Land Use and Water Quality Trends within the Jug Bay Component of the Maryland Chesapeake Bay National Estuarine Research Reserve

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Jug Bay is one of three components of the Maryland Chesapeake Bay National Estuarine Research Reserve (MD-CBNERR). It is located within the Patuxent River watershed and comprises a diversity of habitats including forests, meadows, and tidal freshwater wetlands. Current trends of increased development and associated activities have raised questions about the long term health and sustainability of these natural systems as they act as a buffer zone between uplands and the estuary. In an effort to characterize the status and condition of Jug Bay, multiple long term water quality monitoring data sets (1995-2006) were used to analyze spatial and temporal trends of nutrient concentrations within the Patuxent River and its tributary Western Branch while determining potential relationships with land use information. Additionally, a case study to determine the impact of Western Branch Wastewater Treatment Plant overflows into the Patuxent River was studied. The concentration of nitrate, total nitrogen, phosphate, and total phosphorus during major wastewater treatment plant overflows were analyzed for the period 2003-2006 and compared to natural events such as storms and major rain events at different locations above and below the wastewater treatment plant.

Chesapeake Bay National Estuarine Research Reserve

Reserve Components

Figure 1. Components of the Maryland Chesapeake Bay National Estuarine Research Reserve (MD-CBNERR).

MD-CBNERR is one of 27 Reserves nationwide established as protected areas to "practice and promote coastal and estuarine stewardship through Innovative research and education".

Issue: Development and Wastewater Treatment Overflows

Western Branch Wastewater Treatment Plant – Patuxent River

Western Branch WWTP has currently a capacity 30 million gallons per day (mgd). In 1991, Biological Nutrient Removal Control was initiated to reduce nitrogen loadings on wastewater discharge.

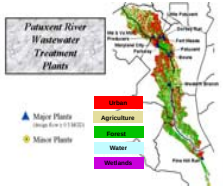

Figure 2. Land use and location of wastewater treatment plants along the Patuxent River

Long Term Water Quality Data

The Maryland Department of Natural Resources (DNR) and MD-CBNERR monitors the Patuxent River using both **long term fixed monitoring stations** and *in situ* **continuous monitors**. In the vicinity of Jug Bay, DNR has monitored four long term fixed stations since 1985 (Figure 5). Nutrient samples are collected monthly from these stations. DNR has maintained three continuous monitors in the Jug Bay are since 2003 (Figure 5). These are YSI 6600™ data sondes attached to piers or pilings that collect ambient water quality data every 15 minutes. These stations are sampled for nutrients every two weeks.

Nutrient water sampling

Continuous water quality monitoring at Iron Pot Landing (IPL)[a] and Mataponi (MTI)[b] stations in Jug Bay, Patuxent River

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We would like to thank John Zimmerelli, Stephanie Thompson and Bill Hamilton for their valuable collaboration to this project through collection of field data.

Water Quality Spatial and Temporal Patterns in Jug Bay, Patuxent River

The Patuxent River has been characterized as a nutrient-overenriched tributary of the Chesapeake Bay due to nutrient inputs from point and nonpoint sources resulting from development within the watershed. In an effort to improve water quality, nutrient control standards (reduction of NPS inputs; limit on nitrogen and phosphorus loadings in sewage discharges) were fully implemented in 1994. This analysis was conducted during the period after this implementation (1995-2006) and it was focused on three subwatersheds of the Patuxent River (Figure 4) which influence water quality at Jug Bay, one of the components of the MD-CBNERR (Figure 1). Each subwatershed is characterized by different land uses and percentages of impervious surface. Mataponi Creek is the most pristine of the three as it is mostly surrounded by wetlands; Western Branch has been developed but less than the Patuxent subwatershed.

Figure 6

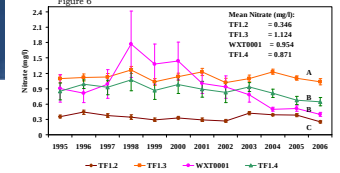
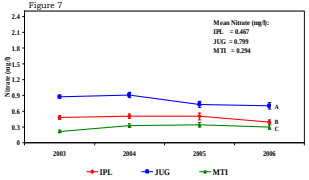


Figure 7



Main Results:

Found spatial significant differences on nitrate concentrations:

- **Lower nitrate values were found at TF1.2 (station located in Western Branch, above the WWTP) and MTI ("pristine site").**
- **Higher nitrate concentrations were measured at TF1.3, station located within the most developed subwatershed.**
- **Intermediate nitrate values were found in stations receiving waters from both Patuxent and Western Branch subwatersheds.**
- **Similar pattern was found for total nitrogen.**

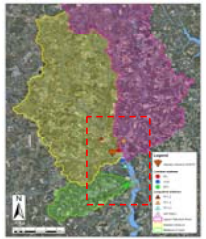


Figure 4. Map delineating Patuxent River, Western Branch, and Mataponi Creek subwatersheds

Enlargement

Figure 5. Enlargement showing water quality monitoring stations within the Jug Bay area.

Figure 8

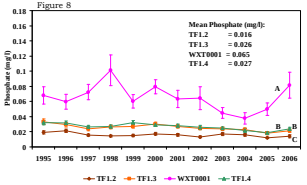
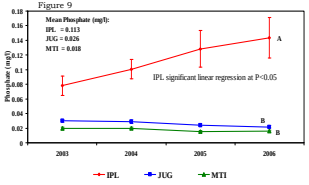


Figure 9



Main Results

- **Stations closer to the WWTP outflow (IPL and WXT0001) showed the highest phosphate concentrations.**
- **TF1.2 and MTI stations showed the lowest phosphate concentrations.**
- **A significant interaction: station* year seems to indicate an increasing trend of higher phosphate concentrations at IPL and WXT0001 (stations closest to WWTP outflow), particularly during the last two years.**
- **For the ConMon Stations, JUG and MTI group together for phosphate concentrations and the values are within the range of values for TF1.2, TF1.3, and TF1.4.**
- **Similar patterns were found for TP.**

Impact of Wastewater Overflows, Storms/Rain Events on Water Quality at Jug Bay, Patuxent River

Wastewater treatment plants within the Patuxent River watershed (including the Western Branch Wastewater Treatment Plant WB-WWTP; Figure 4) started the implementation of biological nitrogen reduction controls to decrease nitrogen loadings into the river. However, due to unforeseen events such as power and mechanical failures, and major storms, the WB-WWTP has experienced sewage overflows that raise water quality concern. The main purpose of this analysis was to look closely at nutrient concentrations after overflows and compare them to major storm events to determine changes in water quality as a result of both types of events. During the period of 2003-2007, the WB-WWTP has experienced two major overflows in 2003 of 19 and 30 million gallons respectively, a medium size overflow of 500 000 gallons during 2004 due to a power failure, and a major overflow of 8 million gallons in 2007. Results of this analysis focus on the years of 2003 and 2006 and considers longterm nutrient data from IPL (closest station to WB-WWTP) and Mataponi as the "reference site".

Table 1. Comparative analysis of nutrient concentrations after a major wastewater overflow and storm event at IPL vs. mean values for IPL (closest station to Western Branch WWTP) and MTI ("reference station").

Event Date	Event Description	# Days After Event	Parameter	Single Value IPL (mg/l)	Mean Value IPL Station (mg/l)	P Value	Mean Value MTI Station (mg/l)	P Value
9/18/03	Tropical Storm Isabel: 20 mm rain WWTP overflow: 30 million gallons	5	TN NO3 TP PO4	3.190 0.466 1.126 0.048	1.346 0.473 0.279 0.113	*** NS *** ***	0.897 0.286 0.121 0.018	*** *** *** ***
		13	TN NO3 TP PO4	1.029 0.484 0.13 0.065	1.346 0.473 0.279 0.113	*** NS *** NS	0.897 0.286 0.121 0.018	*** *** NS ***
10/27/03	Storm: 36 mm rain	1	TN NO3 TP PO4	0.880 0.215 0.185 0.033	1.346 0.473 0.279 0.113	*** *** *** ***	0.897 0.286 0.121 0.018	NS NS *** ***

WWTP = Wastewater Treatment Plant
*** Single value is significantly higher than the mean at P<0.001
*** Single value is significantly lower than the mean at P<0.001
IPL and MTI mean values estimated using data from 2003

TN = Total Nitrogen
NO3 = Nitrate
TP = Total Phosphorus
PO4 = Phosphate

Main Results:

- **Major wastewater overflows represent an episodic short term loading of nutrients to the system, particularly total nitrogen and total phosphorus.**
- **Overall, nutrient concentrations at IPL (closest station to WB-WWTP) were significantly higher than values at MTI ("reference site").**
- **Post-overflow high nutrient concentrations in the water decreased significantly soon after the event (13 days).**

Table 2. Comparative analysis of nutrient concentrations after storm events at IPL vs. mean values for IPL (station close to Western Branch WWTP) and MTI ("reference station").

Event Date	Event Description	# Days After Event	Parameter	Single Value (mg/l)	Mean Value IPL Station (mg/l)	P Value	Mean Value MTI Station (mg/l)	P Value
9/1/06	Storm: 36 mm rain	4	TN NO3 TP PO4	1.049 0.248 0.178 0.052	1.346 0.473 0.279 0.113	*** *** *** ***	0.897 0.286 0.121 0.018	*** NS *** ***
		18	TN NO3 TP PO4	1.093 0.363 0.498 0.079	1.346 0.473 0.279 0.113	*** *** *** NS	0.897 0.286 0.121 0.018	*** *** *** ***
10/6/03	Storm: 20 mm rain	11	TN NO3 TP PO4	0.686 0.227 0.200 0.112	1.346 0.473 0.279 0.113	*** *** NS NS	0.897 0.286 0.121 0.018	*** NS *** ***
		24	TN NO3 TP PO4	0.749 0.179 0.219 0.070	1.346 0.473 0.279 0.113	*** *** NS ***	0.897 0.286 0.121 0.018	*** *** *** ***

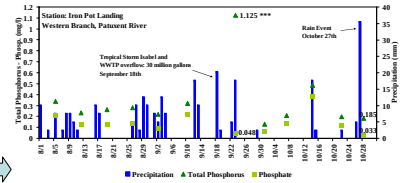
WWTP = Wastewater Treatment Plant
*** Single value is significantly higher than the mean at P<0.001
*** Single value is significantly lower than the mean at P<0.001
IPL and MTI mean values estimated using data from 2003-2006

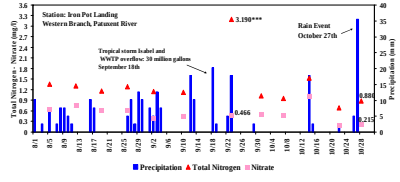
TN = Total Nitrogen
NO3 = Nitrate
TP = Total Phosphorus
PO4 = Phosphate

Main Results:

- **Overall, post storm nutrient concentrations at IPL were not significantly higher than IPL mean values.**
- **Overall, post storm nutrient concentrations at IPL (closest station to WB-WWTP) were significantly higher than values at MTI ("reference site").**
- **Nutrient concentrations around the IPL station are overall high and storm events do not seem to significantly affect nutrient loadings.**

2003





2006