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DISSOLVED OXYGEN AND NUTRIENT FLUX ESTIMATION FROM SEDIMENTS IN THE ANACOSTIA RIVER, PHASE I

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Dissolved Oxygen and Nutrient Flux Estimation from Sediments in the Anacostia River

Prepared by:

E.K. Machelor Bailey[1] Sr. Faculty Research Assistant
R.M. Stankelis[1] Sr. FRA, Field Program Coordinator
Paul W. Smail[1] Faculty Research Assistant
Sarah Greene[1] Graduate Student Fellow
F.M. Rohland[1] Associate Research Scientist
W.R. Boynton[1] Principal Investigator

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[1]University of Maryland Center for Environmental Science
Chesapeake Biological Laboratory
P.O. Box 38, Solomons, MD 20688-0038

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INTRODUCTION

Background

During the last several decades a great deal has been learned about the importance of exchanges of oxygen and nutrients across the sediment-water interface and the dynamics of these interactions in estuarine ecosystems. Sediment oxygen consumption can be an important sink for oxygen in estuarine environments and sediment nutrient releases can be a large internal source of both nitrogen and phosphorous to the water column (Boynton *et al.* 1991; Kemp and Boynton 1992). Both of the latter compounds are essential for phytoplankton growth, which can become excessive when nutrient supplies are large. Thus, sediment processes can play an important role in determining water quality conditions by lowering oxygen levels and promoting excessive algal growth.

Estuarine water quality and habitat conditions are directly affected by fluxes of nutrients from the sediments, especially in summer when temperature is high and hypoxic and anoxic events typically occur. The magnitudes of these sediment oxygen and nutrient fluxes also appear to be directly influenced by nutrient and organic matter loading to the estuarine systems (Kemp and Boynton 1992). Both annual and interannual patterns demonstrate that when these external nutrient and organic matter loadings decrease, the cycle of organic matter deposition to the sediments, sediment oxygen demand, and the release of nutrients into the water column also decrease and water quality and habitat conditions improve (Boynton *et al.* 1995). Evaluation of these processes (*i.e.* exchanges between sediment and the water column) as well as other water column processes (*i.e.* plankton respiration), provides some of the important information necessary to diagnosis the water quality status of an estuary. These data can be used in a variety of diagnostic and forecasting tools, including static nutrient budget computations and for calibration and verification of dynamic water quality models.

Included in the Fiscal Year 2001 Notice of Water Quality Research Grants for the District of Columbia, Department of Health, Environmental Health Division, Bureau of Environmental Quality, Water Quality Division is the following project description and minimum requirement statement:

Call for Proposals Statement

The Department of Health, Environmental Health Administration, Bureau of Environmental Quality, Water Quality Division (WQD) has several years of water quality data for the Anacostia and Potomac Rivers for the conventional parameters including nutrients. A study was conducted by the Interstate Commission on the Potomac River Basin in 1997 in the Anacostia River to estimate the pollutant loads from the upstream sources originating outside the District boundary by analyzing the water column concentrations and known flows from the two branches of the river. Another study conducted by the Metropolitan Washington Council of Governments in 1987 was performed in the Anacostia to estimate the sediment oxygen demand (SOD) exerted by the sediments (and) water column. The District of Columbia is proposing to support another SOD *study to fill caveats that were not addressed in previous studies. Findings from this proposed SOD study will be utilized for modeling efforts which will be necessary for the development of the total maximum daily loads (TMDL) required under the Section 303(d) of the Clean Water Act. WQD does not have any data regarding the nutrient flux from the sediments and the proposed SOD study will include data gathering on this matter. Nutrient flux estimation is critical to the modeling effort as it is an important parameter in the kinetics for the dissolved oxygen (DO) estimation in the water column. Also, the Anacostia River has high nutrient levels in the water column indicating a potential for an algal bloom, which can have a negative impact on living resources and human health.*

A study needs to be conducted to carry out field investigations, laboratory analysis, and technical analysis focusing on the release of nutrients and SOD from the sediments of the Anacostia and Potomac Rivers to the water column. Therefore, WQD is seeking the technical services of a nonprofit organization to conduct tasks to be undertaken for this study. The intent of this work is to estimate the spatial and temporal distribution of nutrient sinks and nutrient flux rates. It is anticipated that field sampling from approximately ten locations (6 in the Potomac and 4 in the Anacostia) will be needed to observe the spatial distribution along the river, with some of the samples near the combined sewer overflow (CSO) outfalls to determine the impact of the CSOs on the nutrient fluxes from the sediments. Temporal or seasonal patterns will be examined by monitoring the nutrient flux at the same locations before and after storm events to indicate the impact of these events on the nutrient flux from the sediments. It has been established that the significant quantities of nutrients and SOD emanate from the CSOs but the nutrient flux from sediments at the CSO outfalls is unknown. The nutrient flux rates determined will assist WQD in estimating the water quality through computer modeling efforts when the CSO abatement program is implemented or pollution reduction takes place due to other pollution abatement measures like Nonpoint Source (NPS) pollution prevention and runoff. Additional analysis may be conducted on some of samples collected to include toxic constituents.

General Study Plan

The program of measurements in this study included: 1) estimates of net sediment-water exchanges of phosphorous (dissolved inorganic phosphorus, DIP), nitrogen (nitrite, NO_2^-; nitrate, NO_3^-; ammonium, NH_4^+) and dissolved oxygen (sediment oxygen consumption, SOC); 2) characterization of the nutrient content and other features of surface sediments, including particulate carbon, nitrogen and phosphorus content, sediment Eh and sediment chlorophyll-*a* concentrations; 3) measurement of water quality conditions in near-bottom waters, including concentrations of dissolved nutrients, dissolved oxygen and hydrogen sulfide (only if measurable salt concentrations are present); and 4) measurements of water column respiration.

Data collections were made monthly during June, July, August and September, 2002 at ten (10) sites, four of which were located in the Potomac River between Arlington Memorial and Wilson Bridges, five in the Anacostia River between Haines Point and Bladensburg, MD, and one in the Washington Channel. These measurements were collected in conjunction with a similar effort covering the remaining portion of the Potomac River estuary from Wilson Bridge to Chesapeake Bay. There were significant methodological and budgetary advantages in coordinating these two projects.

METHODS

Study Site

Sampling was conducted at 10 sites located in the Potomac and Anacostia Rivers in the vicinity of Washington, DC. Four sites were located in the Potomac River between Arlington Memorial and Wilson Bridges, five in the Anacostia River between Haines Point and Bladensburg, MD, and one in the Washington Channel (Figure 1, Table 1).

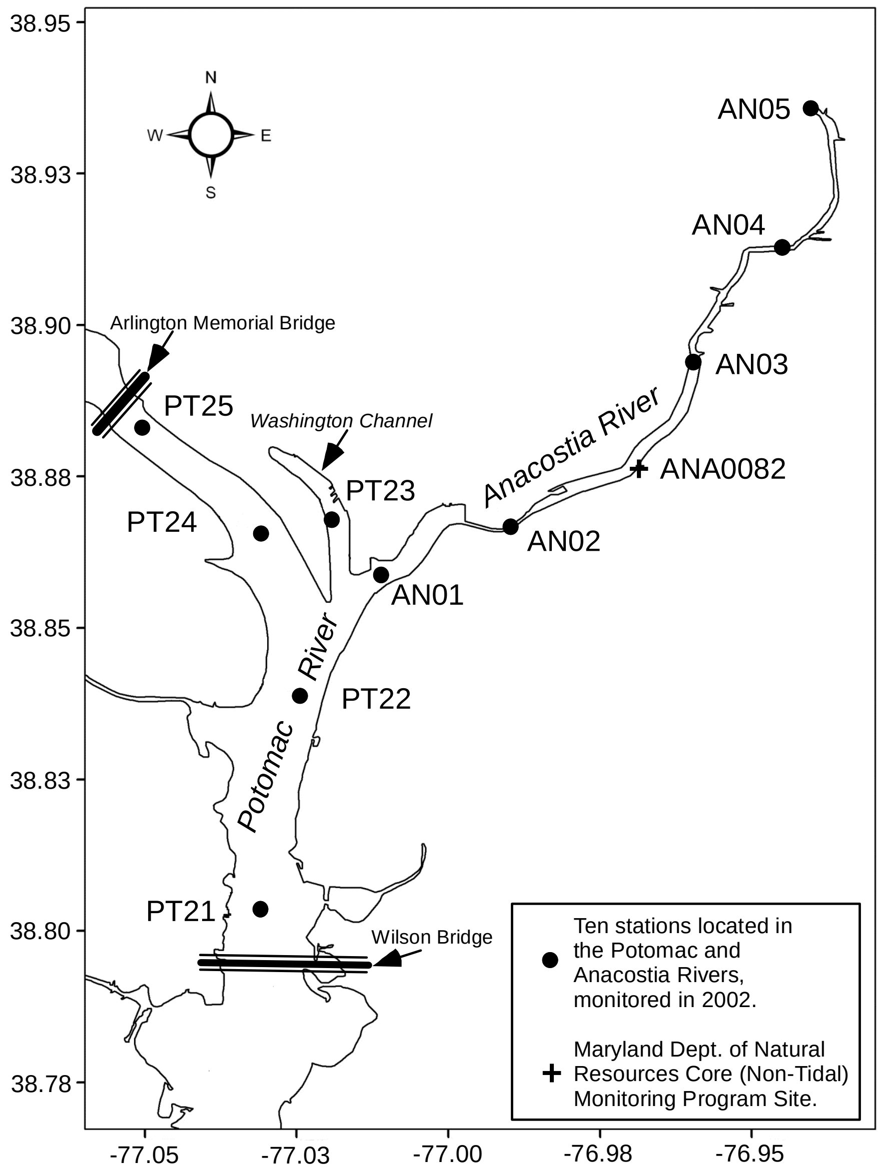


Figure 1. Location of ten stations sampled in the Washington Channel, Potomac and Anacostia Rivers.

Table 1. Anacostia River Monitoring Study Station Code, Grid Locations (decimal degrees; Datum NAD 83), and Mean Depths (meters).

Station	Tributary	Latitude Degrees	Longitude Degrees	Mean Depth (meters)
Anacostia River				
AN01	Anacostia	38.8617	77.0139	2.8
AN02	Anacostia	38.8694	76.9922	2.7
AN03	Anacostia	38.8961	76.9619	4.3
AN04	Anacostia	38.9153	76.9472	2.8
AN05	Anacostia	38.9381	76.9425	2.8
Potomac River				
PT21	Potomac	38.8058	77.0333	2.3
PT22	Potomac	38.8411	77.0269	3.7
PT23	Washington Channel	38.8708	77.0217	7.7
PT24	Potomac	38.8681	77.0336	3.5
PT25	Potomac	38.8853	77.0531	3.0

Station depths ranged from about 1 - 8 m (Figure 2) with the deepest stations located in the Washington Channel (PT23) and at the mouth of the Anacostia River (AN01).

The sampling frequency was based on the seasonal patterns of sediment water exchanges observed in previous studies conducted in the Chesapeake Bay region (Kemp and Boynton 1980, 1981; Boynton *et al.*, 1982; and Boynton and Kemp 1985). In light of these results, the sampling frequency adopted for this monitoring study involved four monthly measurements: June, July, August and September 2002. Sampling dates for these cruises, together with alpha-numeric cruise identification codes, can be found in Table 2.

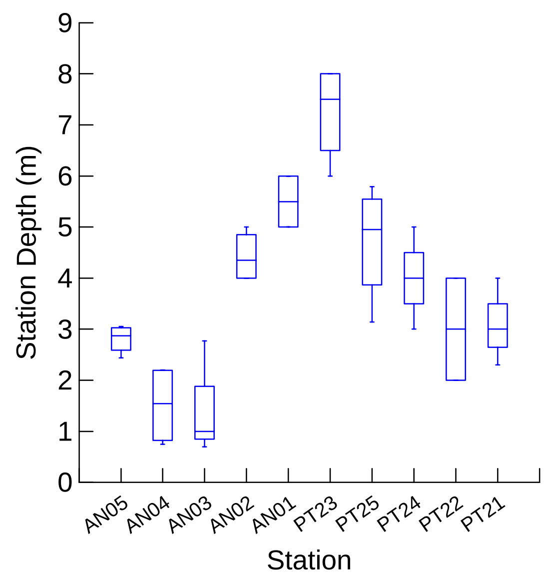


Figure 2. Station depths for 2002 nutrient estimation studies in the Potomac and Anacostia Rivers.

Table 2. Potomac and Anacostia Rivers Cruise Identifier Data

Cruise	Date	Begin Date	End Date	Research Vessel
TMDLAN01	JUN 2002	11 JUN	11 JUN	Orion
TMDLAN02	JUL 2002	23 JUL	23 JUL	Orion
TMDLAN03	AUG 2002	20 AUG	20 AUG	Orion
TMDLAN04	SEP 2002	24 SEP	24 SEP	Orion

Field and Laboratory Methods

Water Column Profiles

At each station, vertical water column profiles of temperature, salinity and dissolved oxygen were measured at 2 meter intervals from 0.5 m below the surface to 0.5 m above the bottom using a Yellow Springs Instrument (YSI) 6920 DataSonde®. Turbidity of surface waters was measured using a Secchi disc.

Water Column Nutrients

Near-bottom (approximately 0.5 m above the bottom) water samples were collected using a high volume submersible pump system. Samples were filtered using 0.7 µm GF/F filter pads, and immediately frozen. Samples were analyzed by Nutrient Analytical Services Laboratory (NASL) for the following dissolved nutrients: ammonium (NH_4^+), nitrite (NO_2^-), nitrite plus nitrate (NO_2^- + NO_3^-) and dissolved inorganic phosphorus, corrected for salinity (DIP or PO_4^{-3}).

Sediment Profiles

At each station an intact sediment core was used to measure the oxidation-reduction (redox) potential (Eh) of the sediment porewater and overlying water (1 cm above sediment surface). Sediment redox (mV) was measured at the sediment surface, 1 and 2 centimeters below the surface. Additionally, surficial sediments were sampled, using a small core, for total and active sediment chlorophyll-*a*, particulate carbon (PC), nitrogen (PN) and phosphorus (PP) to a depth of 1 cm. The surface area of the subcore was 4.91 cm^2 and this dimension was used to convert sediment measurements to an areal basis.

Sediment Flux Measurements

The protocols used in flux estimates were an abbreviated set of measurements of the standard SONE techniques (Rohland *et al*., 2003). A single sediment core was used at each station with no blank. Intact sediment cores constituted a benthic microcosm where changes in oxygen and nutrient concentrations were determined during a fixed incubation period.

A single intact sediment core was collected at each station using a modified Bouma box corer, a light-weight hand hoisted box corer or using a hand coring technique. These cores were then transferred to a Plexiglas cylinder (small - diameter 11cm or large – diameter 13 cm, Figure 3) and inspected for disturbances from large macrofauna or cracks in the sediment surface. If the sample was satisfactory, the core was fitted with an O-ring sealed top containing various sampling ports, and a gasket sealed bottom (Figure 3). The core was then placed in a darkened, temperature controlled holding tank where overlying water in the core was slowly replaced by fresh bottom water to ensure that water quality conditions in the core closely approximated *in situ* conditions.

During the period in which the flux measurements were taken, the cores were placed in a darkened temperature controlled bath to maintain ambient temperature conditions. The overlying water in each core was gently circulated with no induction of sediment resuspension via stirring devices attached to oxygen probes. Oxygen concentrations were recorded and overlying water samples (35 ml) were extracted from each core every 60 minutes for 3 hours with a total of 4 measurements taken. As a water sample was extracted from a core, an equal amount of ambient bottom water was simultaneously added to replace the lost volume. Water samples were filtered using 0.7 µm GF/F filter pads and immediately frozen. Samples were analyzed by Nutrient Analytical Services Laboratory (NASL) for the following dissolved nutrients: ammonium (NH_4^+), nitrite (NO_2^-), nitrite plus nitrate (NO_2^- + NO_3^-) and dissolved inorganic phosphorus corrected for salinity (DIP or PO_4^{-3}). Oxygen and nutrient fluxes were estimated by calculating the rate of change in concentration during the incubation period and converting the volumetric rate to a flux using the volume: area ratio of each core.

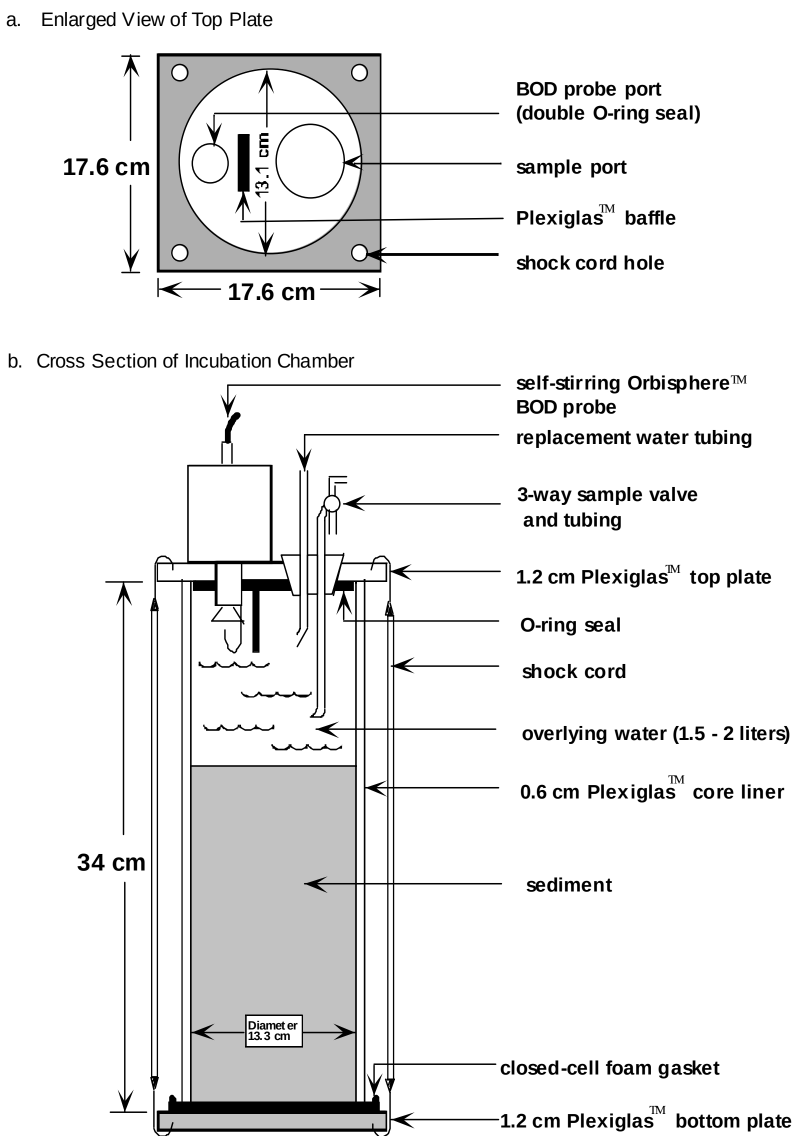


Figure 3. Schematic Diagram of the Incubation Chamber
A. Enlarged View of Top Plate
B. Cross Section of Incubation Chamber
Small Cores: **11 cm x 34 cm = 83.3 cm^2 (Stations, PT25, AN03, AN04, AN05)**
Large Cores: **13 cm x 34 cm = 139 cm^2 (Stations, PT21, PT22, PT23, PT24, AN01, AN02)**

Chemical Analyses

Methods for the determination of dissolved and particulate nutrients were as follows: ammonium (NH_4^+), nitrite (NO_2^-), nitrite plus nitrate (NO_2^- + NO_3^-), and dissolved inorganic phosphorus (DIP or PO_4^-) were measured using the automated method of EPA (1979); particulate carbon (PC) and particulate nitrogen (PN) samples were analyzed using an Elemental Analyzer; particulate phosphorus (PP) concentration is obtained by acid digestion of muffled-dry samples (Aspila *et al.*, 1976); methods of Strickland and Parsons (1972) and Parsons *et al.* (1984) were followed for chlorophyll-*a* analysis (Table 3).

Water Column Respiration

Water column respiration measurements were made using a modified biological oxygen demand (BOD) protocol. Whole water samples were taken from the mixed layer at approximately 1 m below the surface using a high volume submersible pump system. Glass BOD bottles (300 ml) were gently filled with sample water and allowed to overfill, exchanging the volume at least two times. Duplicate samples were taken for initial and final measurements. Initial samples were fixed immediately with reagents for determination of dissolved oxygen (APHA, 1989). Final samples (in dark BOD bottles) were capped, incubated in a dark ambient flowing seawater incubator and fixed with reagents at the termination of the incubation period. Fixed samples were stored at room temperature and returned to the lab for final titration analysis. June samples were incubated for 12 hours. During subsequent cruises samples were allowed to incubate for 24 hours to increase the magnitude of the respired oxygen measurement.

Table 3. A summary of laboratory methods and performance criteria (from Rohland *et al.*, 2003).

Matrix	Variable	Analytical Method	MDL***	Precision (% CV)*	Accuracy (% spike recovery)
Water	Ammonium (NH_4^+)	Berthelot Reaction	0.0030 mg l^{-1}	< 5%	90-110%
Sediment	Active Chlorophyll-*a*	Flourescence after acidification	0.6 μg l^{-1}	-	-
Sediment	Total Chlorophyll-*a*	Flourescence before acidification	0.51 μg l^{-1}	-	-
Water	Dissolved Inorganic Phosphorus (DIP)	Antimony-phospho-molybdate complex	0.0006 mg l^{-1}	< 5%	90-110%
Water	Nitrite (NO_2^-)	Diazo compound	0.0002 mg l^{-1}	< 5%	90-110%
Water	Nitrate + Nitrate (NO_2^- + NO_3^-)	Copper-cadmium reduction	0.0002 mg l^{-1}	< 5%	90-110%
Sediment	Sediment Particulate Carbon	Combustion in O_2	0.13%	< 5%**	-
Sediment	Sediment Particulate Nitrogen	Combustion in O_2	0.0084%	< 5%**	-
Sediment	Sediment Particulate Phosphorus	Antimony-phospho-molybdate complex	0.008%	< 5%**	-
Water	Dissolved Oxygen	Winkler Titration	0.1 mg l^{-1}	< 5%	-

* Concentration dependent
** BCSS-1 Coastal marine sediment: Standard reference material
*** MDL Mean Detection Limit

DATA MANAGEMENT PROCEDURES

Recording of Field Data

All field data were recorded on specially prepared field data sheets and the initials of the person recording the data were recorded on each data sheet. The data sheets were reviewed for possible missing data due to sample collection problems prior to data entry. These sheets were filed in the laboratory. A cruise log book was also kept.

Naming Conventions

Data files were given unique names which were a combination of an alpha code reflecting the name of the data set, the type of data set and a numeric descriptor which indicates the number of the cruise.

Incorporation of Error Codes in Data Tables

In order to keep a record of problems experienced while collecting data, a one or two letter alpha code was entered in the data table, which describes the problems associated with questionable parameter values (Table 4). Valid entries from the Sediment Data Management Plan (EPA, 1989) were used and where necessary additional codes have been added.

Table 4. Analysis Problem Codes.

ANALYSIS PROBLEM CODE	DESCRIPTION
A	Laboratory accident
B	Interference
C	Mechanical/materials failure
D	Insufficient sample
N	Sample Lost
P	Lost results
R	Sample contaminated
S	Sample container broken during analysis
V	Sample results rejected due to QA/QC criteria
W	Duplicate results for all parameters
X	Sample not preserved properly
AA	Sample thawed when received
BB	Torn filter paper
EE	Foil pouch very wet when received from field, therefore poor replication between pads, mean reported
FF	Poor replication between pads; mean reported
HD	Particulate and chlorophyll-*a* samples only taken at -1.0 cm of the Eh profile
HH	Sample not taken
JJ	Amount filtered not recorded (Calculation could not be done)
LL	Mislabeled
NI	Data for this variable are considered to be non-interpretable
NN	Particulates found in filtered sample
NR	No replicate analyzed for epiphyte strip chlorophyll-*a* concentration
PP	Assumed sample volume (pouch volume differs from data sheet volume; pouch volume used)
QQ	Although value exceeds a theoretically equivalent or greater value (*e.g.*, PO4F>TDP), the excess is within precision of analytical techniques and therefore not statistically significant.
SD	All sampling at station discontinued for one or more sampling periods
SS	Sample contaminated in field
TF	Dissolved oxygen probe failure
TL	Instrument failure in research laboratory
TS	Dissolved oxygen probe not stabilized
TT	Instrument failure on board research vessel
UU	Analysis discontinued
WW	Station was not sampled due to bad weather conditions, research vessel mechanical failure, or failure of state highway bridges to open or close
XX	Sampling for this variable was not included in the monitoring program at this time or was not monitored during a specific cruise
YB	No blank measured for MINI-SONE fluxes
YY	Data not recorded

Anacostia River Data Sets

The data collected at each station were organized into six data sets, where nn = cruise number:

WATER COLUMN PROFILES (Filename: **TMDLANPRnn,** Appendix A) contain temperature, salinity and dissolved oxygen data measured at two meter intervals in the water column.

WATER COLUMN NUTRIENTS (Filename: **TMDLANNTnn**, Appendix B) report bottom water dissolved nutrient concentrations.

SEDIMENT PROFILES (Filename: **TMDLANSPnn**, Appendix C) include redox potential and sediment measurements of total and active chlorophyll-*a*, particulate carbon, particulate nitrogen and particulate phosphorus concentrations.

CORE DATA (Filename: **TMDLANCDnn**, Appendix D) lists dissolved oxygen and nutrient measurements in MINI-SONE sediment-water flux chambers.

SEDIMENT-WATER FLUX (Filename: **TMDLANFLnn**, Appendix E) is a summary table providing oxygen and nutrient flux data.

WATER COLUMN RESPIRATION (Filename **TMDLCANWKnn**, Appendix F) is a summary table providing surface water respiration rate data.

Preparation of Data Tables

Data recorded by instruments in the field were entered directly onto specially prepared data sheets. Data from samples analyzed by Nutrient Analytical Services Laboratory (NASL) were returned in written format. Data were keyed into spreadsheets using the data table format developed during the SONE program in August 1989.

Checking of Data Tables

Hard copies of the files were manually checked for errors. Data files were corrected, a second printout produced which was re-verified by a different staff member. The full data set was plotted and outlier values reevaluated. Values below detection limits were also indicated in the data tables.

RESULTS

Water Column Conditions

Water quality conditions in the study area are summarized in a series of box and whisker plots in Figures 4, 5, 6, and 7. In the box and whisker plot format, the top and bottom of the box encompasses 50% of all observations. The horizontal line in the box represents the median value and the vertical lines above and below the box indicate the range of observations. These plots contain all data collected during the June – September, 2002 study period.

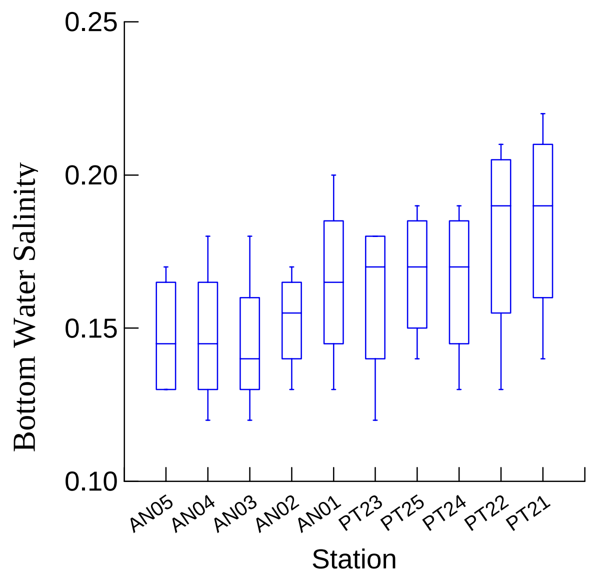


Figure 4. Bottom water salinities for 2002 studies in the Potomac and Anacostia Rivers.

As expected, salinity values were very low at all stations during the full study period (Figure 4). Average values ranged from 0.14 to 0.18. There was a trend of increasing salinity from the upper most station in the Anacostia (AN05) to the most downriver station in the Potomac (PT21), but the differences were very small. Despite the severe drought of 2002, the study area was basically tidal-fresh throughout the study period.

Average bottom water temperature ranged from 27°C to about 28.5°C, typical of summer values in shallow temperate estuarine ecosystems (Figure 5). During the course of the study, temperatures at most stations varied by about 4°C; the summer range and median temperature at AN02 were about 1 degree higher than other stations.

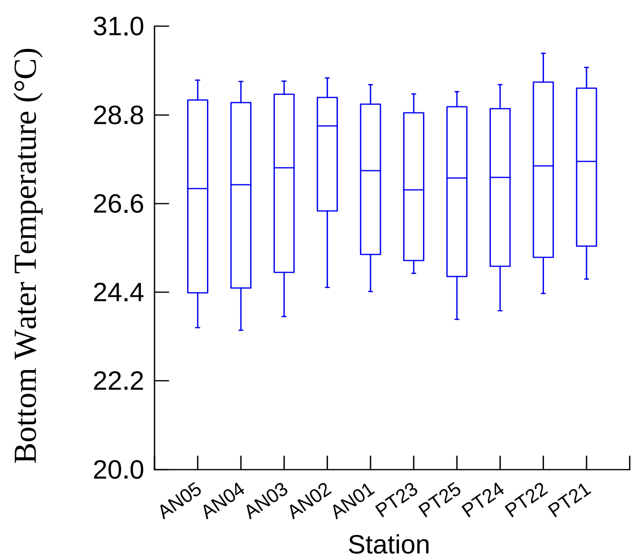


Figure 5. Bottom water temperature for 2002 nutrient estimation studies in the Potomac and Anacostia Rivers.

Water column transparency was also typical of the upper reaches of Chesapeake Bay tributary rivers (Figure 6). Secchi disk depths at the upper three stations in the Anacostia were consistently low, ranging from 0.4 to 0.5m. Based on the color of the water (brown), it appears that most of the turbidity could be attributed to suspended sediments rather than dense algal blooms. Secchi disk depths increased substantially towards the mouth of the river, reaching a median value of 0.8 m at station AN01. Maximum values of just over 1.0 m were observed in the Washington Channel (PT23) and at the most upstream station in the Potomac (PT25). Water column transparency decreased along the main channel of the Potomac between stations PT25 to PT21.

The most unexpected aspect of water column characteristics concerned dissolved oxygen (DO) concentrations in near-bottom waters in the study area (Figure 7). We had expected to observe some very low DO concentrations, at least at stations in the poorly flushed upper portion of the Anacostia River and in the Washington Channel. DO concentrations, even in bottom waters, were mainly above 5 mg l^{-1}. Concentrations of DO were somewhat depressed at the two upper river stations in the Anacostia (AN05 and AN04), but even at these sites median values were about 4 mg l^{-1}. There was but a single measurement where DO was less than 2 mg l^{-1} (AN04) and only a few measurements where DO was less than 3 mg l^{-1}. It might well be that DO concentrations were lower in the pre-dawn hours at some of these sites but it is unlikely that concentrations were much lower than those measured because measurements were made in the mid-morning at the sites in the upper Anacostia River. Such relatively high DO concentrations have important influences on the magnitude and characteristics of sediment-water nutrient exchanges and these will be discussed in later sections of this report.

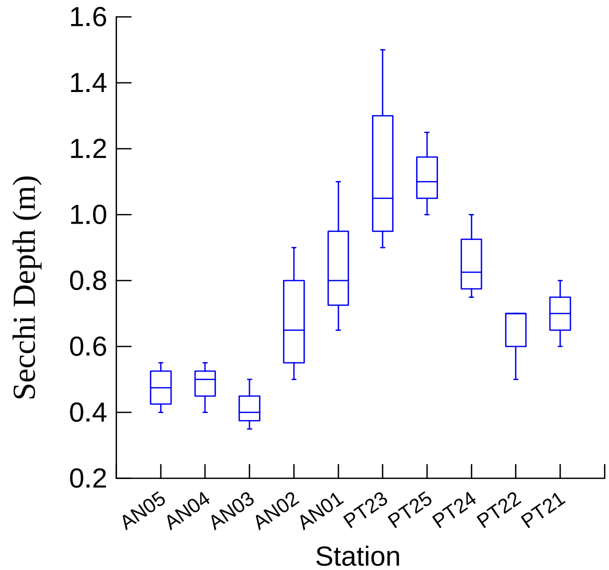


Figure 6. Secchi depth for 2002 studies in the Potomac and Anacostia Rivers.

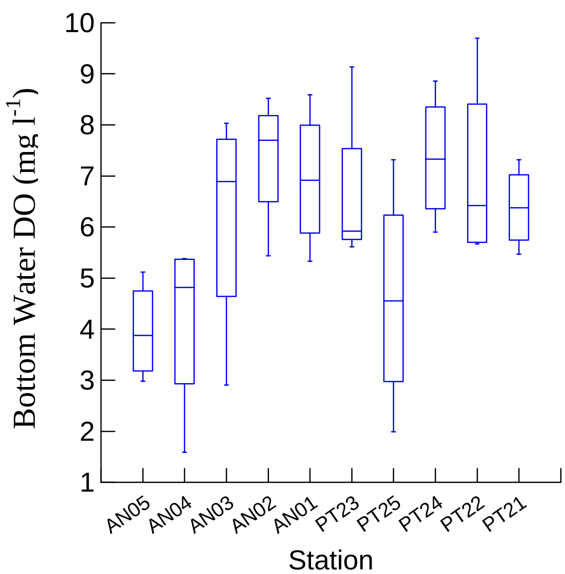


Figure 7. Bottom water dissolved oxygen for 2002 studies in the Potomac and Anacostia Rivers.

Surficial Sediment Conditions

A series of measurements characterizing surface sediment conditions is summarized in Figures 8, 9, and 10. Three measurements of sediment Eh (a measure of the oxidizing or reducing condition of sediments) were made at all stations; one measurement of the overlying water (Eh0), one at one centimeter below the sediment surface (Eh1) and a final measurement two centimeters below the sediment surface (Eh2). At all sediment depths and during all measurements periods during summer, 2002 Eh values were positive. As expected, Eh values decreased with distance from the sediment surface, but still remained positive. There was little change in Eh values between 1 and 2 centimeters of depth, although the deeper sediments were less oxidized. We had expected to see some negative values, particularly at the heavily impacted upper Anacostia River sites but there was no indication of this in the data set. Positive Eh values in the top 2 centimeters of the sediment column are indicative of oxidizing conditions, consistent with the relatively high DO values observed throughout the summer in bottom waters.

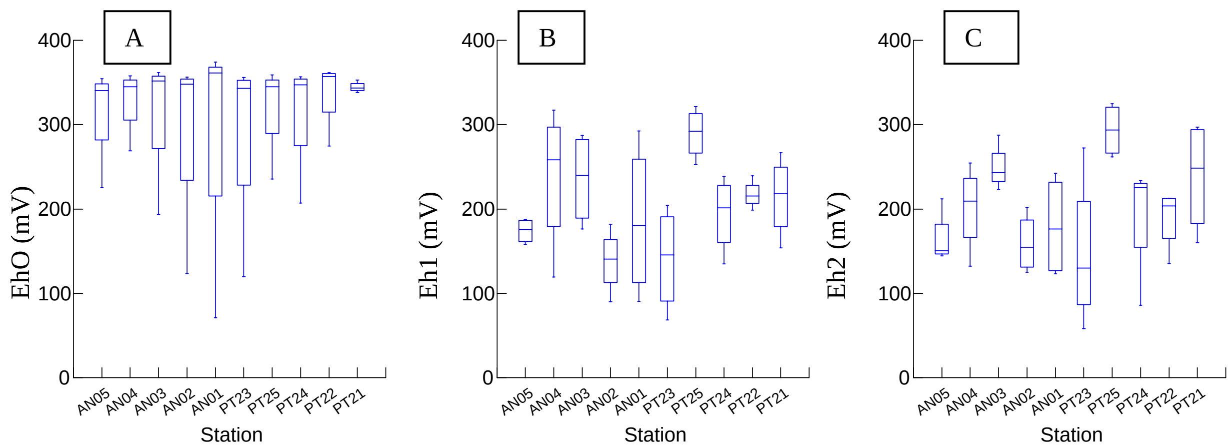
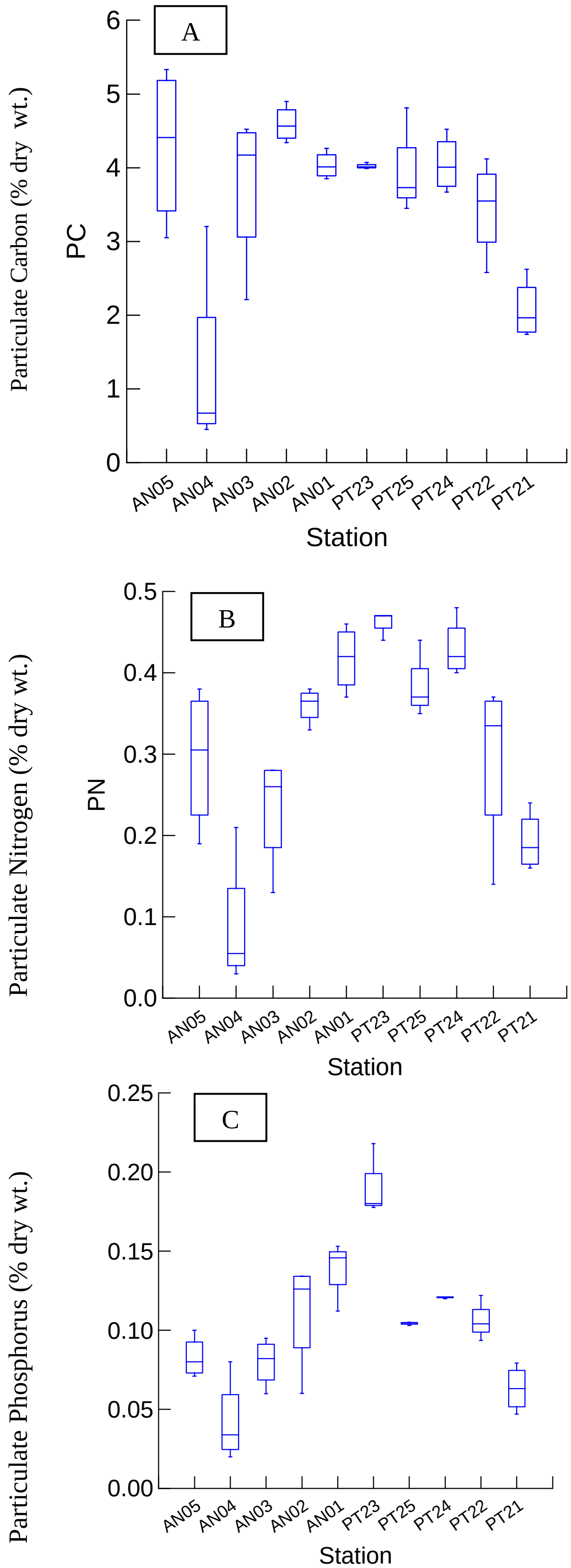


Figure 8. Sediment Eh for 2002 studies in the Potomac and Anacostia Rivers. A: overlying water, B: 1 cm below sediment-water interface, and C: 2 cm below sediment-water interface.

Sediment organic matter content was characterized with measurements of particulate carbon (PC), particulate nitrogen (PN), particulate phosphorus (PP), and two measures of labile organic matter based on total and active chlorophyll-*a* content of surface sediments (Figures 9 and 10). At all but one station (AN04) sediment PC values were typical of those observed in upper reaches of enriched tidal waters of the bay. Median values ranged from 2 – 4.5% of dry sediment weight and there was some indication of lower values at the more down river stations in the Potomac. Very low sediment PC values were measured at station AN04 on three of four sampling occasions. We believe this reflects very local conditions (perhaps a small erosional area of river bottom) rather than general sediment organic matter concentrations in the vicinity of station AN04.

Sediment PN values exhibited a pattern that differed from that of sediment PC and most likely reflects the source of sediment organic matter. At the three most up-river stations in the Anacostia, PN values were moderate to low, especially in comparison to PC values. The low sediment PN content very probably reflects the terrestrial source of much of the organic matter, largely leaves and small twigs that have a low N content. Sediment PN values were higher at other Anacostia and most Potomac River stations. The ratio of sediment PC/PN was about 18 at upriver sites, about three times the expected if sediment organic matter was largely composed of phytoplankton detritus. At other Anacostia and Potomac River sites the PC/PN ratio was closer to 10, indicating considerable more influence on sediment organic matter from phytoplankton than from terrestrial organic matter.



There was a very considerable range in concentrations of PP in surface sediments. Values ranged from about 0.025 – 0.15 % in the upper Anacostia to 0.2% in the Washington Channel (PT23). Values were comparable to or lower than those observed in several other enriched Chesapeake Bay tributary rivers (Boynton *et al*. 1995).

Sediment concentrations of total (active chlorophyll-*a* plus chlorophyll-a degradation products) and active chlorophyll-*a* are used as an indicator of labile organic matter (Figure 10). This differs from total organic matter, some of which is very refractory, and which is measured as sediment PC or sediment PN. Labile organic material is the most likely to be decomposed quickly and the products of that decomposition (*e.g.*, NH_4^+) measured as a sediment nutrient flux. Total sediment chlorophyll-*a* values ranged from about 40 to 200 mg m^{-2}, with most values in the range of 50 to 100 mg m^{-2}. The station to station pattern of active chlorophyll-*a* was very similar to that observed for total chlorophyll-*a*. In general, about 30-40% of total chlorophyll-*a* was in the active form.

Figure 9. Sediment particulate matter for 2002 studies in the Potomac and Anacostia Rivers. A: particulate carbon, B: particulate nitrogen, and C:particulate phosphorus.

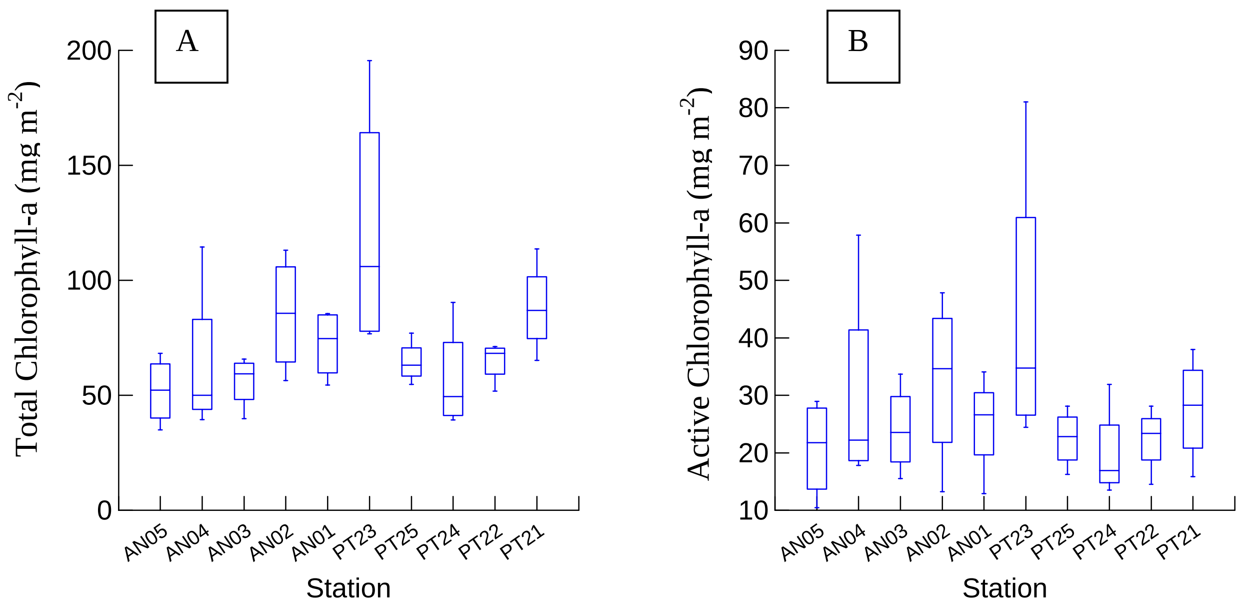


Figure 10. Sediment chlorophyll-*a* for 2002 studies in the Potomac and Anacostia Rivers. A: total chlorophyll-*a* and B: active chlorophyll-*a* .

Water Column Nutrient Concentrations

Bottom water nutrient concentrations are summarized for the study period in Figures 11 and 12. There were strong spatial, and more limited temporal, patterns evident for all three nutrient species. Ammonium concentrations were quite high in the upper Anacostia River stations (12 – 40 µM) and considerably lower (5 – 15 µM) in the lower Anacostia and Potomac River stations. At all sites ammonium concentrations far exceeded nominal limiting nitrogen concentrations for estuarine phytoplankton species.

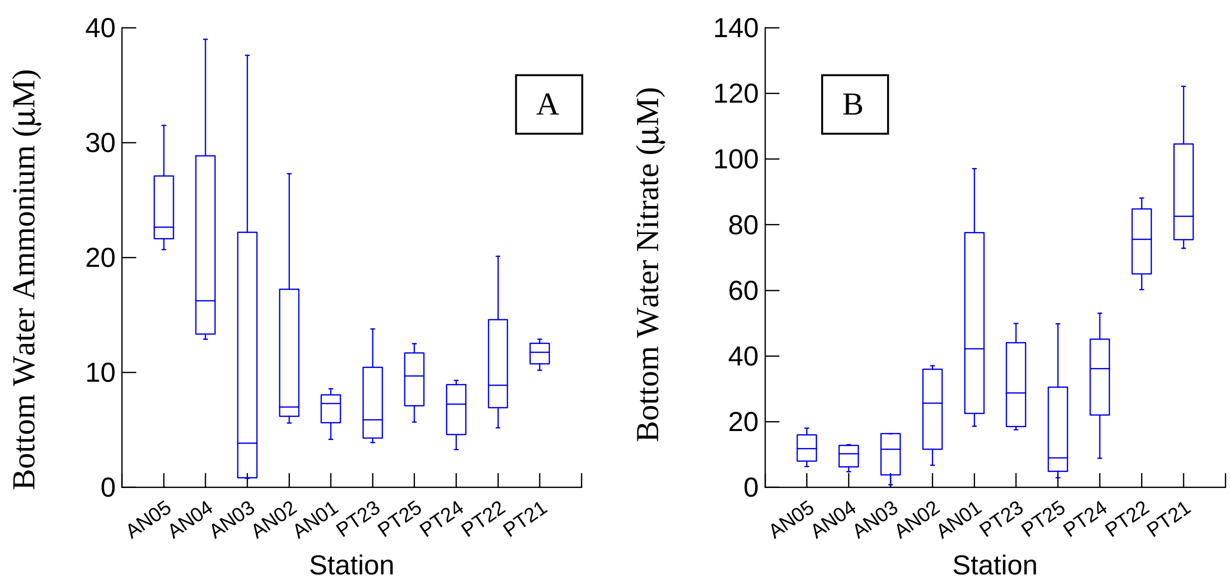


Figure 11. A: Bottom water ammonium and B: nitrate concentrations for 2002 studies in the Potomac and Anacostia Rivers.

The spatial distribution of nitrate concentrations was largely the opposite of ammonium concentrations. Nitrate concentrations ranged from 5-15 µM in the upper Anacostia to as much as 100 µM at the junction of the Anacostia and Potomac Rivers (AN01). Thus, nitrate concentrations exhibited quite an unexpected spatial pattern. The expected nitrate pattern would have been one in which nitrate decreased from the upper to lower portions of the Anacostia River, reflecting the usual strong influence of diffuse source nitrate inputs to the upper river. Such a pattern is frequently observed in other Chesapeake Bay tributary rivers. It may well be that the pattern observed during summer, 2002 resulted, in part, from severe drought conditions of 2002 that would limit diffuse source nitrate input into the upper river and, in part again, from substantial losses of nitrate to upper river sediments and to phytoplankton uptake in the water column. Nitrate also increased with distance downriver in the Potomac, with a median value of about 10 µM at the most upriver Potomac station (PT25) to about 80 µM at station PT21. These substantial increases in nitrate indicate some additional source other than nitrate carried by the river as it crosses the fall line upstream of Washington, DC.

Bottom water dissolved inorganic phosphate (DIP) concentrations were consistently low (< 0.3 µM) at the three upper river stations in the Anacostia (AN05, AN04, AN03) and only slightly higher at station AN02 on one occasion during summer, 2002 (Figure 12). Concentrations of DIP were slightly higher at the mouth of the Anacostia (AN01) and the Washington Channel (PT23). Median concentrations ranged from about 0.75 µM to almost 1 µM in the Potomac and tended to increase in a downstream direction.

Examination of ratios of dissolved inorganic nitrogen (DIN = $NH_4^+ + NO_2^- + NO_3^-$) to DIP (N:P ratios) in the water column have often been used as an indicator of potential nutrient limitation. Because many phytoplankton species use N:P in a molar ratio of about 16:1, ratios in the water of less than this suggest potential N limitation and ratios greater than this suggest possible P limitation. During summer, 2002, N:P ratios in the Anacostia River ranged from about 90 to 370, indicating a relative abundance of DIN relative to DIP. A similar pattern was evident at the Potomac River stations but N:P ratios were not as high (27 – 99).

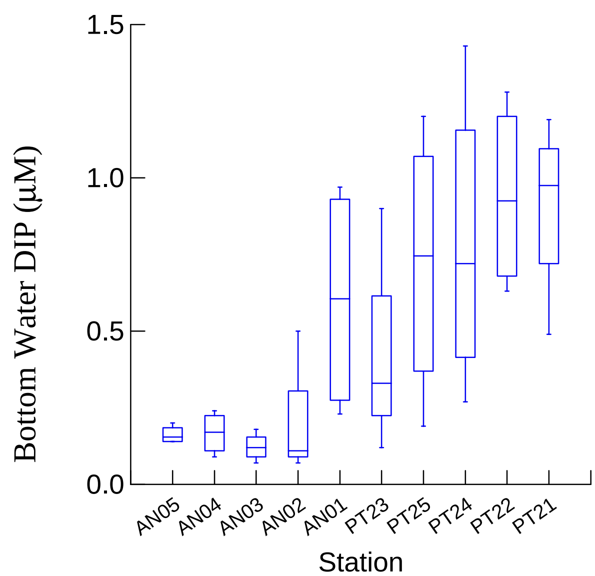


Figure 12. Bottom water inorganic phosphate (DIP) concentrations for 2002 studies in the Potomac and Anacostia Rivers.

Water Column Respiration Rates

Estimates of water column respiration rates are summarized in Figure 13. Rates averaged for the summer period ranged from about 0.25 to 2.8 g O_2 m^{-3} d^{-1}. Highest rates (> 1.0 g O_2 m^{-3} d^{-1}) were observed at the most upriver stations in the Anacostia River while lowest rates (< 1.0 g O_2 m^{-3} d^{-1}) were observed at the most downriver stations in the Potomac River. Rates at stations farther upstream in the Potomac, in the Washington Channel and the lower Anacostia River were all about 1.0 g O_2 m^{-3} d^{-1}. With the exception of rates at the lower Potomac River stations (PT21 and PT22), values were comparable to those commonly observed in enriched estuarine ecosystems (Smith 2000).

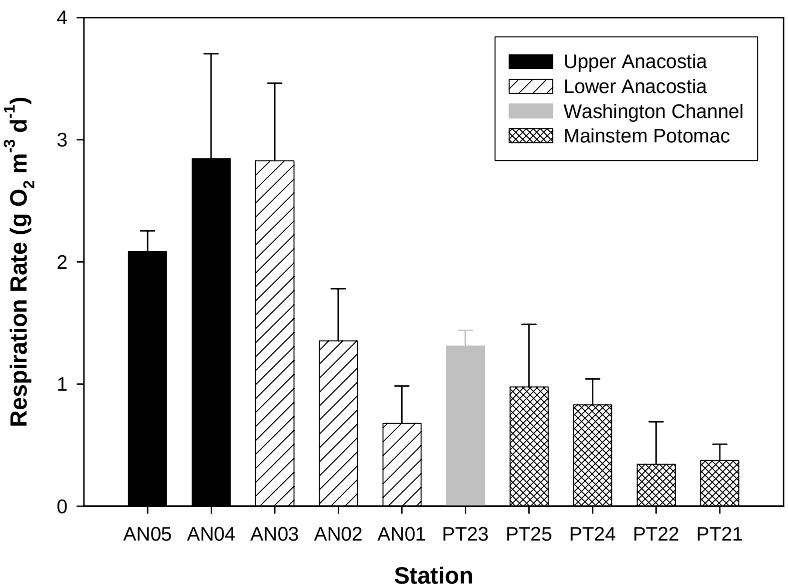


Figure 13. A bar graph summarizing water column respiration rates at stations in the Anacostia and upper tidal Potomac Rivers during summer 2002 (±SE).

Sediment-Water Oxygen and Nutrient Exchanges

Magnitude and Variability in Summer Fluxes: Sediment oxygen consumption (SOC) data are plotted as a series of clustered bar graphs in Figure 14A. SOC ranged from about 1 to 3.6 g O_2 m^{-2} d^{-1} during the course of the study period. Sediment oxygen consumption rates of this magnitude are comparable to those observed in other, enriched estuarine systems (see Discussion, page 21) and are high enough, especially at stations AN02, AN03, and AN04, to have a strong influence on water column dissolved oxygen concentrations. Even though this field study only obtained summer season measurements (June – September), there were some temporal signals in the data set. For example, maximum values of SOC at all stations were observed either during the July or August sampling periods. SOC rates in June and September were always less, occasionally by a large margin. Despite still warm waters in September, SOC rates were lowest in September 70% of the time.

Sediment phosphorus fluxes are shown in Figure 14B. The single most important aspect of these data was that these fluxes were low. In fact, about 50% of phosphorus flux measurements made during this study indicated a net flux of zero. Of the remaining values, all but 5 were less than 10 μmoles-P m^{-2} h^{-1}, a very small flux of P from sediments to the water column. In fact, a sediment P release rate of 10 μmoles-P m^{-2} h^{-1} would support an algal production rate of only about 0.25 g C m^{-2} d^{-1}, a rate generally associated with oligotrophic, rather than eutrophic, ecosystems.

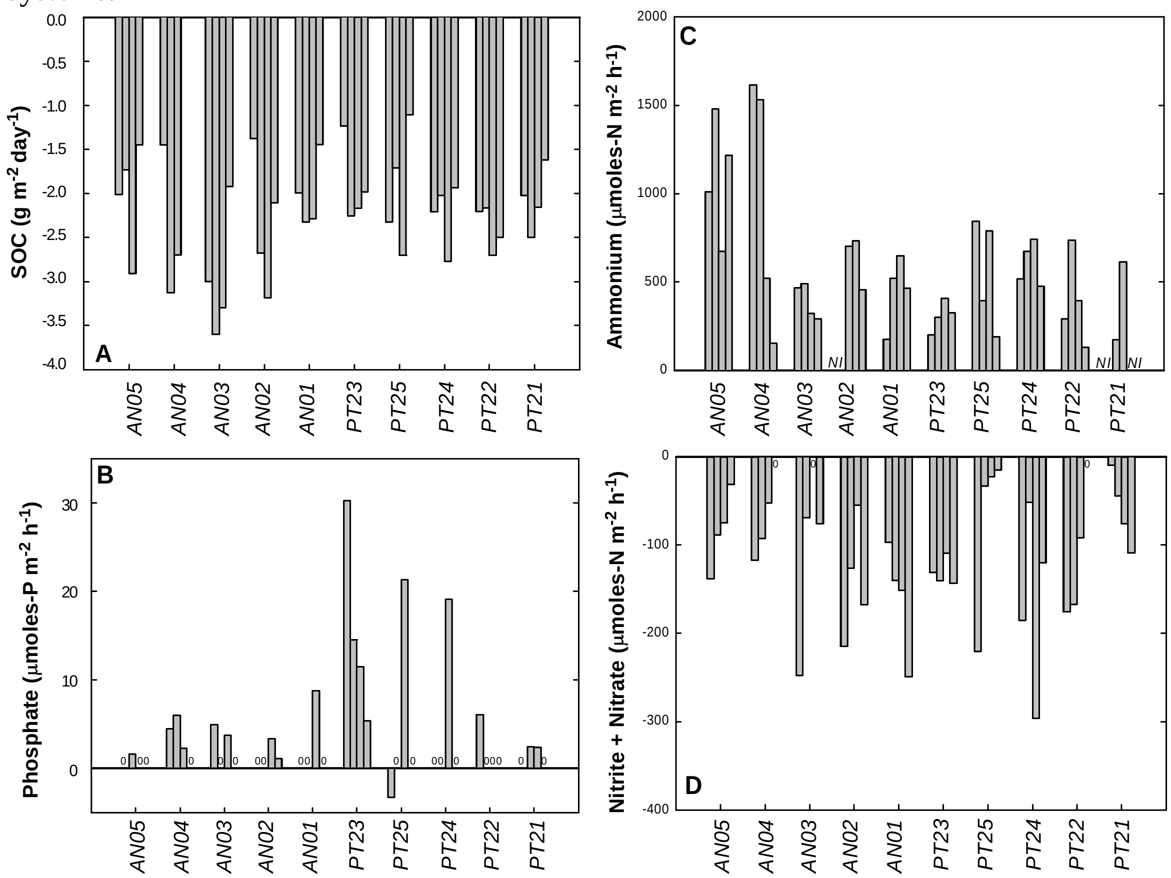


Figure 14. A: Sediment oxygen consumption, B: phosphorus fluxes, C: ammonium fluxes and D: and nitrate fluxes at stations in the Anacostia and upper tidal Potomac Rivers during summer 2002.

In sharp contrast to the very low P release rates from sediments, ammonium releases ranged from large to very large (Figure 14C). In quantitative terms, fluxes ranged from about 100 to 1600 μmoles-N m^{-2} h^{-1}; about half of the measured values were in excess of 500 μmoles-N m^{-2} h^{-1}, a very high rate of sediment ammonium release, even in enriched estuarine ecosystems (see Discussion, page 21). The summer temporal pattern was similar to that observed for SOC in that highest fluxes at most sites occurred in either July or August and lower values were observed in June or September. Sediment fluxes of nitrate (plus nitrite, a minor component of the flux) were consistently directed from the water into sediments (Figure 14D). Fluxes ranged from zero to almost -300 μmoles-N m^{-2} h^{-1}. Slightly more than 50% of measured values exceeded -100 μmoles-N m^{-2} h^{-1}. Nitrate fluxes of this magnitude are high compared to those measured in most other shallow regions of Chesapeake Bay tributary rivers (see Discussion, page 22).

Spatial Patterns of Fluxes: Median values for SOC were substantial (*i.e.*, > 2 g O_2 m^{-2} d^{-1}) at all sites in the study area throughout the study period (Figure 15A). There was a substantial increase in SOC from the upper Anacostia (AN05) through the middle portion of the river (AN03) and this possibly reflects the increasing importance of labile (*i.e.*, phytoplankton) organic matter reaching the sediment surface rather than more refractory material prevalent on sediments of the upper Anacostia. Aside from this spatial trend there was little in the way of other trends evident in the data set.

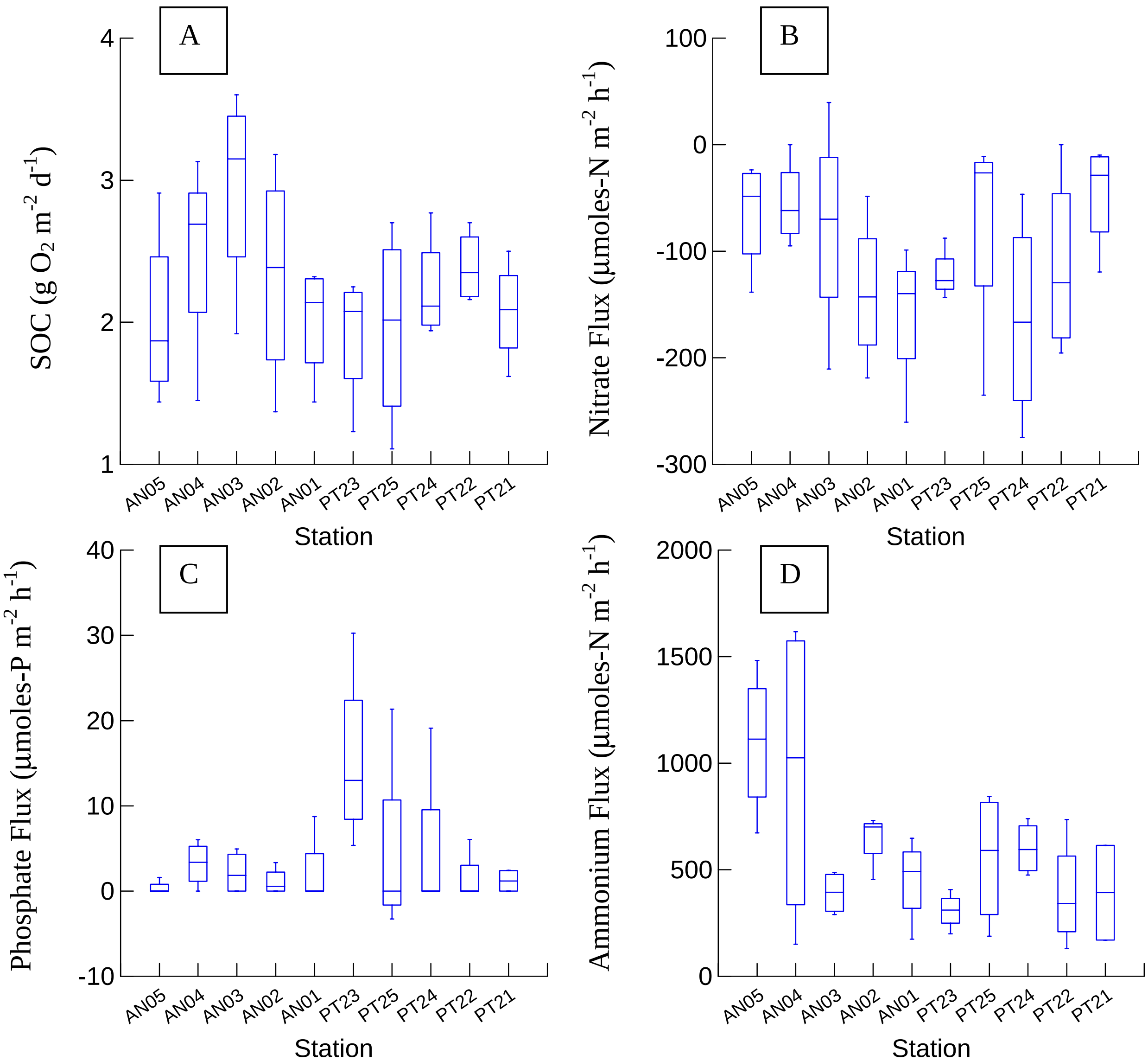


Figure 15. Rates of sediment oxygen consumption (A), nitrate fluxes (B), phosphate fluxes (C), and ammonium fluxes (D) at stations in the Anacostia and upper tidal Potomac Rivers during the summer of 2002.

Nitrate fluxes from water column to sediments were substantial (Figure 15B). Half of the summer median values were greater than 100 µmoles m^{-2} h^{-1}. There was a reasonably clear spatial pattern in nitrate flux wherein fluxes increased from the upper to lower Anacostia River (Stations AN05 to AN01) and from the upper to lower Potomac River sites (PT 24 to PT 21).

As indicated earlier, phosphorus fluxes were quite small. With the exception of the station in the Washington Channel (PT23), summer median fluxes were close to zero (Figure 15C). Phosphorus releases from sediments at the Washington Channel site ranged from about 5 to 30 μmoles-P m^{-2} h^{-1}. There were no indications of an increasing trend in phosphorus fluxes with distance along the mainstem of the Potomac within the study area.

Summer median ammonium fluxes were large at most sites and were very large at two stations in the upper portion of the Anacostia River (AN05 and AN04). Thus, there was a very large spatial gradient in this flux along the axis of the river (Figure 15D). A similar, but much less dramatic spatial pattern was also evident for stations along the mainstem of the Potomac wherein ammonium fluxes were highest upstream and decreased at the more downstream stations.

DISCUSSION

Anacostia Flux Comparisons

Average summer rates of sediment oxygen consumption (SOC), sediment ammonium, nitrate and phosphate flux for selected estuaries are shown in Table 5.

Table 5. Average summer rates of sediment oxygen consumption (SOC, g O_2 m^{-2} d^{-1}) and nutrient flux (µmoles-N or -P m^{-2} h^{-1}) for selected estuaries.

Source	Site	Months of Study	Depth (m)	SOC	NH_4^+	NO_3^-	PO_4^-
This study	Anacostia River,DC	June, July, Aug. & Sept.	3.8	2.2	585	-101.5	3.65
Cowan *et al.* (1996)	Mobile Bay, AL	June, July, Aug. & Sept.	3.0	0.8	109	20.1	9.25
Boynton *et al.* (2003)	Chester River, MD	June, July & August	4.4	2.4	334	-17.0	25.01
Boynton (Pers. Comm.)	Potomac River, MD	June, July & August	9.0	1.9	386	-18.9	20.41
Boynton *et al.* (1999)	Pocomoke River, MD	June, July & August	4.0	1.4	142	-12.9	1.74
Boynton (Pers. Comm.)	Patuxent River, MD	June, July & August	8.2	1.3	273	3.0	26.30
Teague *et al.* (1988)	Fourleague Bay, LA	May, Aug. & Sept.	1.5	2.2	233	-108.3	-6.67
Fisher *et al.* (1982)	South River, NC	May	2.0	1.8	219	0.0	14.70
Hammond *et al.* (1985)	San Francisco Bay, CA	May, June & Sept.	14.0	0.9	83	14.6	0.0
Cowan and Boynton (1996)	Chesapeake Bay, USA	May, June, July, Aug. & Sept.	12.0	0.6	159	-32.5	24.12

Average summer SOC rates for Anacostia and upper tidal Potomac River stations were high, but well within ranges seen in other systems and very close to rates observed in other Chesapeake Bay tributaries. Stations from this study were fairly shallow and had high dissolved oxygen concentrations in bottom water (0.5 m above the sediment surface) during the sampling periods (Figure 7). Anoxic (~ 0 mg l^{-1}) conditions were never observed suggesting that oxygen availability was sufficient to keep up with organic matter supply to the benthos.

A strong exponentially decreasing relationship has been found relating SOC to water column depth (Kemp *et al.* 1992). Figure 16 shows SOC rates from this study and the sites listed in Table 1 plotted against total water column depth. While the stations from the Anacostia and upper tidal Potomac range over a small depth gradient (2 to 7 m), it is apparent that they follow the pattern of lower sediment oxygen consumption rates as water column depth increases. A common interpretation of this relationship is that the deeper the depth, the more time processes in the water column have to act on organic matter as it sinks toward the sediment surface. As this organic matter fuels water column respiration less of it is available for SOC in the sediments. Further confirmation of this relationship can be seen by plotting the percent SOC of total water column respiration versus water column depth (Kemp *et al.* 1992). Figure 17 shows the exponentially declining relationship of SOC : total water column respiration (%) plotted against water column depth using data from Table 1 and stations from the Anacostia and upper tidal Potomac Rivers. Data from this study generally fits the pattern of SOC being less important as an oxygen sink as water column depth increases.

Average sediment ammonium fluxes were directed out of the sediments and were high (> 500 μmoles-N m^{-2} h^{-1}) in comparison to other systems. These high ammonium releases coupled with high rates of sediment oxygen consumption are indicative of eutrophied conditions (Cowan and Boynton 1996) High rates of ammonium release continued well past deposition of the spring bloom into the August and September measurements.

Sediment nitrate fluxes were directed into the sediments and were high (> 100 μmoles-N m^{-2} h^{-1}) compared to tributaries in the Chesapeake Bay and other systems. High nitrate fluxes into sediments may show evidence of dentrification occurring in anaerobic areas of these sediments (Cowan and Boynton 1996).

Average sediment phosphate fluxes were low (~ 3 μmoles-P m^{-2} h^{-1}) and directed out of the sediments. Low phosphate fluxes are usually observed in systems with high dissolved oxygen, low salinity and high sediment iron concentrations (see Discussion, page 28).

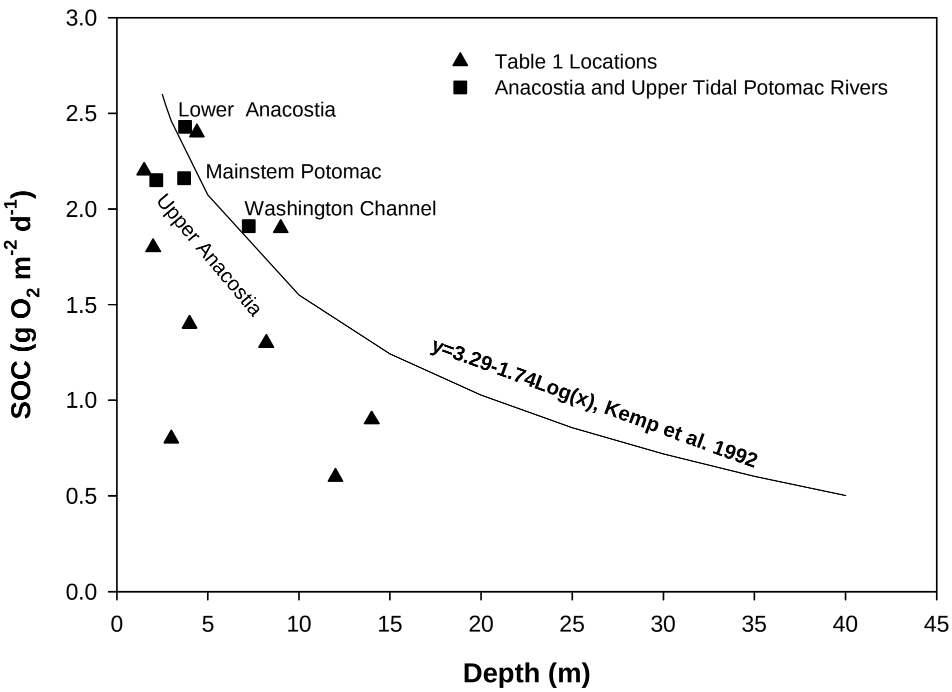


Figure 16. Average spring and summer measurements of sediment oxygen consumption (SOC) plotted against water column depth. Line indicates strong relationship found by Kemp *et al.* 1992, boxes are areas of the Anacostia and upper tidal Potomac Rivers from this study, and triangles represent data from Table 5.

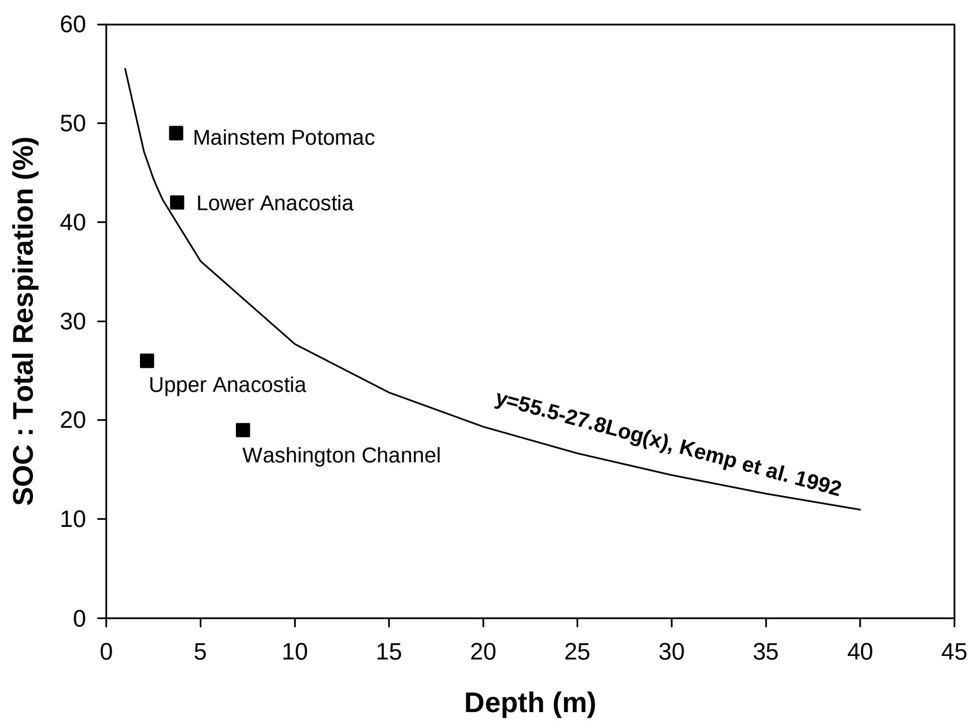


Figure 17. Average spring and summer measurements of sediment oxygen consumption (SOC) as a fraction of total water column respiration plotted against water column depth. Line indicates strong relationship found by Kemp *et al.* (1992).

Environmental Controls on SOC and Nitrogen Fluxes

During the past several decades, coastal marine and estuarine research has gradually identified many of the variables regulating rates and other characteristics of sediment SOC and nutrient exchanges. Factors such as temperature, DO concentration, macrofaunal community structure and abundance, sediment redox conditions and the quality and quantity of organic matter supply to sediments have all been shown to play an important role in regulating exchanges. Cowan and Boynton (1996) have reviewed much of this literature for coastal and estuarine waters.

In many of the sediment-water oxygen and nutrient exchange studies that have been conducted, important regulating factors have been identified by examining sediment flux measurements repeated during an annual cycle (i.e., monthly samples collected for 12 months) relative to contemporaneously measured chemical, physical and biological variables. So, for example, it has often been reported that SOC rates are correlated with water temperature and the mechanistic explanation involves the influence of temperature on diffusion rates and metabolic processes. Similarly, sediment releases of phosphorus have often been reported to be very low except in cases where sediments have low redox conditions or overlying waters are very hypoxic or anoxic. Such a correlative, field-based approach is of limited utility for interpreting data collected in this study because field measurements were restricted to summer. Hence, the range in potential controlling factors was generally small. However, there were some distinctive patterns evident in the data that were consistent with previously reported control mechanisms.

In many instances, SOC rates and sediment ammonium fluxes exhibited a pattern wherein rates reached a maximum in either June-July or July-August. Highest rates were not well correlated with temperature in the present study (although the temperature range was not large and so this result was not unexpected). In other regions of Chesapeake Bay, where flux measurements were made throughout the year, maximum values were mainly observed in June and July, prior to when maximum bottom water temperatures occurred and were much lower in August and September when temperatures were at annual maxima. The point here is that maximum rates in the Anacostia and upper tidal Potomac tended to occur early rather than later in the summer. This pattern suggests some degree of limitation, possibly of labile organic matter, that forms the basis for decomposition, SOC and ammonium release.

Others have found that estuarine sediments responded rapidly to organic matter additions (*e.g.*, Enoksson 1987; Jensen *et al.* 1990). However, in most studies, estimates of organic matter supply rates to estuarine sediments were not available. Cowan and Boynton (1996) proposed using chlorophyll-*a* deposited to estuarine sediments as a surrogate for direct organic matter deposition rate measurements and they found strong, predictive relationships between sediment chlorophyll-*a* concentrations and sediment fluxes if the sediment chlorophyll-*a* values included measurements taken after deposition of the spring diatom bloom. Stankelis *et al.* (1999) found equally strong relationships based on similar measurements made in the Patuxent River estuary. Hence, summer fluxes were related to the average of spring plus summer sediment chlorophyll-*a* concentrations. In the present study, spring sediment chlorophyll-*a* measurements were not taken and the same sort of analysis is not possible. However, the same pattern is evident (with some exceptions) in this study and suggests some degree of substrate limitation, even in a very eutrophic estuarine system.

Another distinctive feature of sediment-water exchanges in the study area concerned nitrate fluxes that ranged from undetectable (in only 3 of 40 measurements) to relatively large and, directed into sediments. Others have observed such fluxes and suggested that the fate of this nitrogen was denitrification in the anaerobic portions of the sediment column (e.g., Boynton and Kemp 1985; Cowan and Boynton 1996; Cowan *et al.* 1996). A similar process may be occurring in the present study area. Nitrate fluxes were often relatively large (> 100 µmoles m^{-2} h^{-1} in 23 of 40 measurements) and thus, if denitrified, represented a substantial terminal nitrogen sink. In a number of studies, nitrate fluxes directed into sediments were reported to be generally proportional to concentrations of nitrate in overlying waters (*e.g.*, Stankelis *et al.* 1999). We have summarized water column nitrate concentrations and nitrate fluxes for the study area in a scatter graph to examine these data for such patterns (Figure 18). For most sites, and for most sampling periods, there was a pattern of increasing nitrate uptake by sediments as nitrate concentrations in the water column increased. However, there were some observations that did not fit this pattern, in particular those observations collected at locations in the mainstem Potomac downstream of the confluence with the Anacostia River (Stations PT21, PT22). The reason(s) for this are not clear at this time.

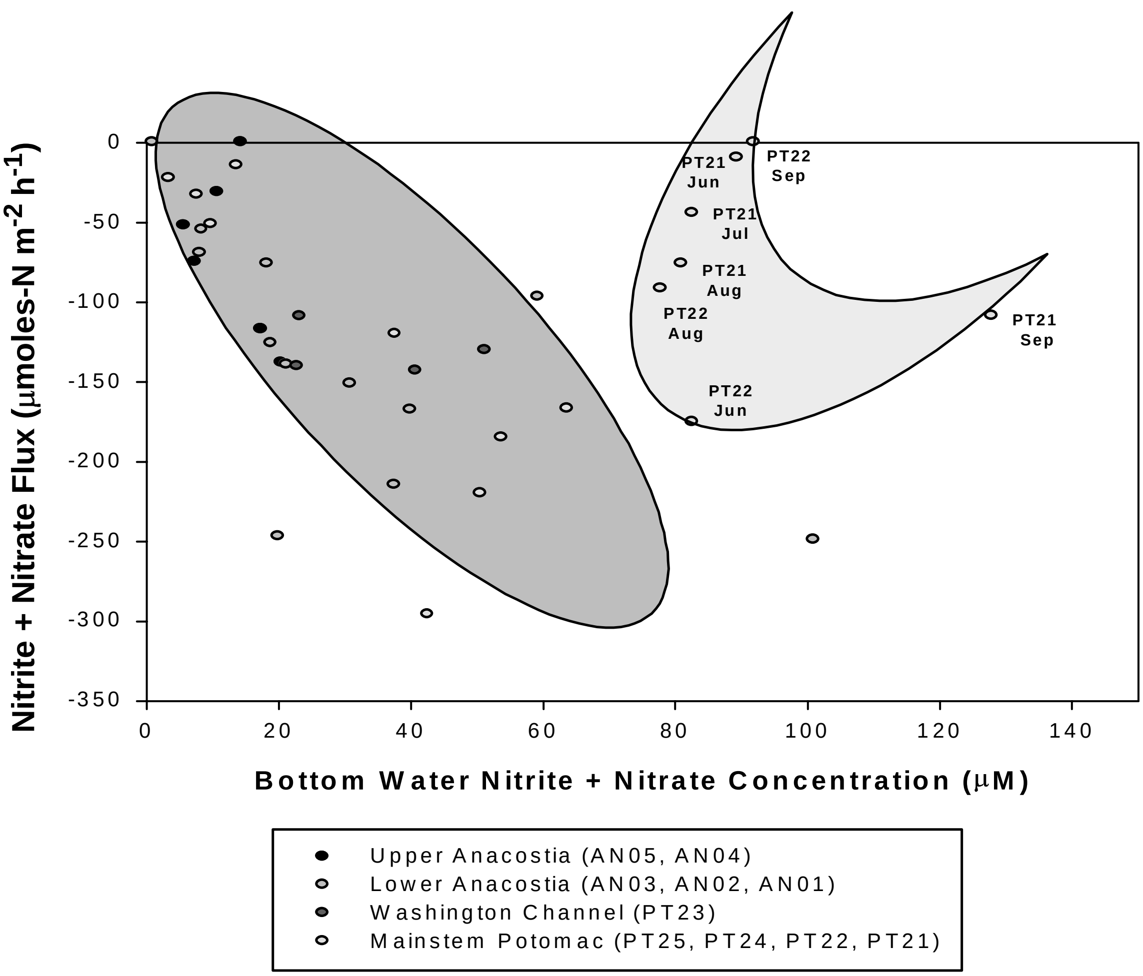


Figure 18. Scatter plot of sediment nitrite + nitrate flux versus bottom water nitrite + nitrate concentrations for all sites sampled in the Anacostia and upper tidal Potomac Rivers during summer 2002. The circled areas are qualitative clusters of observations that generally conform (ellipse) or do not conform (half moon) to expected patterns.

A final approach to gaining understanding of sediment oxygen and nitrogen exchanges is to examine the relative magnitude of various fluxes. Such a stoichiometric approach requires a number of assumptions but can still be useful in suggesting which of many biogeochemical processes are influencing sediment oxygen and nitrogen exchanges. Use of this approach assumes that aerobic decomposition of organic matter originating from phytoplanktonic detritus results in the generation of 1 atom of N (as NH_4^+) for every 13.25 atoms of O consumed (Redfield 1934). In situations where there is less N released than expected, processes such as denitrification are indicated. Conversely, when more N is released from sediments than expected based on oxygen consumed, anaerobic decomposition processes are indicated. Studies conducted in Narragansett Bay (Nixon et al. 1976, 1980; Nixon 1981) found O: N sediment flux ratios that were quite high when compared to the expected Redfield ratio of about 13:1. Nixon and colleagues attributed the proportionately low ammonium fluxes to denitrification. In Chesapeake Bay, Boynton and Kemp (1985) found distinctly different sediment O: N flux ratios during spring and summer. During summer, O: N flux ratios were close to those expected based on Redfield proportions suggesting simple aerobic decomposition of organic matter. However, during spring, O: N flux ratios were very high (~95) indicating that some nitrogen was not released to the water column. These authors came to the same conclusion as Jenkins and Kemp (1984) who found strong seasonal trends for coupled nitrification-denitrification in sediments of the Patuxent River estuary. These authors suggested that the flux ratios were high in spring because a substantial amount of remineralized N was being nitrified in oxidized surface sediments and then denitrified in adjacent anaerobic sediments. It appears that during summer Patuxent estuary sediments had become more reduced, inhibiting nitrification and thus N was simply released during decomposition with little or no nitrification coupled to sediment denitrification. Studies conducted throughout an annual cycle at sites located in the mesohaline and polyhaline portions of Chesapeake Bay found similar patterns of O: N sediment flux ratios and similar conclusions were reached (Cowan and Boynton 1996). Cowan *et al.* (1996) reported seasonally varying O: N flux ratios from Mobile Bay and also found considerable interannual differences in flux ratios. Of special interest to the present study, Cowan *et al.* (1996) also observed O: N flux ratios well below Redfield proportions and suggested the additional ammonium flux was supported by anaerobic processes such as sulfate reduction.

Sediment O: N flux ratios computed by region for the summer period, 2002 are summarized in Table 6 and Figure 19. SOC: NH_4^+ ratios ranged from 5.4 at upper Anacostia River stations (AN05 and AN04) to between 15.6 and 16.4 at all other regions of the study area. SOC: DIN flux ratios at the upper Anacostia River sites were similar (5.96) but were higher (21.4 – 32.8) at the other three regions because NO_3^- uptake by sediments was a more substantial portion of the DIN exchange across the sediment-water interface. At all locations, except those in the upper Anacostia River, SOC: NH_4^+ flux ratios were not far from those expected based on the stoichiometric relationships discussed earlier. They were somewhat elevated beyond the expected 13:1 but the differences were not large.

Table 6. Summary of summer (June - September, 2002) SOC rates and sediment ammonium fluxes for several regions of the Anacostia and upper tidal Potomac Rivers. DIN flux represents the net exchange of ammonium plus nitrite and nitrate fluxes. Flux ratios (SOC: NH_4^+ and SOC: DIN) were computed using individual flux measurements and then averaged. Ratio values in parentheses represent standard errors of the mean.

**** *Note that SOC rates have been converted to molar quantities and expressed as hourly rates.***

Location	Sediment Oxygen Consumption (mmoles O m^{-2} h^{-1})	Sediment Ammonium Flux (mmoles N m^{-2} h^{-1})	Sediment DIN Flux (mmoles N m^{-2} h^{-1})	SOC : NH_4 Flux Ratio (SE)	SOC : DIN Flux Ratio (SE)
Upper Anacostia (AN05, AN04)	5.59	1.02	0.95	5.40 (1.65)	5.96 (1.86)
Lower Anacostia (AN03, AN02, AN01)	6.34	0.48	0.35	15.61 (2.15)	23.94 (4.76)
Washington Channel (PT23)	4.97	0.31	0.18	16.37 (1.19)	32.78 (5.91)
Mainstem Potomac (PT21, PT22, PT24, PT25)	5.63	0.50	0.39	16.05 (3.47)	21.38 (4.44)

These results suggest that much of the surficial sediment organic matter is being remineralized via aerobic decomposition. The slight elevation in flux ratios might indicate that some nitrification in oxidized surface sediments was coupled to denitrification in deeper anaerobic sediments. However, the SOC: NH_4^+ flux ratio for stations located in the upper Anacostia River (AN04 and AN05) was very low, indicating a source of ammonium generated by processes not involving oxygen consumption. Since the upper Anacostia is tidal freshwater, sulfate is not abundant and hence sulfate reduction is not a likely process for anaerobic ammonium production as it is in many estuarine and marine sediments (Cowan *et al.* 1996).

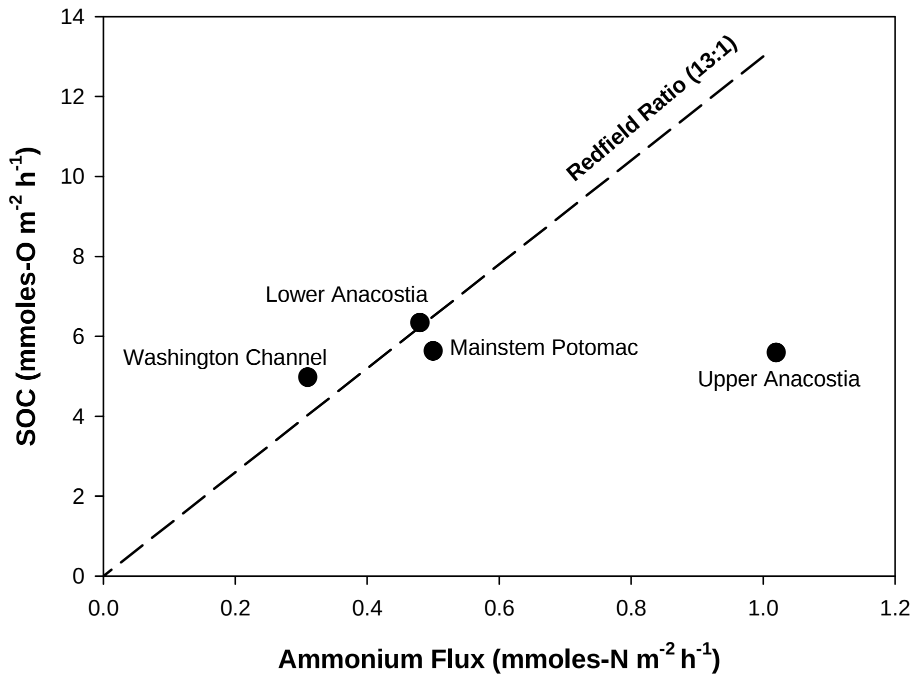


Figure 19. A scatter plot of SOC rates versus sediment ammonium releases for several areas of the Anacostia and upper tidal Potomac Rivers. The significance of the Redfield Ratio is explained in the text. Points shown in the figure are summer (June - September, 2002) average values as given in Table 6.

In fact, there was no smell of hydrogen sulfide associated with any cores collected in the Anacostia and upper tidal Potomac Rivers. The most likely process generating ammonium, in addition to aerobic decomposition in surface sediments, would be the anaerobic process of methanogenesis wherein organic compounds are used as a substrate and methane is one of the end products (Valiela 1984). If denitrification is active in these sediments, as seems likely, some additional ammonium could be generated from the decomposition of organic matter associated with that anaerobic process. Whatever the exact process, much more ammonium was being released by sediments in the upper Anacostia River than could be accounted for by simple, aerobic decomposition of organic matter. As a final, qualitative observation, we made some sediment-water oxygen and nutrient exchange measurements in the lower Anacostia River during May and August, 1990 (Sampou 1990). One difficult aspect of this work was obtaining sediment cores that were not severely disrupted due to methane bubble expansion and migration up through the sediment to the surface and water column contained within the cores. Samples were taken again and again so as to avoid conducting flux measurements on severely disrupted sediments. During the present study, methane bubbles in sediment cores continued to be a frequent problem.

Regulation of Sediment Phosphorus Fluxes

Phosphorus dynamics at the sediment-water interface are subject to multiple controls. Redox potential, pH, and Fe:S:P ratios regulate a complex binding-release cycle involving phosphorus and sediment minerals. Phosphorus binding (or release) to (or from) sediment minerals is of central importance to the sediment-water flux.

In oxidizing sediments, phosphate may bind to or co-precipitate with iron (or aluminum) oxyhydroxide minerals (Sundby *et al.* 1992). In the sorbed or bound state, phosphorus remains in the sediments and is non-bioavailable. However, if the environment becomes reducing, or if newly formed Fe-P minerals are transported to more reducing zones of the sediment column (via advection, diffusion, bioturbation, or sediment accretion), phosphorus may not remain bound. Fe(III) oxides dissolve in reducing environments, releasing Fe(II) and P to the porewater. Porewater Fe(II) and phosphate may diffuse back up to more oxidizing sediments, where Fe(II) is reoxidized to Fe(III). If this occurs, phosphate is again bound by Fe(III) oxides and is thus retained in the sediments (Figure 20A).

However, if Fe(III) oxides are not again made available, due to reducing conditions or the presence of sulfur (discussed below), P remains in the dissolved phase and is released from the sediments to the water column (Figure 20B). High sediment-water P fluxes are often observed in reducing environments. For example, P releases as high as 148 μmoles m^{-2} h^{-1} (six times as high as any flux measured in this study) have been measured in the mid-Chesapeake Bay during summertime anoxic events (Cowan and Boynton 1996).

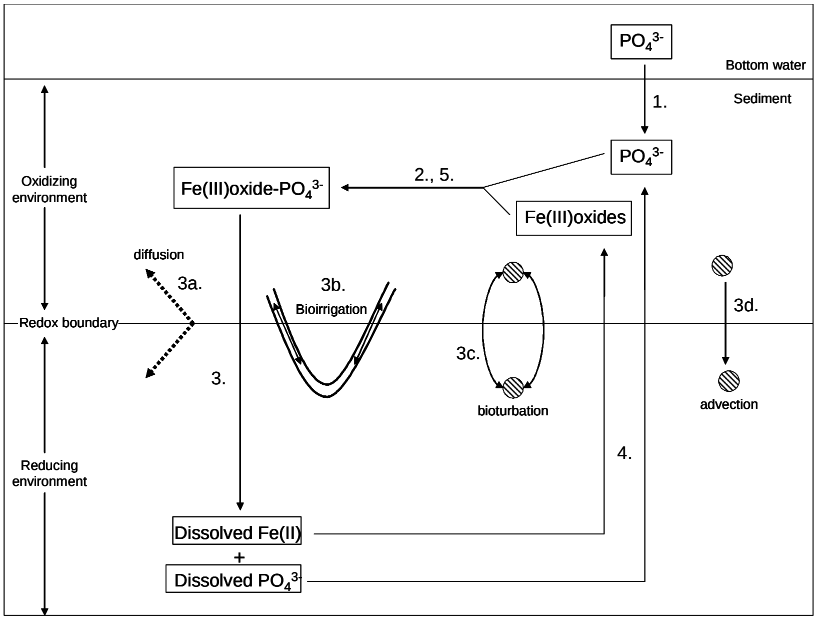


Figure 20A. Simple binding/release of P by Fe(III)oxides with varying redox conditions. 1) Phosphate from overlying water is incorporated into sediment porewater. 2) In oxidizing sediments, Fe(III)oxides bind PO_4^{-3}, making PO_4^{-3} non-bioavailable. 3) Fe(III) oxides with bound PO_4^{-3} are transported across the redox boundary to reducing sediments by a variety of mechanisms. In reducing sediments, Fe(III)oxides with bound PO_4^{-3} are dissolved to yield free Fe(II) and PO_4^{-3}. 3a) Diffusion is the movement of molecules down a concentration gradient in a fluid medium. Diffusion is more important for dissolved species like Fe(II) and free PO_4^{-3} than it is for the movement of Fe(III)oxides. 3b) Bioirrigation is the movement of porewater and its dissolved constituents due to the activity of benthic fauna (e.g. burrowing). Like diffusion, bioirrigation is more important for dissolved species than for sediment particles and minerals. 3c) Bioturbation is the movement of sediment particles and some porewater due to the activity of benthic fauna. 3d) Advection is the movement of sediment particles due to physical processes not mediated by benthic fauna. 4) Dissolved Fe(II) and PO_4^{-3} may be transported back to oxidizing sediments by the mechanisms discussed above. 5) In oxidizing sediments, Fe(II) is oxidized to Fe(III) and forms Fe(III)oxides, which may again bind PO_4^{-3}, retaining P in the sediments. In this figure a latitudinal redox boundary is depicted, but longitudinal redox boundaries may exist as well. The transport mechanisms described above for movement across redox boundaries are also mechanisms for movement across the sediment-water interface. It is also important to note that redox boundaries are not necessarily stationary. Sediment accretion and respiration can cause vertical migration of the redox boundary, causing Fe(III)oxides on the reducing side of the new boundary to dissolve.

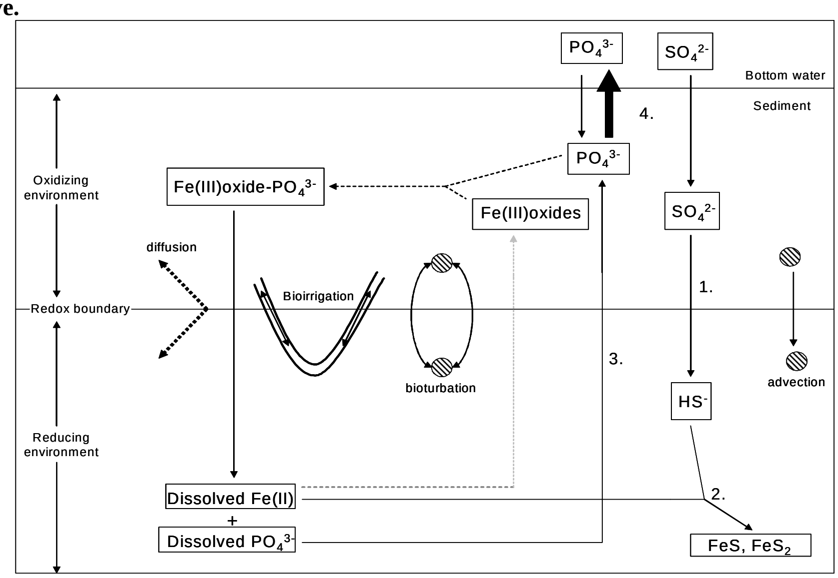


Figure 20B. The effect of S on binding/release of P by Fe minerals. 1) Sulfate reduction produces HS$^-$. 2) HS$^-$ and dissolved Fe(II) form iron monosulfides (FeS) and pyrite (FeS_2), sequestering Fe. 3) PO_4^{-3} is transported back to oxidizing sediments. 4) Since Fe is not available to form PO_4^{-3}–binding Fe(III)oxides, PO_4^{-3} fluxes out of the sediments.

Despite observations of high P fluxes in reducing environments, anoxia does not *always* result in P release from sediments, and oxic conditions do not necessarily result in P retention (Gachter and Muller 2003). Release of P from sediments depends not only on redox conditions, but also on the amount of Fe available to bind P, which is controlled by the precipitation and dissolution of iron sulfur minerals.

Iron sulfur mineral formation reduces the amount of Fe available to bind phosphate in sediments. Sulfate is one of the most abundant ions in seawater, and microbial sulfate reduction to sulfide is ubiquitous in estuarine sediments (Cornwell and Sampou 1995). Sulfide and reduced iron form iron monosulfides (FeS), and eventually pyrite (FeS_2). Iron monosulfides may be reoxidized to Fe(III) and sulfate, but pyrite is generally subject to more permanent burial (Cornwell and Sampou 1995). In either form (FeS or FeS_2), iron is not available to bind phosphate. Iron phosphate mineral formation can occur only if the Fe:P ratio is sufficiently high. Iron sulfide mineral formation lowers this ratio, but is dependent on the availability of S. Thus, the presence of sulfur increases Fe-S mineral formation and impedes Fe-P mineral formation, resulting in higher P fluxes out of sediments (Figure 20B).

It should be noted that S may be present in high enough concentrations to influence P release from sediments in freshwater systems as well. For example, in Lake Sempach, Switzerland, high P release from sediments in spite of artificial hypolimnetic oxygenation prompted researchers to consider Fe-S-P interactions (Gachter and Muller 2003). Those studying Lake Sempach speculated that diagenetic processes in the sediment may have produced enough sulfide to drive FeS formation (Gachter and Muller 2003). As Fe is removed from porewater by FeS formation, higher phosphate concentrations are required to exceed the solubility product of Fe-P minerals (*e.g.* vivianite), which leads to the dissolution of these minerals and subsequent increases in porewater phosphate. Since the Fe that would otherwise be available to bind phosphate is tied up in FeS, porewater phosphate is free to diffuse out of sediments to the water column.

A third major control on phosphorus dynamics in sediments is pH. At pH's observed in estuarine systems (>6), phosphorus solubility exhibits a positive correlation with pH such that a one unit increase in pH corresponds to a 1 to 2 order-of-magnitude increase in phosphate solubility (Stumm and Morgan 1970). This relationship stems from competition between phosphate and hydroxide anions for mineral surface binding sites, as net surface charge becomes more negative with increasing pH.

A study of P distribution along the Delaware Estuary provides an example of the impact of pH on P dynamics (Lebo and Sharp 1993). In that study, Delaware River estuary total (TP), particulate (PP) and dissolved inorganic (DIP) phosphorus data from 1970 to 1990 were compared. Data indicated a large decrease in TP throughout the estuary during this period, but also showed a significant *increase* in DIP near Philadelphia. The authors attribute the increase in DIP to desorption of PP due to increased pH, which was most likely the result of water quality improvements after two Philadelphia wastewater treatment stations upgraded from primary to secondary treatment. The Delaware Estuary study demonstrated that localized changes in pH can have a profound impact on P dynamics, a phenomenon that could prove important as efforts to improve water quality in the Anacostia River progress. The Delaware study also serves as a reminder about the existence of internal sources of bioavailable P, such that reduced P loading to an estuary may not be immediately accompanied by corresponding reductions in bioavailable P.

At most sites in the present study, phosphorus fluxes from sediments to the water column were small, and were often near or equal to zero. Low fluxes are to be expected in systems characterized by high dissolved oxygen, low salinity, and sediments with high iron content because these conditions are conducive to sediment binding and retention of phosphate. All sites exhibited large positive sediment Eh values and very low salinity throughout the study (Table 7). Most sites also exhibited bottom water DO concentrations above 5 mg l^{-1} (Figure 7).

Table 7. Measurements of pH made near study sites in the Washington Channel, lower Anacostia, and Potomac Rivers. Study sites are listed first, with the closest corresponding DC Department of Health monitoring sites listed in parentheses. All pH data from the DC Department of Health (Jarmon 2003).

	June	July	August	September	Summer Average
Washington Channel					
PT23 (DCDOH-PWC04)	7.8	8.4	9	8.2	8.4
Upstream of PT23 (DCDOH-PTB01)	8.7	8.4	8.7	8.6	8.6
Anacostia					
AN01 (DCDOH-ANA21)	7.3	8.1	8.6	7.5	7.9
AN02 (DCDOH-ANA19)	7.1	8.1	8.2	7.4	7.7
Potomac					
PT24 and PT25 (DCDOH-PMS21)	7.7	7.5	8	7.7	7.7

The Washington Channel site was a notable exception to the rule of small sediment-water phosphorus fluxes. Fluxes at this site were consistently large, despite low salinity and high DO. However, sediment Eh at 1 cm and 2 cm below the sediment surface at the Washington Channel site was lower than at any other site. Lower Eh in Washington Channel sediments may have contributed to the higher phosphorus fluxes there, but other data indicate that low oxygen conditions were not prevalent in the Washington Channel. Oxic respiration was a dominant process at that site, as evidenced by the fact that the magnitude of the ammonia flux corresponds well to the magnitude of sediment oxygen consumption (Figure 19). Another possible reason for high P fluxes out of the sediments in the Washington Channel is that sediment organic matter at this site contained a higher percent PP than any other site. A low Fe:P ratio (due to more available P) could lead to saturation of sediment iron mineral binding capacity for P, causing more P to remain in the dissolved phase after remineralization, augmenting the sediment-water flux.

Though no pH measurements were made in this study, pH is perhaps the most likely factor causing higher phosphorus fluxes observed in the Washington Channel. Given the large response in P solubility to small increases in pH, a small localized increase in bottom water or sediment pH would lead to substantial increases in porewater DIP and could thus augment sediment-water P fluxes. A small local increase in pH or higher sediment organic matter percent PP could also explain the temporally isolated high phosphorus fluxes observed at PT25 and PT24.

To investigate the possibility of heterogeneity in pH within the study area, pH data from a DC Department of Health monitoring program were obtained for the Washington Channel and for Anacostia and Potomac sites near the Channel (Jarmon 2003). Average pH was over half a unit higher in the Washington Channel than in nearby areas of the Anacostia and Potomac Rivers (Table 7). This local increase in pH may explain some of the high DIP fluxes observed in the Washington Channel. High DIP fluxes were also observed at PT24 and PT25 in August, coincident with the highest pH measurements made at those sites (Table 7).

Sediment Flux Influences on Water Column Conditions

Comparisons of water column and sediment processes among coastal and estuarine systems have established that sediments can exert substantial influences on water column properties, especially in shallow systems. For example, Kemp *et al.* (1992) have shown that SOC rates varied as an inverse function of depth and that the proportion of total system respiration (water column plus sediments) accounted for by SOC was also an inverse function of depth. In addition, whole system nutrient budgets indicate that despite often large nutrient inputs from atmospheric and terrestrial sources, nutrient recycling from sediments and water column must be important to support observed rates of phytoplanktonic nutrient demand (Boynton *et al.* 1995). Thus, we expected sediment processes in the shallow Anacostia and upper tidal Potomac to be important water quality factors.

To estimate the extent to which sediments in the Anacostia and upper tidal Potomac Rivers act as an oxygen sink, SOC and water column respiration data were summarized by area for the study period (Table 8). SOC represented from 19% of total system aerobic respiration in the deeper Washington Channel to 49% in the upper tidal Potomac River sites. As indicated by Kemp *et al.* (1992), sediments exert less influence on water column dissolved oxygen stocks at the deepest station and considerably more influence at the shallower stations.

Table 8. Estimates of the importance of SOC as an oxygen sink compared to water column respiration for several regions of the Anacostia-Upper Tidal Potomac River study areas. Respiration measurements for the June-September, 2002 period were averaged in developing estimates in the table.

Location	**Average Depth** (m)	**Total Water Column Respiration** ($g\ O_2\ m^{-2}\ d^{-1}$)	**Sediment Oxygen Consumption** ($g\ O_2\ m^{-2}\ d^{-1}$)	**SOC: Total Respiration** (%)
Upper Anacostia (AN05, AN04)	2.16	5.24	2.15	26
Lower Anacostia (AN03, AN02, AN01)	3.76	4.66	2.43	42
Washington Channel (PT23)	7.25	9.32	1.91	19
Mainstem Potomac (PT21, PT22, PT24, PT25)	3.70	2.67	2.16	49

Additional understanding of the probable impact of both water column and sediment oxygen consumption rates can be gained by computing the turnover time of water column dissolved oxygen stocks, assuming that the only losses of oxygen are due to these respiratory processes. In this computation it was assumed that the water could hold about 7 mg l^{-1} of oxygen at summer temperatures and that the stock could be estimated by multiplying this value by the average water column depth of the segments indicated in Table 8. In this scenario water column dissolved oxygen stocks could be depleted in 4 to 6 days based on consumption by water column and sediment heterotrophic processes at all but the shallowest regions (Upper Anacostia; depth = 1.9 m) where the dissolved oxygen stock would be depleted in just under two days. These computations indicate dynamic to very dynamic oxygen conditions. In other words, the oxygen demand is relatively large compared to the stock of oxygen in the water column. Since we did not observe severe hypoxia at these sites during summer, 2002, the supply rates of dissolved oxygen to the water column via air-water reaeration and in-situ oxygen production by phytoplankton must have also been substantial.

The potential impact of sediment nutrient releases on water quality can be estimated by computing the amount of phytoplankton production of organic matter that could be supported. In this exercise, we assume "Redfield Ratio" proportions for phytoplankton nutrient demand (C:N:P demand by phytoplankton = 106:16:1). Results for the summer, 2002 period are summarized in Table 9.

Table 9. Estimates of the importance of sediment ammonium and phosphorus fluxes in supporting phytoplankton production for several regions of the Anacostia-Upper Tidal Potomac River study area. Measurements for the June-September, 2002 period were averaged in developing estimates in the table. Nitrogen and phosphorus fluxes were converted to phytoplankton production rates assuming a C:N:P ratio of 106:16:1.

Location	Sediment Ammonium Flux (µmoles N m^{-2} d^{-1})	Sediment Phosphorus Flux (µmoles P m^{-2} d^{-1})	Ammonium Based Production (g C m^{-2} d^{-1})	Phosphorus Based Production (g C m^{-2} d^{-1})
Upper Anacostia (AN05, AN04)	24596	43	1.96	0.14
Lower Anacostia (AN03, AN02, AN01)	10522	44	0.84	0.14
Washington Channel (PT23)	7379	369	0.59	1.21
Mainstem Potomac (PT21, PT22, PT24, PT25)	11920	72	0.95	0.24

At all sites sediment ammonium fluxes were capable of supporting modest (Washington Channel site) to high (Upper Anacostia sites) rates of phytoplankton nutrient demand. The estimated impact of sediment ammonium fluxes on primary production in the study area is comparable to or somewhat higher than those observed in other nutrient-enriched portions of Chesapeake Bay (Boynton *et al.* 1995). The amount of production that could be supported based on sediment phosphorus fluxes was generally very small at all locations except the Washington Channel

(Station PT23) where phytoplankton production rates of about 1.2 g C m^{-2} d^{-1} could be supported. In this study, sediment phosphorus fluxes were of little significance except in the Washington Channel. It should be noted that substantial phosphorus may well be sorbed to sediments and, should environmental conditions become favorable, this phosphorus could be released to the water column in a form that is bioavailable.

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APPENDICES A - F
Anacostia River Monitoring Study
2002

Data Sets

Table 1. Anacostia River Monitoring Study Station Code, Grid Locations and Mean Depths (meters).
Datum NAD 83
Latitude and longitude values are expressed as decimal degrees.

This table is also added here for reference

Station	Tributary	Latitude Degrees	Longitude Degrees	Mean Depth (meters)
Anacostia River				
AN01	Anacostia	38.8617	77.0139	2.8
AN02	Anacostia	38.8694	76.9922	2.7
AN03	Anacostia	38.8961	76.9619	4.3
AN04	Anacostia	38.9153	76.9472	2.8
AN05	Anacostia	38.9381	76.9425	2.8
Potomac River				
PT21	Potomac	38.8058	77.0333	2.3
PT22	Potomac	38.8411	77.0269	3.7
PT23	Washington Channel	38.8708	77.0217	7.7
PT24	Potomac	38.8681	77.0336	3.5
PT25	Potomac	38.8853	77.0531	3.0

Table 4. Analysis Problem Codes

This table is also added here for reference.

ANALYSIS PROBLEM CODE	DESCRIPTION
A	Laboratory accident
B	Interference
C	Mechanical/materials failure
D	Insufficient sample
N	Sample Lost
P	Lost results
R	Sample contaminated
S	Sample container broken during analysis
V	Sample results rejected due to QA/QC criteria
W	Duplicate results for all parameters
X	Sample not preserved properly
AA	Sample thawed when received
BB	Torn filter paper
EE	Foil pouch very wet when received from field, therefore poor replication between pads, mean reported
FF	Poor replication between pads; mean reported
HD	Particulate and chlorophyll-a samples only taken at -1.0 cm of the Eh profile
HH	Sample not taken
JJ	Amount filtered not recorded (Calculation could not be done)
LL	Mislabeled
NI	Data for this variable are considered to be non-interpretable
NN	Particulates found in filtered sample
NR	No replicate analyzed for epiphyte strip chlorophyll-a concentration
PP	Assumed sample volume (pouch volume differs from data sheet volume; pouch volume used)
QQ	Although value exceeds a theoretically equivalent or greater value (*e.g.*, PO4F>TDP), the excess is within precision of analytical techniques and therefore not statistically significant.
SD	All sampling at station discontinued for one or more sampling periods
SS	Sample contaminated in field
TF	Dissolved oxygen probe failure
TL	Instrument failure in research laboratory
TS	Dissolved oxygen probe not stabilized
TT	Instrument failure on board research vessel
UU	Analysis discontinued
WW	Station was not sampled due to bad weather conditions, research vessel mechanical failure, or failure of state highway bridges to open or close
XX	Sampling for this variable was not included in the monitoring program at this time or was not monitored during a specific cruise
YB	No blank measured for MINI-SONE fluxes
YY	Data not recorded

SEDIMENT OXYGEN AND NUTRIENT EXCHANGES
ANACOSTIA RIVER TMDL DATA SET:

Page No.

TABLE A-1. SEDIMENT OXYGEN AND NUTRIENT EXCHANGES
ANACOSTIA RIVER: MINI-SONE
WATER COLUMN PROFILES: Vertical profiles of temperature, salinity, dissolved oxygen and other characteristics at TMDL stations

ANACOSTIA RIVER CRUISE: 1
FILENAME : TMDLANPR01
REVISED : 20020816

STATION	DATE	TIME	TOTAL DEPTH (m)	SECCHI DEPTH (m)	GEAR CODE	SAMPLE DEPTH (m)	TEMP (ºC)	COND (mS cm^{-1})	SALIN	DO (mg l^{-1})	DO SAT (%)
AN01	20020611	933	6.0	1.1	WP13	0.5	26.4	0.3	0.1	7.64	94.9
						3.0	26.3	0.3	0.1	7.45	92.4
						5.0	26.3	0.3	0.1	7.40	91.7
AN02	20020611	1025	5.0	0.9	WP13	0.5	28.5	0.3	0.1	7.59	97.9
						2.0	28.4	0.3	0.1	7.57	97.6
						4.0	28.3	0.3	0.1	7.56	97.2
AN03	20020611	1045	1.0	0.5	WP13	0.5	26.0	0.3	0.1	2.91	35.9
AN04	20020611	935	2.2	0.6	WP13	0.5	25.9	0.3	0.1	2.18	26.8
						1.0	25.8	0.3	0.1	1.96	24.1
						2.0	25.6	0.3	0.1	1.59	19.5
AN05	20020611	900	2.4	0.5	WP13	0.5	25.3	0.3	0.1	2.80	34.1
						1.5	25.3	0.3	0.1	2.98	36.3
PT21	20020611	643	3.0	0.7	WP13	0.5	26.3	0.3	0.1	6.79	84.3
						1.0	26.3	0.3	0.1	6.33	78.5
						2.0	26.4	0.3	0.1	6.73	83.6
PT22	20020611	735	2.0	0.7	WP13	0.5	26.2	0.3	0.1	7.13	88.3
						1.0	26.2	0.3	0.1	7.11	88.0
PT23	20020611	900	8.0	1.5	WP13	0.5	26.2	0.3	0.1	6.33	78.4
						3.0	26.2	0.3	0.1	6.18	76.5
						5.0	25.7	0.3	0.1	5.21	63.9
						7.0	25.5	0.3	0.1	5.61	68.6
PT24	20020611	820	4.0	1.0	WP13	0.5	26.1	0.3	0.1	7.98	98.7
						3.0	26.1	0.3	0.1	7.84	97.0
PT25	20020611	1250	3.1	1.3	WP13	0.5	27.4	0.3	0.1	8.28	104.9
						1.5	26.2	0.3	0.1	7.76	96.1
						2.5	25.9	0.3	0.1	7.32	90.1

TABLE A-2. SEDIMENT OXYGEN AND NUTRIENT EXCHANGES
ANACOSTIA RIVER: MINI-SONE
WATER COLUMN PROFILES: Vertical profiles of temperature, salinity, dissolved oxygen and other characteristics at TMDL stations

ANACOSTIA RIVER CRUISE: 2
FILENAME : TMDLANPR02
REVISED : 20020816

STATION	DATE	TIME	TOTAL DEPTH (m)	SECCHI DEPTH (m)	GEAR CODE	SAMPLE DEPTH (m)	TEMP (ºC)	COND (mS cm^{-1})	SALIN	DO (mg l^{-1})	DO SAT (%)
AN01	20020723	1129	6.0	0.7	WP13	0.5	28.9	0.4	0.2	8.78	114.0
						1.0	28.8	0.4	0.2	8.68	112.6
						3.0	28.7	0.4	0.2	8.69	112.5
						5.0	28.6	0.4	0.2	8.59	111.0
AN02	20020723	1004	4.0	0.6	WP13	0.5	28.9	0.3	0.2	8.74	113.6
						1.0	28.8	0.3	0.2	8.35	108.4
						2.0	28.8	0.3	0.2	8.23	106.8
						4.0	28.7	0.3	0.2	8.52	110.4
AN03	20020723	1300	2.8	0.4	WP13	0.5	29.1	0.3	0.1	8.20	107.0
						1.0	29.0	0.3	0.1	8.10	105.5
						2.0	29.0	0.3	0.1	8.03	104.5
AN04	20020723	1200	2.2	0.5	WP13	0.5	29.3	0.3	0.1	7.14	93.5
						1.0	28.9	0.3	0.1	6.30	81.9
						2.0	28.6	0.3	0.1	5.36	69.3
AN05	20020723	1050	2.7	0.6	WP13	0.5	29.2	0.3	0.1	5.39	70.4
						1.0	28.9	0.3	0.1	4.53	58.9
						2.0	28.7	0.3	0.1	3.33	43.1
						2.5	28.7	0.3	0.1	3.38	43.8
PT21	20020723	700	4.0	0.6	WP13	0.5	28.8	0.4	0.2	7.89	102.4
						1.0	28.9	0.4	0.2	7.33	95.3
						3.0	28.9	0.4	0.2	7.32	95.2
PT22	20020723	756	4.0	0.7	WP13	0.5	28.9	0.4	0.2	8.58	111.5
						1.0	28.9	0.4	0.2	8.50	110.5
						3.0	28.9	0.4	0.2	9.70	126.1
PT23	20020723	914	8.0	1.1	WP13	0.5	29.1	0.4	0.2	12.04	157.1
						1.0	28.7	0.4	0.2	10.03	130.0
						3.0	28.5	0.4	0.2	9.51	122.7
						5.0	28.4	0.4	0.2	9.30	119.8
						7.0	28.4	0.4	0.2	9.13	117.6
PT24	20020723	831	4.0	0.9	WP13	0.5	28.4	0.4	0.2	8.56	110.3
						1.0	28.4	0.4	0.2	8.66	111.5
						3.0	28.4	0.4	0.2	8.86	114.1

TABLE A-2. SEDIMENT OXYGEN AND NUTRIENT EXCHANGES
ANACOSTIA RIVER: MINI-SONE
WATER COLUMN PROFILES: Vertical profiles of temperature, salinity, dissolved oxygen and other characteristics at TMDL stations

ANACOSTIA RIVER CRUISE: 2
FILENAME : TMDLANPR02
REVISED : 20020816

STATION	DATE	TIME	TOTAL DEPTH (m)	SECCHI DEPTH (m)	GEAR CODE	SAMPLE DEPTH (m)	TEMP (ºC)	COND (mS cm^{-1})	SALIN	DO (mg l^{-1})	DO SAT (%)
PT25	20020723	1440	5.3	1.1	WP13	0.5	30.1	0.4	0.2	9.20	122.1
						1.0	30.1	0.4	0.2	9.37	124.3
						2.0	30.0	0.4	0.2	9.24	122.5
						3.0	29.3	0.4	0.2	6.59	86.3
						4.0	28.9	0.4	0.2	5.04	65.5
						5.0	28.6	0.4	0.2	3.96	51.2

TABLE A-3. SEDIMENT OXYGEN AND NUTRIENT EXCHANGES
ANACOSTIA RIVER: MINI-SONE
WATER COLUMN PROFILES: Vertical profiles of temperature, salinity, dissolved oxygen and other characteristics at TMDL stations

ANACOSTIA RIVER CRUISE: 3
FILENAME : TMDLANPR03
REVISED : 20021007

STATION	DATE	TIME	TOTAL DEPTH (m)	SECCHI DEPTH (m)	GEAR CODE	SAMPLE DEPTH (m)	TEMP (ºC)	COND (mS cm^{-1})	SALIN	DO (mg l^{-1})	DO SAT (%)
AN01	20020820	1159	5.0	0.8	WP13	0.5	29.9	0.4	0.2	7.91	104.6
						1.0	29.6	0.4	0.2	7.25	95.5
						2.0	29.6	0.4	0.2	6.91	90.9
						4.0	29.6	0.4	0.2	6.43	84.5
AN02	20020820	1042	4.0	0.5	WP13	0.5	29.8	0.4	0.2	7.89	104.2
						1.0	29.7	0.4	0.2	7.90	104.2
						3.0	29.7	0.4	0.2	7.84	103.4
AN03	20020820	1011	1.0	0.4	WP13	0.2	29.7	0.4	0.2	6.62	87.2
						0.8	29.6	0.4	0.2	6.37	83.9
AN04	20020820	907	0.8	0.4	WP13	0.2	29.7	0.4	0.2	5.17	68.1
						0.7	29.6	0.4	0.2	5.38	70.8
AN05	20020820	800	3.0	0.5	WP13	0.5	29.7	0.4	0.2	5.60	73.8
						1.0	29.7	0.4	0.2	5.23	68.9
						2.0	29.7	0.4	0.2	5.39	71.0
						3.0	29.7	0.4	0.2	5.12	67.4
PT21	20020820	730	3.0	0.8	WP13	0.5	30.0	0.5	0.2	5.35	70.9
						1.0	30.0	0.5	0.2	5.33	70.6
						2.0	30.0	0.5	0.2	5.47	72.5
PT22	20020820	824	4.0	0.7	WP13	0.5	30.4	0.5	0.2	5.64	75.2
						1.0	30.3	0.5	0.2	5.58	74.4
						3.0	30.3	0.5	0.2	5.73	76.4
PT23	20020820	952	7.0	1.0	WP13	0.5	29.7	0.4	0.2	8.76	115.4
						1.0	29.7	0.4	0.2	8.97	118.2
						2.0	29.6	0.4	0.2	8.72	114.8
						4.0	29.5	0.4	0.2	7.82	102.7
						6.0	29.3	0.4	0.2	5.94	77.8
PT24	20020820	909	5.0	0.8	WP13	0.5	29.6	0.4	0.2	6.90	90.9
						1.0	29.6	0.4	0.2	6.78	89.3
						2.0	29.6	0.4	0.2	6.72	88.4
						4.0	29.6	0.4	0.2	6.82	89.7

TABLE A-3. SEDIMENT OXYGEN AND NUTRIENT EXCHANGES
ANACOSTIA RIVER: MINI-SONE
WATER COLUMN PROFILES: Vertical profiles of temperature, salinity, dissolved oxygen and other characteristics at TMDL stations

ANACOSTIA RIVER CRUISE: 3
FILENAME : TMDLANPR03
REVISED : 20021007

STATION	DATE	TIME	TOTAL DEPTH (m)	SECCHI DEPTH (m)	GEAR CODE	SAMPLE DEPTH (m)	TEMP (ºC)	COND (mS cm^{-1})	SALIN	DO (mg l^{-1})	DO SAT (%)
PT25	20020820	1141	4.6	1.1	WP13	0.2	29.7	0.4	0.2	6.02	79.4
						1.0	29.6	0.4	0.2	6.00	79.0
						2.0	29.5	0.4	0.2	5.92	77.8
						3.0	29.4	0.4	0.2	5.72	75.0
						4.5	29.4	0.4	0.2	5.15	67.5

TABLE A-4. SEDIMENT OXYGEN AND NUTRIENT EXCHANGES
ANACOSTIA RIVER: MINI-SONE
WATER COLUMN PROFILES: Vertical profiles of temperature, salinity, dissolved oxygen and other characteristics at TMDL stations

ANACOSTIA RIVER CRUISE: 4
FILENAME : TMDLANPR04
REVISED : 20021007

STATION	DATE	TIME	TOTAL DEPTH (m)	SECCHI DEPTH (m)	GEAR CODE	SAMPLE DEPTH (m)	TEMP (ºC)	COND (mS cm^{-1})	SALIN	DO (mg l^{-1})	DO SAT (%)
AN01	20020924	1059	5.0	0.8	WP13	0.5	24.5	0.4	0.2	5.54	66.5
						1.0	24.5	0.4	0.2	5.44	65.3
						2.0	24.4	0.4	0.2	5.47	65.6
						4.0	24.4	0.4	0.2	5.33	63.9
AN02	20020924	1019	4.7	0.7	WP13	0.5	24.7	0.3	0.2	5.88	70.9
						1.0	24.5	0.3	0.2	5.47	65.7
						3.0	24.5	0.3	0.2	5.44	65.3
AN03	20020924	1030	0.7	0.4	WP13	0.5	23.8	0.3	0.1	7.41	87.8
AN04	20020924	1005	0.9	0.5	WP13	0.5	23.5	0.3	0.2	4.28	50.4
						0.9	23.5	0.3	0.2	4.27	50.3
AN05	20020924	912	3.0	0.4	WP13	0.5	23.6	0.3	0.2	4.36	51.4
						1.0	23.6	0.3	0.2	4.31	50.8
						1.5	23.6	0.3	0.2	4.38	51.7
						2.5	23.5	0.3	0.2	4.38	51.6
PT21	20020924	705	2.3	0.7	WP13	0.5	24.7	0.5	0.2	4.99	60.2
						1.0	24.7	0.4	0.2	6.02	72.6
PT22	20020924	750	2.0	0.5	WP13	0.5	24.5	0.4	0.2	5.45	65.4
						1.0	24.4	0.4	0.2	5.67	67.9
PT23	20020924	924	6.0	0.9	WP13	0.5	24.7	0.4	0.2	5.92	71.4
						1.0	24.8	0.4	0.2	5.94	71.7
						3.0	24.8	0.4	0.2	5.88	71.0
						5.0	24.9	0.4	0.2	5.90	71.3
PT24	20020924	836	3.0	0.8	WP13	0.5	23.9	0.4	0.2	5.88	69.9
						1.0	24.0	0.4	0.2	5.91	70.2
						2.0	23.9	0.4	0.2	5.90	70.1
PT25	20020924	1200	5.8	1.0	WP13	0.5	24.5	0.4	0.2	6.80	81.6
						1.5	24.2	0.4	0.2	6.39	76.3
						2.5	24.1	0.4	0.2	6.21	73.9
						3.5	24.0	0.4	0.2	5.69	67.6
						4.5	23.9	0.4	0.2	2.54	30.1
						5.5	23.7	0.4	0.2	1.99	23.5

SEDIMENT OXYGEN AND NUTRIENT EXCHANGES
ANACOSTIA RIVER TMDL DATA SET:

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TABLE B-1. SEDIMENT OXYGEN AND NUTRIENT EXCHANGES
ANACOSTIA RIVER: MINI-SONE
WATER COLUMN NUTRIENTS: Dissolved and particulate nutrient concentrations in bottom waters

ANACOSTIA RIVER CRUISE: 1
FILENAME : TMDLANNT01
REVISED : 20021120

STATION	DATE	TOTAL DEPTH (m)	SAMPLE DEPTH (m)	SAMPLE #	NH_4^+ (µM)	NO_2^- (µM)	NO_2^-+NO_3^- (µM)	CORR DIP (µM)
AN01	20020611	6.0	5.0	71	4.2	1.25	59.30	0.97
AN02	20020611	5.0	4.0	76	27.3	2.73	37.60	0.50
AN03	20020611	1.0	0.5	152	37.6	3.62	20.00	0.18
AN04	20020611	2.2	2.0	151	39.0	4.42	17.40	0.21
AN05	20020611	2.4	1.5	150	20.7	2.45	20.50	0.17
PT21	20020611	3.0	2.0	51	10.2	2.42	89.40	1.19
PT22	20020611	2.0	1.0	56	5.2	1.29	82.70	1.28
PT23	20020611	8.0	7.0	66	13.8	1.33	51.30	0.90
PT24	20020611	4.0	3.0	61	3.3	0.72	53.80	1.43
PT25	20020611	3.1	2.5	153	5.7	0.79	50.60	1.20

TABLE B-2. SEDIMENT OXYGEN AND NUTRIENT EXCHANGES
ANACOSTIA RIVER: MINI-SONE
WATER COLUMN NUTRIENTS: Dissolved and particulate nutrient concentrations in bottom waters

ANACOSTIA RIVER CRUISE: 2
FILENAME : TMDLANNT02
REVISED : 20021120

STATION	DATE	TOTAL DEPTH (m)	SAMPLE DEPTH (m)	SAMPLE #	NH_4^+ (µM)	NO_2^- (µM)	$NO_2^-+NO_3^-$ (µM)	CORR DIP (µM)
AN01	20020723	6.0	5.0	123	7.1	2.68	21.30	0.32
AN02	20020723	4.0	4.0	118	7.2	2.42	18.90	0.11
AN03	20020723	2.8	2.0	AN03	0.8	1.18	8.16	0.07
AN04	20020723	2.2	2.0	AN04	13.8	1.20	8.99	0.13
AN05	20020723	2.7	2.5	AN05	31.5	1.43	15.50	0.20
PT21	20020723	4.0	3.0	94	11.3	4.60	82.70	0.49
PT22	20020723	4.0	3.0	99	8.7	3.45	63.70	0.63
PT23	20020723	8.0	7.0	109	7.1	3.40	22.90	0.33
PT24	20020723	4.0	3.0	104	5.9	0.98	9.87	0.88
PT25	20020723	5.3	5.0	PT25	10.9	0.84	7.72	0.94

TABLE B-3. SEDIMENT OXYGEN AND NUTRIENT EXCHANGES
ANACOSTIA RIVER: MINI-SONE
WATER COLUMN NUTRIENTS: Dissolved and particulate nutrient concentrations in bottom waters

ANACOSTIA RIVER CRUISE: 3
FILENAME : TMDLANNT03
REVISED : 20021120

					DISSOLVED NUTRIENTS			
STATION	DATE	TOTAL DEPTH (m)	SAMPLE DEPTH (m)	SAMPLE #	NH_4^+ (µM)	NO_2^- (µM)	$NO_2^-+NO_3^-$ (µM)	CORR DIP (µM)
AN01	20020820	5.0	4.0	123	7.5	4.48	30.90	0.23
AN02	20020820	4.0	3.0	118	5.6	1.65	8.44	0.11
AN03	20020820	1.0	0.8	AN03	0.9	0.22	1.00	0.11
AN04	20020820	0.8	0.7	AN04	12.9	0.90	5.75	0.09
AN05	20020820	3.0	3.0	AN05	22.6	1.05	7.41	0.14
PT21	20020820	3.0	2.0	94	12.9	8.11	81.00	0.95
PT22	20020820	4.0	3.0	99	20.1	8.11	77.90	1.12
PT23	20020820	7.0	6.0	109	4.7	5.67	23.30	0.33
PT24	20020820	5.0	4.0	104	9.3	5.37	42.60	0.56
PT25	20020820	4.6	4.5	PT25	8.5	0.54	3.48	0.55

TABLE B-4. SEDIMENT OXYGEN AND NUTRIENT EXCHANGES
ANACOSTIA RIVER: MINI-SONE
WATER COLUMN NUTRIENTS: Dissolved and particulate nutrient concentrations in bottom waters

ANACOSTIA RIVER CRUISE: 4
FILENAME : TMDLANNT04
REVISED : 20021120

					DISSOLVED NUTRIENTS			
STATION	DATE	TOTAL DEPTH	SAMPLE DEPTH	SAMPLE #	NH_4^+	NO_2^-	$NO_2^-+NO_3^-$	CORR DIP
		(m)	(m)		(µM)	(µM)	(µM)	(µM)
AN01	20020924	5.0	4.0	60	8.6	3.89	101.00	0.89
AN02	20020924	4.7	3.0	55	6.8	2.93	40.00	0.07
AN03	20020924	0.7	0.5	AN03	6.8	1.87	18.30	0.13
AN04	20020924	0.9	0.9	AN04	18.7	1.71	14.40	0.24
AN05	20020924	3.0	2.5	AN05	22.7	1.16	10.80	0.14
PT21	20020924	2.3	1.0	35	12.2	5.86	128.00	1.00
PT22	20020924	2.0	1.0	40	9.1	3.84	92.00	0.73
PT23	20020924	6.0	5.0	50	3.9	2.63	40.80	0.12
PT24	20020924	3.0	2.0	45	8.6	2.50	37.70	0.27
PT25	20020924	5.8	5.5	PT25	12.5	2.50	13.70	0.19

SEDIMENT OXYGEN AND NUTRIENT EXCHANGES
ANACOSTIA RIVER TMDL DATA SET:

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TABLE C-1. SEDIMENT OXYGEN AND NUTRIENT EXCHANGES
ANACOSTIA RIVER: MINI-SONE
SEDIMENT PROFILES: Vertical sediment profiles of Eh and surficial sediment characteristics at TMDL stations

ANACOSTIA RIVER CRUISE: 1
FILENAME : TMDLANSP01
REVISED : 2002081

						SURFICIAL SEDIMENT PARTICULATES				
STATION	DATE	TIME	CORE DEPTH (cm)	Eh MEAS (mV)	Eh CORR (mV)	SED PC %(wt)	SED PN %(wt)	SED PP %(wt)	SED CHL*a* TOTAL (mg m^{-2})	SED CHL*a* ACTIVE (mg m^{-2})
AN01	20020611	952	1.0	118	362					
			0.0	-101	143					
			-1.0	-153	91	3.85	0.370	0.153	54.5	12.9 (1 cm)
			-2.0	-113	131					
AN02	20020611	1045	1.0	112	356					
			0.0	37	281					
			-1.0	-154	90	4.34	0.330	0.134	56.4	13.2 (1 cm)
			-2.0	-119	125					
AN03	20020611	1402	1.0	110	354					
			0.0	-7	237					
			-1.0	-68	177	3.91	0.240	0.087	56.7	21.3 (1 cm)
			-2.0	-2	242					
AN04	20020611	1328	1.0	114	358					
			0.0	-92	152					
			-1.0	-125	120	3.20	0.210	0.080	48.3	17.8 (1 cm)
			-2.0	-112	132					
AN05	20020611	1250	1.0	110	354					
			0.0	40	284					
			-1.0	-58	186	3.05	0.190	0.071	35.0	10.5 (1 cm)
			-2.0	-32	212					
PT21	20020611	638	1.0	109	353					
			0.0	106	350					
			-1.0	23	267	1.74	0.170	0.056	65.2	15.9 (1 cm)
			-2.0	53	297					
PT22	20020611	740	1.0	118	362					
			0.0	-16	228					
			-1.0	-45	199	3.40	0.310	0.104	69.9	23.0 (1 cm)
			-2.0	-109	135					
PT23	20020611	901	1.0	105	349					
			0.0	13	257					
			-1.0	-175	69	3.99	0.440	0.218	76.7	24.4 (1 cm)
			-2.0	-186	58					

TABLE C-1. SEDIMENT OXYGEN AND NUTRIENT EXCHANGES
ANACOSTIA RIVER: MINI-SONE
SEDIMENT PROFILES: Vertical sediment profiles of Eh and surficial sediment characteristics at TMDL stations

ANACOSTIA RIVER CRUISE: 1
FILENAME : TMDLANSP01
REVISED : 2002081

						SURFICIAL SEDIMENT PARTICULATES				
STATION	DATE	TIME	CORE DEPTH (cm)	Eh MEAS (mV)	Eh CORR (mV)	SED PC %(wt)	SED PN %(wt)	SED PP %(wt)	SED CHL*a* TOTAL (mg m^{-2})	SED CHL*a* ACTIVE (mg m^{-2})
PT24	20020611	838	1.0	113	357					
			0.0	-118	126					
			-1.0	-109	135	3.67	0.400	0.121	43.3	17.7 (1 cm)
			-2.0	-158	86					
PT25	20020611	1455	1.0	115	359					
			0.0	78	322					
			-1.0	9	253	4.81	0.440	0.105	62.0	28.1 (1 cm)
			-2.0	27	271					

TABLE C-2. SEDIMENT OXYGEN AND NUTRIENT EXCHANGES
ANACOSTIA RIVER: MINI-SONE
SEDIMENT PROFILES: Vertical sediment profiles of Eh and surficial sediment characteristics at TMDL stations

ANACOSTIA RIVER CRUISE: 2
FILENAME : TMDLANSP02
REVISED : 20021014

STATION	DATE	TIME	CORE DEPTH (cm)	Eh MEAS (mV)	Eh CORR (mV)	SURFICIAL SEDIMENT PARTICULATES: SED PC %(wt)	SED PN %(wt)	SED PP %(wt)	SED CHL*a* TOTAL (mg m^{-2})	SED CHL*a* ACTIVE (mg m^{-2})
AN01	20020723	1157	1.0	116	360					
			0.0	35	279					
			-1.0	49	293	3.93	0.400	0.146	85.6	34.1 (1 cm)
			-2.0	-23	221					
AN02	20020723	1030	1.0	107	351					
			0.0	-64	180					
			-1.0	-99	145	4.90	0.370	0.134	113.0	47.9 (1 cm)
			-2.0	-42	202					
AN03	20020723	1343	1.0	106	350					
			0.0	-65	179					
			-1.0	-42	202	4.43	0.280	0.095	62.0	25.8 (1 cm)
			-2.0	-21	223					
AN04	20020723	1438	1.0	98	342					
			0.0	57	301					
			-1.0	33	277	0.74	0.060	0.029	114.4	57.9 (1 cm)
			-2.0	-26	218					
AN05	20020723	1518	1.0	98	342					
			0.0	18	262					
			-1.0	-57	188	5.33	0.380	0.100	68.3	28.9 (1 cm)
			-2.0	-100	145					
PT21	20020723	YY	1.0	100	344					
	.		0.0	87	331					
			-1.0	-12	232	2.13	0.200	0.047	113.6	38.0 (1 cm)
			-2.0	-38	206					
PT22	20020723	805	1.0	111	355					
			0.0	46	290					
			-1.0	-29	215	3.70	0.360	0.122	66.6	23.8 (1 cm)
			-2.0	-31	213					
PT23	20020723	926	1.0	93	337					
			0.0	-23	221					
			-1.0	-67	177	A	A	A	195.5	81.0 (1 cm)
			-2.0	-98	146					

TABLE C-2. SEDIMENT OXYGEN AND NUTRIENT EXCHANGES
ANACOSTIA RIVER: MINI-SONE
SEDIMENT PROFILES: Vertical sediment profiles of Eh and surficial sediment characteristics at TMDL stations

ANACOSTIA RIVER CRUISE: 2
FILENAME : TMDLANSP02
REVISED : 20021014

						SURFICIAL SEDIMENT PARTICULATES				
STATION	DATE	TIME	CORE DEPTH (cm)	Eh MEAS (mV)	Eh CORR (mV)	SED PC %(wt)	SED PN %(wt)	SED PP %(wt)	SED CHLa TOTAL ($mg\ m^{-2}$)	SED CHLa ACTIVE ($mg\ m^{-2}$)
PT24	20020723	843	1.0	99	343					
			0.0	40	284					
			-1.0	-27	217	4.52	0.430	0.121	39.3	13.5 (1 cm)
			-2.0	-21	223					
PT25	20020723	1556	1.0	99	343					
			0.0	84	328					
			-1.0	78	322	A	A	A	64.2	21.3 (1 cm)
			-2.0	72	316					

TABLE C-3. SEDIMENT OXYGEN AND NUTRIENT EXCHANGES
ANACOSTIA RIVER: MINI-SONE
SEDIMENT PROFILES: Vertical sediment profiles of Eh and surficial sediment characteristics at TMDL stations

ANACOSTIA RIVER CRUISE: 3
FILENAME : TMDLANSP03
REVISED : 20021014

STATION	DATE	TIME	CORE DEPTH (cm)	Eh MEAS (mV)	Eh CORR (mV)	SURFICIAL SEDIMENT PARTICULATES: SED PC %(wt)	SED PN %(wt)	SED PP %(wt)	SED CHLa TOTAL (mg m^{-2})	SED CHLa ACTIVE (mg m^{-2})
AN01	20020820	YY	1.0	130	374					
			0.0	-3	241					
			-1.0	-18	226	4.26	0.460	0.112	65.0	26.8 (1 cm)
			-2.0	-2	242					
AN02	20020820	1052	1.0	100	344					
			0.0	66	310					
			-1.0	-62	182	4.67	0.380	0.060	72.6	30.4 (1 cm)
			-2.0	-72	172					
AN03	20020820	1320	1.0	118	362					
			0.0	46	290					
			-1.0	33	277	4.52	0.280	0.077	39.8	15.5 (1 cm)
			-2.0	0	244					
AN04	20020820	1410	1.0	104	348					
			0.0	17	261					
			-1.0	73	317	0.60	0.050	0.020	39.5	19.5 (1 cm)
			-2.0	11	255					
AN05	20020820	1443	1.0	95	339					
			0.0	-28	216					
			-1.0	-79	165	3.78	0.260	0.075	45.4	16.9 (1 cm)
			-2.0	-95	149					
PT21	20020820	720	1.0	98	342					
			0.0	-59	185					
			-1.0	-90	154	1.80	0.160	0.070	84.3	30.7 (1 cm)
			-2.0	-84	160					
PT22	20020820	834	1.0	115	359					
			0.0	-43	201					
			-1.0	-28	216	4.12	0.370	0.104	71.2	28.1 (1 cm)
			-2.0	-32	212					
PT23	20020820	1006	1.0	112	356					
			0.0	0	244					
			-1.0	-40	204	4.01	0.470	0.180	78.9	28.7 (1 cm)
			-2.0	28	272					

TABLE C-3. SEDIMENT OXYGEN AND NUTRIENT EXCHANGES
ANACOSTIA RIVER: MINI-SONE
SEDIMENT PROFILES: Vertical sediment profiles of Eh and surficial sediment characteristics at TMDL stations

ANACOSTIA RIVER CRUISE: 3
FILENAME : TMDLANSP03
REVISED : 20021014

						SURFICIAL SEDIMENT PARTICULATES				
			CORE	Eh	Eh	SED	SED	SED	SED CHLa	SED CHLa
STATION	DATE	TIME	DEPTH	MEAS	CORR	PC	PN	PP	TOTAL	ACTIVE
			(cm)	(mV)	(mV)	%(wt)	%(wt)	%(wt)	(mg m^{-2})	(mg m^{-2})
PT24	20020820	919	1.0	107	351					
			0.0	-105	139					
			-1.0	-58	186	3.82	0.410	0.121	90.4	31.9 (1 cm)
			-2.0	-17	227					
PT25	20020820	1245	1.0	103	347					
			0.0	66	310					
			-1.0	60	304	3.73	0.370	0.103	54.8	16.3 (1 cm)
			-2.0	81	325					

TABLE C-4. SEDIMENT OXYGEN AND NUTRIENT EXCHANGES
ANACOSTIA RIVER: MINI-SONE
SEDIMENT PROFILES: Vertical sediment profiles of Eh and surficial sediment characteristics at TMDL stations

ANACOSTIA RIVER CRUISE: 4
FILENAME : TMDLANSP04
REVISED : 20021014

STATION	DATE	TIME	CORE DEPTH (cm)	Eh MEAS (mV)	Eh CORR (mV)	SURFICIAL SEDIMENT PARTICULATES: SED PC %(wt)	SED PN %(wt)	SED PP %(wt)	SED CHLa TOTAL (mg m^{-2})	SED CHLa ACTIVE (mg m^{-2})
AN01	20020924	1104	1.0	94	338					
			0.0	-173	71					
			-1.0	-109	135	4.09	0.440	0.145	84.5	26.4 (1 cm)
			-2.0	-121	123					
AN02	20020924	1018	1.0	100	344					
			0.0	-121	123					
			-1.0	-108	136	4.46	0.360	0.118	98.6	38.9 (1 cm)
			-2.0	-107	137					
AN03	20020924	1256	1.0	70	314					
			0.0	-50	194					
			-1.0	43	287	2.21	0.130	0.060	65.8	33.7 (1 cm)
			-2.0	44	288					
AN04	20020924	1141	1.0	101	345					
			0.0	25	269					
			-1.0	-5	240	0.45	0.030	0.039	51.7	24.9 (1 cm)
			-2.0	-43	201					
AN05	20020924	1216	1.0	86	330					
			0.0	-19	225					
			-1.0	-86	158	5.04	0.350	0.085	59.0	26.7 (1 cm)
			-2.0	-92	152					
PT21	20020924	714	1.0	116	360					
			0.0	94	338					
			-1.0	-40	204	2.62	0.240	0.079	89.5	25.8 (1 cm)
			-2.0	47	291					
PT22	20020923	757	1.0	120	364					
			0.0	31	275					
			-1.0	-5	239	2.58	0.140	0.094	51.9	14.5 (1 cm)
			-2.0	-48	196					
PT23	20020924	927	1.0	103	347					
			0.0	-124	120					
			-1.0	-131	113	4.07	0.470	0.178	133.0	40.8 (1 cm)
			-2.0	-129	115					

**TABLE C-4. SEDIMENT OXYGEN AND NUTRIENT EXCHANGES
ANACOSTIA RIVER: MINI-SONE
SEDIMENT PROFILES: Vertical sediment profiles of Eh and surficial sediment characteristics at TMDL stations**

ANACOSTIA RIVER CRUISE: 4
FILENAME : TMDLANSP04
REVISED : 20021014

						SURFICIAL SEDIMENT PARTICULATES				
STATION	DATE	TIME	CORE DEPTH (cm)	Eh MEAS (mV)	Eh CORR (mV)	SED PC %(wt)	SED PN %(wt)	SED PP %(wt)	SED CHLa TOTAL (mg m^{-2})	SED CHLa ACTIVE (mg m^{-2})
PT24	20020924	843	1.0	102	346					
			0.0	-37	207					
			-1.0	-6	238	4.19	0.480	0.120	55.6	16.1 (1 cm)
			-2.0	-11	234					
PT25	20020924	1333	1.0	87	331					
			0.0	-8	236					
			-1.0	36	280	3.45	0.350	0.105	77.1	24.4 (1 cm)
			-2.0	18	262					

SEDIMENT OXYGEN AND NUTRIENT EXCHANGES
ANACOSTIA RIVER TMDL DATA SET:

Page No.

D. **CORE DATA:**

FILE NAME: TMDLANCDnn

2002

TABLE D-1. SEDIMENT OXYGEN AND NUTRIENT EXCHANGES
ANACOSTIA RIVER: MINI-SONE
CORE DATA: Dissolved nutrient and oxygen concentrations in TMDL sediment-water flux chambers

ANACOSTIA RIVER CRUISE: 1
FILENAME : TMDLANCD01
REVISED : 20021120

STATION	DATE	CORE NO	TIME OF SAMPLE (h	min)	TIME DELTA (min)	TIME SUM (min)	DO (mg l^{-1})	AA VIAL NO	NH_4^+ (µM)	NO_2^- (µM)	NO_2^-+NO_3^- (µM)	DIP (µM)
AN01	20020611	1	11	10	0	0	7.07	72	4.40	1.16	58.30	0.97
			12	10	60	60	6.37	73	5.70	1.17	57.40	0.97
			13	11	61	121	5.87	74	7.10	1.19	57.00	0.94
			14	12	61	182	5.50	75	7.60	1.19	56.40	0.96
AN02	20020611	1	12	0	0	0	3.43	77	28.40	2.76	34.60	0.68
			13	4	64	64	2.79	78	41.80	2.80	33.20	0.59
			14	8	64	128	2.60	79	34.70	2.82	31.50	0.64
			15	3	55	183	2.11	80	34.90	2.81	30.00	0.54
AN03	20020611	1	15	10	0	0	3.13	90	42.00	3.41	17.60	0.32
			16	10	60	60	2.49	91	42.90	3.13	16.90	0.38
			17	10	60	120	2.01	92	44.40	2.99	15.30	0.36
			18	10	60	180	1.61	93	47.80	2.96	14.80	0.38
AN04	20020611	1	14	25	0	0	1.80	86	49.60	4.59	16.80	0.22
			15	25	60	60	1.52	87	57.50	4.52	16.20	0.24
			16	27	62	122	1.35	88	61.60	4.42	15.80	0.32
			17	25	58	180	1.30	89	68.00	4.35	15.50	0.27
AN05	20020611	1	13	45	0	0	2.54	82	29.30	2.33	19.30	0.12
			14	49	64	64	2.12	83	29.10	2.29	18.70	0.16
			15	45	56	120	1.86	84	31.10	2.32	18.20	0.17
			16	45	60	180	1.56	85	36.60	2.28	17.70	0.14
PT21	20020611	1	8	25	0	0	6.68	52	9.40	2.34	87.90	1.20
			9	25	60	60	5.99	53	9.20	2.29	87.80	1.15
			10	25	60	120	5.41	54	9.00	2.27	87.90	1.12
			11	25	60	180	5.05	55	13.30	2.33	87.70	1.20
PT22	20020611	1	9	30	0	0	6.90	57	5.50	1.30	83.30	1.18
			10	30	60	60	6.14	58	7.30	1.48	82.40	1.22
			11	30	60	120	5.57	59	9.60	1.61	81.00	1.24
			12	33	63	183	5.02	60	11.30	1.71	79.80	1.31

TABLE D-1. SEDIMENT OXYGEN AND NUTRIENT EXCHANGES
ANACOSTIA RIVER: MINI-SONE
CORE DATA: Dissolved nutrient and oxygen concentrations in TMDL sediment-water flux chambers

ANACOSTIA RIVER CRUISE: 1
FILENAME : TMDLANCD01
REVISED : 20021120

STATION	DATE	CORE NO	TIME OF SAMPLE (h	min)	TIME DELTA (min)	TIME SUM (min)	DO (mg l^{-1})	AA VIAL NO	NH_4^+ (µM)	NO_2^- (µM)	NO_2^-+NO_3^- (µM)	DIP (µM)
PT23	20020611	1	10	35	0	0	4.61	67	12.00	1.30	49.10	1.72
			11	35	60	60	4.17	68	15.60	1.27	48.40	1.83
			12	37	62	122	3.87	69	16.40	1.27	47.50	2.15
			13	36	59	181	3.61	70	16.00	1.22	46.60	2.26
PT24	20020611	1	10	33	0	0	7.10	62	8.60	0.80	52.60	1.08
			11	33	60	60	6.31	63	12.30	0.92	51.60	0.91
			12	35	62	122	5.76	64	16.30	1.13	50.00	1.02
			13	30	55	177	5.28	65	18.50	1.17	49.10	0.91
PT25	20020611	1	15	50	0	0	6.85	94	17.30	0.73	48.40	1.10
			16	50	60	60	5.97	95	22.40	0.79	47.40	1.07
			17	50	60	120	5.44	96	26.70	0.87	45.90	1.06
			18	50	60	180	5.05	97	33.10	1.00	44.40	0.66

TABLE D-2. SEDIMENT OXYGEN AND NUTRIENT EXCHANGES
ANACOSTIA RIVER: MINI-SONE
CORE DATA: Dissolved nutrient and oxygen concentrations in TMDL sediment-water flux chambers

ANACOSTIA RIVER CRUISE: 2
FILENAME : TMDLANCD02
REVISED : 20021120

STATION	DATE	CORE NO	TIME OF SAMPLE (h	min)	TIME DELTA (min)	TIME SUM (min)	DO (mg l^{-1})	AA VIAL NO	NH_4^+ (µM)	NO_2^- (µM)	$NO_2^-+NO_3^-$ (µM)	DIP (µM)
AN01	20020723	1	13	5	0	0	5.99	124	9.60	2.66	21.10	0.34
			14	5	60	60	4.98	125	16.80	2.73	20.10	0.45
			15	5	60	120	4.29	126	19.30	2.54	18.80	0.45
			16	7	62	182	3.70	127	22.30	2.48	17.90	0.45
AN02	20020723	1	11	35	0	0	6.62	119	6.90	2.39	18.10	0.06
			12	36	61	61	5.46	120	13.60	2.32	17.10	0.09
			13	35	59	120	4.63	121	18.60	2.27	16.10	0.06
			14	35	60	180	3.87	122	24.30	2.28	15.00	0.09
AN03	20020723	1	15	10	0	0	7.00	136	2.00	1.09	7.36	0.06
			16	11	61	61	5.87	137	3.80	1.04	6.70	0.06
			17	11	60	121	5.14	138	8.80	1.02	6.39	0.06
			18	11	60	181	4.49	139	9.30	0.99	6.19	0.07
AN04	20020723	1	14	40	0	0	4.81	128	15.20	1.27	9.09	0.19
			15	40	60	60	4.13	129	14.80	1.13	8.69	0.09
			16	42	62	122	3.68	130	18.00	1.22	8.32	0.14
			17	40	58	180	3.28	131	18.30	1.13	8.02	0.07
AN05	20020723	1	14	45	0	0	2.71	132	28.60	1.39	14.10	0.21
			15	45	60	60	2.26	133	44.30	1.33	13.70	0.20
			16	45	60	120	1.97	134	48.80	1.33	13.20	0.25
			17	47	62	182	1.69	135	50.00	1.29	12.90	0.14
PT21	20020723	1	8	30	0	0	6.93	95	8.40	4.67	83.40	0.45
			9	32	62	62	6.13	96	9.40	4.46	83.40	0.48
			10	30	58	120	5.65	97	10.30	4.32	82.90	0.48
			11	30	60	180	5.17	98	8.70	4.32	82.70	0.49
PT22	20020723	1	9	45	0	0	6.67	100	13.60	3.45	63.30	0.61
			10	46	61	61	5.56	101	21.00	3.42	61.30	0.50
			11	45	59	120	4.90	102	27.60	3.45	59.90	0.57
			12	45	60	180	4.32	103	32.40	3.46	59.00	0.57

TABLE D-2. SEDIMENT OXYGEN AND NUTRIENT EXCHANGES
ANACOSTIA RIVER: MINI-SONE
CORE DATA: Dissolved nutrient and oxygen concentrations in TMDL sediment-water flux chambers

ANACOSTIA RIVER CRUISE: 2
FILENAME : TMDLANCD02
REVISED : 20021120

STATION	DATE	CORE NO	TIME OF SAMPLE (h	min)	TIME DELTA (min)	TIME SUM (min)	DO (mg l^{-1})	AA VIAL NO	NH_4^+ (µM)	NO_2^- (µM)	NO_2^-+NO_3^- (µM)	DIP (µM)
PT23	20020723	1	11	50	0	0	5.96	110	10.90	3.40	22.00	0.54
			12	51	61	61	4.89	111	17.80	3.34	20.50	0.65
			13	51	60	121	4.17	112	15.30	3.20	19.70	0.77
			14	50	59	180	3.55	113	18.70	3.10	18.40	0.91
PT24	20020723	1	9	50	0	0	6.13	105	8.60	0.95	9.39	0.88
			10	50	60	60	5.12	106	12.20	0.96	9.00	0.76
			11	52	62	122	4.43	107	19.80	0.92	8.38	0.74
			12	49	57	179	3.90	108	25.80	0.87	8.09	0.80
PT25	20020723	1	16	5	0	0	3.84	140	13.40	0.87	7.30	0.98
			17	5	60	60	3.13	141	18.70	0.85	7.11	0.89
			18	5	60	120	2.69	142	19.10	0.82	6.77	0.85
			19	4	59	179	2.28	143	22.70	0.81	6.62	0.87

TABLE D-3. SEDIMENT OXYGEN AND NUTRIENT EXCHANGES
ANACOSTIA RIVER: MIN-SONE
CORE DATA: Dissolved nutrient and oxygen concentrations in TMDL sediment-water flux chambers

ANACOSTIA RIVER CRUISE: 3
FILENAME : TMDLANCD03
REVISED : 20021120

STATION	DATE	CORE NO	TIME OF SAMPLE (h	min)	TIME DELTA (min)	TIME SUM (min)	DO (mg l^{-1})	AA VIAL NO	NH_4^+ (µM)	NO_2^- (µM)	$NO_2^-+NO_3^-$ (µM)	DIP (µM)
AN01	20020820	1	13	50	0	0	6.04	124	11.60	5.01	32.60	0.30
			14	51	61	61	4.86	125	19.40	4.86	31.10	0.39
			15	50	59	120	4.09	126	23.70	4.77	29.80	0.49
			16	50	60	180	3.32	127	30.40	4.64	28.30	0.54
AN02	20020820	1	11	50	0	0	7.82	119	6.70	1.62	8.25	0.12
			12	50	60	60	6.09	120	14.60	1.62	7.63	0.16
			13	47	57	117	5.06	121	20.60	1.79	7.18	0.18
			14	50	63	180	4.11	122	27.00	1.46	6.72	0.17
AN03	20020820	1	13	40	0	0	6.05	132	10.40	0.23	0.75	0.08
			14	40	60	60	5.38	133	14.40	0.26	0.80	0.09
			15	40	60	120	4.94	134	13.40	0.28	0.75	0.11
			16	40	60	180	4.47	135	13.90	0.24	0.78	0.12
AN04	20020820	1	14	25	0	0	4.44	136	15.60	0.82	5.52	0.09
			15	25	60	60	3.75	137	17.30	0.82	5.22	0.11
			16	26	61	121	3.29	138	20.60	0.85	4.99	0.12
			17	25	59	180	2.95	139	22.10	0.84	4.83	0.12
AN05	20020820	1	14	30	0	0	4.75	140	25.80	1.08	7.40	0.19
			15	31	61	61	3.93	141	28.90	1.01	6.55	0.09
			16	31	60	121	3.40	142	30.70	0.99	6.36	0.10
			17	30	59	180	2.95	143	36.20	0.95	6.24	0.10
PT21	20020820	1	9	20	0	0	5.43	95	12.60	8.16	81.20	0.74
			10	20	60	60	4.77	96	16.30	7.88	80.80	0.86
			11	20	60	120	4.36	97	19.60	7.71	79.30	0.77
			12	21	61	181	3.85	98	15.20	7.61	79.90	0.78
PT22	20020820	1	10	15	0	0	5.66	100	17.50	7.96	76.60	0.98
			11	16	61	61	4.84	101	20.60	7.78	75.80	0.90
			12	16	60	121	3.89	102	23.30	7.85	74.60	1.04
			13	16	60	181	3.99	103	26.90	7.87	74.60	0.95

TABLE D-3. SEDIMENT OXYGEN AND NUTRIENT EXCHANGES
ANACOSTIA RIVER: MIN-SONE
CORE DATA: Dissolved nutrient and oxygen concentrations in TMDL sediment-water flux chambers

ANACOSTIA RIVER CRUISE: 3
FILENAME : TMDLANCD03
REVISED : 20021120

STATION	DATE	CORE NO	TIME OF SAMPLE (h	min)	TIME DELTA (min)	TIME SUM (min)	DO (mg l^{-1})	AA VIAL NO	NH_4^+ (µM)	NO_2^- (µM)	NO_2^-+NO_3^- (µM)	DIP (µM)
PT23	20020820	1	11	10	0	0	6.37	110	6.40	5.99	23.10	0.39
			12	10	60	60	5.15	111	10.60	5.82	22.00	0.45
			13	10	60	120	4.32	112	15.60	5.61	21.10	0.59
			14	10	60	180	3.84	113	17.40	5.39	20.00	0.68
PT24	20020820	1	10	35	0	0	6.14	105	10.20	5.52	43.80	0.66
			11	35	60	60	4.38	106	20.70	5.30	409.00	0.89
			12	35	60	120	3.15	107	26.60	5.05	37.40	1.14
			13	37	62	182	2.12	108	36.60	4.77	33.60	1.13
PT25	20020820	1	13	25	0	0	5.57	128	10.60	0.56	3.56	0.58
			14	20	55	55	4.59	129	17.40	0.54	3.47	0.72
			15	24	64	119	3.76	130	23.40	0.54	3.27	0.87
			16	25	61	180	3.15	131	27.50	0.54	3.09	1.04

TABLE D-4. SEDIMENT OXYGEN AND NUTRIENT EXCHANGES
ANACOSTIA RIVER: MIN-SONE
CORE DATA: Dissolved nutrient and oxygen concentrations in TMDL sediment-water flux chambers

ANACOSTIA RIVER CRUISE: 4
FILENAME : TMDLANCD04
REVISED : 20021120

STATION	DATE	CORE NO	TIME OF SAMPLE (h	min)	TIME DELTA (min)	TIME SUM (min)	DO (mg l^{-1})	AA VIAL NO	NH_4^+ (µM)	NO_2^- (µM)	NO_2^-+NO_3^- (µM)	DIP (µM)
AN01	20020924	1	12	5	0	0	6.35	61	10.10	3.90	100.00	0.68
			13	5	60	60	3.96	62	15.50	3.97	98.00	0.85
			14	5	60	120	5.57	63	17.90	4.03	97.00	0.65
			15	7	62	182	4.94	64	21.10	4.16	94.00	0.76
AN02	20020924	1	11	20	0	0	6.52	56	8.10	2.92	37.00	0.07
			12	22	62	62	5.67	57	11.80	2.87	37.60	0.07
			13	20	58	120	5.08	58	14.40	2.98	36.40	0.09
			14	20	60	180	4.60	59	18.20	2.70	35.20	0.09
AN03	20020924	1	12	20	0	0	6.91	65	6.30	1.87	18.50	0.08
			13	21	61	61	6.34	66	7.10	1.83	18.10	0.07
			14	21	60	121	5.99	67	7.40	1.83	17.60	0.05
			15	20	59	180	5.80	68	10.20	1.86	17.50	0.08
AN04	20020924	1	12	55	0	0	4.21	69	18.30	1.71	13.50	0.10
			13	59	64	64	3.92	70	19.30	1.70	13.90	0.10
			14	58	59	123	4.14	71	20.70	1.71	13.60	0.09
			15	57	59	182	4.00	72	19.20	1.73	13.60	0.13
AN05	20020924	1	13	10	0	0	3.84	73	44.60	1.12	10.20	0.14
			14	10	60	60	3.25	74	55.10	1.11	10.00	0.33
			15	9	59	119	2.84	75	70.70	1.11	9.60	0.14
			16	10	61	180	2.47	76	69.90	1.09	9.30	0.14
PT21	20020924	1	8	25	0	0	6.40	36	12.10	5.65	128.00	1.01
			9	25	60	60	5.60	37	12.10	5.70	127.00	0.98
			10	26	61	121	5.02	38	12.40	5.77	126.00	0.95
			11	25	59	180	4.53	39	12.10	5.95	125.00	1.01
PT22	20020924	1	8	55	0	0	6.90	41	8.60	3.89	93.00	0.76
			9	55	60	60	5.96	42	9.00	3.86	92.00	0.80
			10	55	60	120	5.43	43	9.50	4.03	92.00	0.91
			11	55	60	180	5.01	44	11.00	3.45	92.00	0.83

TABLE D-4. SEDIMENT OXYGEN AND NUTRIENT EXCHANGES
ANACOSTIA RIVER: MIN-SONE
CORE DATA: Dissolved nutrient and oxygen concentrations in TMDL sediment-water flux chambers

ANACOSTIA RIVER CRUISE: 4
FILENAME : TMDLANCD04
REVISED : 20021120

STATION	DATE	CORE NO	TIME OF SAMPLE (h	min)	TIME DELTA (min)	TIME SUM (min)	DO (mg l^{-1})	AA VIAL NO	NH_4^+ (µM)	NO_2^- (µM)	NO_2^-+NO_3^- (µM)	DIP (µM)
PT23	20020924	1	10	45	0	0	7.28	51	4.20	2.65	40.70	0.16
			11	45	60	60	6.21	52	8.60	2.64	39.40	0.19
			12	45	60	120	5.62	53	9.00	2.66	38.50	0.22
			13	45	60	180	5.17	54	13.10	2.64	37.00	0.30
PT24	20020924	1	9	35	0	0	7.06	46	9.30	2.54	39.00	0.19
			10	34	59	59	6.13	47	14.00	2.60	38.00	0.23
			11	35	61	120	5.63	48	17.50	2.65	37.20	0.15
			12	35	60	180	5.21	49	20.00	3.07	32.20	0.24
PT25	20020924	1	13	35	0	0	6.12	77	13.70	2.50	13.50	0.19
			14	36	61	61	5.45	78	15.10	2.47	13.30	0.20
			15	35	59	120	5.14	79	16.90	2.42	13.00	0.22
			16	35	60	180	4.88	80	18.60	2.41	13.10	0.45

SEDIMENT OXYGEN AND NUTRIENT EXCHANGES
ANACOSTIA RIVER TMDL DATA SET:

TABLE E-1. SEDIMENT OXYGEN AND NUTRIENT EXCHANGES
ANACOSTIA RIVER: MINI-SONE
SEDIMENT-WATER FLUX: Net sediment-water exchange rates of dissolved oxygen (g O_2 m^{-2} d^{-1}) and nutrients (µmoles-N m^{-2} h^{-1}, and µmoles-P m^{-2} h^{-1})

ANACOSTIA RIVER CRUISE: 1
FILENAME : TMDLANFL01
REVISED : 20030216

		CORE							
			H_2O			DO	DO	NH_4^+	NH_4^+
STATION	DATE	NO	VOL	DEPTH	SIZE	SLOPE	FLUX	SLOPE	FLUX
			(ml)	(m)	(cm^2)	(mg l^{-1} min^{-1})	(g O_2 m^{-2} d^{-1})	(µmoles-N l^{-1} min^{-1})	(µmoles-N m^{-2} h^{-1})
AN01	20020611	1	2240	0.161	139	-0.008578	-1.99	0.018114	175.1
AN02	20020611	1	1960	0.141	139	-0.006761	-1.37	NI	NI
AN03	20020611	1	2060	0.247	83.32	-0.008425	-3.00	0.031500	467.3
AN04	20020611	1	2280	0.274	83.32	-0.003683	-1.45	0.098430	1616.1
AN05	20020611	1	2160	0.259	83.32	-0.005379	-2.01	0.064976	1010.7
PT21	20020611	1	2140	0.154	139	-0.009117	-2.02	NI	NI
PT22	20020611	1	2080	0.150	139	-0.010188	-2.20	0.032331	290.3
PT23	20020611	1	2180	0.157	139	-0.005455	-1.23	0.021188	199.4
PT24	20020611	1	2100	0.151	139	-0.010147	-2.21	0.056957	516.3
PT25	20020611	1	1360	0.163	83.32	-0.009883	-2.32	0.086167	843.9

TABLE E-1. SEDIMENT OXYGEN AND NUTRIENT EXCHANGES
ANACOSTIA RIVER: MINI-SONE
SEDIMENT-WATER FLUX: Net sediment-water exchange rates of dissolved oxygen (g O_2 m^{-2} d^{-1}) and nutrients (µmoles-N m^{-2} h^{-1}, and µmoles-P m^{-2} h^{-1})

ANACOSTIA RIVER CRUISE: 1
FILENAME : TMDLANFL01
REVISED : 20030216

STATION	DATE	NO	CORE $H_2$0 VOL (ml)	CORE DEPTH (m)	CORE SIZE (cm^2)	NO_2^- SLOPE (µmoles-N l^{-1} min^{-1})	NO_2^- FLUX (µmoles-N m^{-2} h^{-1})	NO_2^- + NO_3^- SLOPE (µmoles-N l^{-1} min^{-1})	NO_2^- + NO_3^- FLUX (µmoles-N m^{-2} h^{-1})
AN01	20020611	1	2240	0.161	139	0.000181	1.75	-0.010043	-97.11
AN02	20020611	1	1960	0.141	139	0.000481	4.07	-0.025389	-214.80
AN03	20020611	1	2060	0.247	83.32	-0.002483	-36.83	-0.016667	-247.24
AN04	20020611	1	2280	0.274	83.32	-0.001363	-22.38	-0.007148	-117.36
AN05	20020611	1	2160	0.259	83.32	0.000000	0.00	-0.008896	-138.37
PT21	20020611	1	2140	0.154	139	0.000000	0.00	-0.001071	-9.89
PT22	20020611	1	2080	0.150	139	0.002230	20.02	-0.019544	-175.47
PT23	20020611	1	2180	0.157	139	-0.000395	-3.72	-0.013883	-130.64
PT24	20020611	1	2100	0.151	139	0.002237	20.28	-0.020433	-185.22
PT25	20020611	1	1360	0.163	83.32	0.001483	14.53	-0.022500	-220.36

TABLE E-1. SEDIMENT OXYGEN AND NUTRIENT EXCHANGES
ANACOSTIA RIVER: MINI-SONE
SEDIMENT-WATER FLUX: Net sediment-water exchange rates of dissolved oxygen (g O_2 m^{-2} d^{-1}) and nutrients (µmoles-N m^{-2} h^{-1}, and µmoles-P m^{-2} h^{-1})

ANACOSTIA RIVER CRUISE: 1
FILENAME : TMDLANFL01
REVISED : 20030216

STATION	DATE	CORE NO	CORE H_2O VOL (ml)	CORE DEPTH (m)	CORE SIZE (cm^2)	DIP SLOPE (µmoles-P l^{-1} min^{-1})	DIP FLUX (µmoles-P m^{-2} h^{-1})
AN01	20020611	1	2240	0.161	139	0.000000	0.00
AN02	20020611	1	1960	0.141	139	0.000000	0.00
AN03	20020611	1	2060	0.247	83.32	0.000333	4.94
AN04	20020611	1	2280	0.274	83.32	0.000274	4.50
AN05	20020611	1	2160	0.259	83.32	0.000000	0.00
PT21	20020611	1	2140	0.154	139	0.000000	0.00
PT22	20020611	1	2080	0.150	139	0.000675	6.06
PT23	20020611	1	2180	0.157	139	0.003212	30.23
PT24	20020611	1	2100	0.151	139	0.000000	0.00
PT25	20020611	1	1360	0.163	83.32	-0.000333	-3.26

TABLE-2. SEDIMENT OXYGEN AND NUTRIENT EXCHANGES
ANACOSTIA RIVER: MINI-SONE
SEDIMENT-WATER FLUX: Net sediment-water exchange rates of dissolved oxygen (g O_2 m^{-2} d^{-1}) and nutrients (µmoles-N m^{-2} h^{-1}, and µmoles-P m^{-2} h^{-1})

ANACOSTIA RIVER CRUISE: 2
FILENAME : TMDLANFL02
REVISED : 20030216

		CORE							
			H_2O			DO	DO	NH_4^+	NH_4^+
STATION	DATE	NO	VOL	DEPTH	SIZE	SLOPE	FLUX	SLOPE	FLUX
			(ml)	(m)	(cm^2)	(mg l^{-1} min^{-1})	(g O_2 m^{-2} d^{-1})	(µmoles-N l^{-1} min^{-1})	(µmoles-N m^{-2} h^{-1})
AN01	20020723	1	1800	0.129	139	-0.012464	-2.32	0.066906	519.8
AN02	20020723	1	1700	0.122	139	-0.015166	-2.67	0.095523	701.0
AN03	20020723	1	1520	0.182	83.32	-0.013705	-3.60	0.044606	488.2
AN04	20020723	1	2160	0.259	83.32	-0.008376	-3.13	0.098430	1531.0
AN05	20020723	1	1820	0.218	83.32	-0.005504	-1.73	0.113007	1481.1
PT21	20020723	1	2500	0.180	139	-0.009645	-2.50	0.015837	170.9
PT22	20020723	1	1620	0.117	139	-0.012881	-2.16	0.105199	735.6
PT23	20020723	1	1640	0.118	139	-0.013262	-2.25	0.042298	299.4
PT24	20020723	1	1580	0.114	139	-0.012334	-2.02	0.098814	673.9
PT25	20020723	1	1150	0.138	83.32	-0.008580	-1.71	0.047404	392.6

TABLE E-2. SEDIMENT OXYGEN AND NUTRIENT EXCHANGES
ANACOSTIA RIVER: MINI-SONE
SEDIMENT-WATER FLUX: Net sediment-water exchange rates of dissolved oxygen (g O_2 m^{-2} d^{-1}) and nutrients (µmoles-N m^{-2} h^{-1}, and µmoles-P m^{-2} h^{-1})

ANACOSTIA RIVER CRUISE: 2
FILENAME : TMDLANFL02
REVISED : 20030216

STATION	DATE	CORE NO	CORE H_20 VOL (ml)	CORE DEPTH (m)	CORE SIZE (cm^2)	NO_2^- SLOPE (µmoles-N l^{-1} min^{-1})	NO_2^- FLUX (µmoles-N m^{-2} h^{-1})	NO_2^- + NO_3^- SLOPE (µmoles-N l^{-1} min^{-1})	NO_2^- + NO_3^- FLUX (µmoles-N m^{-2} h^{-1})
AN01	20020723	1	1800	0.129	139	0.000181	1.41	-0.017979	-139.69
AN02	20020723	1	1700	0.122	139	0.000283	2.08	-0.017194	-126.17
AN03	20020723	1	1520	0.182	83.32	-0.000531	-5.81	-0.006342	-69.42
AN04	20020723	1	2160	0.259	83.32	-0.001363	-21.20	-0.005949	-92.53
AN05	20020723	1	1820	0.218	83.32	-0.004950	-64.88	-0.006761	-88.61
PT21	20020723	1	2500	0.180	139	-0.002922	-31.53	-0.004119	-44.45
PT22	20020723	1	1620	0.117	139	0.000000	0.00	-0.023888	-167.04
PT23	20020723	1	1640	0.118	139	-0.001732	-12.26	-0.019833	-140.40
PT24	20020723	1	1580	0.114	139	-0.000755	-5.15	-0.007559	-51.55
PT25	20020723	1	1150	0.138	83.32	-0.000352	-2.92	-0.003988	-33.03

TABLE E-2. SEDIMENT OXYGEN AND NUTRIENT EXCHANGES
ANACOSTIA RIVER: MINI-SONE
SEDIMENT-WATER FLUX: Net sediment-water exchange rates of dissolved oxygen (g O_2 m^{-2} d^{-1}) and nutrients (µmoles-N m^{-2} h^{-1}, and µmoles-P m^{-2} h^{-1})

ANACOSTIA RIVER CRUISE: 2
FILENAME : TMDLANFL02
REVISED : 20030216

STATION	DATE	NO	CORE H_20 VOL (ml)	CORE DEPTH (m)	SIZE (cm^2)	DIP SLOPE (µmoles-P l^{-1} min^{-1})	DIP FLUX (µmoles-P m^{-2} h^{-1})
AN01	20020723	1	1800	0.129	139	0.000000	0.00
AN02	20020723	1	1700	0.122	139	0.000000	0.00
AN03	20020723	1	1520	0.182	83.32	0.000000	0.00
AN04	20020723	1	2160	0.259	83.32	0.000387	6.02
AN05	20020723	1	1820	0.218	83.32	0.000121	1.59
PT21	20020723	1	2500	0.180	139	0.000226	2.44
PT22	20020723	1	1620	0.117	139	0.000000	0.00
PT23	20020723	1	1640	0.118	139	0.002049	14.51
PT24	20020723	1	1580	0.114	139	0.000000	0.00
PT25	20020723	1	1150	0.138	83.32	0.000000	0.00

TABLE E-3. SEDIMENT OXYGEN AND NUTRIENT EXCHANGES
ANACOSTIA RIVER: MINI-SONE
SEDIMENT-WATER FLUX: Net sediment-water exchange rates of dissolved oxygen (g O_2 m^{-2} d^{-1}) and nutrients (µmoles-N m^{-2} h^{-1}, and µmoles-P m^{-2} h^{-1})

ANACOSTIA RIVER CRUISE: 3
FILENAME : TMDLANFL03
REVISED : 20030216

STATION	DATE	CORE NO	CORE H_2O VOL (ml)	CORE DEPTH (m)	CORE SIZE (cm^2)	DO SLOPE (mg l^{-1} min^{-1})	DO FLUX (g O_2 m^{-2} d^{-1})	NH_4^+ SLOPE (µmoles-N l^{-1} min^{-1})	NH_4^+ FLUX (µmoles-N m^{-2} h^{-1})
AN01	20020820	1	1480	0.106	139	-0.014917	-2.29	0.101396	647.8
AN02	20020820	1	1510	0.109	139	-0.020344	-3.18	0.112327	732.1
AN03	20020820	1	2210	0.265	83.32	-0.008633	-3.30	0.020238	322.1
AN04	20020820	1	1900	0.228	83.32	-0.008207	-2.69	0.037966	519.5
AN05	20020820	1	1700	0.204	83.32	-0.009893	-2.91	0.054930	672.5
PT21	20020820	1	2440	0.176	139	-0.008539	-2.16	0.058333	614.4
PT22	20020820	1	1780	0.128	139	-0.014625	-2.70	0.051240	393.7
PT23	20020820	1	1490	0.107	139	-0.014033	-2.17	0.063333	407.3
PT24	20020820	1	1220	0.088	139	-0.021911	-2.77	0.140454	739.7
PT25	20020820	1	1170	0.140	83.32	-0.013354	-2.70	0.093605	788.7

TABLE E-3. SEDIMENT OXYGEN AND NUTRIENT EXCHANGES
ANACOSTIA RIVER: MINI-SONE
SEDIMENT-WATER FLUX: Net sediment-water exchange rates of dissolved oxygen (g O_2 m^{-2} d^{-1}) and nutrients (µmoles-N m^{-2} h^{-1}, and µmoles-P m^{-2} h^{-1})

ANACOSTIA RIVER CRUISE: 3
FILENAME : TMDLANFL03
REVISED : 20030216

		CORE							
			H_20			NO_2^-	NO_2^-	NO_2^- + NO_3^-	NO_2^- + NO_3^-
STATION	DATE	NO	VOL	DEPTH	SIZE	SLOPE	FLUX	SLOPE	FLUX
			(ml)	(m)	(cm^2)	(µmoles-N l^{-1} min^{-1})	(µmoles-N m^{-2} h^{-1})	(µmoles-N l^{-1} min^{-1})	(µmoles-N m^{-2} h^{-1})
AN01	20020820	1	1480	0.106	139	-0.002004	-12.80	-0.023709	-151.46
AN02	20020820	1	1510	0.109	139	-0.001017	-6.63	-0.008437	-54.99
AN03	20020820	1	2210	0.265	83.32	-0.002483	-39.52	0.000000	0.00
AN04	20020820	1	1900	0.228	83.32	0.000000	0.00	-0.003829	-52.39
AN05	20020820	1	1700	0.204	83.32	-0.000684	-8.37	-0.006137	-75.13
PT21	20020820	1	2440	0.176	139	-0.003016	-31.77	-0.007219	-76.03
PT22	20020820	1	1780	0.128	139	0.000000	0.00	-0.011947	-91.79
PT23	20020820	1	1490	0.107	139	-0.003350	-21.55	-0.017000	-109.34
PT24	20020820	1	1220	0.088	139	-0.004127	-21.73	-0.056290	-296.43
PT25	20020820	1	1170	0.140	83.32	0.000000	0.00	-0.002675	-22.54

TABLE E-3. SEDIMENT OXYGEN AND NUTRIENT EXCHANGES
ANACOSTIA RIVER: MINI-SONE
SEDIMENT-WATER FLUX: Net sediment-water exchange rates of dissolved oxygen (g O_2 m^{-2} d^{-1}) and nutrients (µmoles-N m^{-2} h^{-1}, and µmoles-P m^{-2} h^{-1})

ANACOSTIA RIVER CRUISE: 3
FILENAME : TMDLANFL03
REVISED : 20030216

		CORE					
			H_20	CORE		DIP	DIP
STATION	DATE	NO	VOL	DEPTH	SIZE	SLOPE	FLUX
			(ml)	(m)	(cm^2)	(µmoles-P l^{-1} min^{-1})	(µmoles-P m^{-2} h^{-1})
AN01	20020820	1	1480	0.106	139	0.001369	8.75
AN02	20020820	1	1510	0.109	139	0.000514	3.35
AN03	20020820	1	2210	0.265	83.32	0.000233	3.71
AN04	20020820	1	1900	0.228	83.32	0.000167	2.28
AN05	20020820	1	1700	0.204	83.32	0.000000	0.00
PT21	20020820	1	2440	0.176	139	0.000225	2.37
PT22	20020820	1	1780	0.128	139	0.000000	0.00
PT23	20020820	1	1490	0.107	139	0.001783	11.47
PT24	20020820	1	1220	0.088	139	0.003628	19.11
PT25	20020820	1	1170	0.140	83.32	0.002533	21.34

TABLE E-4. SEDIMENT OXYGEN AND NUTRIENT EXCHANGES
ANACOSTIA RIVER: MINI-SONE
SEDIMENT-WATER FLUX: Net sediment-water exchange rates of dissolved oxygen (g O_2 m^{-2} d^{-1}) and nutrients (µmoles-N m^{-2} h^{-1}, and µmoles-P m^{-2} h^{-1})

ANACOSTIA RIVER CRUISE: 4
FILENAME : TMDLANFL04
REVISED : 20030216

STATION	DATE	CORE NO	CORE H_2O VOL (ml)	CORE DEPTH (m)	CORE SIZE (cm^2)	DO SLOPE (mg l^{-1} min^{-1})	DO FLUX (g O_2 m^{-2} d^{-1})	NH_4^+ SLOPE (µmoles-N l^{-1} min^{-1})	NH_4^+ FLUX (µmoles-N m^{-2} h^{-1})
AN01	20020924	1	1840	0.132	139	-0.007578	-1.44	0.058373	463.6
AN02	20020924	1	1910	0.137	139	-0.010630	-2.10	0.055044	453.8
AN03	20020924	1	1760	0.217	83.32	-0.006144	-1.92	0.022268	289.9
AN04	20020924	1	1780	0.128	83.32	C	C	0.019749	151.7
AN05	20020924	1	1850	0.133	83.32	-0.007544	-1.44	0.152411	1216.2
PT21	20020924	1	1515	0.109	139	-0.010302	-1.62	NI	NI
PT22	20020924	1	2340	0.168	139	-0.010333	-2.50	0.012833	129.6
PT23	20020924	1	1660	0.119	139	-0.011533	-1.98	0.045167	323.6
PT24	20020924	1	1860	0.134	139	-0.010056	-1.94	0.059200	475.3
PT25	20020924	1	1580	0.114	83.32	-0.006736	-1.11	0.027537	188.3

TABLE E-4. SEDIMENT OXYGEN AND NUTRIENT EXCHANGES
ANACOSTIA RIVER: MINI-SONE
SEDIMENT-WATER FLUX: Net sediment-water exchange rates of dissolved oxygen (g O_2 m^{-2} d^{-1}) and nutrients (µmoles-N m^{-2} h^{-1}, and µmoles-P m^{-2} h^{-1})

ANACOSTIA RIVER CRUISE: 4
FILENAME : TMDLANFL04
REVISED : 20030216

STATION	DATE	CORE NO	CORE $H_2$0 VOL (ml)	CORE DEPTH (m)	CORE SIZE (cm^2)	NO_2^- SLOPE (µmoles-N l^{-1} min^{-1})	NO_2^- FLUX (µmoles-N m^{-2} h^{-1})	NO_2^- + NO_3^- SLOPE (µmoles-N l^{-1} min^{-1})	NO_2^- + NO_3^- FLUX (µmoles-N m^{-2} h^{-1})
AN01	20020924	1	1840	0.132	139	0.001388	11.02	-0.031395	-249.35
AN02	20020924	1	1910	0.137	139	-0.001251	-10.31	-0.020337	-167.67
AN03	20020924	1	1760	0.217	83.32	0.000000	0.00	-0.005841	-76.05
AN04	20020924	1	1780	0.128	83.32	0.000000	0.00	0.000000	0.00
AN05	20020924	1	1850	0.133	83.32	-0.000151	-1.20	-0.003935	-31.40
PT21	20020924	1	1515	0.109	139	0.001611	10.54	-0.016638	-108.81
PT22	20020924	1	2340	0.168	139	0.000000	0.00	0.000000	0.00
PT23	20020924	1	1660	0.119	139	0.000000	0.00	-0.020000	-143.31
PT24	20020924	1	1860	0.134	139	0.000916	7.36	-0.014989	-120.34
PT25	20020924	1	1580	0.114	83.32	-0.000534	-3.65	-0.002148	-14.69

TABLE E-4. SEDIMENT OXYGEN AND NUTRIENT EXCHANGES
ANACOSTIA RIVER: MINI-SONE
SEDIMENT-WATER FLUX: Net sediment-water exchange rates of dissolved oxygen (g O_2 m^{-2} d^{-1}) and nutrients (µmoles-N m^{-2} h^{-1}, and µmoles-P m^{-2} h^{-1})

ANACOSTIA RIVER CRUISE: 4
FILENAME : TMDLANFL04
REVISED : 20030216

STATION	DATE	CORE NO	CORE H_20 VOL (ml)	CORE DEPTH (m)	CORE SIZE (cm^2)	DIP SLOPE (µmoles-P l^{-1} min^{-1})	DIP FLUX (µmoles-P m^{-2} h^{-1})
AN01	20020924	1	1840	0.132	139	0.000000	0.00
AN02	20020924	1	1910	0.137	139	0.000133	1.10
AN03	20020924	1	1760	0.217	83.32	0.000000	0.00
AN04	20020924	1	1780	0.128	83.32	0.000000	0.00
AN05	20020924	1	1850	0.133	83.32	0.000000	0.00
PT21	20020924	1	1515	0.109	139	0.000000	0.00
PT22	20020924	1	2340	0.168	139	0.000000	0.00
PT23	20020924	1	1660	0.119	139	0.000750	5.37
PT24	20020924	1	1860	0.134	139	0.000000	0.00
PT25	20020924	1	1580	0.114	83.32	0.000000	0.00

SEDIMENT OXYGEN AND NUTRIENT EXCHANGES
ANACOSTIA RIVER TMDL DATA SET:

Page No.

TABLE F-1. **SEDIMENT OXYGEN AND NUTRIENT EXCHANGES**
ANACOSTIA RIVER: MINI-SONE
WATER COLUMN RESPIRATION: Dissolved oxygen in surface waters
($g\ O_2\ m^{-3}\ d^{-1}$)

ANACOSTIA RIVER CRUISE: **T_I : TIME INITIAL**
FILENAME: **TMDLCANWK01** **T_F : TIME FINAL**
REVISED: **20031028**

STATION	DATE	SAMPLE	DATE/TIME T_I	DATE/TIME T_F	DO ($mg\ l^{-1}$) T_I	DO ($mg\ l^{-1}$) T_F	Respiration Rate ($g\ O_2\ m^{-3}\ d^{-1}$)
AN01	20020611	A	HH	HH	HH	HH	HH
		B	HH	HH	HH	HH	HH
			HH	HH	HH	HH	HH
AN02	20020611	A	HH	HH	HH	HH	HH
		B	HH	HH	HH	HH	HH
			HH	HH	HH	HH	HH
AN03	20020611	A	HH	HH	HH	HH	HH
		B	HH	HH	HH	HH	HH
			HH	HH	HH	HH	HH
AN04	20020611	A	HH	HH	HH	HH	HH
		B	HH	HH	HH	HH	HH
			HH	HH	HH	HH	HH
AN05	20020611	A	HH	HH	HH	HH	HH
		B	HH	HH	HH	HH	HH
			HH	HH	HH	HH	HH
PT21	20020611	A	6/11/02 6:45	6/11/02 18:47	5.81	5.49	0.64
		B	6/11/02 6:45	6/11/02 18:47	5.69	5.31	0.76
			HH	HH	HH	HH	HH
PT22	20020611	A	HH	HH	HH	HH	HH
		B	HH	HH	HH	HH	HH
			HH	HH	HH	HH	HH
PT23	20020611	A	HH	HH	HH	HH	HH
		B	HH	HH	HH	HH	HH
			HH	HH	HH	HH	HH
PT24	20020611	A	HH	HH	HH	HH	HH
		B	HH	HH	HH	HH	HH
			HH	HH	HH	HH	HH
PT25	20020611	A	HH	HH	HH	HH	HH
		B	HH	HH	HH	HH	HH

TABLE F-2. **SEDIMENT OXYGEN AND NUTRIENT EXCHANGES**
ANACOSTIA RIVER: MINI-SONE
WATER COLUMN RESPIRATION: Dissolved oxygen in surface waters
($g\ O_2\ m^{-3}\ d^{-1}$)

ANACOSTIA RIVER CRUISE: **T_I : TIME INITIAL**
FILENAME: TMDLCANWK02 **T_F : TIME FINAL**
REVISED: 20031028

STATION	DATE	SAMPLE	DATE/TIME T_I	DATE/TIME T_F	DO (mg l^{-1}) T_I	DO (mg l^{-1}) T_F	Respiration Rate ($g\ O_2\ m^{-3}\ d^{-1}$)
AN01	20020723	A	7/23/02 11:39	7/24/02 11:39	6.40	6.19	0.21
		B	7/23/02 11:39	7/24/02 11:39	6.40	6.38	0.02
AN02	20020723	A	7/23/02 10:12	7/24/02 10:12	6.50	4.50	2.00
		B	7/23/02 10:12	7/24/02 10:12	7.08	4.87	2.21
AN03	20020723	A	7/23/02 13:00	7/24/02 12:56	8.51	4.58	3.94
		B	HH	HH	HH	HH	HH
AN04	20020723	A	7/23/02 12:00	7/24/02 12:00	7.73	3.25	4.48
		B	HH	HH	HH	HH	HH
AN05	20020723	A	7/23/02 10:50	7/24/02 10:50	5.49	3.29	2.20
		B	HH	HH	HH	HH	HH
PT21	20020723	A	7/23/02 7:07	7/24/02 7:12	6.51	6.19	0.32
		B	7/23/02 7:07	7/24/02 7:12	6.85	6.98	-0.13
PT22	20020723	A	7/23/02 8:02	7/24/02 8:00	6.45	6.78	-0.33
		B	HH	HH	HH	HH	HH
PT23	20020723	A	7/23/02 9:25	7/24/02 9:22	7.30	5.79	1.51
		B	7/23/02 9:25	7/24/02 9:22	7.28	5.69	1.59
PT24	20020723	A	7/23/02 8:39	7/24/02 8:45	5.70	5.27	0.43
		B	7/23/02 8:39	7/24/02 8:45	5.68	5.10	0.58
PT25	20020723	A	7/23/02 14:40	7/24/02 14:41	9.08	7.48	1.60
		B	HH	HH	HH	HH	HH

TABLE F-3. **SEDIMENT OXYGEN AND NUTRIENT EXCHANGES**
ANACOSTIA RIVER: MINI-SONE
WATER COLUMN RESPIRATION: Dissolved oxygen in surface waters
($g\ O_2\ m^{-3}\ d^{-1}$)

ANACOSTIA RIVER CRUISE: **T_I : TIME INITIAL**
FILENAME: TMDLCANWK03 **T_F : TIME FINAL**
REVISED: 20031028

STATION	DATE	SAMPLE	DATE/TIME T_I	DATE/TIME T_F	DO ($mg\ l^{-1}$) T_I	DO ($mg\ l^{-1}$) T_F	Respiration Rate ($g\ O_2\ m^{-3}\ d^{-1}$)
AN01	20020820	A	8/20/02 12:06	8/21/02 12:07	7.00	6.12	0.88
		B	8/20/02 12:06	8/21/02 12:07	7.09	5.64	1.45
AN02	20020820	A	8/20/02 10:48	8/21/02 10:48	7.58	6.29	1.29
		B	8/20/02 10:48	8/21/02 10:48	7.57	6.22	1.35
AN03	20020820	A	8/20/02 10:14	8/21/02 10:15	6.51	3.71	2.80
		B	8/20/02 10:14	8/21/02 10:15	HH	HH	HH
AN04	20020820	A	8/20/02 9:11	8/21/02 9:10	5.27	2.79	2.48
		B	8/20/02 9:11	8/21/02 9:10	HH	HH	HH
AN05	20020820	A	8/20/02 8:07	8/21/02 8:24	5.51	3.18	2.30
		B	8/20/02 8:07	8/21/02 8:24	HH	HH	HH
PT21	20020820	A	8/20/02 7:37	8/21/02 7:35	5.13	4.61	0.52
		B	8/20/02 7:37	8/21/02 7:35	5.11	4.68	0.43
PT22	20020820	A	8/20/02 8:31	8/21/02 8:28	5.28	4.58	0.70
		B	8/20/02 8:31	8/21/02 8:28	5.37	4.39	0.98
PT23	20020820	A	8/20/02 10:02	8/21/02 10:03	8.40	7.18	1.22
		B	8/20/02 10:02	8/21/02 10:03	8.48	7.16	1.32
PT24	20020820	A	8/20/02 9:15	8/21/02 9:16	6.42	5.28	1.14
		B	8/20/02 9:15	8/21/02 9:16	6.63	5.32	1.31
PT25	20020820	A	8/20/02 11:50	8/21/02 11:49	6.01	6.05	-0.04
		B	8/20/02 11:50	8/21/02 11:49	HH	HH	HH

TABLE F-4. **SEDIMENT OXYGEN AND NUTRIENT EXCHANGES**
ANACOSTIA RIVER: MINI-SONE
WATER COLUMN RESPIRATION: Dissolved oxygen in surface waters
($g\ O_2\ m^{-3}\ d^{-1}$)

ANACOSTIA RIVER CRUISE: | **T_I : TIME INITIAL**
FILENAME: TMDLCANWK04 | **T_F : TIME FINAL**
REVISED: 20031028

STATION	DATE	SAMPLE	DATE/TIME T_I	DATE/TIME T_F	DO (mg l^{-1}) T_I	DO (mg l^{-1}) T_F	Respiration Rate ($g\ O_2\ m^{-3}\ d^{-1}$)
AN01	20020924	A	9/24/02 11:09	9/25/02 11:11	7.00	6.26	0.74
		B	9/24/02 11:09	9/25/02 11:11	7.01	6.23	0.78
AN02	20020924	A	9/24/02 10:29	9/25/02 10:30	6.79	6.20	0.59
		B	9/24/02 10:29	9/25/02 10:30	6.81	6.13	0.68
AN03	20020924	A	9/24/02 11:00	9/25/02 11:00	6.99	5.26	1.73
		B	9/24/02 11:00	9/25/02 11:00	7.07	5.31	1.76
AN04	20020924	A	9/24/02 10:15	9/25/02 10:14	4.78	3.19	1.59
		B	9/24/02 10:15	9/25/02 10:14	4.71	3.15	1.56
AN05	20020924	A	9/24/02 9:31	9/25/02 9:31	4.49	2.75	1.74
		B	9/24/02 9:31	9/25/02 9:31	4.60	2.83	1.77
PT21	20020924	A	9/24/02 7:16	9/25/02 7:20	5.99	5.70	0.29
		B	9/24/02 7:16	9/25/02 7:20	6.00	5.83	0.17
PT22	20020924	A	9/24/02 7:59	9/25/02 7:59	6.70	6.24	0.46
		B	9/24/02 7:59	9/25/02 7:59	6.76	6.19	0.57
PT23	20020924	A	9/24/02 9:35	9/25/02 9:36	7.48	6.32	1.16
		B	9/24/02 9:35	9/25/02 9:36	7.47	6.40	1.07
PT24	20020924	A	9/24/02 8:46	9/25/02 8:47	7.20	6.45	0.75
		B	9/24/02 8:46	9/25/02 8:47	7.29	6.51	0.78
PT25	20020924	A	9/24/02 12:41	9/25/02 12:42	7.17	5.73	1.44
		B	9/24/02 12:41	9/25/02 12:42	7.09	5.79	1.30