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Phytoplankton Productivity in the Tidal Regions of four Chesapeake Bay (U.S.A.) Tributaries

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ABSTRACT

Monthly and annual phytoplankton productivity rates of four Virginia tidal rivers were determined based on a 12-year monitoring study that included sampling stations from tidal freshwater, oligohaline, and mesohaline regions in these rivers. The mean monthly rates and range at these locations were 5.52 (Dec.) to 175.12 (Aug.) mg C m^{-3} h^{-1} for tidal freshwater, 12.21 (Jan.) to 149.90 (May) mg C m^{-3} h^{-1} in oligohaline regions, and 16.20 (Jan.) to 151.33 (May) mg C m^{-3} h^{-1} for the mesohaline. The estimated mean annual 12 year productivity for the different Virginia river sites in this study ranged from 49 g C m^{-2} yr^{-1} to 230 g C m^{-2} yr^{-1}. The dominant phytoplankton during periods of high productivity included a changing seasonal dominance of flora among the different salinity regions. At least one station from each river experienced a significant decrease in productivity rates during the 12 years of this analysis. In comparison to an earlier segment of this study, the results indicate the value of long term monitoring to more accurately characterize the productivity dynamics in estuarine locations.

INTRODUCTION

The four rivers in this study are tidal tributaries of the Chesapeake Bay drainage basin in Virginia, with tidal ranges ca. <0.5-1.0 m. These are the James, Pamunkey, York, and Rappahannock rivers, with the Pamunkey representing one of two smaller rivers forming the York (Fig. 1). The James, York, and Rappahannock rivers flow southeasterly through predominantly forest, crop-land, and pasture prior to entering Chesapeake Bay. Each river is included in the Chesapeake Bay Phytoplankton Monitoring Program, with emphasis placed on phytoplankton composition, abundance, and productivity measurements. Several previous reports associated with this program have described phytoplankton composition and abundance in these rivers (Marshall and Alden 1990; Marshall and Burchardt 1998, 2003, 2004, 2005; Marshall and Nesius 1993). These studies identified a diverse and generally similar phytoplankton flora within these rivers, with freshwater diatoms, chlorophytes, and cyanobacteria the dominant flora upstream, yielding in dominance and abundance to a more varied estuarine population of diatoms, dinoflagellates, and cryptophytes downstream. Seasonal variations also exist in productivity contributions among the phytoplankton categories, with diatoms the predominant component and contributor to productivity in spring, and the autotrophic picoplankton among other phytoplankton groups as the major contributors during the summer and early autumn (Marshall and Nesius 1993). Characteristic phytoplankton assemblages were discussed by Marshall et al. (2006) regarding salinity regions and water quality parameters in the Chesapeake Bay

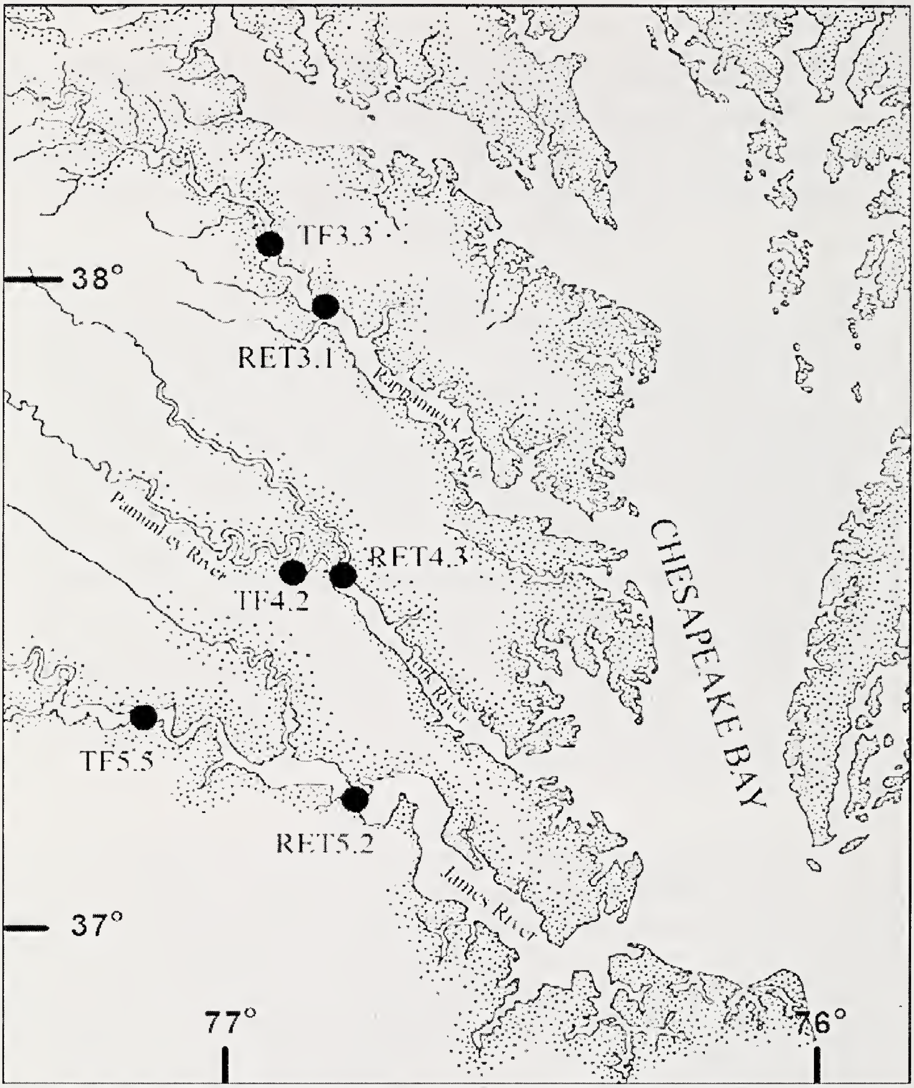

FIGURE 1. Lower Chesapeake Bay indicating location of monitoring stations in the Rappahannock, York, Pamunkey, and James Rivers.

estuarine system. These and other factors that have been associated with productivity in these rivers include long term trends of increasing total suspended solids, decreasing concentrations of total nitrogen and dissolved inorganic nitrogen, plus increasing trends in total phosphorus and dissolved inorganic phosphorus (Marshall and Nesius 1998; Marshall et al. 2002). Although diatoms remain the dominant flora within these rivers, there is evidence for increased abundance of cyanobacteria, plus concern regarding the frequent dinoflagellate blooms occurring in the lower reaches of these rivers (Marshall et al. 2002).

The major objective of this study is to provide a 12-year (1989-2001) synopsis of phytoplankton productivity within the tidal freshwater, oligohaline, and mesohaline regions of four river basins in southeastern Virginia. The rivers are the James, York, Pamunkey, and the Rappahannock. Additional relationships to phytoplankton composition and several water quality parameters during this period are also discussed.

METHODS

Field and laboratory methods

Monthly productivity measurements were taken from stations in tidal freshwater (<0.5 ppt), oligohaline (0.5-5.0 ppt), and mesohaline (>5.0-18.0 ppt) regions of these rivers from July 1989 through June 2001 (Fig. 1). The tidal freshwater stations were located in the Pamunkey (TF4.2) and James (TF5.5) rivers. The oligohaline stations were in the Rappahannock (TF3.3) and James (RET5.2) rivers, with the mesohaline stations in the Rappahannock (RET3.1) and York (RET4.3). Although the Rappahannock River TF3.3 station has long been given the classification (TF), a designation for tidal freshwater, salinity readings over this time period indicated salinity intrusion was common and that it was more appropriately considered an oligohaline site in this study (Marshall and Burchardt 2003).

Two sets of 3 L water samples were taken over a vertical series of 5 depths at each station between the surface and pycnocline and placed in two separate carboys as 15 L composites (Marshall and Nesius 1993). Immediately after mixing, 2-1 L water samples are taken from each of the two carboys and stored in an ice cooler in the dark for transportation to the laboratory. In the absence of a pycnocline the series of water samples were collected from the surface to the lower depth of the photic zone as determined by Secchi depth readings. In the laboratory, after gentle mixing, two 100 mL aliquots were taken from each 1 L sample for productivity analysis, with another 100 mL aliquot having a 15 mL sub-sample filtered immediately for time zero ^{14}C-incorporation. For productivity the sub-samples were placed in 250 mL acid washed dilution bottles, inoculated with 5 µCi $NaH^{14}CO_3$ (specific activity 50-58 µCi µmole^{-1}), and incubated 2-3 hours under saturated light conditions. The time zero ^{14}C incorporation sample was filtered immediately after inoculation with 5 µCi $NaH^{14}CO_3$. Water temperatures in the incubator were the same as when the samples were collected. After incubation, 15 mL sub-samples from each dilution bottle were filtered through 0.45 µm Millipore filters, fumed over concentrated HCl under a vacuum of less than 5 cm Hg pressure and placed in a scintillation vial containing 7 mL scintillation fluid. The ^{14}C-activity was determined using a Beckman LS1701 liquid scintillation counter. Alkalinity was determined from station samples to calculate available inorganic carbon present. Carbon fixation rates (mg C m^{-3} h^{-1}) were determined according to Strickland and Parsons (1972).

From the same 15 L carboys two additional 500 mL and 125 mL samples were obtained. One set (500 mL samples) was processed for phytoplankton analysis using a modified Utermöhl method (Marshall and Alden 1990). The other sub-set (125 mL samples) was examined by epifluorescence microscopy to determine autotrophic picoplankton abundance (Marshall 1995). During these collections, or within a 3-day window of opportunity, water samples were collected and analyzed by the Virginia Department of Environmental Quality (VDEQ) and the Old Dominion University Department of Chemistry for determining the water quality parameters. These include

TABLE 1. Mean Secchi depth, total suspended solids (TSS), total nitrogen (TN), total phosphorus (TP), and surface temperatures (Temp.) for July 1989 to June 2001. A practical salinity scale was used to determine salinity regions: Tidal fresh (TF) stations (<0.5 ppt) are TF5.5 and TF4.2; Oligohaline (Olig.) stations (0.5-5.0 ppt) RET5.2 and TF3.3; Mesohaline (Mes.) stations (>5.0-18 ppt) RET 3.1 and RET4.3 (1989-2001).

Stations	Secchi (m)	TSS (mgL^{-1})	TN (mgL^{-1})	TP (mgL^{-1})	Temp. (°C)
James River					
TF5.5 (TF)	0.53	28.8	1.10	0.100	19.0
RET5.2 (Olig)	0.45	39.7	0.85	0.097	18.3
York/Pamunkey					
TF4.2 (TF)	0.70	16.5	0.71	0.063	18.2
RET4.3 (Mes)	0.50	36.5	0.77	0.098	17.7
Rappahannock					
TF3.3 (Olig)	0.43	38.9	0.89	0.098	18.3
RET3.1 (Mes)	0.42	46.6	0.86	0.090	17.8

total nitrogen (TN), total phosphorus (TP), and total suspended solids (TSS), which are referred to in this study. Secchi depth, water temperature, and salinity measurements were determined on station during plankton collections. The US Geological Survey (USGS) records were the basis of annual river discharge periods in this region.

Data analysis

Average yearly productivity rates were compared between stations using ANOVA and the REGWF post hoc analysis (SPSS for Windows 14.0). To test for a long term trend from 1989 to 2001 and still account for seasonal variability, the data was divided into 3-month seasonal averages (e.g. the spring months as March, April, and May, with summer, autumn, and winter following respectively each in subsequent 3-month segments). A Pearson Correlation analysis was performed for each station between the seasonal productivity averages and years to test the significance of long term trends.

RESULTS

Station relationships

The mean station Secchi depths ranged from 0.53 m to 0.70 m in tidal freshwater (TF), and from 0.42 m to 0.50 m at the oligohaline (Olig) and mesohaline (Mes) stations (Table 1). Seasonally, low Secchi depths and high total suspended solids (TSS) were common during spring which included months of increased precipitation and river flow. In general, average Secchi depths decreased and the TSS increased moving down stream from the tidal freshwater stations. There were generally similar annual mean surface water temperatures at each river station and when comparing the three salinity regions. These were 18.2 & 19.0, 18.0 & 18.3, and 17.7 & 17.8 °C respectively for stations classified in the tidal fresh, oligohaline, and mesohaline regions.

The mean annual TN and TP concentrations for these river segments ranged from 0.71 to 1.10 mg L^{-1} for TN, and 0.063 to 0.100 mg L^{-1} for TP (Table 1). The mean TN and TP levels were greater at tidal freshwater stations in the James R. and Rappahannock R. and decreased downstream. In contrast, TN and TP were lower at

TABLE 2. Annual range and averages of river productivity rates from stations from 1989-2001. Tidal freshwater (TF), Oligohaline (Olig). Mesohaline (Mes).

		Range of annual productivity (mg C m^{-3} h^{-1})	Average annual productivity (mg C m^{-3} h^{-1})
Rappahannock River			
TF3.3	(Olig)	38.51-87.33	64.68
RET3.1	(Mes)	28.20-95.66	62.42
Average			63.55
York River			
TF4.2	(TF)	8.93-37.06	19.65
RET4.3	(Mes)	27.58-78.55	52.19
Average			35.92
James River			
TF5.5	(TF)	43.75-132.97	89.70
RET5.2	(Olig)	37.20-172.93	76.79
Average			83.24

the tidal freshwater station (TF4.2) in the Pamunkey R. compared to the downstream mesohaline station (RET4.3) in the York R. The mean TN and TP levels in the Pamunkey R. (TF4.2) were the lowest of the six river stations. In the Rappahannock the oligohaline and mesohaline regions showed little change in TN, TP, and Secchi readings, with TSS increasing downstream. Seasonally, greater nutrient concentrations were associated with winter/spring months and spring rains, however, rainfall and river flow varied annually. The periods of reduced river discharge (dry years) occurred in 1991, 1995, 1999, and 2001, in contrast to years of increased river discharge (wet years) of 1993, 1994, 1996 and 1998 (USGS). Marshall and Burchardt (2003, 2004) reported seasonal changes of phytoplankton development within these rivers were associated with the onset and duration of these wet and dry periods. These relationships included community abundance, a changing community structure, and a seasonal expression of dominant taxa during the year.

Seasonal productivity

The yearly range and 12 year averages of the productivity rates and mean annual productivity at the 6 stations in these rivers are given in Table 2. There were significant differences ($p<0.05$) between stations in yearly average productivity (Fig. 2). The Pamunkey R. TF4.2 had the lowest average productivity of 19.65 mg C m^{-3} h^{1}, while the James R. TF5.5 had the highest average of 89.70 mg C m^{-3} h^{1}. Closer similarity in productivity occurred in the oligohaline sites with a broader range of high productivity extending from mid-spring to mid-autumn. These were 64.68 and 76.79 mg C m^{-3} h^{-1} at stations in the Rappahannock R. (TF3.3) and James R. (RET5.2). In the

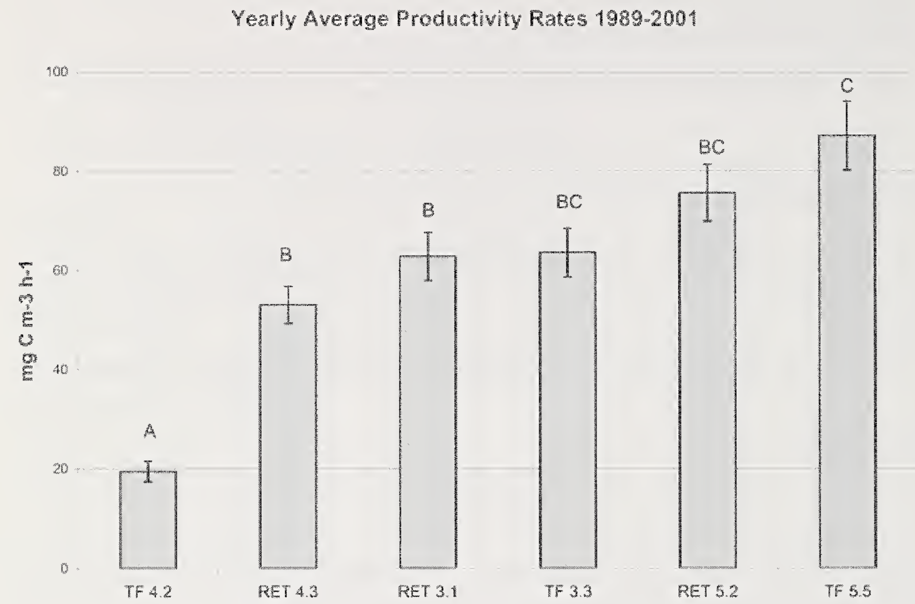

FIGURE 2. Average yearly primary productivity (mg C m^{-3} h^{-1}) of six tributary stations 1989-01. Results of ANOVA post hoc REGWF test identified by letters A-C. Stations in significantly different (α <0.05) groups identified by different letters.

mesohaline, the average yearly productivity rates for the Rappahannock R. (RET3.1) and York R. (RET4.3) were 62.42 and 52.19 mg C m^{-3} h^{-1} respectively. Monthly productivity rates increased from winter into spring and summer; then declined during autumn into winter (Figs. 3-5).

These river patterns showed mean productivity decreased slightly downstream in the James R. and Rappahannock R., but increased from the Pamunkey to the York R. Decreasing productivity was associated with increased total suspended solids and lower Secchi depths moving from the tidal freshwater to mesohaline regions. These conditions and productivity levels were likely influenced by the degree of river flow and subsequent entry of nutrients, light availability, and suspended solids carried in these waters. Such variability in flow and its influence on productivity would be expected, and this influence is generally recognized in long-term studies. For instance, compared to what is considered normal flow years (4), there were 4 years of high and 4 years of low river discharge interspaced during the 12 years of this study.

Monthly productivity

The mean monthly productivity rates at each of these stations are given in Figs. 3-5. Although these varied, the lowest productivity occurred during winter, with increased productivity often beginning in late winter, and continuing to reach highest levels during spring, summer, or early autumn. The mean monthly productivity among the stations seasonally varied over a wide range of values. In the James R. these were from 9.03 to 175.12 mg C m^{-3} h^{-1} at TF 5.5 for January and July, and 16.28 to 133.58 mg C

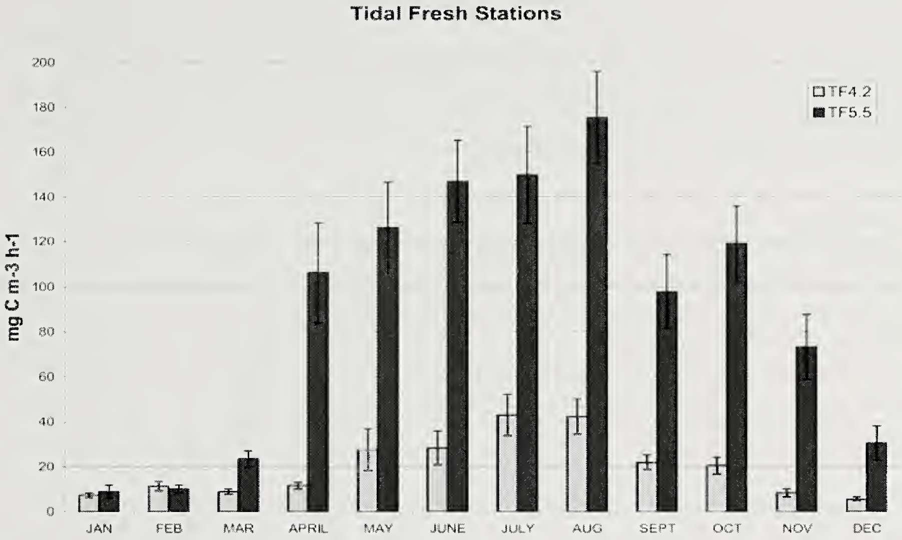

FIGURE 3. Average monthly productivity (mg C m^{-3} h^{-1}) for tidal freshwater stations 1989-2001, (Pamunkey River station TF4.2, and James River station TF5.5).

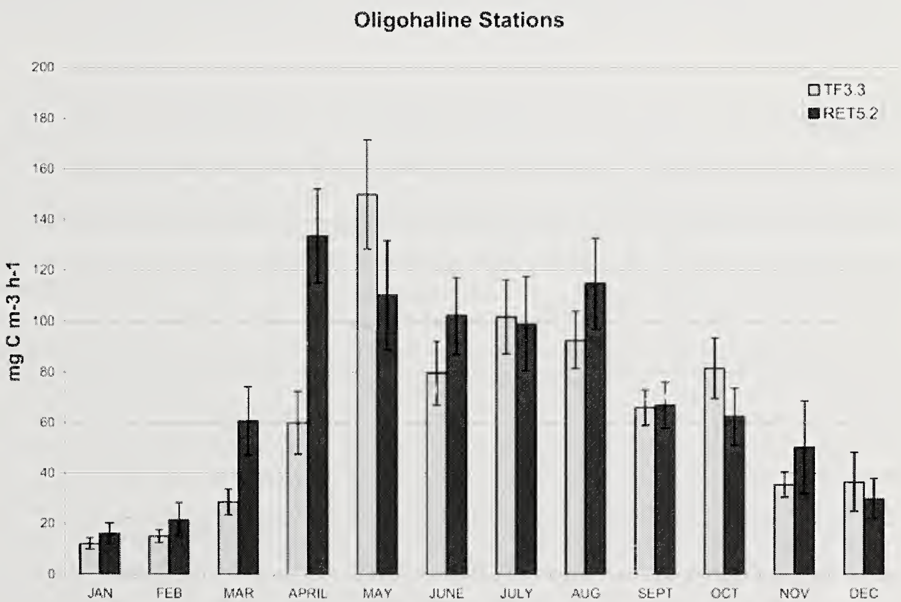

FIGURE 4. Average monthly productivity (mg C m^{-3} h^{-1}) for oligohaline stations 1989-2001, (Rappahannock River station TF3.3, and James River station RET5.2).

$m^{-3} h^{-1}$ at RET 5.2 for January and April. The Pamunkey/York R. monthly productivity means were from 5.52 to 42.94 mg C $m^{-3} h^{-1}$ at TF 4.2, for December and July, and 16.26 to 94.73 mg C $m^{-3} h^{-1}$ for January and March at RET 4.3. The greatest range in monthly means occurred between January and May at both stations in the Rappahannock R., with rates from 12.21 to 149.90 mg C $m^{-3} h^{-1}$ at TF 3.3, and from 19.92 to 151.33 mg C $m^{-3} h^{-1}$ at RET 3.1.

Annual productivity

Subsequent conversion of the productivity rates to estimates of total annual production indicates a range from the least productive site in the Pamunkey R. (TF4.2) at ca. 49 g C $m^{-2} yr^{-1}$, and the highest in the James R. (TF5.5), at ca. 230 g C $m^{-2} yr^{-1}$. The annual production varied from ca. 159 to 190 g C $m^{-2} yr^{-1}$ for the oligohaline and 126 to 153 g C $m^{-2} yr^{-1}$ in mesohaline waters. Results from the initial 2 year segment of this study were reported by Marshall and Nesius (1993) and which also included stations bordering the Chesapeake Bay. When comparing these 2 year productivity means to the 12 year averages at similar stations they show both comparable and widely different rates. Similar values of least productivity occurred in the Pamunkey R., with highest productivity in the James R. However, mean production varied from 298.9 to 190 g C $m^{-2} yr^{-1}$ at RET5.2 (James R.), and 109.2 to 153 g C $m^{-2} yr^{-1}$ at RET3.1 (Rappahannock R.), for the earlier and present study respectively. More consistent was the productivity at the Pamunkey R. station TF4.2, with the rates of 44.7 and 49 g C $m^{-2} yr^{-1}$ in comparison. These results over the longer period of analysis produced a more representative appraisal of productivity in these rivers compared to the shorter period (1-2 yrs) of study.

Trends

Over the 12 year period of this study (1989-2001), significant long term decreasing trends were present at four of the six stations, occurring in spring, summer, and autumn, with none during winter (Table 3). In spring, these were at the tidal fresh Pamunkey R. station (TF4.2) and the oligohaline site of the James R. (RET5.2). However, productivity had the largest reduction in terms of degree and number of stations affected during the summer season. These occurred in both tidal fresh (TF4.2) and mesohaline (RET4.3) sites in the Pamunkey/York R. series, and the oligohaline stations in the Rappahannock R. (TF3.3) and James R. (RET5.2). The two decreasing trends in autumn were in the tidal fresh Pamunkey R. (TF4.2) and the mesohaline York R. (RET4.3). No trends were noted at the tidal fresh station in the James R. (TF5.5), or at the Rappahannock R. mesohaline station (RET3.1). Although not significant at $\alpha = 0.05$ level, stations TF5.5 and RET4.3 had increasing long term trends during winter, and these represented the only increasing trends in productivity for the period analyzed. Using the combined seasonal data set, the tidal fresh station in the Pamunkey (TF4.2) and the oligohaline stations in the Rappahannock (TF3.3) and James (RET5.2) rivers had significant annual trends which indicated decreasing productivity. The largest number of seasonal decreasing productivity trends occurred in this fresh station in the Pamunkey R. and the oligohaline station in the James R. These decreasing trends were accompanied by mean Secchi readings of generally < 1 m, and increasing TSS downstream.

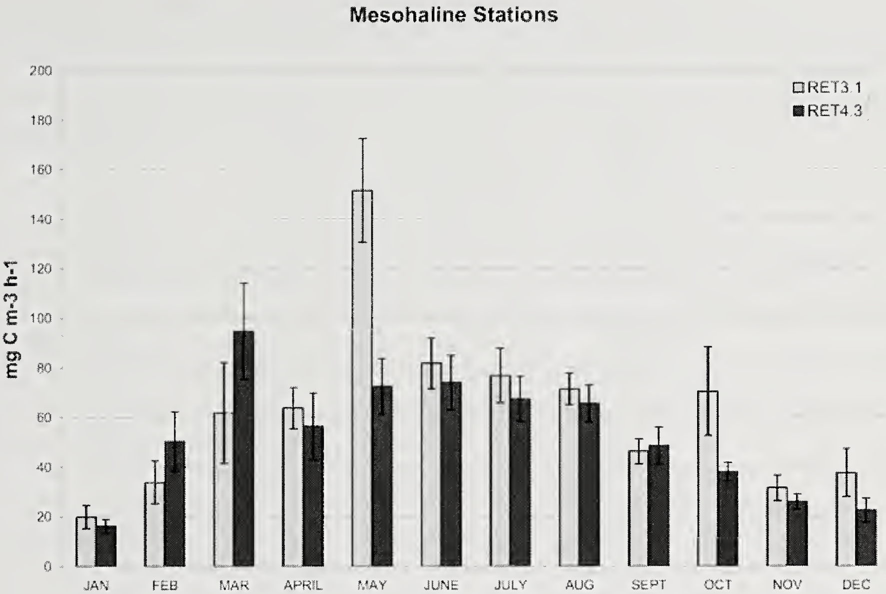

FIGURE 5. Average monthly productivity (mg C m^{-3} h^{-1}) for mesohaline stations 1989-2001, (Rappahannock River station RET3.1, and James River station RET4.3).

Associated phytoplankton

Peak algal productivity occurred from mid-spring to early autumn, and coincided with the periods of maximum phytoplankton abundance. The river stations contained a diverse representation of taxa characterized by seasonal succession patterns and a changing species assemblage, with other algae ubiquitous throughout the year. These transitions begin with the spring bloom of diatoms, followed by a summer assortment of diatoms, cyanobacteria, and chlorophytes. In tidal freshwater the dominant diatoms were *Skeletonema potamos* (Weber) Hasle, *Asterionella formosa* Hass., *Aulacoseira granulata* (Her.) Sim., *Cyclotella meneghiniana* Kütz., *Cyclotella striata* (Kütz) Grun., and a variety of small pennates. A diverse composition of cyanobacteria (e.g. *Microcystis aeruginosa, Chroococcus* spp., *Merismopedia* spp.), chlorophytes (*Ankistrodesmus falcatus*, *Scenedesmus* spp.), and cryptophytes (*Cryptomonas erosa*) were also present. In addition to these taxa the oligohaline and mesohaline regions contained an increase in abundance of estuarine diatoms that included *Skeletonema costatum* (Greville) Cleve, *Cerataulina pelagica* (Cleve) Hendy, *Leptocylindrus minimus* Gran, *Thalassionema nitzschioides* (Grun.) Grun., and several *Cyclotella* spp. Dinoflagellates were more common downstream in late spring, including high concentrations of *Prorocentrum minimum* (Pavillard) Schiller, *Heterocapsa triquetra* (Ehr.) Stein, and *Heterocapsa rotundata* (Lohmann) Hansen. The most ubiquitous components throughout the year were autotrophic picoplankton. They represented a major contributor to the summer productivity maximum in each river (Marshall and Nesius 1998), and were composed predominantly of isolated or colonial cyanobacteria,

TABLE 3. Results of Pearson Correlation analysis comparing seasonal productivity rates for years 1989-2001. Slope indicates direction (negative denotes decreasing) and amplitude of trend. Significant trends indicated by bold font.

Spring (n=36)

	Station	Slope	R^2	Significance
Tidal Fresh	TF4.2	-2.40	0.135	**0.028**
	TF5.5	-6.27	0.073	0.112
Oligohaline	TF3.3	-2.80	0.016	0.460
	RET5.2	-6.95	0.098	**0.039**
Mesohaline	RET3.1	-2.41	0.011	0.541
	RET4.3	-2.07	0.014	0.491

Summer (n=36)

	Station	Slope	R^2	Significance
Tidal Fresh	TF4.2	-3.70	0.150	**0.020**
	TF5.5	-6.82	0.086	0.082
Oligohaline	TF3.3	-6.18	0.176	**0.011**
	RET5.2	-14.70	0.588	**0.000**
Mesohaline	RET3.1	-3.48	0.107	0.052
	RET4.3	-6.02	0.342	**0.000**

Autumn (n=36)

	Station	Slope	R^2	Significance
Tidal Fresh	TF4.2	-1.34	0.115	**0.043**
	TF5.5	-1.06	0.003	0.737
Oligohaline	TF3.3	-1.06	0.009	0.588
	RET5.2	-9.70	0.404	**0.000**
Mesohaline	RET3.1	-1.41	0.011	0.550
	RET4.3	-2.21	0.115	**0.044**

Winter (n=36)

	Station	Slope	R^2	Significance
Tidal Fresh	TF4.2	-0.56	0.103	0.056
	TF5.5	1.81	0.104	0.054
Oligohaline	TF3.3	-0.84	0.010	0.562
	RET5.2	-1.16	0.024	0.368
Mesohaline	RET3.1	-1.59	0.029	0.331
	RET4.3	2.76	0.084	0.087

Yearly (n=144)

	Station	Slope	R^2	Significance
Tidal Fresh	TF4.2	-0.0056	0.0869	**0.000**
	TF5.5	-0.0091	0.0193	0.064
Oligohaline	TF3.3	-0.0075	0.026	**0.041**
	RET5.2	-0.0223	0.1723	**0.000**
Mesohaline	RET3.1	-0.0057	0.0157	0.143
	RET4.3	-0.0049	0.019	0.140

Bold= Significance at < 0.05 level

in addition to lesser numbers of eukaryotes. Their development and contribution to total production in these rivers increased during periods of reduced river flow and greater residency time associated with late summer and early autumn (Marshall and Burchardt 1998). A diverse phytoplankton assemblage characterized the summer and autumn flora, with major representation by diatoms, cyanobacteria, chlorophytes, dinoflagellates, and cryptophytes. The lower concentrations during winter were mainly dominated by diatoms, which continued to increase into the spring diatom bloom

(Marshall and Burchardt 2003, 2004). The primary algal biomass and carbon producers in these rivers were diatoms throughout the year, with a variety of eukaryote and prokaryote taxa in abundance and composition. These changing and diverse populations were collectively responsible for often variable monthly productivity levels that occurred within these waters.

DISCUSSION

Phytoplankton productivity within river systems is known to vary seasonally and inter-annually (e.g. Admiraal et al. 1994; Cole and Cloern 1984, 1987; Dokulil 1994; Malone 1976; Joint and Pomeroy 1981; Peterson and Festa 1984). The productivity and species composition will also be influenced by a variety of conditions including differences associated with light availability, nutrient concentrations, residency time and degree of river flow, among combinations with other factors (Peterson et al. 1985; Jassby et al. 2002; Lehman 1992, 2000; Sellers and Bukaveckas 2003). The common pattern in temperate regions is for lower productivity during winter, with increased productivity associated with spring, summer and autumn. The estimated mean annual 12 year productivity for the different Virginia river sites in this study ranged from 49 g C m^{-2} yr^{-1} to 230 g C m^{-2} yr^{-1}. In comparison, Boynton et al. (1982) reviewed the primary production at 43 estuarine sites (North Carolina, USA) and reported a mean value of 190 g C m^{-2} yr^{-1}. Further regional comparisons from North Carolina in the Neuse River include a 4-year study by Boyer et al. (1993), with productivity ranging from 395 to 493 g C m^{-2} yr^{-1}. In a 2-year study in the lower River Spree (Germany), Köhler (1995) indicated station rates of 310-358 g C m^{-2} yr^{-1}, whereas, Jassby et al. (2002) in a 9 year monthly study for the Sacromento-San Joaquin River (California) gave an annual production range of 39-131 g C m^{-2} yr^{-1} and a mean of 70 g C m^{-2} yr^{-1}. They also noted seasonal differences and stress the importance of extended studies for obtaining a more accurate appraisal of annual productivity within aquatic systems. For example, the seasonal productivity in the Loire River estuary (France) was given by Relexans et al. (1988) as between <0.1 to 1.6-7.3 g C m^{-2} day^{-1} for winter and summer months respectively. A wide productivity range would also be expected with different site locations within an estuary as was noted from 32 North Carolina estuarine locations with rates that ranged from 16 to 153 g C m^{-2} y^{-1} (Thayer 1971). In their study of the Neuse River (North Carolina) Mallin and Paerl (1992) stress the influence of seasonal and daily mixing patterns within a river's water column (river flow, tidal periods, etc.) that would effect turnover conditions, light attenuation and re-suspension of substances and their influence to algal productivity. In another study of a Chesapeake Bay tributary, Stross and Stottlmyer (1966) sampled stations in the Patuxent River (Maryland, USA), and reported primary productivity between 384.8 to 647.2 g C m^{-2} yr^{-1}. In another comparison, the Gun Powder River (Maryland, USA) had a range of 3.1 to 142.4 mg C m^{-3} h^{-1} (Sellner 1983), whereas, Köhler (1995) reported a mean 2-year value of ca. 58.6 mg C m^{-3} h^{-1} in the River Spree (Germany). The Virginia river stations had annual mean values that ranged from 19.6 to 89.70 mg C m^{-3} h^{-1} (Table 2).

Compared to other river and estuarine locations, the productivity results from the Virginia rivers were generally comparable, but not grossly higher, or characteristic of increased eutrophic status. However, these results were applicable to this 12 year period, and with future single year, or more extended periods of study (and changes in trophic status) the productivity may likely vary in degree and possibly direction. For example, this long-term data base included years of variable rainfall within the individual watersheds and subsequent flow within these rivers. These events and accompanying conditions will vary in future years, but continue to influence the structure of the phytoplankton composition and their productivity in these rivers. Although intrinsic differences were present within each watershed and tidal sections of these rivers, the general seasonal expression of phytoplankton development and productivity followed similar developmental patterns for the region. The results also indicated the value of long-term monitoring studies to more accurately characterize specific productivity dynamics in these estuarine habitats.

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This study was supported by the Virginia Department of Environmental Quality (VDEQ) and the U.S. Environmental Protection Agency as a component of the Chesapeake Bay Monitoring Program. Special appreciation is extended to VDEQ and Dr. John Donat of the Old Dominion University Chemistry and Biochemistry Department for providing results of the water quality analysis during this period, in addition to the numerous graduate student assistants who participated in these collections and analyses. The productivity and phytoplankton analyses were conducted by Drs. Nesius and Marshall respectively, with Todd Egerton contributing the statistical analysis.

LITERATURE CITED

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Stormwater Influence on Phytoplankton Composition and Dynamics in Lake Joyce, Virginia

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ABSTRACT

A three year study of Lake Joyce, Virginia revealed relationships between the timing, duration, and amount of stormwater runoff and phytoplankton abundance and composition. Major phytoplankton taxa were identified and cyanophytes dominanted during periods of decreased rainwater input and increased lake water retention times. Increased freshwater input was associated with the growth of a diverse assemblage of both chlorophytes and diatoms. Phytoplankton dynamics as a result of significant rain events (i.e., hurricanes Floyd and Irene, 1999) were documented and specific taxa involved in nuisance algal blooms were identified.

INTRODUCTION

Lake Joyce, located in Virginia Beach, Virginia (36° 54' 44" Lat., 76° 7' 19" Long.) is a 60.7 hectare freshwater lake with an average depth of 1.1meters. Lake overflow empties to the lower Chesapeake Bay via Pleasure House Creek and the Lynnhaven River. Because the lake is surrounded by residential housing, a major nutrient nonpoint source results from urban stormwater runoff (United States Environmental Protection Agency 1983). Local changes in the seasonal periods of precipitation will influence the amount of this surface runoff that will enter Lake Joyce. The lake is an unstratified, hyper-eutrophic system with reports of nuisance algal blooms documented since 1978 (Roger K. Everton, Virginia Department of Environmental Quality, Tidewater Region, personal communication). While once a water reservoir for the City of Norfolk, Virginia, its current use is now recreational and includes boating, fishing and water skiing.

The objectives of this study were: 1) identify phytoplankton composition and abundance within Lake Joyce, and 2) compare phytoplankton population dynamics to precipitation data over the three year study period.

METHODS

Three replicate surface grab samples (125 milliliters (ml)) were collected weekly from a pier in Lake Joyce over a 36 month period (May 4, 1999 to May 20, 2002). All samples were preserved with buffered glutaraldehyde to yield a final concentration of 2% (American Public Health Association 1998). Phytoplankton abundance was determined using the mean cell concentrations from two replicate samples and mean autotrophic picoplankton abundance from all three replicate samples. Five to ten ml subsamples were drawn on to a 0.2 micrometer (μm) Nucleopore filter stained in Irgalan Black using a mechanical pump at pressures less than 10 centimeters (cm) of Hg to prevent cell rupture. A Zeiss Axiolab Microscope equipped with a 50 watt mercury bulb and a Zeiss 450–490 excitation filter, 510 dichromatic mirror and 520 barrier filter and Zeiss 546 excitation filter, FT580 dichromatic mirror and 590 barrier filter were used to identify the autotrophic picoplankton, colonial cyanoprokaryotes and the presence of dominant nanoplankton and microplankton forms (at 1000X). Identification of dominant nanoplankton and microplankton species was verified using light and phase contrast microscopy (at 400X). For consistency, autotrophic picoplankton abundance was measured using the Zeiss 450-490 excitation filter set. For each replicate sample, four randomly chosen fields were examined for the representative nanoplankton, microplankton and autotrophic picoplankton components (Affronti and Duquette, 2002). A full filter scan was performed to identify other non dominant phytoplankton species present in the sample. A one way Model I ANOVA was performed on total phytoplankton abundance data with year as a treatment (1st year – May 4, 1999 to May 1, 2000, 2nd year – May 8, 2000 to May 7, 2001 and 3rd year – May 14, 2001 to May 20, 2002) to determine if there were significant differences in phytoplankton abundance. Average phytoplankton abundance was compared to weekly precipitation data (National Oceanic and Atmospheric Administration/National Climatic Data Center 1999-2002).

RESULTS

Average total phytoplankton and autotrophic picoplankton abundance over the three year period is shown in Figure 1. Cell abundance ranged from 3.70×10^7 to 7.75×10^9 cells per Liter (L) with onset growth occurring in late spring and early summer. Seasonal maximum abundance varied the three years with numbers generally decreasing into winter. Results of the one way Model I ANOVA indicated total phytoplankton abundance was affected by year ($P<0.0001$). Tukey's *a posteriori* tests verified all pair- wise comparisons of abundance by year were significantly different (1st and 2nd years; $P<0.05$, 1st and 3rd years: $P<0.05$, 2nd and 3rd years; $P<0.05$). Phytoplankton abundance for the second year was less than the first and third years of the study where an extended and greater growth period was observed from May 14, 2001 to May 20, 2002 (Figure 1).

Throughout the study, Lake Joyce flora consisted primarily of cyanophytes, chlorophytes and diatoms. Cyanophytes dominated total phytoplankton abundance and ranged from 0.00 to 7.71×10^9 cells L^{-1}. Peak abundance occurred in late summer to early autumn and often associated with bloom events (Figure 2). Three dominant cyanophyte groups were observed. These included filamentous forms (*Anabaena* sp. and *Lyngbya* sp.) colonial taxa that included the temporarily identified *Aphanocapsa holsatica* (Affronti and Duquette 2002) as described by Komárek and Anagnostidisk (2000), plus *Gloeocapsa* sp., *Gomphosphaeria* sp., and *Merismopedia* sp. Unicellular forms included *Synechococcus* sp. and individual cells of *Aphanocapsa holsatica*, both of which dominated the autotrophic picoplankton component which ranged from1.98 $\times 10^6$ to 2.14×10^8 cells L^{-1}.

Chlorophytes were the most diverse phytoplankton group observed and ranged in abundance from 3.16×10^6 to 6.06×10^8 cells L^{-1}. Growth periods varied over the study with peak abundance occurring in late autumn and an increase in numbers beginning each spring (Figure 2). Representative forms were *Ankistrodesmus* sp., *Closterium* sp., *Cosmarium* sp., *Crucigenia rectangularis*, *Crucigenia tetrapedia*, *Desmidium* sp., *Kirchneriella* sp., *Oocystis* sp., *Pediastrum duplex*, *Pediastrum simplex*, *Quadrigula*

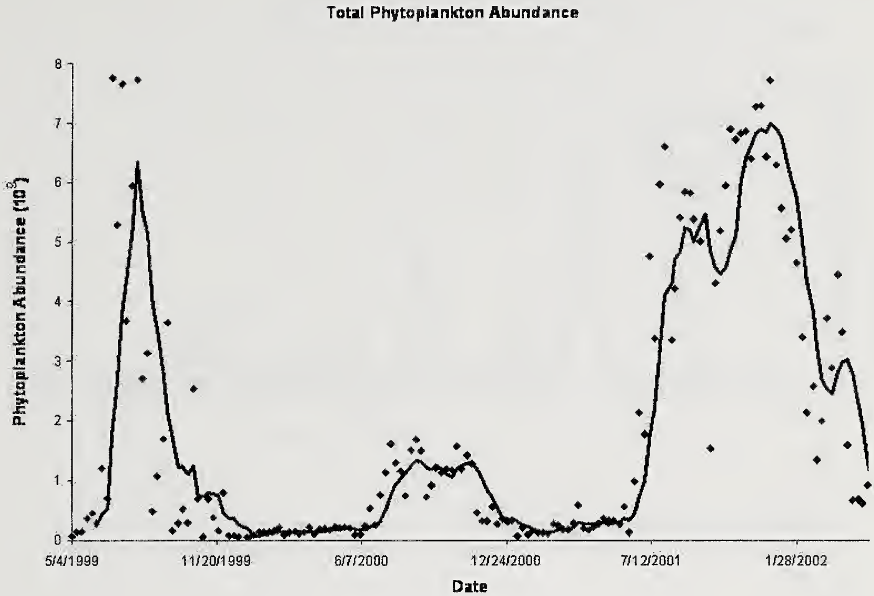

FIGURE 1. Average total phytoplankton abundance from two replicate samples. A moving average best fit line was used to fit data series.

sp., *Scenedesmus alternans*, *Scenedesmus dimorphus*, *Desmodesmus quadricauda*, *Staurastrum* sp., and *Tetraedron* sp.. Unidentified chlorophyte cells <2μm also contributed to autotrophic picoplankton abundance.

The diatoms consisted of centric and pennate forms that included *Asterionella* sp., Cyclotella sp., *Leptocylindricus minimus*, *Navicula* sp., and *Skeletonema potamos*. Increased abundance occurred during early spring and again in late autumn, with reduced concentrations during winter (Figure 2). Diatom abundance varied from 0.00 to 2.69 x 10^7 cells L^{-1}. Additional phytoplankton groups were observed, but did not contribute significantly to overall abundance. These included dinoflagellates (e.g. *Amphidinium* sp., *Ceratium hirundianella*), euglenoids and chrysophytes (*Synura* sp. and *Dinobryon* sp.).

Weekly rainfall for this region ranged from 0.00 to 18.64cm over the three years (Figures 3-5). Precipitation and phytoplankton data were compared for each year. Two significant rain events occurred in September and October 1999 (16.66cm and 18.64cm, respectively) resulting in substantial freshwater input to the lake. Also, there were significant periods (i.e., 12 consecutive weeks from February to May 2000) without rain. Average phytoplankton abundance the first year had a single peak in June/July, then decreased with an increase in precipitation during autumn and remained low into winter and early spring (Figure 3). The opposite was true the second year as maximum precipitation occurred during summer and phytoplankton abundance remained low in summer and during a second rainfall peak the following spring (Figure

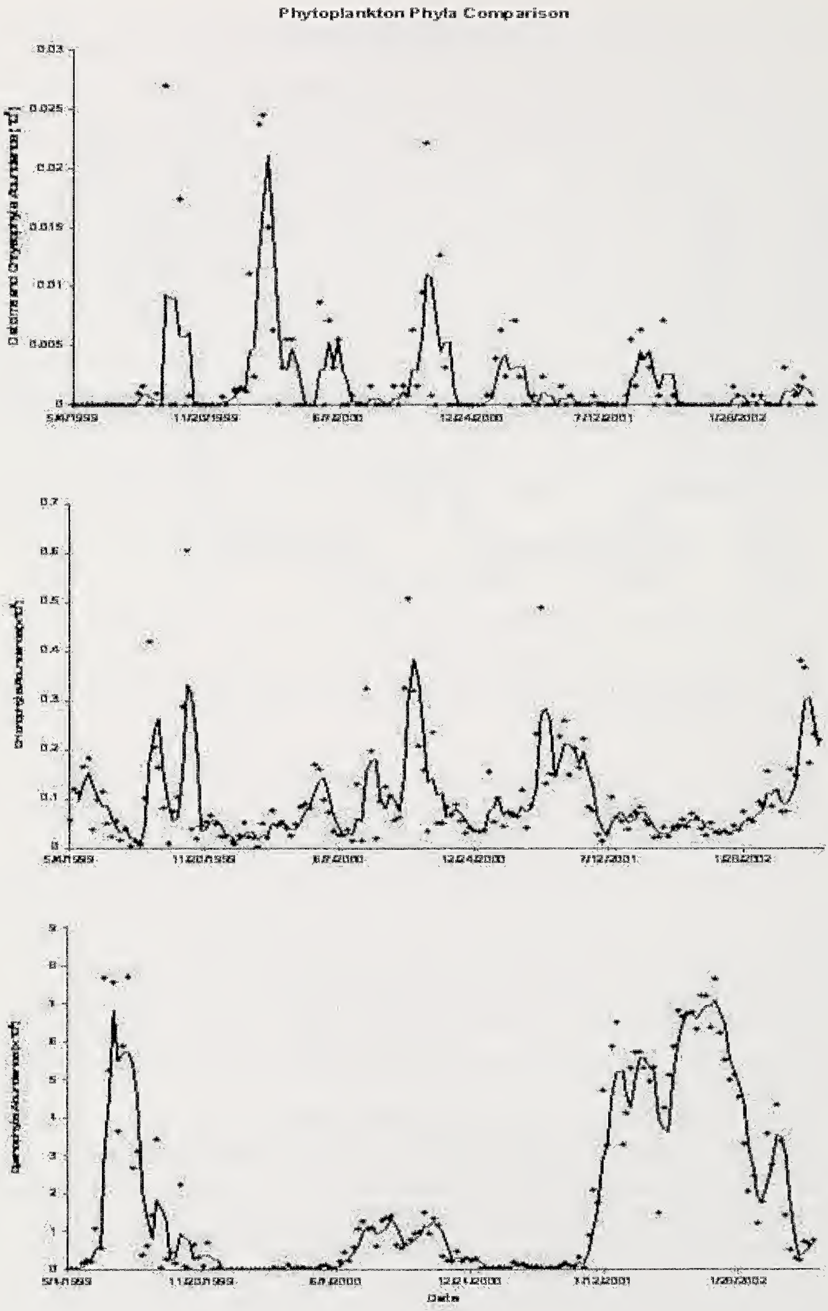

FIGURE 2. Comparison of phytoplankton phyla patterns. Patterns are a result of moving average best fit trend lines of representative data series.

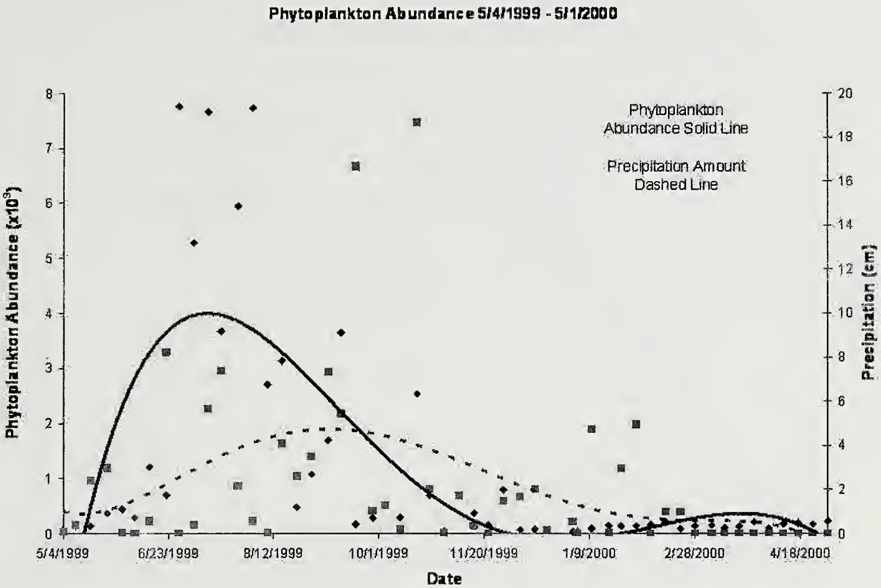

FIGURE 3. Comparison of total phytoplankton abundance (diamond) and precipitation (square) for first year of study. Polynomial best fit lines are used for each data series.

4). The third year of the study was the driest with total precipitation 19.05cm lower than year two, which was the wettest year (118.95cm). Maximum phytoplankton growth occurred during this period of reduced precipitation and surface runoff, and was dominated by *Aphanocapsa holsatica* and *Anabaena* sp. into late autumn.

DISCUSSION

Numerous studies have implicated phytoplankton abundance and diversity being influenced by the complex interaction of many variables that include physical, chemical and environmental factors (Harris 1986; Padisák et al. 1988; Ochs et al. 1995 and Chen et al. 2003). Because a major source of freshwater input to Lake Joyce includes stormwater runoff, rain events also have an important influence on lake dynamics. Timing, duration, and amount of rainwater input for Lake Joyce not only influenced lake depth and nutrient input, but influenced phytoplankton abundance and composition. Total phytoplankton abundance during the second year of the study was significantly lower than years one and three when total rainfall during this period was high. Likewise, the inverse relationship between phytoplankton abundance and rainwater input during autumn of the first year implied periods of increased freshwater input influenced phytoplankton abundance and composition. As a result of rain events, increased flushing rates and simple dilution of organism abundance would be expected. Over 35.3cm of rain as a result of hurricanes Floyd and Irene provided these conditions during September and October of 1999 which decreased phytoplankton abundance.

Timing of freshwater input to Lake Joyce also influenced phytoplankton dynamics. Most rainfall during the first year occurred from late summer into autumn and resulted in a decline of established phytoplankton growth. However, the major rain events

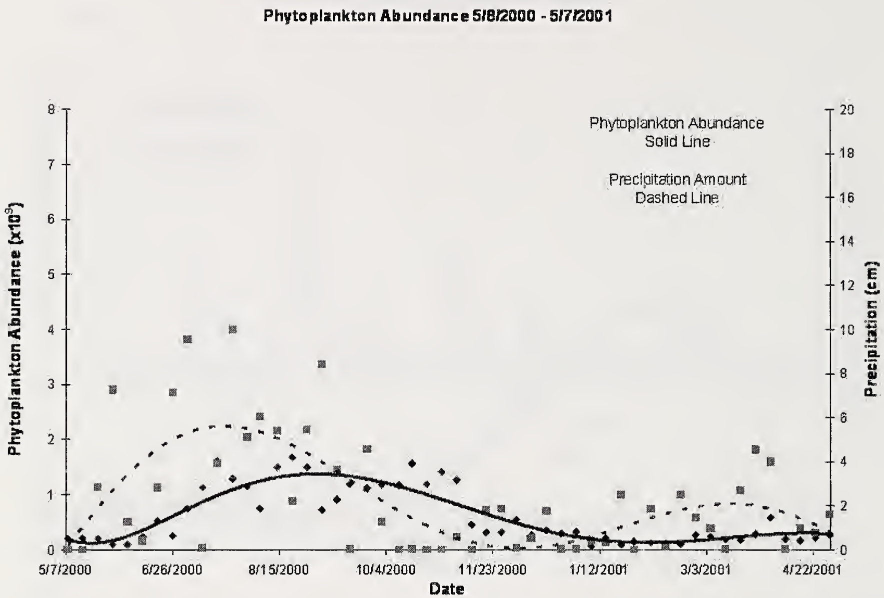

FIGURE 4. Comparison of total phytoplankton abundance (diamond) and precipitation (square) for second year of study. Polynomial best fit lines are used for each data series.

during the second year occurred from late spring into summer where phytoplankton growth responded to this input. Most likely, this response was related to nutrient input which in conjunction with other environmental factors promoted phytoplankton growth (United States Environmental Protection Agency 1983). During periods of reduced precipitation and runoff, residency time within the lake was increased allowing for greater phytoplankton development (Figure 5).

Over the study period, changes in phytoplankton composition were associated with the amount of precipitation. During the second year, high rainfall in late spring resulted in more chlorophyte and diatom growth compared to years one and three where cyanophytes dominated phytoplankton composition. The third year was the driest of the study, with only 99.90cm of rainfall measured. During this year, the lake became stagnant, resulting in increased residency time and favorable conditions for cyanophyte growth. The dominant phytoplankton species during this period were *Aphanocapsa holsatica* and *Anabaena* sp. Both are common forms that thrive in nutrient rich warm waters and have been involved in bloom development (Edson and Jones 1988; Tsujimura and Okubo 2003). Humphries and Lyne (1988) report cyanophytes are able to out-compete other phytoplankton in part because of their increased nutrient uptake kinetics and ability to control cell buoyancy.

Prior to the hurricane events, rainwater input in spring and early summer of 1999 was minimal when phytoplankton composition was dominated by cyanophytes. After the hurricanes and resulting input of a significant amounts of freshwater, cyanophyte abundance decreased and conditions were more favorable for diatom growth, especially during cooler temperatures. The third year followed a similar onset growth of

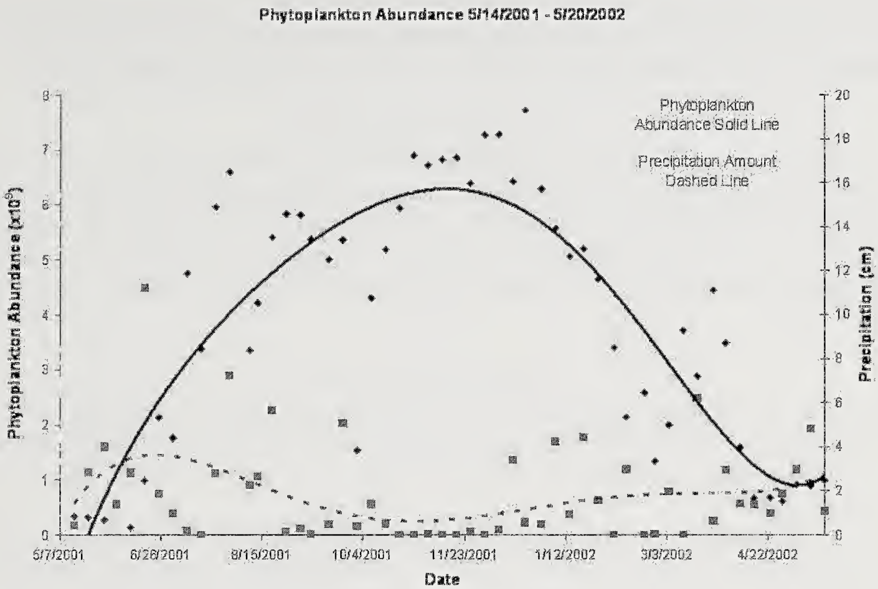

FIGURE 5. Comparison of total phytoplankton abundance (diamond) and precipitation (square) for third year of study. Polynomial best fit lines are used for each data series.

cyanophytes as the first year, but without significant rain events. In this case, cyanophytes continued to thrive and bloom conditions resulted. In a study of urban lakes, reservoirs and ponds, Olding et al. (2000) reported cyanophytes dominating phytoplankton abundance as a result of high water retention times.

The autotrophic picoplankton abundance reported in this study is conservative compared to those values reported by Affronti and Duquette (2002) where a different filter set was used (Zeiss 546 excitation filter). However, the patterns of autotrophic picoplankton abundance are similar and followed precipitaton patterns. In their study, Affronti and Duquette (2002) suggested the composition of autotrophic picoplankton in Lake Joyce was influenced by freshwater input as the colonial cyanophyte, *Aphanocapsa holsatica* disaggregated into individual cells within the picoplankton size range (0.2 – 2.0μm).

CONCLUSION

Lake Joyce is an enclosed natural resource with restricted outflow where rainfall events have a significant impact on lake dynamics. Rainwater is not the only factor influencing phytoplankton growth, but data from this study indicated their abundance and composition were affected by the timing and duration of freshwater input. Similar results were reported by Edson and Jones (1988) in a study of Lake Fairfax, Virginia where differences in stormwater runoff influenced phytoplankton community structure. Phytoplankton composition and abundance was more diverse with increased freshwater input that resulted in lower water retention times and less nuisance bloom conditions.

Because stormwater quality entering the lake is influenced by a variety of sources common in residential areas (i.e. lawn fertilizer, lawn debris, pet waste, sediment erosion), lake water quality can be managed partially by focusing on these sources.

ACKNOWLEDGMENTS

We gladly acknowledge the assistance of Norfolk Academy students who were involved in the many aspects of this study. A special thanks to Dr. H. G. Marshall for his guidance in preparing this manuscript. L. F. Affronti was responsible for sample collections and phytoplankton analysis and B. T. Duquette was involved with data management and analysis. The Science Department at Norfolk Academy supported this research.

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JEFFRESS RESEARCH GRANT AWARDS

The Allocations Committee of the Thomas F. and Kate Miller Jeffress Memorial Trust has announced the award of Jeffress Research Grants to the institutions listed below to support the research of the investigator whose name is given. The Jeffress Trust, established in 1981 under the will of Robert M. Jeffress, a business executive and philanthropist of Richmond, supports research in chemical, medical and other natural sciences through grants to non-profit research and educational institutions in the Commonwealth of Virginia. The Jeffress Research Grants being announced here have been awarded in 2007.

The Jeffress Memorial Trust is administered by Bank of America. Additional information about the program of the Trust may be obtained by writing to: Richard B. Brandt, Ph.D., Advisor, Thomas F. and Kate Miller Jeffress Memorial Trust, Bank of America, Mail Code VA2-300-12-99, P. 0. Box 26688, Richmond, VA 2326 1-6688. An unofficial website is listed under Grants and Awards, www.vacadsci.org.

Antonio Abbate, Virginia Commonwealth University/Medical College of Virginia. Cardioprotective Effects of the Interleukin-1 Receptor Antagonist in Acute Myocardial Infarction. $25,000. (one year).

Seth A. M. Aubin, The College of William and Mary. Fermion Interferometry. $25,000. (one year).

Ancha Baranova, George Mason University. Melanin Biosynthesis in Adipocytes: Crosstalk Between Energy Balance and Pigmentation Control. $10,000. (one year renewal).

Ian Bartol, Old Dominion University Research Foundation. Locomotive Role of Fins in the Brief Squid *Lolliguncula brevis*. $20,000. (one year).

Jill C. Bettinger, Virginia Commonwealth University/Medical College of Virginia. Role of Altering Synaptic Transmission in the Development of Acute Tolerance to Ethanol. $10,000. (one year renewal).

Linda Boland, University of Richmond. Fatty Acid Modulation of Kv4 Potassium Channels. $25,000. (one year).

George M. Brooke, IV, Virginia Military Institute. Real-Time In-Situ Characterization of Trace Compounds and Aerosols using Cavity Ring-Down Spectroscopy. $10,000. (one year renewal).

Joshua Burk, College of William and Mary. Posterior Parietal Cortical Acetyicholine and Attention. $10,000. (one year renewal).

Jason J. Chruma, University of Virginia. Employing Solvophobic Effects Toward the Synthesis of Bioactive Biaryl and Diarylether Macrocycles. $10,000. (one year renewal).

Daniela Cimini, Virginia Polytechnic Institute and State University. Live Cell Analysis of Chromosome Instability in Colorectal Cancer Cells. $10,000. (one year renewal).

Mark A. Cline, Radford University. Effects of Amylin on Ingestion and Ingestive-Related Process in Two-Lines of Chickens: One Containing Anorexic and the Other Obese Individuals. $10,000. (one year renewal).

Linda Columbus, University of Virginia. Determining the Structure and Molecular Determinants of Membrane Protein Interactions Involved in Bacterial Pathogenesis using NMR and EPR Spectroscopy. $20,000. (one year).

Benjamin Corl, Virginia Polytechnic Institute and State University. Bovine Scd: Characterizing an Ortholog of Human Scd5, A Novel Stearoyl-CoA Desaturase Expressed in Brain. $25,000. (one year).

Robin D. Couch, George Mason University. Elucidating the Structural Basis of HMGCoA Reduction in Lovastatin Derivitives. $24,000. (one year).

Daniel N. Cox, George Mason University. Dissecting Class-Specific Dendrite Morphogenesis via Laser Capture Microdissection with TranscriptionalExpression Profiling. $22,000. (one year).

Rafael Davalos, Virginia Polytechnic Institute and State University. Quantitative Evaluation of Micro-Electroporation. $20,000. (one year).

C. Wade Downey, University of Richmond. The Development of New Stereo-Selective Intra Molecular Pericyclic Reactions. $10,000. (one year renewal).

Malgorzata Dukat, Virginia Commonwealth University/Medical College of Virginia. Novel Approaches to Pain Management. $10,000. (one year renewal).

Jeffrey L. Dupree, Virginia Commonwealth University/Medical College of Virginia. The Role of Sulfatide in Regulating Oligodendrocyte Population and Maturation. $10,000. (one year renewal).

Sarah H. Elsea, Virginia Commonwealth University/Medical College of Virginia. Investigating the Role of TomlL2 in Immune Response and Susceptibility to Infection. $25,000. (one year).

Alev Erisir, University of Virginia. Afferent-target Relations in Developing Visual Cortex: Recovery from Deprivation. $10,000. (one year renewal).

Joshua Erlich, College of William and Mary. Hadrons, Strings, and Cosmology. $10,000. (one year renewal).

Mirela S. Fetea, University of Richmond. Dynamic Symmetries in Nuclei. $10,000. (one year renewal).

James A. Foster, Randolph-Macon College. A Focused Proteomic Approach to Identify Novel Sperm a Surface Adhesion Proteins and Receptors for the Egg Zona Pellucida. $20,000. (one year).

Laura F. Galloway, University of Virginia. Evolution at the Edge: The Role of Genetic Variation in the North American Invasion by the Japanese Honeysuckle *(Lonicerajaponica)*. $26,492. (one year).

Phillip M. Gerk, Virginia Commonwealth University/Medical College of Virginia. Acute Effects of Oxidative Stress on Placental ABC Transporters. $10,000. (one year renewal).

Siddhartha S. Ghosh, Virginia Commonwealth University/Medical College of Virginia. Regulation of Renalase, the Enzyme Modulating Hypertension and Renal Disease. $10,000. (one year renewal).

Glenda Gillaspy, Virginia Polytechnic Institute and State University. The Biochemistry of PHD Fingers. $15,000. (one year).

Daniel Gottlieb, Sweet Briar College. The Role of a Number of Trials in the Acquisition of Conditional Responding. $10,000. (one year renewal).

Lesley H. Greene, Old Dominion University Research Foundation. Elucidating the Key Determinants of Protein Folding and Stability in the Death Domain Superfamily. $22,000. (one year).

Alex Greenwood, Old Dominion University Research Foundation. Forensics Analysis of the Distant Past: Population Genetics of the Woolly Mammoth *(Mammuthusprimigenius)* Using Various Variable Loci. $25,000. (one year).

Heather Griscom, James Madison University. The Effect of Environmental Factors on the Performances of Pure and Hybrid American Chestnut Seedlings. $25,000. (one year).

Gregorio G. Gomez, Virginia Commonwealth University/Medical College of Virginia. Role of Extracellular Adenosine on Immunological Activation of Human Mature Mast Cells. $20,000. (one year).

Georgia Hammond, Radford University. Examining Arsenic Metabolism in Bacterial Communities Present in an Abandoned Arsenic Mine. $20,000. (one year).

April L. Hill, University of Richmond. Development of a "Model Sponge System" to Study the Evolution of Early Animal Body Plans and Sensory Systems. $25,000. (one year).

Robert Humston, Virginia Military Institute. Reconstructing Movement Patterns of Smallmouth Bass *(Micropterus dolomieu)* from Elemental Chemistry of Otoliths. $10,000. (one year renewal).

Carol A. Hurney, James Madison University. Cloning and Expression of *MyoD* and *Myf5* in the Four-Toed Salamander: Insights into Segmentation and Tail Development. $10,000. (one year renewal).

Scott Huxtable, Virginia Polytechnic Institute and State University. Thermal Management Through Understanding and Control of Solid-State Interfacial Thermal Conductance. $10,000. (one year renewal).

Michael Klemba, Virginia Polytechnic Institute and State University. Roles of Aminopeptidase P in Peptide Catabolism in the Human Malaria Parasite *Plasmodium falciparum*. $10,000. (one year renewal).

Scott W. Knight. University of Richmond. The Role of Zinc-Finger Protein in RNA Interference. $10,000. (one year renewal).

Eugene B. Kolomeisky, University of Virginia. Theoretical Aspects of Ground-State Manipulation of Individual Particles. $7,000. (one year renewal).

Joel P. Kuehner, Washington and Lee University. Investigation of Nonresonant Laser-Induced Electrostrictive Gratings for Temperature Measurements in Air at Subatmospheric Pressure. $10,000. (one year renewal).

Buoy K. Kundu, University of Virginia Medical School. *In vivo* FDG-PET Imagining to Evaluate Glucose Uptake, Metabolism and Cardiac Function in a Mouse Model of Myocardial Hypertrophy. $20,000. (one year).

David A. Lanning. Virginia Commonwealth University/Medical College of Virginia. Homeobox Gene Expression in Fetal and Rabbit Wounds. $10,000. (one year renewal).

Chris Lantz, James Madison University. Regulation of Contact Hypersensitivity and Basophil Development in Mice by Interleukin-3 Derived from CD4 Cells. $10,000. (one year renewal).

Jonathan M. Link, Virginia Polytechnic Institute and State University. The LENS Solar Neutrino Detector and Sterile Neutrinos. $20,000. (one year).

Joyce Lloyd, Virginia Commonwealth University/Medical College of Virginia. Roles of ELKF and KLF2 in Embryonic Erythropoiesis and Globin Gene Regulation. $20,000. (one year).

John M. McDowell, Virginia Polytechnic Institute and State University. Functional Conserved Oomycyte Effector Proteins. $20,000. (one year).

Kevin P. C. Minbiole, James Madison University. Amphibian Protection: The Antifungal Effects of Beneficial Bacteria on Salamander Skin. $25,000. (one year).

Jonathan D. Monroe, James Madison University. Subcellular Localization of Nine BetaAmylases from *Arabidiopsis thaliana. $25,000.* (one year).

Isis Mullarky, Virginia Polytechnic Institute and State University. Mechanisms of Immune Evasion by Intracellular *Staphylococcus aureus.* $20,000. (one year).

Anthony V. Nicola, Virginia Commonwealth University/Medical College of Virginia. Cellular Function Required for an Early Stage of Herpesvirus Entry into Host Cells. $10,000. (one year renewal).

Irma Novikova, College of William and Mary. Investigation of All-Optical Resonances for Compact Atomic Clocks using VCSEL-based Laser System. $10,000. (one year renewal).

Konstantinos Orginos, College of William and Mary. Hadron Physics with Lattice QCD. $10,000. (one year renewal).

Kyungwha Park, Virginia Polytechnic Institute and State University. Computational Study of Magnetic Properties of Molecular Nanomagnets Tethered to Gold Surfaces. $10,000. (one year renewal).

Carol Parish, University of Richmond. Potential Anti-Cancer Warhead Drugs: A Theoretical Investigation of the Electronic Nature of Enediyne Cyclization. $10,000. (one year renewal).

K. Kevin Pfister, University of Virginia Medical School. The Interaction of Cytoplasmic Dynein and the Spindle Checkpoint Protein Bub3. $20,000. (one year).

Tara Phelps-Durr, Radford University. Molecular and Genetic Analysis of HIRA Function During *Arabidopsis* Development. $25,244. (one year).

Padma Rajagopalan, Virginia Polytechnic Institute and State University. The Design of Cellular Architectures using Polyelectrolyte Scaffolds. $20,000.

Maria Redlak, Virginia Commonwealth University/Medical College of Virginia. Deoxycholatate-Induced Apoptosis in Gastric Epithelial Cells: HSP7O in Mediation and Prevention. $25,000. (one year).

Hans Robinson, Virginia Polytechnic Institute and State University. Optically Controlled Spin Transport in Semiconductor Nanostructures. $10,000. (one year renewal).

Phillip D. Rubin, George Mason University. Simulation and Code Development for the Daya Bay Neutrino Oscillation Experiment. $25,700. (one year).

Laura Runyon-Janecky, University of Richmond. Characterization of Intracellular Adaptation Genes in the Tsetse Fly Secondary EndosymbiontSodalis *glossinidius*. $10,000. (one year renewal).

Masahiro Sakagami, Virginia Commonwealth University/Medical College of Virginia. Pulmonary Delivery of Gut Secreting Peptides for Appetite Suppression in Rats. $20,000. (one year).

Webster L. Santos, Virginia Polytechnic Institute and State University. Synthesis of Borinic and N-Terminal Borinic Acids as Inhibitors of the Malarial Proteases Facilysin. $20,000. (one year).

Catherine Sarisky, Roanoke College. From Peptide to Protein: Does the Larger Context Matter for Strand Register Development? $20,000. (one year).

Harry D. Schreiber, Virginia Military Institute. Coloring Mechanism in Hydrangea Sepals and Related Flowers. $10,000. (one year renewal.)

Sean T. Scully, James Madison University. Neutrino Constraints on the Origin of UltraHigh Energy Cosmic Rays. $10,000. (one year renewal).

Kyle N. Seifert, James Madison University. The Role of Ssr-2 and Accessary Secretory Genes in the Pathogenesis of a Highly Virulent Lineage of Group B streptococci. $10,000. (one year renewal).

Dana E. Selley, Virginia Commonwealth University/Medical College of Virginia. Investigation of a Novel CB1 Receptor-Interacting Protein. $21,000. (one year).

Leah B. Shaw, The College of William and Mary. Modeling Epidemics Across Space and Through Dynamic Social Networks. $25,000. (one year).

Rita Shiang, Virginia Commonwealth University/Medical College of Virginia. Characterization of Genes Downstream of the Treacher Collins Syndrome Gene, Tcofl. $20,000. (one year).

Matthew S. Siderhurst, Eastern Mennonite University. Identifying Attractants for the Spotted Cucumber Beetle and the Striped Cucumber Beetle from Sprouting/Seedling Host Plants. $25,000. (one year).

Laura Sim-Selley, Virginia Commonwealth University/Medical College of Virginia. Sphingosine-1-Phosphate Receptors: Regulation of a Novel CNS Receptor with Therapeutic Potential. $21,000. (one year).

Ronald B. Smeltz, Virginia Commonwealth University/Medical College of Virginia. Synergy of Inflammation and Interleukin- 15 in Development of Effector Cytotoxic T Cells. $10,000. (one year renewal).

Janet Steven, Sweet Briar College. The Evolution of Hermaphroditic and Unisexual Flowers in *Thalictrum macrostylum:* A Test of Multiple Causal Hypotheses. $10,000. (one year renewal).

Traci Stevens, Randolph-Macon College. Analysis of the Effects of Bcr-Abl Expression in *Drosophila melanogaster.* $10,000. (one year renewal.)

Jennifer Stewart, Virginia Commonwealth University. Biological Activity of CisTerpenones. $10,000. (one year renewal).

David B. Strauss, Virginia Commonwealth University/Medical College of Virginia. Novel Regulation of the Lck Tyrosine Kinase and T Lymphocyte Activation. $20,000. (one year).

John D. Styrsky, Lynchburg College. The Utilization of an Ant-Defended Acacia by an Orb-Weaving Spider: Potential Mechanism and Consequences for an Ant-Acacia Mutualism. $24,817. (one year).

Kam W. Tang, The College of William and Mary-VIMS. Linking Zooplankton Ecology and Microbial Ecology: Experimental Study of Microbial Processes on Copepod Carcasses. $21,000. (one year).

Dorothea Tholl, Virginia Polytechnic Institute and State University. Terpene Volatile Messengers in Plant Roots. $10,000. (one year renewal).

David W. Thompson, The College of William and Mary. Silver Nanowire, Nanorod, and Nanosphere-High Performance Polymer Composites. $10,000. (one year renewal).

Amy L. Throckmorton, Virginia Commonwealth University. Mechanical Cavopulmonary Assist for the Neonatal Single Ventricle Physiology. $30,000. (one year).

James Tokuhisa, Virginia Polytechnic Institute and State University. Potato Tuber Toxins: The Biosynthesis of Steroid Glycoalkaloids in *Solanum chacoense.* $22,000. (one year).

Amy Treonis, University of Richmond. Nematode Community Structure and Trophic Interactions in Agricultural Soil Amended with Cover Crops. $10,000. (one year renewal).

James M. Turbeville, Virginia Commonwealth University. *Ramphogordius sanguineus:*
(Nemerta, Heteroemerta): Phylogeography and Specific Delimitation. $20,000. (one year).

Erich Uffelman, Washington and Lee University. ^{1}H-^{15}N HMBC Spectroscopy of Complexes Relevant to Green Chemistry. $10,000. (one year renewal).

Christopher R. Watts, James Madison University. A Mouse Model for Studying the Role of the Elastin Gene (ELN) in Vocal Fold Development and Structure. $23,500. (one year).

Sandra P. Welch, Virginia Commonwealth University/Medical College of Virginia. Sphingosine-1 Phosphate Receptor Induced Modulation of Endogenous Opioids. $25,000. (one year).

James H. Westwood, Virginia Polytechnic Institute and State University. A Parasitic Plant as a Novel Tool for Studying Mobile mRNA. $10,000. (one year renewal).

Sungsool Wi, Virginia Polytechnic Institute and State University. Membrane-Induced Conformation and Dynamics Study of Antimicrobial Peptide. $10,000. (one year renewal.)

Ping Xu, Virginia Commonwealth University/Medical College of Virginia. Comparative Genome of Virulence Related Genes in Streptococcus. $10,000. (one year renewal).

Hu Yang, Virginia Commonwealth University. A Multifunctional Dendritic Drug Delivery System for Brain-targeted Drug Delivery. $15,300. (one year).

Zhongming Zhao, Virginia Commonwealth University/Medical College of Virginia. Analysis of Genetic Variation in Human CpG Islands. $10,000. (one year renewal).

Kevin Zhou, Virginia Polytechnic Institute and State University. Investigation of a Robust Natural Alpha-glucosidase Inhibitor for Potential Prevention and Treatment of Type-2 Diabetes. *$29,540.* (one year).

Virginia Academy of Science, Executive Committee Meeting
Sunday, November 18, 2007
Science Museum of Virginia
Presiding: Werner Wieland

Call to Order: The meeting was called to order at 9:30 am

Approval of Minutes: There were no minutes to approve.

Local Arrangements Committee:

Dr. Whitney was appointed as the chair of the Local Arrangement Committee of The Annual Meetings of the VAS and VJAS to be held at Hampton University (HU) during May 20 – 23, 2008.
It was decided to have same place for accommodations.
Make arrangement for coffee and other shops to remain open during meeting days.
Executive committee to visit HU on Dec. 18, 2007 and meet at 10:00 am.
Direction to HU , meeting location and parking details to be e-mailed to members
Issue of overhead and LCD projectors were discussed. HU may not have enough LCD projectors for junior academy presentations and schools be requested to bring their own LCD projectors, however, HU can meet the need of projectors for Senior academy presentations.

Officers Report:

President:

For some reason Fall UG Research Meeting was poorly attended. There were only 9 presenters but they were all good projects.
More publicity about this meeting is needed
Getting judges for Fall UG Research Meeting are an issue too.
Responsibilities of President Elect is under review and identify what exactly President-elect is supposed to do

Vice President: Absent

Secretary: Nothing to report

Treasurer: Presented Statement of Cash- General Fund with notes (Appendix-A)*

Executive Officer: Nothing to report

VJAS Director:

Following handouts were distributed and discussed (Appendix-B):

VJAS meeting happenings
Flier, Report and Survey on the Science Career Symposium
Rubric for Judging VJAS written papers for judges
A VAST article (vol. 2, no. 1): Inquiry-based Science through Participation in the VJAS - by Susan Booth and Brendan Doyle

Reported that 5K race was a success. VJAS will receive $6,000 in Jan. 08 from the race proceeds. The funds will be moved around and be used for Virginia Environment Endowment. The next race will be held around same time on Sept. 20, 2008

Old Business:

Future Meetings:

2008 – Hampton University - Confirmed
2009 – VCU - On Track
2010 – JMU – Call Joe and confirm, and to get into some kind of agreement
2011 – Radford University – Figures and no. of rooms needed for the annual meeting to be sent to appropriate university official/ OR possibly host at JMU
2012 – CNU ???

New Business: Salary for Staff

A 3% raise, budgeted towards salary for staff (Executive Officer, VJAS Director and Administrative Assistant), is recommended for approval by the Council as budgeted.

Adjournment:

Meeting adjourned at 10:14 am

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* Handout passed out during the meeting

2007 COUNCIL MEETING
Sunday November 18, 2007
Science Museum of Virginia

Call to Order: The Academy Council Meeting called to order at 10:22 AM

Approval of Minutes: A draft of minutes of 2007/2008 Council meeting held at JMU on Saturday May 26, 2007 was presented for approval. The minutes were approved with the following Corrections:

Annual Meeting Update: 'Jerry Taylor thanked the Academy' should read as 'Jerry Taylor thanked Community College'...

Executive Officer: 'Saturday November 18' should read as 'Sunday November 18'
Committee Reports – under Trust Committee: Take off (1) needs new members
Appendix 1: Take away '??' before Thomas Haas
Appendix 1: Correction in Phone No. of Michael Renfroe, Treasurer (540) 568-6617(W)

Financial Report: Jerry presented the Income/Expense Comparison by Category 1-1-06 through 10-31-07(Appendix-A)* and following were noted:

Lower income from VJAS meeting ~ $30K vs. ~$23K, whereas for VAS the meeting income was higher from $3,761 to $5,247 (~ $1,500). Not much can be controlled regarding this.

Flora Project was paid as moved

Expenses AJAS was higher, need to figure out how to economize. Presently we send Two winners, Two sponsors and Two overseers

Research award under special research for VJAS ~$800 more than previous year

Jerry justified a question on why projected expenses are $14,500 more than previous year

Jerry mentioned about his move from 2nd floor to 3rd floor – with very short notice

Annual Meeting update: Council noted that decline in no. of participants at the annual meeting held at JMU, the reason could be date and Memorial Day weekend. (The numbers in parenthesis indicate the number of registered guests)

For VJAS the nos. are 2001 (1000) to 2005 (587) and 2007 even lower, and

for VAS the nos. are 2001 (342) to 2005 (222) to 2007 (193)

The council is financially okay to host the annual meeting.

For next annual meeting at HU, the days (Tue, Wed, and Thu) would be same as they were 5 years back when HU hosted the meeting last time. On the day of site-visit, Dec. 18, 07 more details including speaker will be available.

Reports: Following reports were presented

Awards: Carolyn Conway

One nomination for fellow has been received

Jerry requested information about Senior Student Presentation Award

Section officers need to work on details

Work on stream lining the process including whether or not the winners have to be academy members.

Reporting on few section officers are not members, the matter was passed on to membership committee to handle.

Constitution & By-laws – Jerry Taylor

A report of the committee submitted clarifying few constitution articles (Appendix B- Constitution & Bylaws Committee Report to Council)*.

Environment: Michael Bass

The chair requested to represent the academy at the Virginia Science Forum at their next meeting. Energy issues in VA is the focus of the next meeting. Mike is representing the University of Mary Washington. Motion approved as moved.

Fellows – Rae Carpenter

Dr. Kenneth R. Lawless donated about 3000 pictures. Dr. Lawless, who was an academy fellow died in August 2007. He was 85.

Finance & Endowment – Art Burke

Burke was not informed about the meeting and could not attend the meeting. No report.

Flora of Virginia – Marion Lobstein

Submitted a progress report on *Flora of Virginia* Project (Appendix C)*

Reported that the manuscript will be finished by 2009.

Possible publication in 2011

Sample chapter is ready to review

One volume book

Using thesis papers

Funding is critical for next year because of 2009 deadline.

$6,000 is requested from Academy

Mentioned various levels one can support the project

Fund Raising – Jim O'Brien

Requested advise from the Council for exploring a plan for fund-raising campaign with 90th anniversary celeberation.

Long Range Planning – Werner Wieland

Proposed dates for annual meetings at various location and sought input

Suggested to sign a lease with JMU for 2010, 2013 and 2016

Other possible venue suggested – Norfolk State University, George Mason University

Pursue with Radford and CNU for hosting the annual meeting

Membership – Richard Groover

Presented the report on Membership Growth Strategy Plan (Appendix D)*

The Council thanks to Rich for his effort. Current membership tally is 687.

Nominations –

Judy is not here

Ballot must go through the Executive Committee

Publication – Jim Martin

Journal is set up – 1 sent and 3 under revision

digitized all the journals and they will be placed online

Any news should go to Jim

Kudos to Jim for job well done

Reported that Rae is going through surgery, council wishes him speedy recovery

Research – Mohamed Ali - Absent and no report

Science Advisory – Alan Griffith - No report

Science Education – No report

Trust – Elsa Falls - Report submitted (Appendix E)* and highlights of committee report presented

Reported the annual meetings are not helpful in terms of earning

JMU and Va Tech are better; HU and VCU are making money

Revised "Chemistry Award guidelines" were approved

Establishment of "Botany Award" was put on hold until further clarification from would be $5,000 donor, whether the winner has to be a member of academy, and it is not explicit that the winner has to be either faculty or a student.

VJAS – Susan Booth

Regional director submitted a report on the Science Career Symposium (Appendix F)*

VRSN – David Hagen

Report presented (Appendix G)*

To open Website for students to track scientists

Publicized VSRN various ways

Expenses discussed

Request for funding $5k was explained and justified

New director of Science Museum needs to be updated on VAS presence, hence moved that Jim, President, Jerry and Susan see the director in this regard.

Kudos to David for excellent job of VSRN

Section Reports:

Aeronautical & Aerospace Sciences-No Report

Agricultural, Forestry, and Aquaculture-No Report

Archeology-No Report

Astronomy, Math, Physics, with Material Science-No Report

Biology with Microbiology-No Report

Biomedical & General Engineering -Expect to have good meeting

Botany:-Strong Section

Chemistry -No Report

Computer Science-No Report

Education-No Report

Environmental Science-No Report

Geography with Geology -No Report

Medical Sciences-No Report

Molecular Biology-No Report

Natural History & Biodiversity-No Report

Psychology:-All is well

Statistics-No Report

Old Business

The finance and Endowment Committee went over the budget : Statement of Cash and General Fund (Appendix H)* :

Dues figures will go up

AAAS is budgeted for $5,000 but will not use all

Under Major Equipment $2,500 is allocated towards purchase a laptop and a copier for VJAS Director

Special meetings category is merged with Research awards

Flora project -- budgeted for $6,000

VSRN - $5,000 this year and no funds were requested last year

AJAS - $9,000

A motion was moved to amend the proposed budget for the amount requested for VSRN and Flora project be cut in half (VSRN-$2,500 and Flora project $3,000) based on the trust committee recommendations. Motion carried

Jim O'Brien will see that the Academy President, Jim Martin and Jerry get invitation to the political meetings

Jim O'Brien will participate in Industrial Award meeting

New Business

Council congratulated Jim O'Brien for winning 2007 Chancellor's Award for Teaching Excellence

Next Council meeting March 29, 2008

Names proposed for Research Committee – Joe D. Rudmin, Allison Baski, Lisa Alty, William Starnes

Thoughts over meeting in Richmond from 10 – 5 in September in place of overnight Chanco Retreat

Adjournment: The council adjourned at 2:30 PM.

* Handout passed out during the meeting

Council has recommended this Slate of Officers for 2008 – 2009

President –	Jim. Martin	(jmartin@reynolds.edu)
President Elect –	Darcy Mays	(dpmays@vcu.edu)
Vice President –	Arun Verma	(Arun.verm@hampton.edu)
Secretary –	Michael Renfroe	(renfromh@jmu.edu)
Treasurer –	Rodney J. Dyer	(rjdyer@vcu.edu)

See the Academy web site (www.vacadsci.org) or
the News Letter (Virginia Scientists) for personal profiles.

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VIRGINIA ACADEMY OF SCIENCE

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Office Phone (____) ____________

E-mail ____________________

Address ____________________

City ____________ State _____ Zip ________

Institution or Business ____________________

Position -- Title ____________________

Interest -- Section No.(s) ________ First no. indicates major interest

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7. Biomedical & General Engineering
8. Geology
9. Medical Sciences
10. Psychology
11. Education
12. Statistics
13. Aeronautical & Aerospace Sciences
14. Botany
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All manuscripts and correspondence should be addressed to the Editor. The Virginia Journal of Science welcomes for consideration original articles and short notes in the various disciplines of engineering and science. Cross-disciplinary papers dealing with advancements in science and technology and the impact of these on man and society are particularly welcome. Submission of an article implies that the article has not been published elsewhere while under consideration by the Journal.

Three complete copies of each manuscript and figures are required. It is also required that authors include a diskette in PC compatible format containing a text file (ASCII or acceptable word processing file) of the manuscript. Original figures need not be sent at this time. Authors should submit names of three potential reviewers. All manuscripts must be double-spaced. **Do not** use special effects such as bold or large print.

The title, author's name, affiliation, and address should be placed on a cover page. An abstract (not to exceed 200 words) summarizing the text, particularly the results and conclusions, is required. The text should follow the general format used by professional journals in the author's discipline and the Virginia Journal of Science has an on-line style manual. Literature cited in the text should follow the name-year format: (McCaffrey and Dueser, 1990) or (Williams et al., 1990). In the Literature Cited section at the end of the article, each reference should include the full name of the author(s), year, title of article, title of journal (using standard abbreviations), volume number and first and last page of the article. For a book, include author(s), year, title, pages or number of pages, publisher and city of publication. Examples:

McCaffrey, Cheryl A. and Raymond D. Dueser. 1990. Plant associations of the Virginia barrier islands. Va. J. Sci. 41:282-299.

Spry, A. 1969. Metamorphic Textures. Pergamon Press, New York. *350* pp.

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