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Seasonal Abundance of Autotrophic Picoplankton in the Pagan River, a Nutrient Enriched Subestuary of the James River, Virginia

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ABSTRACT

Autotrophic picoplankton had average monthly concentrations of 73.5×10^6 cells/L in the Pagan River, with summer-early fall maxima of 10^8 cells/L. The abundance peaks increased with rising water temperatures, declining to their least abundance in mid-winter (10^5 cells/L).

INTRODUCTION

Picoplankton represent a ubiquitous component and major producer within marine and freshwater ecosystems (Johnson and Sieburth, 1979; Waterbury et al., 1979). They are represented by heterotrophic and autotrophic cells that by definition are 0.2-2.0 microns in size (Sieburth et al., 1978). Stockner and Anita (1986) have identified picoplankton cell concentrations in the North Atlantic as increasing progressively from oceanic, slope, and coastal waters, at 10^6 , 10^7 , and 10^8 cells/L respectively. The associated development of picoplankton with increased water temperature has been indicated by Waterbury et al. (1979), El Hag and Fogg (1986) and others. They are described as an essential food source for the microzooplankton and an important linkage within the trophic network regarding carbon production and its utilization within various marine and freshwater habitats (Pomeroy, 1974; Stockner, 1988; Laval-Pluto et al., 1986).

Picoplankton were first recognized as an important productivity component in Chesapeake Bay by McCarthy et al. (1974) and Van Valkenburg and Flemer (1974). Ray et al. (1989) also found these cells abundant in a Chesapeake Bay estuary and that in summer, they represented 7% of the autotrophic biomass. Marshall and Nesius (1993) noted summer maxima of autotrophic picoplankton as 10^8 to 10^9 cells/L in the James, York, and Rappahannock Rivers, in which these periods of high cell abundance were associated with increased productivity. Affronti and Marshall (1993; 1994) reported cell concentrations in the southern Chesapeake Bay ranged from a winter low of 7.2×10^6 to 9.2×10^8 cells/L in summer. These cells were composed of mainly cyanobacteria, with chlorophytes present in lower concentrations. In another Chesapeake Bay study, Marshall (1995) indicated summer maxima reached 10^9 cells/L and these were dominated by cyanobacteria.

The Pagan River is a shallow tidal estuary of the James River, 16.9 km in length, that bisects the town of Smithfield, Virginia. It is a shallow and well mixed estuary having no detectable pycnocline, with tidal amplitude and salinity decreasing upstream. Smithfield has a population of approximately 4,800, and is the location of meat-packing plants which together slaughter and process approximately 4.6 million

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hogs annually (The Times, 1991). It has been reported, that processing this many hogs has resulted in 9.5×10^6 liters of nitrogen and phosphorus enriched waste water being discharged into the Pagan River daily (VWCB, 1990). In a corresponding phytoplankton study in the Pagan River, Seaborn (1994) has reported high nutrient concentrations were present throughout the year, with total nitrogen and total phosphorus annual means of 1.8 and 0.8 mg/L respectively. The meat-packing companies are beginning the process of joining the Hampton Roads Sanitation District (HRSD) sewage system. This action is designed to eliminate this point source of nutrients to the Pagan River. Since higher concentrations of autotrophic picoplankton are generally associated with increased nutrient levels (Fogg, 1986), the major objective of this study is to establish the present baseline distribution and abundance pattern of autotrophic picoplankton in the Pagan River during this period of high nutrient concentrations. This information may then be used for comparative purposes regarding these cell concentrations after nutrients entering the Pagan River from the meat packing plants are reduced.

METHODS

Monthly water collections were taken at 3 stations in the Pagan River from October 1992 through September 1994, and seasonally in Cypress Creek, a tributary of the Pagan River (Figure 1). Water was collected at each station from the upper meter of the water column using a 1 liter Kemmerer bottle. Replicate 125 ml sub-samples were then taken and preserved immediately with glutaraldehyde (1% final concentration), placed in an ice chest, and then stored in a refrigerator prior to analysis.

Within 10 days after collection, 1-4 ml (based on cell density) of the sub-samples were filtered using a Millipore apparatus on a 0.2 micron Nuclepore filter previously stained with Irgalan black and backed with a separate 0.45 micron filter, at a vacuum pressure of 10 cm of Hg. The Nuclepore filter was examined using a Zeiss Axioskop epifluorescence microscope equipped with a 100 watt mercury bulb and a green filter set (G546, FT580, LP590). The picoplankton that fluoresced red or orange were counted as autotrophic cells (Davis and Sieburth, 1982). Twenty random fields and a minimum of 300 cells were counted at 1000x magnification using an oil immersion objective (100x/1.30). Counts of the replicate samples were averaged for the representative concentrations. The ranges and mean values for the water quality parameters of the river stations are given in Table 1. Water quality information on total nitrogen (TN), total phosphorus (TP), and silicon were obtained from the Virginia Department of Environmental Quality and represent average values between February 1988 and September 1994. This information was not available for the Cypress Creek station. Salinity, temperature, and dissolved oxygen readings were determined at each station during the collection period using a Hydrolab Surveyor II unit, in addition to determining secchi depths.

RESULTS AND DISCUSSION

The mean salinity for stations in the Pagan River decreased upstream from 9.99 to 4.46 ppt, with a maximum reading of 19.5 ppt at Station 1 (Table 1). The mean salinity in Cypress Creek was 5.3 ppt. TP and TN levels both increased upstream,

PICOPLANKTON IN THE PAGAN RIVER

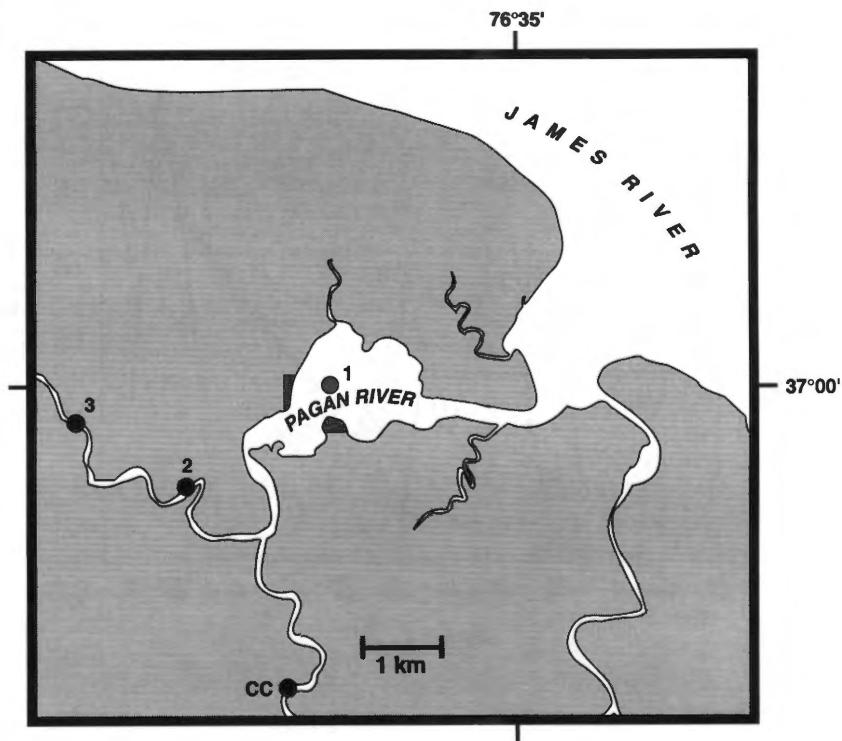


FIGURE 1. Station locations in the Pagan River and Cypress Creek (CC).

TABLE 1. Mean water quality measurements, and Secchi depth ranges for stations in the Pagan River and Cypress Creek.

Parameter	Station 1	Station 2	Station 3	Cypress Creek
TP mg/L	0.3	0.85	0.9	--
TN mg/L	0.8	1.8	2.25	--
O ₂ mg/L	9.54	9.16	9.29	9.69
Salinity, ppt	9.99	6.01	4.46	5.33
Si mg/L	5.1	5.25	5.0	--
Secchi m	0.2-0.8	0.4-0.6	0.2-0.6	0.2-0.8

and consistently were high throughout the river. The station ranges for TP and TN were 0.3-0.9 and 0.8-2.25 mg/L respectively. These ranges are higher than 5 year mean values (1985-1990) for James River stations located upstream from the Pagan River and at the mouth of the James River (Marshall and Nesius, 1993). In the James River upstream to the mouth of the Pagan, TP and TN means were 0.10 and 0.69 mg/L respectively; while at the mouth of the James River they were 0.06 and 0.55 mg/L for TP and TN. Although these records are for a different time period, they

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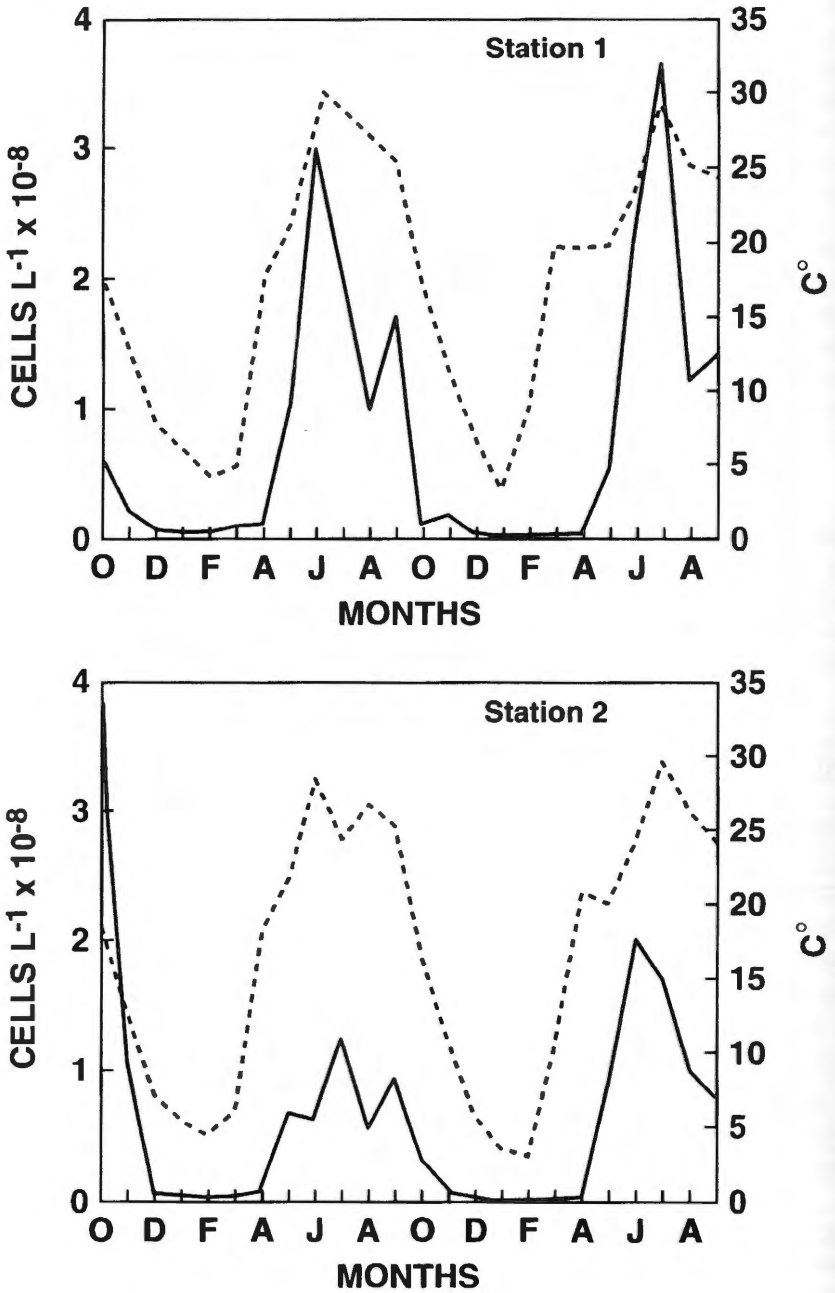


FIGURE 2. Autotrophic picoplankton concentrations (—) and temperatures (- - -) between October 1992 and September 1994 at stations 1 and 2 in the Pagan River.

PICOPLANKTON IN THE PAGAN RIVER

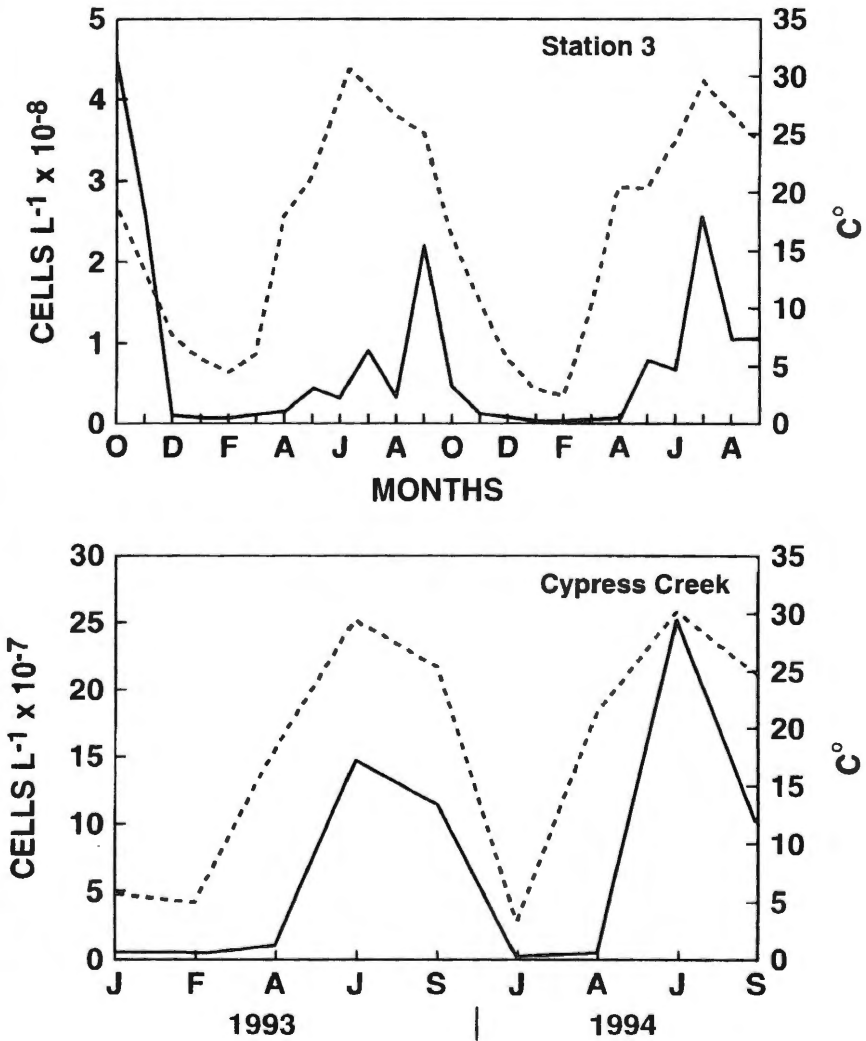


FIGURE 3. Autotrophic picoplankton concentrations (—) and temperatures (---) between October 1992 and September 1994 at station 3 in the Pagan River, and between January 1993 and September 1994

indicate that higher TP and TN concentrations characterize the Pagan River in comparison to the James River. The mean silicon values (5.0-5.25 mg/L) and oxygen levels (9.16-9.54 mg/L) for the Pagan stations were very similar. However, there were occasions each summer when oxygen concentrations at stations 2 and 3 dropped to 3-4 mg/L. There were low secchi depth readings that ranged from 0.2 to 0.8 m.

TABLE 2. Monthly mean cell concentrations ($\times 10^6/L$) from all Pagan River stations from October 1992 through September 1994.

J	F	M	A	M	J	J	A	S	O	N	D
2.5	2.3	4.4	6.6	71.6	148.6	201.4	84.5	134.7	163.5	56.4	5.6

The autotrophic picoplankton consisted of mainly single cell cyanobacteria. The baseline picoplankton concentrations from winter into mid-spring (December-April) were between 2.3 and 6.0 $\times 10^6$ cells/L. Cell concentrations then increased to summer-early fall maxima that persisted into September during 1993 and 1994 (Figures 2, 3). There was a remnant of a more extended development into fall with the October samples taken in 1992. Highest cell concentrations occurred during this month at stations 2 and 3, when numbers reached 3.8 and 4.5 $\times 10^8$ cells/L respectively. The summer picoplankton development in 1993 and 1994 was similar at stations 1 and 2, lagging the increase in water temperature by about one month. The highest concentrations within the Pagan River occurred in June and July, then decreased into August, before rising to another pulse in September. In contrast, at the upstream and less saline station 3, there was less development in June, with later pulses in September (1993) and July (1994). The Cypress Creek station gave a unimodal seasonal pattern, with cell maxima occurring in July of 1993 and 1994 (Figure 3). These maxima averaged 198.3 $\times 10^6$ cells/L compared to the monthly mean concentrations 148.6 and 201.4 $\times 10^6$ cells/L in July and August for the stations in the Pagan River (Table 2). Cell abundance declined in November and into winter at all stations. Lowest concentrations occurred throughout the river and in Cypress Creek in January 1994, with water temperatures between 2.8 and 3.4 $^{\circ}C$, and cell counts at 0.55 to 0.85 $\times 10^6$ cells/L. The mean monthly concentrations for the Pagan River over this two year sampling period was 73.5 $\times 10^6$ cells/L. These cell concentrations and summer maxima are comparable to those found in the Chesapeake Bay and regional rivers (Marshall, 1995; Marshall and Nesius, 1993). Although these patterns were closely linked to temperature changes in the water column, a variety of water quality variables would be expected to also influence the development of these cells (e.g. light, nutrients, predation, residency time, etc., Waterbury et al., 1979) and are not addressed here.

In conclusion, the Pagan River has an abundant and ubiquitous autotrophic picoplankton component within its water column. The concentrations in the Bay and regional tributaries are generally similar to those found in the present study. There did not appear to be a more extended, or a considerably greater development of the autotrophic picoplankton populations in the Pagan River than in the Chesapeake Bay and its tributaries.

The peak population levels which occurred in summer and early fall are comparable to concentrations that are common for other regional estuarine waters. Lower cell densities at other times in the Pagan River coincided with conditions that did not favor greater picoplankton development, e.g. reduced water temperatures. The high

concentrations of TN and TP in the river did not produce cell densities greater than those found in the Chesapeake Bay and its tributaries that have lower concentrations of these nutrients. Although there may be a potential for a greater level of picoplankton abundance in the Pagan River, higher concentrations were not attained during this study period. Environmental factors that would influence this growth potential in the Pagan River would require further study.

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