Tidal Potomac Integrative Analysis Project, A Series of Reports on the Water Quality and Living Resources Responses to Management Actions to Reduce Nutrients in the Potomac River Estuary, Final Draft.

Buchanan, C. [ed.] 1999.
Prepared for the Chesapeake Bay Program.
ICPRB Report 99-4, 268 pp.

APPENDIX D

LONG-TERM TRENDS IN SUMMER PHYTOPLANKTON CHLOROPHYLL A IN THE TIDAL FRESHWATER POTOMAC RIVER, USA: RELATIONSHIP TO CLIMATIC AND MANAGEMENT FACTORS

R. Christian Jones
George Mason University
Fairfax, VA
rcjones@gmu.edu

Long-term Trends in Summer Phytoplankton Chlorophyll a in the Tidal Freshwater Potomac River, USA: Relationship to Climatic and Management Factors

R. Christian Jones

Keywords: phytoplankton, climate, tidal freshwater, interannual trends

Introduction

The management of freshwater systems has been prefaced on the belief that nutrient reduction from point sources is an effective way to control eutrophication. This paradigm is based on results from a number of studies relating dramatic reductions in algal standing crops which have occurred when loading of nutrients, notably phosphorus, has been substantially reduced. However, in any given situation the response to point source nutrient control may be influenced by a number of other factors such as flushing, turbidity, or temperature which may limit algal growth for at least part of the year. Furthermore, the system may also be influenced by non-controlled sources such as runoff and sediment release. Since these factors may vary in importance from year-to-year, interannual trends and relationships to nutrient loading changes may be difficult to decipher. These factors may be especially important in tidal freshwater.

The Potomac River is the second largest tributary of Chesapeake Bay and one of the largest rivers on the Atlantic drainage of North America. The tidal freshwater section extends some 60 km from the head of tide at the western edge of the Washington, D.C. to near Quantico, Virginia. River inflow varies seasonally resulting in much longer residence times in summer and fall than in winter and spring. Over 1 million cubic meters per day of treated sewage is discharged into the tidal freshwater Potomac which at low flow may represent roughly half of the freshwater input to the river. Further description of the tidal Potomac may be found in JONES (1991) and LIPPSON et al. (1979). The expenditure of large amounts of public funds to upgrade sewage treatment in the region has resulted in strong interest in the success of these efforts in controlling excess algal growths.

Since 1984 algal populations have been monitored in the Gunston Cove region of the tidal freshwater Potomac River as part of a broad ecological study (JONES et al. 1992). Gunston Cove is a moderately large (4 km long x 1 km wide), shallow ($z \leq 2$ m) embayment of the river located about 35 km downstream from the head of tide. The cove receives $204 \times 10^3\ m^3 \cdot day^{-1}$ of treated sewage daily from the Noman Cole Pollution Control Plant through one of its tributaries. The river mainstem is about 2 km wide in this area with z_{max}=15 m. The tidal Potomac is typified by semidiurnal tides with an amplitude of about 0.5 m. Phytoplankton populations show a strong seasonal trend with highest densities during the summer months from mid June through mid September (JONES et al. 1992). High algal densities in summer have been identified as a major water quality concern in the tidal freshwater Potomac River.

The objective of this paper is to examine interannual trends in summer phytoplankton chlorophyll *a* and relate them to the success of management actions. To achieve this goal, variability attributable to significant relationships with climatic variables was removed by regression and the residuals from these regressions examined for trends that could be related to management efforts.

Methods

Samples were collected on a typically biweekly basis from March through December during the years 1984 to 1997. Stations were sited to characterize both the shallow embayment habitat (cove stations) and the deeper river channel area (river stations); up to six stations were located in each area. Only samples collected between June 15 and September 15 are utilized in this paper. Depth-integrated samples were formed by combining equal amounts of water collected with a submersible pump from three depths: 0.3 m, mid-depth, and 1.0 m above the bottom. Water was maintained at *in situ* temperature in the dark and returned to the lab for filtration within six hours. Aliquots were filtered through 0.45 µm membrane filters which were extracted in DMSO-acetone overnight followed by fluorometric assay (JONES 1998). Total phosphorus was determined by stannous chloride method following persulfate digestion, nitrate by cadmium reduction method, and ammonia and total kjeldahl nitrogen by automated phenate method.

Mean daily air temperature, mean wind speed and direction, and total daily sunshine data for Reagan National Airport located 23 km north of the study area were obtained from the U.S. National Climatic Data Center. Previous work established a strong relationship between minutes of sunshine at Reagan National Airport and photosynthetically active radiation in the study area (Jones 1998). Daily river and tributary flow data were furnished by the U.S. Geological Survey for the Potomac River at Little Falls (representing mainstem flow into the tidal Potomac) and Accotink Creek at Braddock Road (representing a portion of local tributary flow). Average values for the climatic parameters were computed for a range of time periods preceding and including the date of sampling (3-4 days, 7 days, 14 days, 28 days, and in some cases 42 days and 56 days). Correlations of log of daily chlorophyll *a* with the suite of weather and flow variables were calculated. For those variables that showed a significant correlation, regression was attempted with the chlorophyll variables. The residuals of the most significant regression at each station were plotted as a yearly time series to determine if any consistent trends were visible. Trend lines were established by LOWESS (locally weighted regression) with a tension of 0.5.

Results

Chlorophyll *a* values in Gunston Cove demonstrated a consistent increase from 1984 through 1987 (Figure 1). The LOWESS trend line rose from 70 µg/L in 1984 to about 150 µg/L in 1987 and 1988. Beginning in 1989 and continuing through 1997 a steady decline in summer chlorophyll a has occurred at cove stations resulting in the trend line reaching about 60 µg/L in 1997. Correlations with flow parameters revealed that cove summer chlorophyll was more strongly related to Potomac River discharge at Little Falls than with local inputs from Accotink Creek. Log of average Potomac flow for the 28 days preceding sampling was the most highly correlated flow variable ($r=-0.517$, $n=309$). Temperature demonstrated significant positive correlations with chlorophyll, the highest being with 28 ($r=0.386$) and 42 day ($r=0.409$) averages. Two wind parameters were significantly correlated with summer phytoplankton chlorophyll: wind direction ($r=-0.288$) and 4-day average wind velocity ($r=0.208$). No solar radiation parameter exhibited significant correlation.

Chlorophyll *a* values at the river stations were lower, but demonstrated a less consistent interannual pattern (Figure 2). The LOWESS line rose slightly from 1984-1987 and then dropped about the same amount from 1987 to 1990. This was followed by another small rise from 1990 until 1993 with little change thereafter. Average Potomac flow for the 28 days preceding sampling (not logged) was the most significantly correlated flow parameter ($r=-0.481$, $n=224$). Temperature with a 28 day averaging period was very strongly correlated with river summer chlorophyll a ($r=0.510$). Solar radiation was correlated to chlorophyll with a 28 day averaging period being most signficant ($r=0.402$). Wind parameters failed to demonstrate significant correlation to river chlorophyll.

The most significant regression between chlorophyll and climatic parameters in the cove utilized log Potomac flow (28-day average), air temperature (28-day average), wind direction (degrees from north), and wind velocity (4-day average). This regression was highly significant, accounting for 38.4% of the variance in summer chlorophyll *a* in the cove. Residuals from this regression were plotted against years to determine trends independent of significant climatic relationships (Figure 3). The residuals demonstrate the same basic interannual pattern as was found in the raw data (Figure 1). An increase was observed through 1987 followed by a consistent decline through 1997. The main effect of removing the climatic relationships appears to be a dampening of the late 1980's peak in chlorophyll.

At river stations the most significant regression involved Potomac flow (28-day average), air temperature (28-day average), and solar radiation (minutes of sunshine, 28-day average). This regression was highly significant, accounting for 45% of the variance in summer chlorophyll in the river. Residuals from this regression demonstrated a slightly different trend than those from the raw data. The early 1980's increase was not apparent. The late 1980's decline was accentuated. The gradual increase and stabilizing of river chlorophylls during the 1990's was still apparent.

Trends in nutrient concentrations were examined to determine if they could help explain the chlorophyll trends. Total phosphorus at cove stations demonstrated a pattern very similar to that observed in both the raw and residual cove chlorophyll values (Figure 4). The LOWESS trend line suggests increasing amounts of chlorophyll through 1986 followed by a slow gradual decline in phosphorus through 1997. The trend line in 1997 reached 0.1 mg/L whereas nearly double that amount was suggested for 1986. Total nitrogen followed a similar pattern, but with a much smaller relative decline. Total inorganic nitrogen remained constant at about 2 mg/L through 1990 and then decreased steadily falling below 1 mg/L in 1997.

At river stations there was virtually no change in total phosphorus over the study period with the trend line remaining near 0.1 mg/L. Total nitrogen showed a consistent drop from about 3 mg/L during the period with the decline accelerating in the late 1990's and dropping below 2 mg/L in 1997. Total inorganic nitrogen declined from values near 2 mg/L in 1984 to about 1.5

mg/L by 1990 and more rapidly to about 0.6 mg/L by 1997.

Discussion

Significant relationships were found between summer phytoplankton chlorophyll *a* and various climatic variables. At both sites freshwater inflow was negatively correlated, not surprising in importance of flushing and dilution in the tidal freshwater environment. Temperature was also a consistent correlate consonant with its effect on metabolism. The importance of solar radiation in the river and its lack of importance in Gunston Cove is probably related to the relative depths in each area. The shallow cove is less likely to be light limited than the deeper river, particulary since water transparency does not differ greatly between the two areas. Winds from the east and southeast were correlated with higher chlorophyll levels possibly by slowing tidal flushing of the cove.

The persistence of interannual trends in the cove after removal of significant climatic variables suggests a relationship of these trends to management factors. In the cove the correspondence between the chlorophyll a trend and that of total phosphorus suggests a direct link between the two. While nitrogen followed the same general pattern, the percent decline was small and nitrogen remained at non-limiting values with N:P ratio generally above 20 (by weight) and almost never below 10. Interestingly, the major decline in phosphorus loading to the cove occurred in 1983 when the Noman Cole plant began removing phosphorus in its discharge to a level of 0.18 mg/L. Water column phosphorus continued to increase for several more years apparently due to sediment release of phosphorus stored during years of higher loading (CERCO 1988). Thus, the chlorophyll trends observed in the cove are consistent with a response to management actions in the form of enhanced phosphorus removal.

The main trend in summer phytoplankton in the river was the decline in chlorophyll centered in 1990. This trend does not seem to be attributable to climatic factors since it remained when significant climatic variables were removed. No simple relationship to nutrient concentrations was found.

Acknowledgments

These studies have been funded by the Department of Public Works of Fairfax County, Virginia. Special thanks there goes to Elaine Schaeffer and Jimmie Jenkins. The assistance of numerous students and technicians is gratefully acknowledged. My colleague Don Kelso has been a continuing source of help and encouragement throughout this project. I thank Ann Powel for her careful reading of this manuscript.

References

CERCO, C.F., 1988: Sediment nutrient fluxes in a tidal freshwater embayment. - *Water Resour. Bull.* 24: 255-260.

JONES, R.C., 1991: Spatial and temporal patterns in a cyanobacterial phytoplankton bloom in the tidal freshwater Potomac River, USA.- *Verh. Internat. Verein. Limnol.* 24: 1698-1702.

JONES, R.C., 1998: Seasonal and spatial patterns in phytoplankton photosynthetic parameters in a tidal freshwater river. - *Hydrobiologia* 364: 199-208.

JONES, R.C., BUCHANAN, C., and ANDRLE, V., 1992: Spatial, seasonal, and interannual patterns in the phytoplankton communities of a tidal freshwater ecosystem. - *Virginia Journal of Science* 43: 25-40.

LIPPSON, A.J., HAIRE, M.S., HOLLAND, A.F., JACOBS, F., JENSON, J., MORAN-JONSON, R.L., POLGAR, T.T. & RICHKUS, W.A., 1981: *Environmental Atlas of the Potomac Estuary*. - Johns Hopkins University Press, Baltimore, MD, USA.

Author's Address

Dr. R. Christian Jones
Biology Department, MSN 3E1
George Mason University
4400 University Drive
Fairfax, VA 22030
rcjones@gmu.edu

Figure Legends

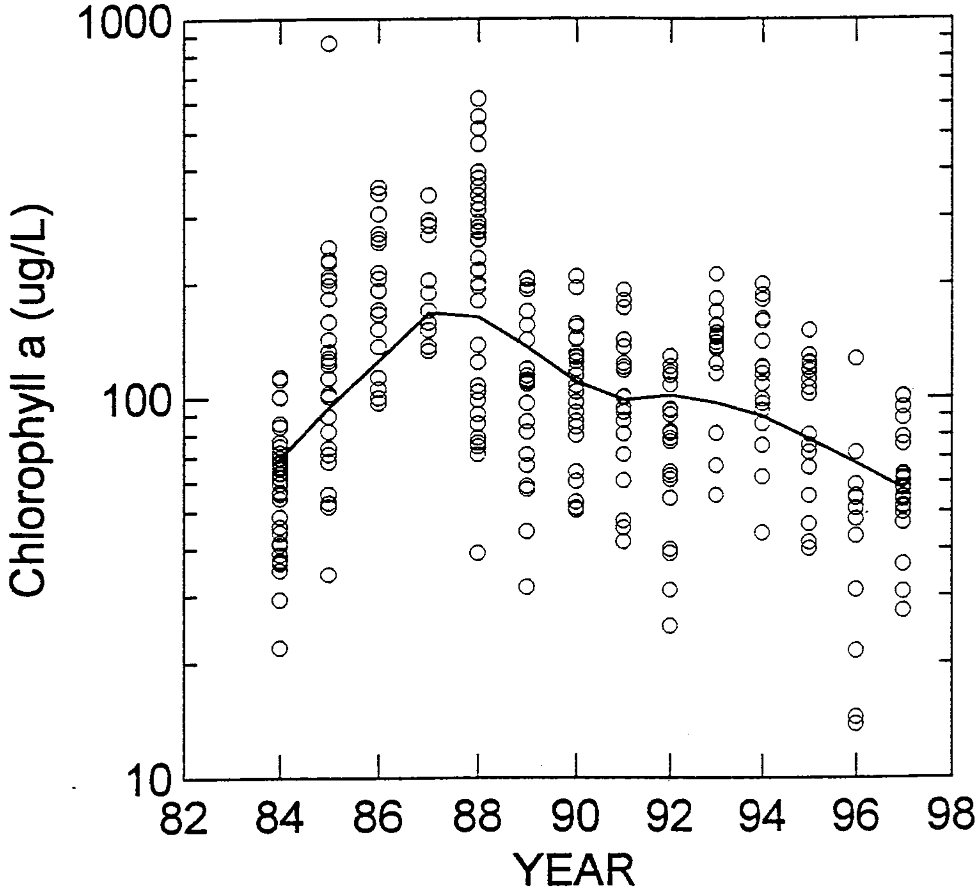
Figure 1. Depth-integrated summer chlorophyll *a* concentrations for Gunston Cove stations from 1984 to 1997. Line is LOWESS smoothing function with a tension of 0.5.

Figure 2. Depth-integrated summer chlorophyll *a* concentrations for Potomac River mainstem stations near Gunston Cove from 1984 to 1997. Line is LOWESS smoothing function with a tension of 0.5.

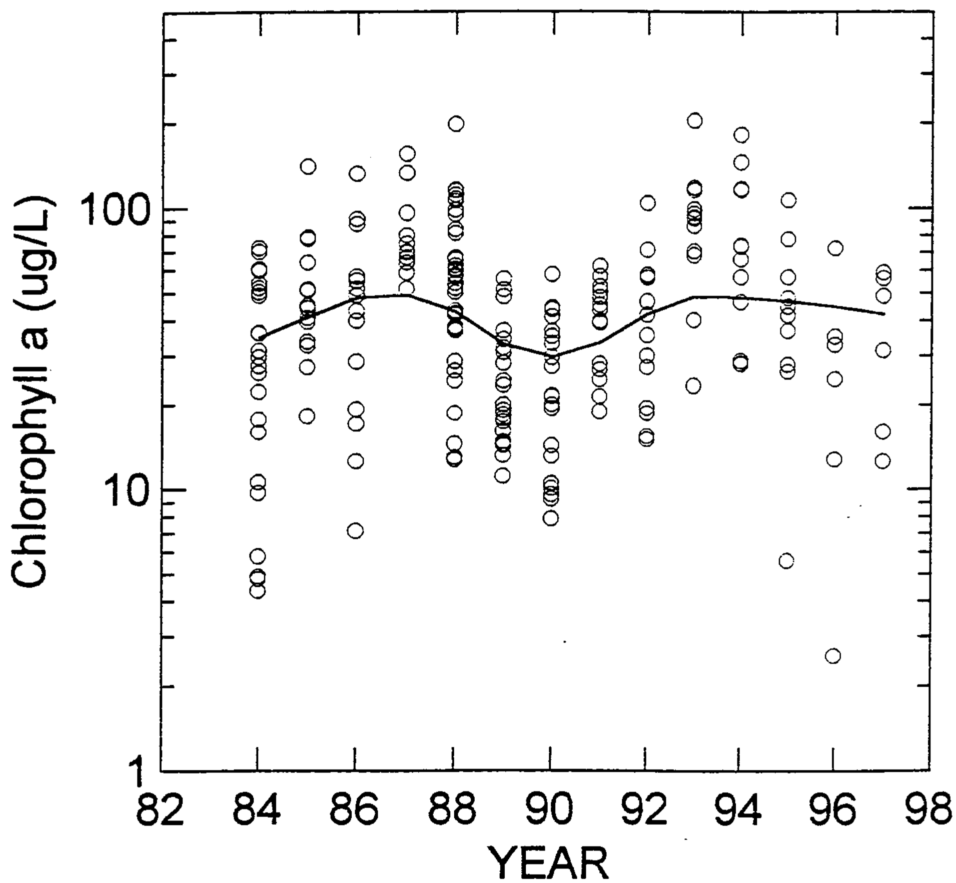
Figure 3. Residual values from the most significant regression between chlorophyll and climate for Gunston Cove stations from 1984 to 1997. Line is LOWESS smoothing function with a tension of 0.5.

Figure 4. Total phosphorus concentrations for Gunston Cove stations from 1983 to 1997. Line is LOWESS smoothing function with a tension of 0.5.

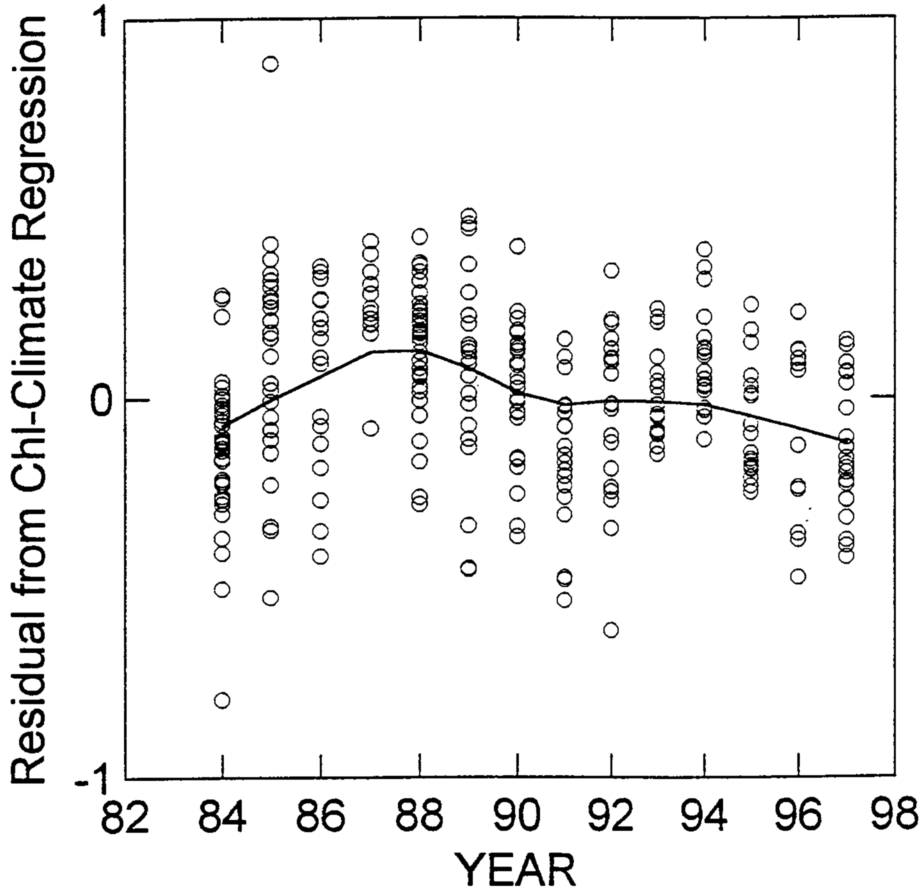
Cove Stations: June 15-Sept 15



River Stations: June 15-Sept 15



Cove Stations: June 15-Sept 15



Cove Stations: June 15-Sept 15