COO-3278-35

TITLE: Phytoplankton Growth, Dissipation and Succession in Estuarine Environments

CONTRACT NUMBER: AT(11-1) 3278

PRINCIPAL INVESTIGATOR: H. H. Seliger, Professor of Biology

CONTRACTOR: The Johns Hopkins University
Baltimore, Maryland 21218

PROGRESS REPORT: 1 year period through April, 1976

Submitted by:

H. H. Seliger
Professor of Biology

DISCLAIMER

A. During the past year the following papers have been written or presented

1. Seliger, H. H. Environmental Photobiology. Chap. 6 in Photobiology, ed. K. C. Smith, to be published. COO-3278-33
2. Owens, O., C. Crawford, P. Dresler, M. Tyler and H. H. Seliger. The Use of Phytoplankton Cages for Measuring Growth Rates of Natural Populations In situ. Paper at Ann. Mtg. Estuarine Research Federation, Galveston, Texas, October, 1975. -3278-31
3. Tyler, M. A. and H. H. Seliger. Long-range, Subsurface Transport of the Mahogany Tide-forming Dinoflagellate in the Chesapeake Bay. Paper at Ann. Mtg. Amer. Soc. Limnol. Oceanogr., Savanah, Georgia, June, 1976. -3278-32
4. Owens, O., P. Dresler, C. C. Crawford, M. A. Tyler, S. Chipman, and H. H. Seliger. Membrane Cages for Measurement of In situ Growth Rates of Natural Phytoplankton Populations, Ches. Sci. submitted. -3278-34

B. Research Summary

During the past year we have made two major advances in our study of phytoplankton ecology in the Chesapeake Bay.

1. We have been able to follow the annual subsurface transport of a dinoflagellate species (Prorocentrum mariae labouriae) from the mouth of the bay a distance northward of 120 nautical miles to the region of the Bay Bridge. Prorocentrum is a major seasonal dinoflagellate in the Chesapeake Bay and annually has been reported to form "mahogany tides", dense reddish-brown patches, in the northern bay beginning in late spring and continuing through the summer. Subsequent to this annual "appearance" the Prorocentrum spread southward and into the western tributary estuaries. We have been able to correlate the physiological behavioral charactertistics of the Prorocentrum with the physical water movements in the bay and have developed an internally consistent sequence of biological and physical events which allow Prorocentrum and Prorocentrum alone, to fill this very special set of ecological requirements. For example the organisms are transported and accumulated in the net northward-moving bottom waters of the bay. In order for this to be successful

a) the organisms must exhibit a negative phobotaxis at the very

low light intensities which are present in the bottom waters.

b) in addition the organisms must be shear sensitive so that their net positive phototaxis is inhibited at the pycnocline between the southward-moving surface waters and the northward-moving bottom waters.

c) in addition these phytoplankton must be able to exist for extended periods of 1-3 weeks at the negligible light intensities in the bottom waters, i.e. in the absence of photosynthesis.

d) the water movements in the bay must be such that during the period of the northward transport (January-April) the pycnocline must be maintained in the central bay in the presence of pulses of runoff waters from the western tributary estuaries, mainly the Patuxent and the Potomac Rivers. Turbulent mixing and the loss of the sharp density discontinuity provides a loss mechanism from the northward transport mechanism.

e) the ability of the dinoflagellates to be thus transported in water masses also permits their introduction into the tributary estuaries by a two layered tidal exchange mechanism.

We have made an intensive series of cruises throughout the entire year on all of the vessels available to us. These have included the R/V Rhode Worker of the Smithsonian Institution; R/V Aquarius of the Chesapeake Biological Laboratories of the University of Maryland; the R/V Pritchard, Maury and Warfield of the Chesapeake Bay Institute of The Johns Hopkins University. We have studied the area from 30 miles outside of the mouth of the bay into the ocean to the Magothy River and occasionally as far north as Pooles Island opposite Middle River. For most of the

migration period Prorocentrum is not dominant and cannot be followed by the simple expedient of chlorophyll assay; either in vivo or by extraction. Microscopic identification and counting are necessary.

We believe that this is the first direct evidence for a large scale lateral transport of an estuarine phytoplankton. It is quite probable that elements of this transport mechanism have applicability to the occurrence of blooms of the toxic dinoflagellates Gymnodinium breve in the Gulf of Mexico off the west coast of Florida and Gonyaulax tamarensis and G. catenella on the east and west coasts, respectively, of the United States.

We are presenting a paper on this continuing study at the June meeting of the American Society of Limnology and Oceanography.

2. The second major advance is the development of the phytoplankton cage technique for the measurement in situ of the growth rates of natural mixed populations (see COO-3278-34 enclosed with this report). The heart of the system is the use of defined pore-size non-toxic, minimum-fouling, Nucleopore(R) filters as the bars of the cage. This retains the captured phytoplankton while still permitting soluble nutrient exchange across the membrane with a half-time for exchange (< 1 hour) much less than the miminum doubling time for the phytoplankton (ca. 12 hours). Therefore to a first approximation the captured organisms are exposed to the nutrient concentrations at the site of the in situ incubation. The net rate of growth is determined by microscopic counting or by chlorophyll a assay as functions of time. The in situ technique is amenable to the Latin Square experimental design and a two-way analysis of variance. So far as we know this is the first time that a

factorial design experiment with mixed natural phytoplankton populations can be used in situ to assess localized environmental impacts of power plant heat and toxic chemical discharges.

We have four different experimental protocols:

a) In Situ 3 X 3 Latin Square with replication. In this case captured natural samples from above (A), opposite (B) and below (C) the plant are incubated in situ at each of the three sites.

b) Pumped Natural Water 3 X 1 design with replication. In this case captured natural samples from A, B and C are delivered to cages in a Lucite channel on the shore through which natural waters from B are pumped, so that effectively the organisms in the cages are exposed to B waters. The advantage of this pumped natural water technique is that additional channels can be used for metered additions (or deletions) of heat, nutrients or toxic chemicals and the whole again subjected to the powerful analysis of variance statistical analysis.

c) Recirculating Centrifuged Natural Water factorial design with treatment and replication. In this case the captured natural phytoplankton samples are delivered to cages in channels. However captured natural waters from A, B and C, centrifuged clear of all particulates including bacteria, are recirculated through the canals. Since the volume of the recirculating clarified water is very much larger than the volume of the cage samples, throughout the course of the growth experiment

the captured phytoplankton will be subjected to the same nutrient concentrations as at the time of capture. Since we again are working in channels we can add additional channels and captured, centrifuged water samples to which additions or deletions can be made. The technique permits "treatment" effects to be analyzed by analysis of variance, similar to the Pumped Natural Waters design.

d) Predator Dilution - In all of the cases above, if one is concerned with the potential for net primary production, it is necessary to filter for zooplankton so that there is no predation inside the cages. However in cases where the phytoplankton and the herbivores are tiny (in the spring bloom) it is quite difficult to completely separate the one from the other. In these cases the predation is approximately a second order reaction

$$\frac{dN}{dt} \simeq -k_{Predation}(N)(P).$$

A dilution of the captured natural sample with particulate-clarified water by a factor of α will reduce the predation rate by α^2. Therefore, provided (N), the concentration of nannoplankton, is large enough to be able to measure $\frac{N}{\alpha}$ with reasonable precision, it is possible to make separate estimates of net growth (including predation) and net growth potential (excluding predation) by the simple expedient of dilution.

The Phytoplankton Cage Technique is thus a significant tool for both basic research and environmental monitoring in phytoplankton ecology.

3. We have extended our measurements of scalar spectral irradiance of underwater sunlight to overlap a complete seasonal cycle from the mouth of the bay north to the Magothy River. We are in the process of calculating these data. We expect to be able to extend the prediction of light-limiting and nutrient-limiting conditions in the surface waters of the bay to the complete annual cycle of phytoplankton succession.

4. We have just received and have completed the tests of the fluorescence microscope photometer. We intend to use this instrument to measure chlorophyll in vivo distributions in natural samples and together with absorption measurements of stained cells and ^{14}C uptake autoradiography we intend to measure chlorophyll to protein ratios and photosynthetic assimilation ratios for different species in mixed natural populations of phytoplankton - measurements previously possible only in artificial, unialgal, laboratory cultures. Since without this type of instrument these measurements have never been made for natural populations, this work should be very exciting.