Reconstruction of Historic Water Quality in the Tidal Christina River from Pre-European Settlement through the Present

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Introduction

- Determine how water quality varied over the last 1000 years in a tidal river through analysis of sediment cores and diatoms
- Increase understanding of changes in water quality before European settlement
- Determine continuing impacts of land-use changes on water quality
Hypotheses

- Post-settlement water quality will degrade due to land-use changes, which increase sediments and nutrient loads.
- 20th century perturbations to water quality include input of heavy metals and further inputs of nutrients and sediments.
Background

- European settlement in the Mid-Atlantic US began in the late 1600s

- Impacts include: increased sedimentation, vegetation changes, increased nutrient levels, changes in carbon storage, and increased heavy metals (Boesch et al., 2001; Bratton et al., 2003; Cooper & Brush, 1991)

- Christina River is also influenced by “natural” processes

- This research is significant because tidal river systems are:
  - Lacking research on historical changes
  - Likely impacted by sea level change
Study Sites

- Three sites selected in marshes surrounding Christina River near Wilmington, DE
- Marshes are tidally inundated 2x per day, oligohaline
- Watershed contains a variety of land-uses (agriculture, urban, forest, industry); Sites impacted by multiple Brownfields and a Superfund site
Methods

- Two 2-2.5 m cores from each site
- Brown-grey clay/mud throughout the core. Organics were variable.

Chronology

- Gamma counting (Pb-210, Cs-137): every 2 cm in top meter of core
- Pollen analysis: every 5-10 cm between 1 and 1.5 m
  - Used % Ambrosia and Quercus:Ambrosia to identify settlement horizons
- Radiocarbon dating: 2-3 samples taken below 1.5 m
Methods

**Diatoms**
- Samples taken every 10 cm
- >500 valves identified and counted at 1000x
- Stratigraphically constrained cluster analysis, a trophic index, and a transfer function were used to analyze the diatom data

**Chemistry**
- Sediment chemistry analyses were performed by Plant and Soil Sciences at the University of Delaware
Age-Depth Model

- Focus on Site 1, other sites similar
- Error based on methods and depth intervals (light blue)
- Flat area at 150 m corresponds to both a change in dating methods and sediment type
Sediment Chemistry Results: Metals

- Zinc from National Vulcanized Fiber Co. (~1900-1990s) and DuPont Pigment Plant (closed in 1950s)
- Pb from gasoline, 1920s-1970s
- Other metals from other industries along river
Sediment Chemistry Results: Phosphorus

- Phosphorus is generally variable in Christina River
- After 200 YBP, consistently high
- Agricultural and phosphorus detergents
Sediment Chemistry Results: Nitrogen

- Similar pattern to Phosphorus
- Recent increases partially due to agriculture? Overall not as clearly responding to anthropogenic activity
Cluster Analysis of Diatom Data

Pre-European Settlement to Early Settlement:
- Low nutrients
- Forested

Mid-settlement: Deforestation Starts
- Major industrial increases
- Green revolution

Post-deforestation, early industrialization
- Increasing inputs of nutrients

Runoff? Changes to pollution laws?
Post Enviro movement?
Continuing nutrients?

Cophen. Corr. 0.844
Trophic Index (Porter, 2008; vanDam et al., 1994)

- Percent abundance of species preferring high nutrient conditions increases over past 200yrs, particularly past 100yrs
- Species preferring moderate nutrient conditions decrease over the same period
- Species preferring low nutrient conditions low to absent throughout
Diatom Species Analysis

- Black: Mesotraphenic; Grey: Eutraphenic, as grouped by Porter (2008) and van Dam (1994)

- Species track trophic levels through time
Trophic Index Results vs. Sediment Chemistry

R² = 0.59

% Eutraphenic

Sediment Phosphorus, (mg/kg)

R² = 0.09

% Eutraphenic

Sediment Nitrogen (%)
Transfer Function Results

The graph shows the changes in Total Phosphorus (µg/L) over different ages (YBP) with shaded areas indicating Mesotrophentic and Eutrophentic conditions. The x-axis represents age in years before present, while the y-axis represents total phosphorus concentration. The graph also includes a dendrogram on the right side, likely representing a phylogenetic tree or similar data structure.
Transfer Function Results

Site 1

R² = 0.40

% Eutraphentic

Total Phosphorus (µg/L)
Conceptual Model: Regional Water Quality History

- **700 CE**
- **1650**
- **1780**
- **1800**
- **1900**
- **1940**
- **1970**
- **2013**

**Nutrients**
- European Settlement
- Increase of Industry
- DuPont, NVF open (ZN)

**Metals**
- Maximum Deforestation
- Industrial Fertilizers
- Enviro. Legislation

Core Collected
Conclusions

- Diatoms were used to identify nutrient-related changes caused by land-use shifts in a transitional environment
  - This allowed the influences of different land-use strategies to be better understood
  - In particular, van Dam’s Trophic Index seems to track phosphorous in this site
  - While sediment P remains high in recent samples, the diatom trophic index shows a decrease/variation in recent samples
- Metals were important pollutants in the Christina River following the industrial revolution and have declined since the 1970s, likely due to improved environmental laws
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Questions?

Over 40,000 Diatoms Counted!