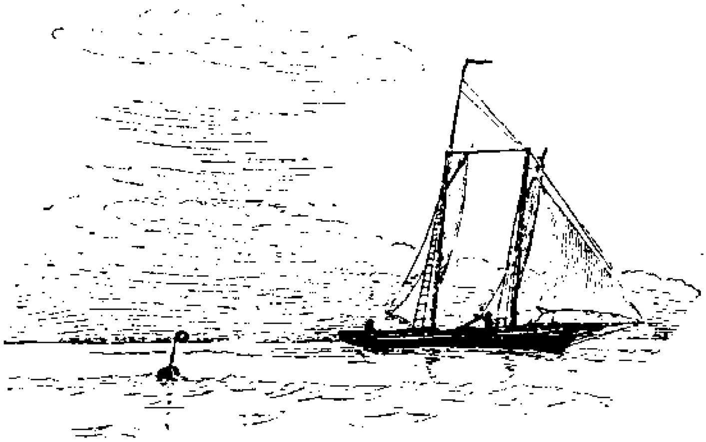

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