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Seasonal Phytoplankton Development Within Three Rivers In The Lower Chesapeake Bay Region.

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ABSTRACT

The seasonal and inter-annual concentrations of phytoplankton were studied over a 50 month period in the lower James, York and Rappahannock Rivers. Differences in the onset, duration and magnitude of major seasonal growth periods varied from year to year. There was a tendency for spring, summer and fall maxima, with a winter period of reduced abundance. An additional study of picoplankton over a 12 month period indicated greatest abundance during summer and fall, with least development in winter.

INTRODUCTION

Schubel and Pritchard (1987) described the James, York and Rappahannock Rivers as three major tributaries of the Chesapeake Bay, collectively responsible for 18.6% of its total annual stream flow. In these three rivers, Anderson (1986) noted phytoplankton maxima occurred in areas of tidal freshwater. Filardo and Dunstan (1985) reported an inverse relationship between phytoplankton abundance in the upper oligohaline reach of the James River and the biomass in the mesohaline sections. They related the nutrient dynamics of the oligohaline region of the James with nutrient levels and the onset of the spring bloom downstream. Marshall and Alden (1990a) identified phytoplankton differences in seasonal and site assemblages in the James, York and Rappahannock Rivers. They reported decreasing concentrations downstream in these rivers and that spatial (site) effects are responsible for the majority of the explained variance (58%) among the floral assemblages. Major temporal influences included the onset and duration of the spring rains. Further associations between specific nutrient concentrations and growth of different assemblages in freshwater and marine habitats were presented by Hecky and Kilham (1988), and in the Chesapeake Bay by McCarthy et al. (1977) and Sellner (1987), among others. Phytoplankton assemblages in the lower Chesapeake Bay were discussed by Marshall and Lacouture (1986), who reported these populations were dominated by neritic diatoms, dinoflagellates, cryptomonads and a cyanobacteria picoplankton component.

Marshall and Alden (1990a) described the initial results of a phytoplankton monitoring program of the lower James, York and Rappahannock Rivers. By applying a series of discriminant and multivariate analysis procedures to a 16 month data set, they identified 3 station (spatial) groups and 5 seasonal assemblages within these rivers. Seasonal and spatial phytoplankton assemblages were also identified in the lower Chesapeake Bay by Marshall and Alden (1990b). This paper will focus on the composite phytoplankton concentrations within these three station groups presented by Marshall and Alden (1990a) to identify year to year fluctuations in abundance. The objectives of this report include 1) the comparison of the annual

composition and cycles in phytoplankton abundance at sites within the lower James, York and Rappahannock Rivers over a four year period, and 2) the identification of year to year variation in the phytoplankton abundance during this period.

METHODS

This report is based on a 50 month study between March 1986 and April 1990. Monthly collections were taken from two stations in the James and Rappahannock Rivers and one station in both the York River and Pamunkey River, which is a tributary to the York River (Figure 1). At each station, a 15 liter composite water sample was taken by water pump and hose at five depths from just above the pycnocline to the surface. From this composite a 500 ml sub-sample was preserved with Lugols solution. A similar procedure was followed for waters below the pycnocline to a near bottom depth. Sites lacking a pycnocline were sampled in the upper and lower third of the water column. After 48 hours these sub-samples were processed through a series (3) of siphoning and settling procedures to obtain a 20-25 ml concentrate that was placed in a settling chamber and analyzed with an inverted plankton microscope. Cell counts were made at 315X and 500X with a minimum count and random field approach to produce an 85% accuracy estimate for cell concentrations (Venrick, 1978). These cell counts do not include the picoplankton. Analysis of this component was added in 1988 when counts of the picoplankton autotrophic cells were based on another sub-sample taken from the composite water sample and prepared for epifluorescent microscopy according to methods given by Porter and Feig (1980) and Waterbury et al. (1986). The mean monthly phytoplankton concentrations, for stations within each site group, were used in depicting the computer generated annual abundance patterns using Harvard Graphics.

RESULTS

Phytoplankton Composition

Marshall and Alden (1990a) originally identified three groups of phytoplankton assemblages associated with station sites in these rivers. The three site groups were designated according to common salinity ranges for these areas as I. Tidal Fresh (station TF 5.5 in the James River), II. Oligo-mesohaline (station RET 5.2 in the James, TF 3.3 in the Rappahannock, and the York station RET 4.1), and III. Mesohaline (station RET 4.3 and RET 3.1 from the York and Rappahannock). Over the 16 month study period the James River Group I station (TF 5.5) was characterized by fresh water flora dominated by chlorophytes, diatoms and cyanobacteria. The major diatoms included *Skeletonema potamos*, *Melosira* (*Aulacoseira*) *granulata*, *Melosira* (*Aulacoseira*) *distans*, *Cyclotella striata* and a variety of benthic species. Peak concentrations were associated with late winter-early spring (February-April) and late summer-early fall (August-October). The chlorophytes consisted of a diverse group of unicellular and colonial forms such as *Scenedesmus quadricauda*, *Scenedesmus dimorphus*, *Chlorella* sp., *Ankistrodesmus falcatus*, *Pandorina* spp., *Tetrastrum* spp., and *Crucigenia tetrapedia*, among others. Although common year round, they generally had major growth periods in early spring and summer. Filamentous chlorophytes were rare and associated with entry from shoreline vegetation. In contrast, two cyanophyte groups were present

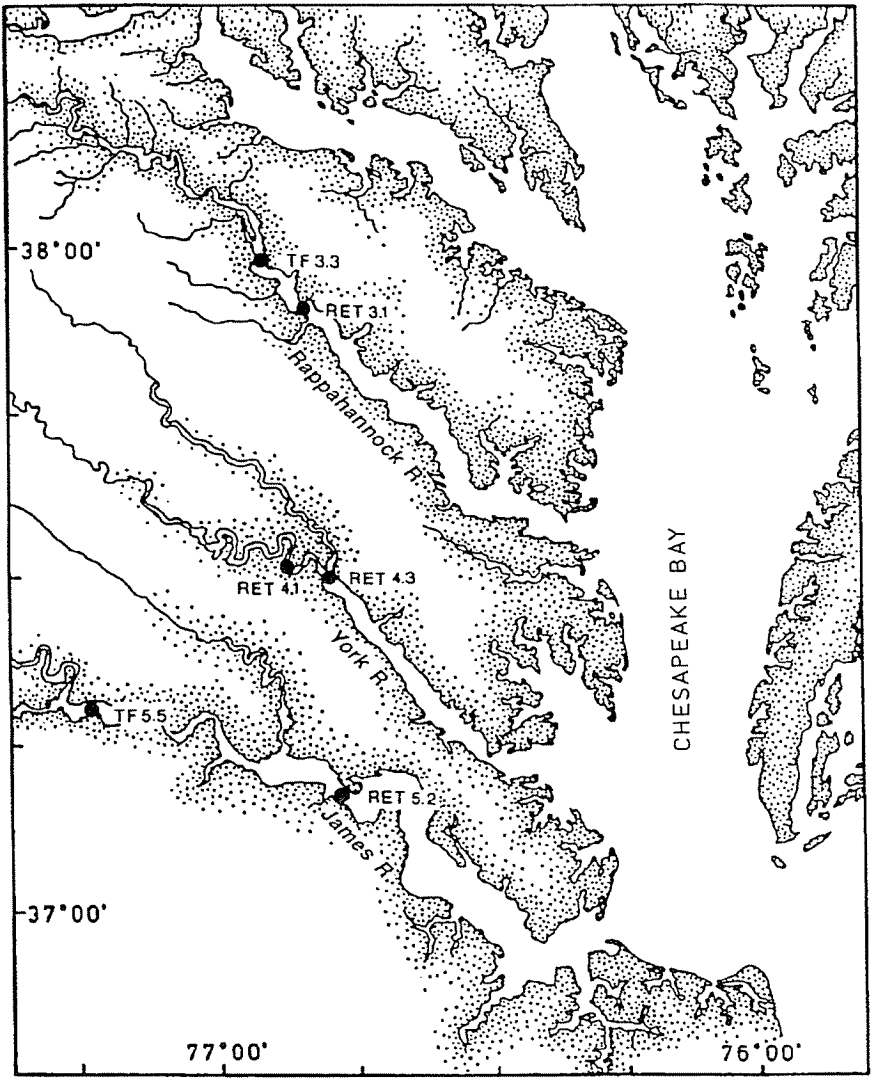

FIGURE 1. Station locations in the James, York and Rappahannock Rivers.

in all the collections. One was the ubiquitous picoplankton component (0.2 -2.0 microns) that included cyanobacteria of mainly *Synechococcus* spp. These cells had a major summer-early fall growth (10^9 - 10^{10} cells/L) with a seasonal low in winter. The other cyanobacteria groups were composed of mainly unicellular or colonial forms. These included *Microcystis aeruginosa*, *Microcystis incerta*, *Merismopedia tenuissima* and *Chroococcus limneticus*. Filamentous genera (e.g. *Nostoc, Anabaena*) were also common, but not abundant. The cyanobacteria were most numerous during summer and early fall. In addition to these categories, there was representation by cryptomonads, euglenoids, dinoflagellates and a mixed category of micro-flagellates.

The oligo-mesohaline Group II stations represented a transition to a mixed assemblage of fresh water and estuarine flora. The representation common to the lower Chesapeake Bay included the diatoms *Skeletonema costatum*, *Leptocylindrus minimus*, *Cyclotella caspia*, and numbers of others. Cryptomonads and dinoflagellates were also greater in numbers down stream, with concentrations of chlorophytes and cyanobacteria decreasing. The estuarine species were noted throughout the year in the more saline sub-pycnocline waters, which were associated with the transport of these species upstream. In contrast, higher concentrations of the tidal freshwater diatoms, chlorophytes and cyanobacteria were found above the pycnocline (moving downstream), than below the pycnocline. A variety of other neritic species were also found in the sub-pycnocline waters (e.g. *Chaetoceros* spp. silicoflagellates, among others).

In contrast, the mesohaline Group III stations were dominated by estuarine and neritic species. Common freshwater forms in the tidal fresh or oligo-mesohaline stations were replaced by species associated with more saline waters. For instance, *Skeletonema potamos*, *Cyclotella striata*, *Cyclotella* sp. and several *Melosira* (*Aulacoseira*) spp. were replaced by *Skeletonema costatum*, *Cyclotella caspia*, *Asterionella glacialis* and *Leptocylindrus minimus*. Dinoflagellates, cryptomonads and euglenoids also became more abundant. Among the dinoflagellates, a common species was *Katodinium rotundatum*, with *Prorocentrum minimum* and *Heterocapsa triguetra* having highest concentrations in the downstream reach of the rivers and in waters below the pycnocline. The cyanobacteria and chlorophytes decreased in abundance downstream, but *Microcystis* spp. and *Merismopedia* spp. were still common, specially during late summer and early fall. There were no major algal blooms observed during the collection period. However, between collection dates, several small and very localized dinoflagellate blooms were noted in mesohaline regions of these rivers (Marshall, 1989).

Phytoplankton Abundance

I. Tidal Fresh Water

Over the four year period, peaks (10^7 - 10^8 cells/L) in phytoplankton abundance above the pycnocline occurred between spring (April) and fall (October), with lowest concentrations in winter (Figure 2-I). There was a modest increase in the 1986 spring-summer development followed by a slight decline in late summer and a fall peak in October. There were no major spring pulses in 1987 and 1988, but a major summer peak occurred in 1987 followed by a modest development in fall before the winter decline. In 1988, the fall abundance was larger than in summer. In contrast, there were major spring (April) maxima in 1989 and an early spring growth beginning in January 1990, and only modest summer and fall growth in 1989. Concentrations in the waters below the pycnocline generally mimicked the surface waters in composition and abundance, often exceeding them in concentrations (e.g. spring 1986, fall 1988), but were usually less abundant. Species mainly responsible for the peaks in spring and fall were diatoms and chlorophytes, while diatoms, cyanophytes, and chlorophytes were abundant in summer.

II. Oligo-mesohaline

In 1986, the phytoplankton concentrations above the pycnocline developed a modest spring (April) pulse (10^7 cells/L) followed by another pulse in summer

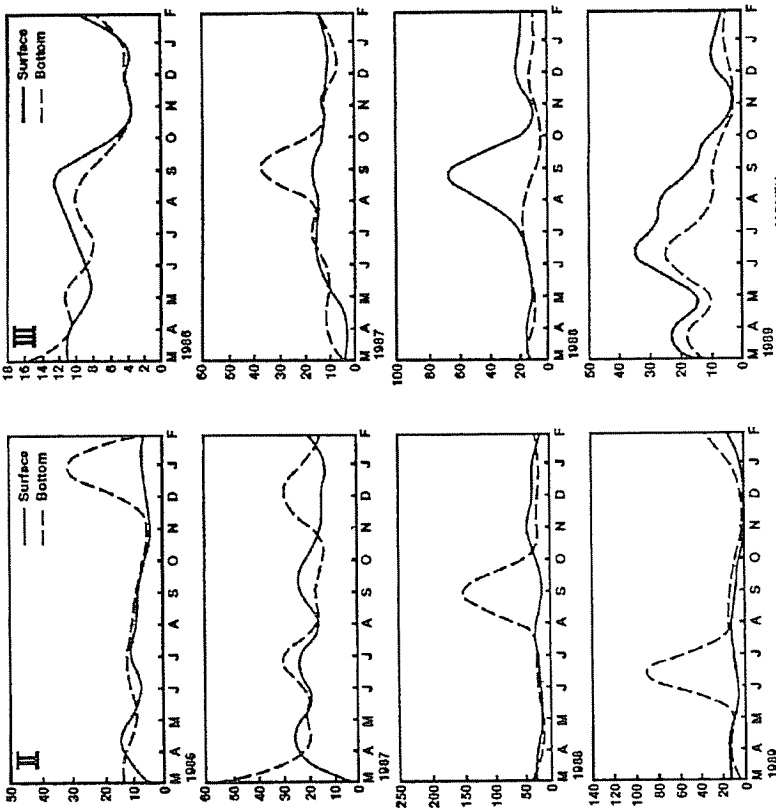

FIGURE 2. Mean monthly concentrations of phytoplankton above and below the pycnocline for all stations within each site group between 1986 and 1989 (Site Group I includes station TF 5.5, Site Group II stations TF 3.3, RET 4.1, RET 5.2 and Site Group III contains stations RET 3.1 and RET 4.3). Values are in number of cells/l x10^6.

(July), before decreasing into winter, when another increase took place in January. There were modest peaks (10^7 cells/L) in 1987 during spring (April), summer (July), and fall (September), before declining in winter. Another early spring development began in January, leading to modest pulses (10^7 cells/L) in 1988 during spring, summer and fall. In 1989, a spring (April) pulse and an extended summer development occurred before declining into winter. Concentrations below the pycnocline in general followed this pattern, but there were occasions where cell abundance was greater below the pycnocline, e.g. winter (1986, 1987); summer (1987, 1989), and in fall (1988). During these periods, the populations below the pycnocline were usually dominated in abundance by diatoms. There were also distinct differences in the composition of the assemblages above and below the pycnocline during the collections. The floral composition below the pycnocline was mainly composed of neritic and estuarine species common to the Bay, compared to a tidal freshwater-estuarine mixture in the upper strata. These sites had a pattern of spring, summer and fall peaks that were mainly the product of diatoms, dinoflagellates, chlorophyceans and cyanobacteria, which reached concentrations of 10^7 to 10^8 cells/L. Abundance levels were generally higher at the James River Station (RET 5.2) compared to oligo and mesohaline stations in the other two rivers.

III. Mesohaline

The largest concentrations of phytoplankton above the pycnocline for 1986 occurred in spring (April) and summer (August) and were at mean values of 10^7 cells/L. These values were followed by winter lows of 10^6 cells/L. In 1987, cell concentrations were generally low, with a modest increase in cell abundance over the summer to a fall maxima (10^7 cells/L), that remained fairly constant into winter. During 1988, a modest spring development was followed by a maximum of 10^7 cells/L in fall (September), then a smaller pulse in winter (December). The abundance pattern in 1989 had several distinct maxima (10^7 cells/L). These occurred in spring (March), summer (June) and winter (December). The winter-spring and late fall assemblages were dominated by diatoms, with diatoms, dinoflagellates, cyanobacteria, cryptomonads and euglenoids common dominants during summer and early fall. Many of the same species were abundant above and below the pycnocline, with a tendency for greater concentrations of diatoms below the pycnocline, but more phytoplankton above the pycnocline. The abundance of cells were generally less below the pycnocline, but seasonal maxima also occurred at these lower depths during spring, summer and fall. The dominant species at these stations were consistently estuarine and neritic species common to the Chesapeake Bay (Marshall and Lacouture, 1986). The freshwater cyanobacteria, chlorophyceans and diatoms were present, but in low concentrations and more common in the surface waters than below the pycnocline.

Picoplankton

Concentrations of autotrophic cells over a 12 month period at station TF 5.5 in the James River are given in Figure 3. In addition to the phytoplankton cells described above the picoplankton represent a major autotrophic component of the local estuaries (Ray et al., 1989). Cell abundance was greatest during summer (June) followed by another pulse in fall (10^8 to 10^9 cells/L), with lowest concentra-

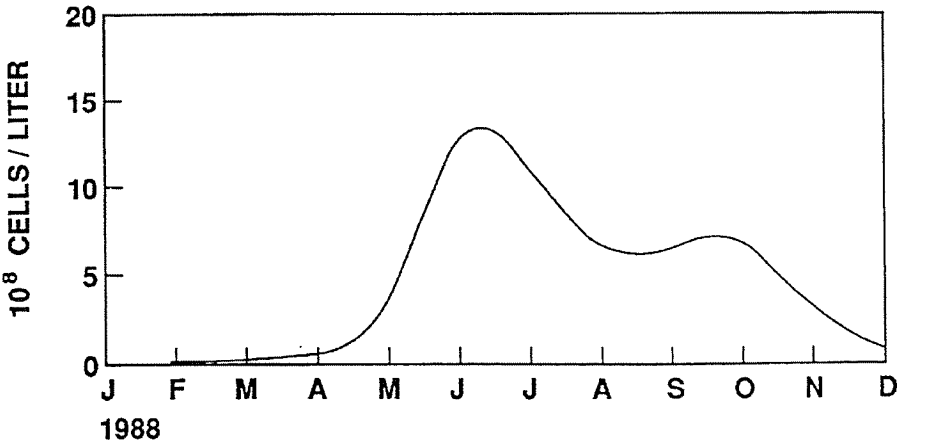

FIGURE 3. Picoplankton cell concentrations at station TF 5.5 for 1988.

tions in winter. The major component within this group was cyanobacteria, with other autotrophs being chlorophytes and several unidentified forms. Measurements of picoplankton abundance were also made at stations in the lower Chesapeake Bay during this period and indicated a pronounced single summer-early fall peak, with maximum concentrations in July (Birdsong et al. 1989).

CONCLUSIONS

This study of the seasonal and inter-annual variation in phytoplankton abundance at stations in the James, York and Rappahannock Rivers was based on the previous identification of three site groups in these rivers. Within the groups there was a tendency to have major periods of growth in spring, summer, or fall, with the lowest concentrations in winter. The tidal fresh water station (TF 5.5) in the James River had typically higher cell densities (10^7 to 10^8 cells/L) than what developed in the oligo-mesohaline and mesohaline stations, with seasonal maxima seldom coinciding with those in the higher saline sections of the rivers. This is explainable on the basis of different growth responses in the regional sections of the rivers by two different sets of dominant species that were present. One is composed of fresh water species, the other has dominant estuarine and neritic species. There were also major differences in the magnitude, onset, and duration of major seasonal growth periods from year to year. Seasonal differences were associated with different sections in the same river, with concentrations and composition of the phytoplankton having distinct changes in composition and abundance during passage downstream. The transition from a dominant fresh water flora to estuarine assemblages was often rapid and accompanied by decreasing cell abundance and a pattern of reduced nutrient levels (Marshall and Alden, 1990a).

It should be stressed these patterns represent a total composite of different phytoplankton components. These abundance numbers come from several major and diverse phytoplankton categories that separately exhibit seasonal patterns of change and different periods of representation. Diatoms generally have spring and late summer-early fall peaks of abundance, cyanobacteria and picoplankton are

most abundant in summer, with the chlorophytes in early spring and summer, etc. In turn, there is also great variability in the times of maxima and minima exhibited by the individual taxa within these categories (Marshall and Alden, 1990a). In addition, results of the picoplankton analysis indicated major development occurred during summer and early fall where mean concentrations reached 10^8 to 10^9 cells/L. Factors that influence the development of these various seasonal maxima are the spring rains, nutrient replenishment, temperature changes, salt water entry, stratification and mixing events, among others (Anderson, 1986; Filardo and Dunstan, 1985; Malone, 1987; Ray et al., 1989). In addition, these rivers represent seasonally dynamic habitats, with each river having a river basin and watershed that contain a unique combination and sequence of interacting seasonal conditions. These factors may change annually, and subsequently influence the type and abundance of phytoplankton that develop in these rivers. Common phytoplankton assemblages to each rivers system may be exposed to different environmental conditions that may result in periods and magnitude of population abundance that will differ not only seasonally, but annually from each other.

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