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Pinellas County

PALEOLIMNOLOGICAL METHODS FOR LAKE MANAGEMENT

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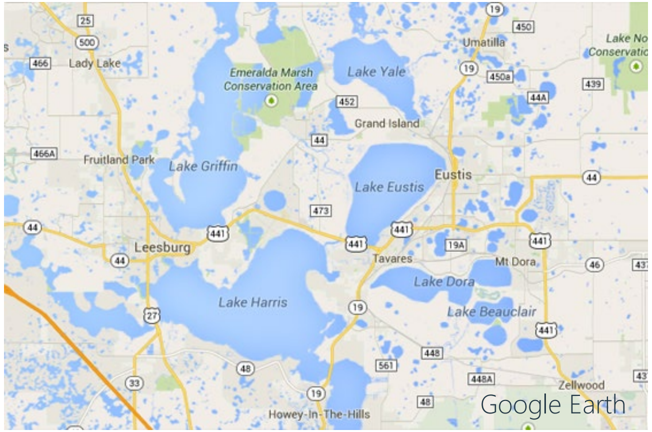
Trajectory of Florida Lakes

- 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)

How to fill data gaps… Paleolimnology

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

- 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

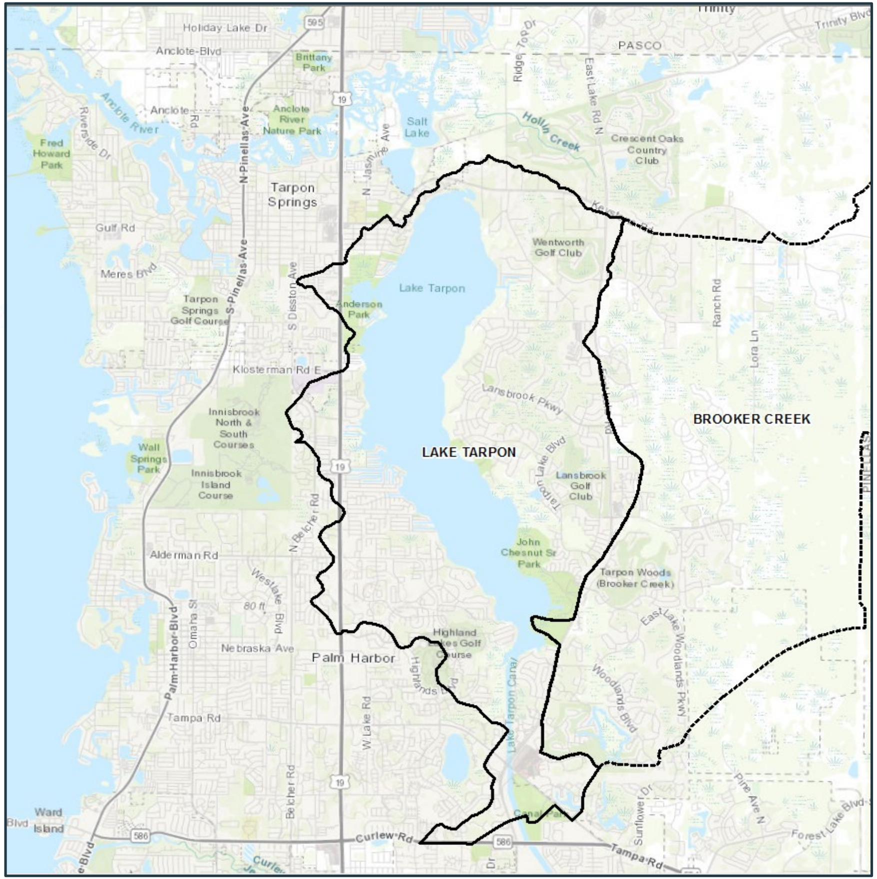
- ^{210}Pb dating
- Diatoms
- Sedimented blue-green algal pigments
- Stable Isotopes $\delta^{13}C$ and $\delta^{15}N$
- Pollen and plant macrofossils
- Charcoal, metals, testate amoeba, chrysophyte scales, phytoliths, chironomids, cladocera, ostracodes, freshwater sponges

(Lauterman, 2016)

Paleoecological Assessment of Lake Tarpon

Sediment core data and diatom assemblage analysis

Study Site: Lake Tarpon in Pinellas County

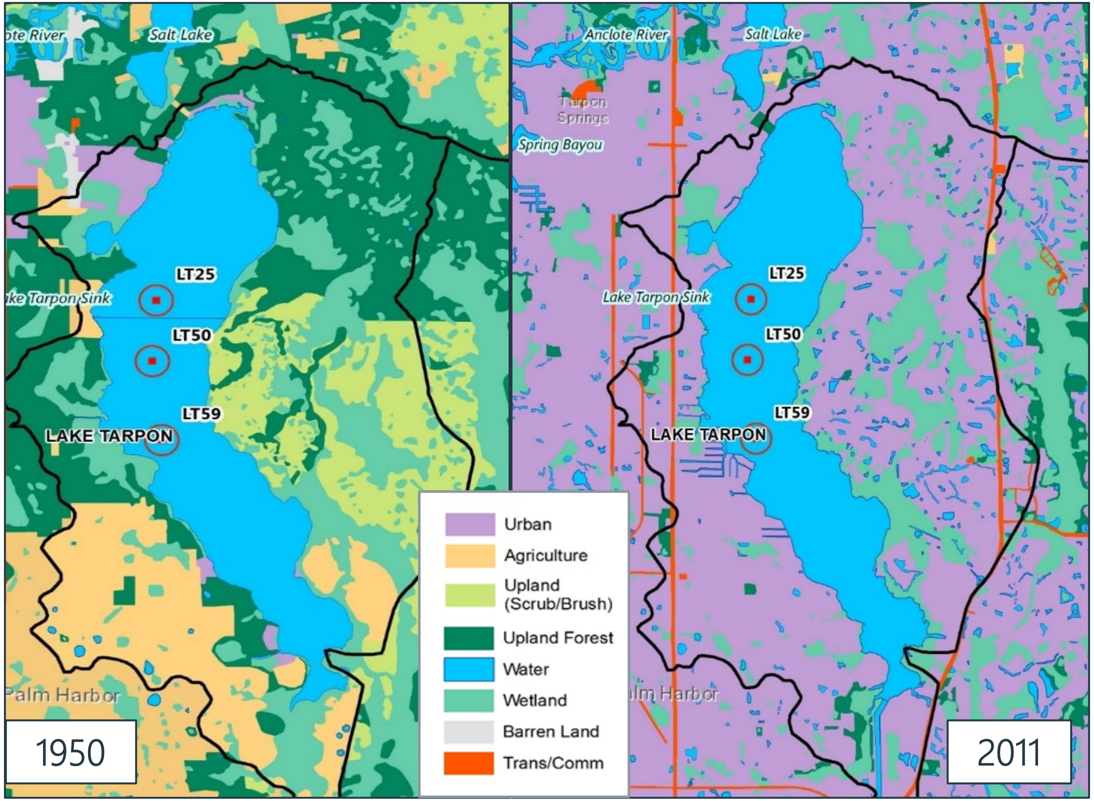


- ~1,000 ha lake, east of Gulf of Mexico
- ~4,000 ha catchment basin
- **Historical condition**: Brackish, well-mixed due to connection to estuary through sinkhole and underground conduit, high hydrologic variability
- **Modern condition**: Sink connection terminated, converted to freshwater with managed 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 + Catchment History = Onset of Eutrophication

Paleolimnology Data

Pb-210 dating
Algal pigments
Diatom assemblages

Catchment History

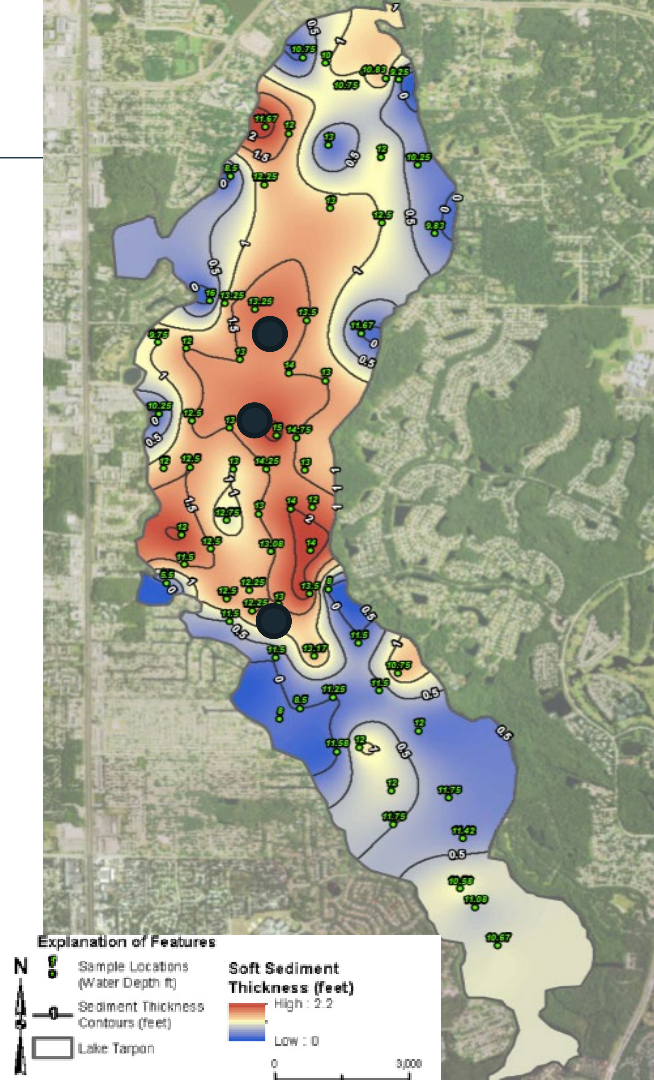
Land Use Change
Impoundments
Hydrologic Fluctuations

Onset of Eutrophication

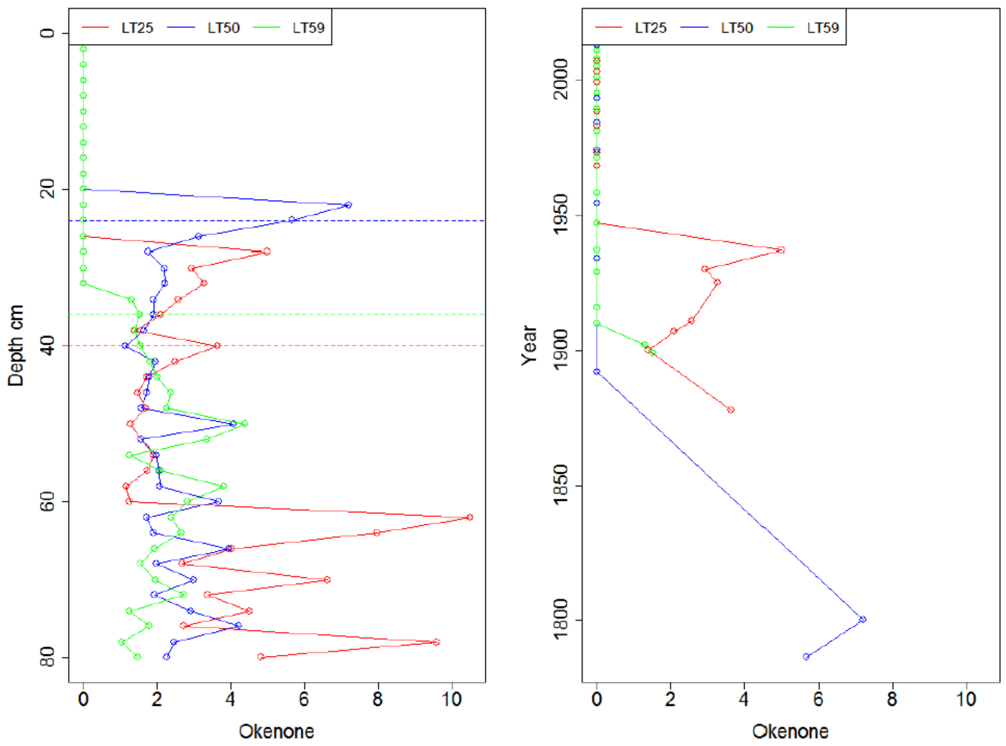
Pre-disturbance Conditions

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}Pb and ^{226}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



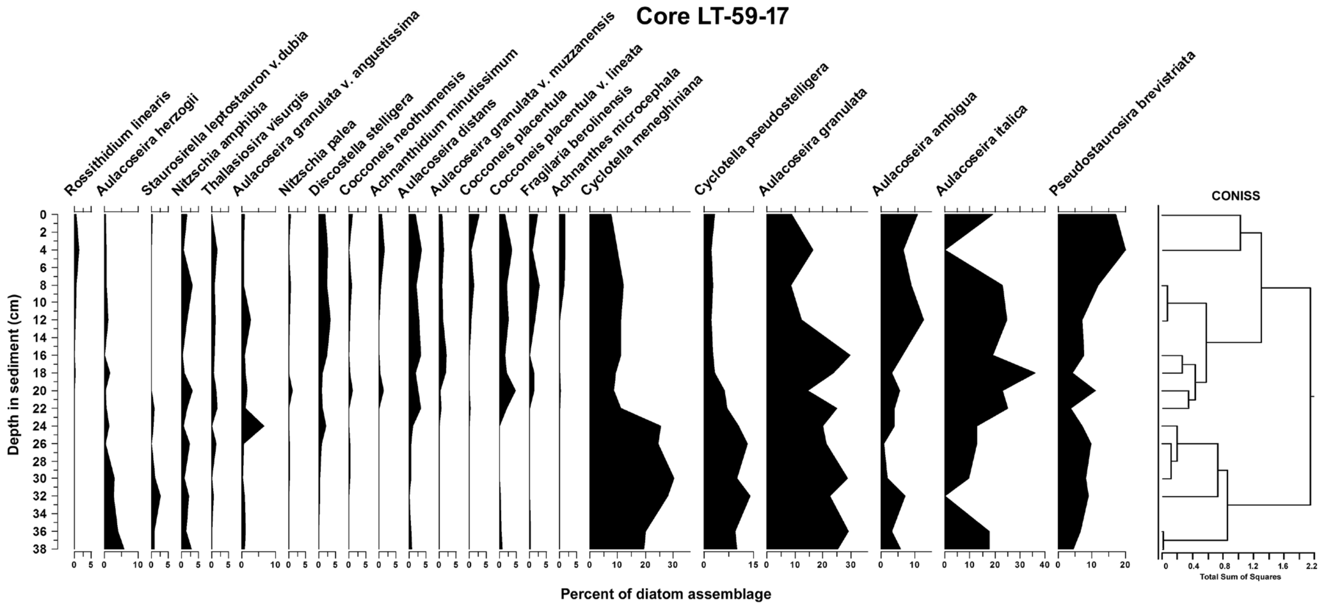
Sediment Core Pigment Results



- 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

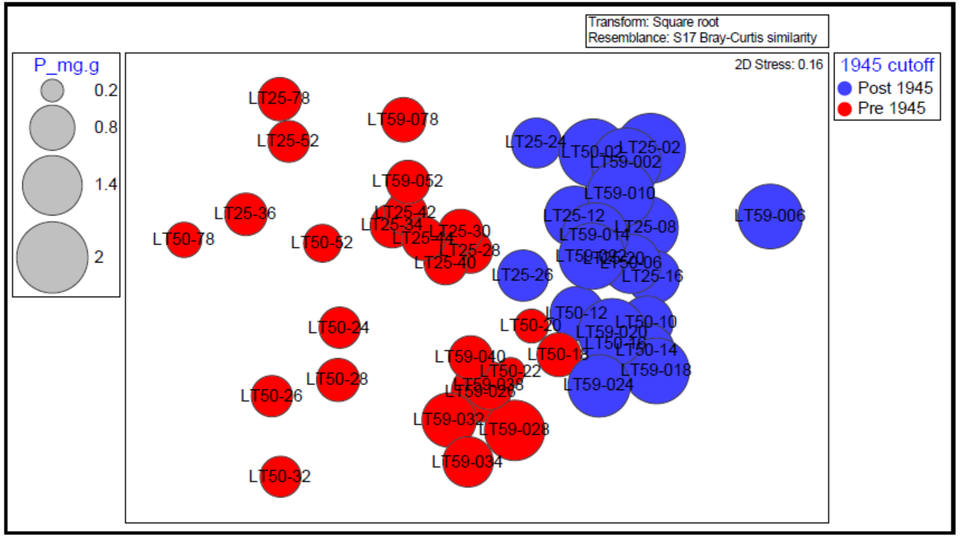
Diatom Autecological Preferences and Eutrophication

- 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**



(Lauterman et al. 2018)

Diatom Assemblage Multivariate Analysis



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

- 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)

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

Used for SSAC →

Inferred Water Quality in Core LT-25		
Year	Total P ug L^{-1}	Chl-a ug L^{-1}
2017	72	52.7
2011	64.1	44.6
2003	66	40.2
1993	61.8	39.3
1983	64.8	44.9
1975	69.8	46
1968	58.9	33.8
1947	58	33.3
1937	58.6	37.1
1930	57.7	30.2
1911	51.3	25.6
1907	55.7	32.1
1878	56.9	30.7
*Pre-1878	56.4	29.6
**Pre-1878	52.4	27.3
***Pre-1878	53	24.5

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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