PALEOLIMNOLOGICAL METHODS FOR LAKE MANAGEMENT

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Trajectory of Florida Lakes

- The state of Florida contains over 7,800 lakes
  - 6% of Florida’s landscape (Brenner, 1990)
- Surge of development and population growth in watersheds
  - Florida’s population has grown to 21.9 million as of 2020
  - Expected to reach 26 million by 2030
  - 45% of lakes, ponds, and reservoirs have been documented as impaired (Southwest Florida Management District)
A Time Line of Improving Data Availability

- Early 1900s: Significant population growth
  - Land use changes: agriculture, urbanization, phosphate mining
- Early 1960s: EPA began STORET data set – limited water quality data
- Late 1960s: Significant water quality degradation in many Florida lakes
- 1972: Clean Water Act = more data
- 1986: Volunteer citizen-science program groups such as Lakewatch
- 1987: Surface Water Improvement and Management Program established

Long-term (pre-disturbance) limnological data are sparse

(Brenner et al., 1993; Riedinger-Whitmore et al., 2005; Riedinger-Whitmore et al., 2017)
The study of lakes and their sediments to reconstruct past climatic and environmental changes

- Combines limnology, geology, and ecology
- Study natural changes in a lake system
- Assess human-induced changes in water quality and introduction of contaminants
  - Shifts in pH, shifts in salinity, changes in plant and animal communities
- Assist in defining appropriate natural background conditions for lakes
- Expand datasets for water quality criteria

How to fill data gaps… Paleolimnology
How to fill data gaps... Paleolimnology

• Studies use preserved lake sediment retrieved by sediment coring

• The last ~120 years represented in the top 50-100 cm of sediment

• Use biological and chemical lines of evidence in sediment to assess past conditions
Multiple Lines of Evidence

- $^{210}\text{Pb}$ dating
- Diatoms
- Sedimented blue-green algal pigments
- Stable Isotopes $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$
- Pollen and plant macrofossils
- Charcoal, metals, testate amoeba, chrysophyte scales, phytoliths, chironomids, cladocera, ostracodes, freshwater sponges

(Lauterman, 2016)
Paleoecological Assessment of Lake Tarpon

Sediment core data and diatom assemblage analysis
Study Site: Lake Tarpon in Pinellas County

- ~1,000 ha lake, east of Gulf of Mexico
- ~4,000 ha catchment basin
- **Historical condition**: Brackish, well-mixed due to connection to estuary through sinkhole and underground conduit, high hydrologic variability
- **Modern condition**: Sink connection terminated, converted to freshwater with managed lake levels and outfall canal to Tampa Bay
- Verified “Impaired” for chlorophyll $a$ by State Regulatory Agency (FDEP)
Multi-Proxy Study Objectives

- Understand historic hydrological and water quality conditions
- Conduct paleostratigraphical analysis in relation to historical records
- Show changes in algal communities, indicate onset of advancing eutrophication, identify pre-disturbance period
- Propose site-specific alternative criteria (SSAC) for TN, TP, Chl-a
Lake Tarpon Catchment Basin History

1880s - Settlements and impoundments

1940s - Agricultural land use

1950s - 1970s - Rapid urbanization with lack of water/wastewater regulation

1967 - Outfall canal constructed, only outflow after sink disconnection

1969 - Natural sink conduit to estuary disconnected

1970s - Present - Agriculture and uplands converted to urban
Defining Background or Pre-disturbance Conditions

Paleolimnology Data
- Pb-210 dating
- Algal pigments
- Diatom assemblages

Catchment History
- Land Use Change
- Impoundments
- Hydrologic Fluctuations

Onset of Eutrophication
- Pre-disturbance Conditions
Paleolimnology Methods

- Soft sediment pre-screening survey at 70 locations
- Three 80-cm in-tact sediment cores, 2-cm intervals
- **UF**: Core strata radioactive dated with models based on $^{210}\text{Pb}$ and $^{226}\text{Ra}$ activity (age-depth profile), calculated mean settling rates
- **USF**: Fossil diatom assemblages – transfer functions, limnetic inferred TP and Chl-a
- **Auburn**: Nutrients, photosynthetic pigments, loss on ignition, sediment physicochemical
- **Wood**: Synthesized paleo, water quality, hydrologic data – multivariate ordination techniques
Sediment Core Pigment Results

- Aphanizophyll (pigment diagnostic of cyanobacteria) showed large, sustained increases in the 1700s-1800s
  - Cyanobacteria likely abundant before human-influenced disturbance
  - Increases occurred before modern period
- Chlorophyll high well before 1950, but increased throughout modern period
- Okenone (PSB, diagnostic of stratified, saline lakes) vanished around 1900-1940
  - Brackish before disconnection
Diatom Autecological Preferences and Eutrophication

- Lake Tarpon has been eutrophic/mesotrophic through entire fossil record
  - >60% of diatom assemblages were eutrophic pre-disturbance
  - Recent conditions are similar, but with more hypereutrophic taxa
- The lake has never been oligotrophic
Diatom Assemblage Multivariate Analysis

- The number of individual diatoms was significantly higher in the pre-1945 period.
- Diatom community structure experienced a shift around 1945.
- The diatom community structure was most closely correlated to okenone and phosphorus concentrations.
  - Okenone (marine pigment) disappeared
  - Phosphorus increased
- Eutrophic and meso-eutrophic diatom species were present throughout the core (pre- and post-disturbance)

nMDS plot of diatom community structure for all cores with pre- and post-modern date (1945) as a factor and sediment phosphorous concentrations overlaid as bubbles on the sample points
Developing Alternative Water Quality Criteria

Deriving site-specific alternative criteria from inferred limnetic water quality data
Inferred Limnetic Water Quality

- Diatom assemblages used in statistical transfer-function models to derive inferred limnetic TP and Chl-a concentrations
- Human disturbance in Lake Tarpon began in the 1800’s
- 1878 dated sediments in Core LT-25 selected as representative pre-disturbance concentrations
- Prior to 1880 Chl-a was always above 20 ug L\(^{-1}\)
- Lake is **not impaired** based on paleo results

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<th>Total P ug L(^{-1})</th>
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Summary

- Paleo methods can be used to reconstruct past water quality conditions:
  - Assess water quality changes during last ~120 years
  - Track shifts in biological communities (e.g. diatoms to blue-green algae)
  - Define reference/background conditions for management and restoration
  - Establish pre-disturbance site-specific water quality criteria
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