GEER 2015

Greater Everglades Ecosystem Restoration

Mathematical Analysis of the Influence of Naturally Occurring vs Anthropogenic Events on Water Quality in Florida Bay

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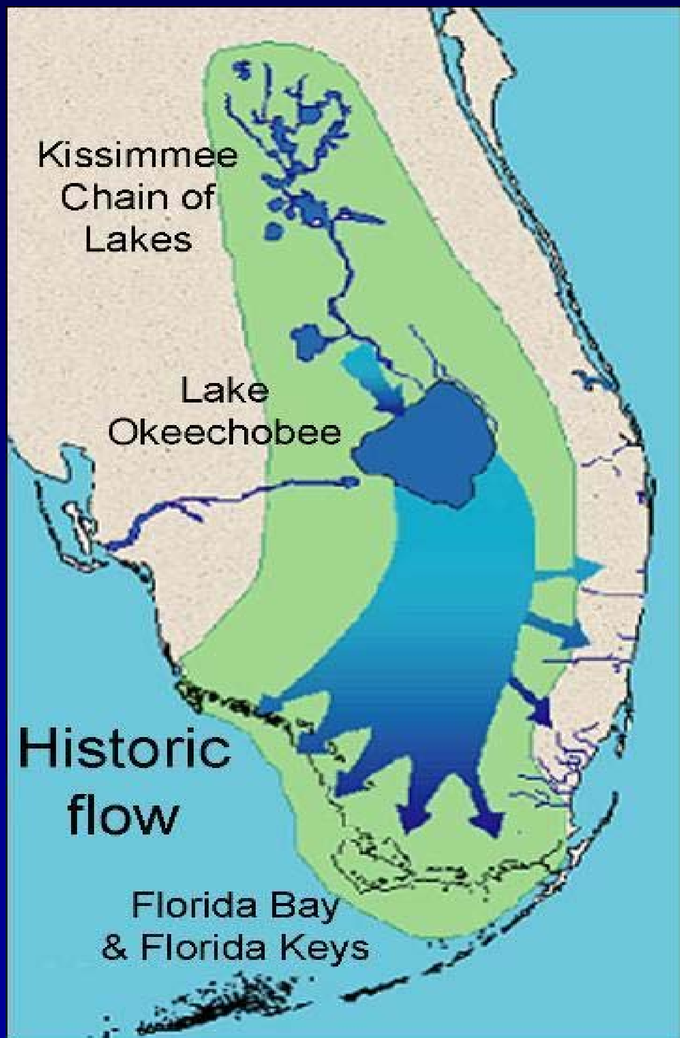
FLOW TO FLORIDA BAY

Historical Pattern



Interrupted Flow

Barriers: Major Canals, Levees, Roads & Water Retention Areas

- 1880-1883, canals in central Florida
- 1881-1894, initial W redirection of water from Lake Okeechobee
- 1906-1926, more canals in central Florida
- 1907-1912, Flagler RR and infill of most Atlantic-Florida Bay passages
- 1912-1915, Tamiami Trail (road) and Tamiami Canal
- 1921-1938, Lake Okeechobee Levee
- 1952-1954, Lake Okeechobee E Perimenter Levee
- 1954-1959, Everglades Agricultural Area, separating N and S
- 1960-1963, Completion of Water Retention Areas in Everglades
- 1968, Everglades Natl. Park – S Dade Conveyance System
- 1965-1970, SFWMD Minimum Allocation Plan for freshwater flow
- 1970-early 1980s, Monthly Allocation Plan for flow to Taylor Slough
- mid-1980s, SFWMD Rainfall Plan for flow to Shark R Slough and Taylor Slough began; closure of Buttonwood Canal in NE Florida Bay
- 1995-2000, Increased water flow to S ENP and NE Florida Bay

Other Activities and Events in S Florida

- Agriculture in S Florida
  - 1906, buildup began
  - 1951-1986, intensification of agriculture
- Housing development, increased in 1960s after A/C became common
- Natural events
  - 1915-1928, Atlantic Multidecadal Oscillation cool phase/ENSO: higher precipitation, probable increased frequency of hurricanes
  - 1926, cat 4 Great Miami Hurricane, mainland to Keys
  - 1928, cat 5 San Felipe-Okeechobee Hurricane, S Florida
  - 1935, cat 5 Labor Day Hurricane, Keys
  - 1954-1959, AMO warm phase: lower precipitation
  - 1955-1957, drought
  - 1960, cat 4 Hurricane Donna, Keys and up W coast
  - 1961-1963 drought
  - 1971-1974, drought
  - 1980-1982, drought
  - 1985, drought
  - 1987-1994, large seagrass die-off
  - 1992, cat 5 Hurricane Andrew, S mainland - Florida Bay hit hardest

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Main Questions

- How does the timing of changes in environmental indicators correspond to the timing of anthropogenic and natural events, so we can determine probable causes of environmental changes?
- What environmental conditions were changed by the anthropogenic and natural events?

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Environmental Indicators and Scientists

- Ages, mostly ^{210}Pb (C. Holmes, USGS)
- Stable isotopes – $\delta^{13}C$, $\delta^{15}N$ (Anderson, FIU)
- Nutrients (Fourqurean, FIU)
  - Total P and N
  - Carbon: Total, Inorganic, Organic
- Bulk density and porosity (Fourqurean, FIU)
- Organic chemistry (Jaffe, FIU)
  - C_{29} n-alkane, taraxerol, dinosterol
  - C_{25}/C_{27} *n*-alkan-2-ones
  - C_{20} and C_{25} highly branched isoprenoids
- Diatoms (Wachnicka, Gaiser), foraminifera (me)

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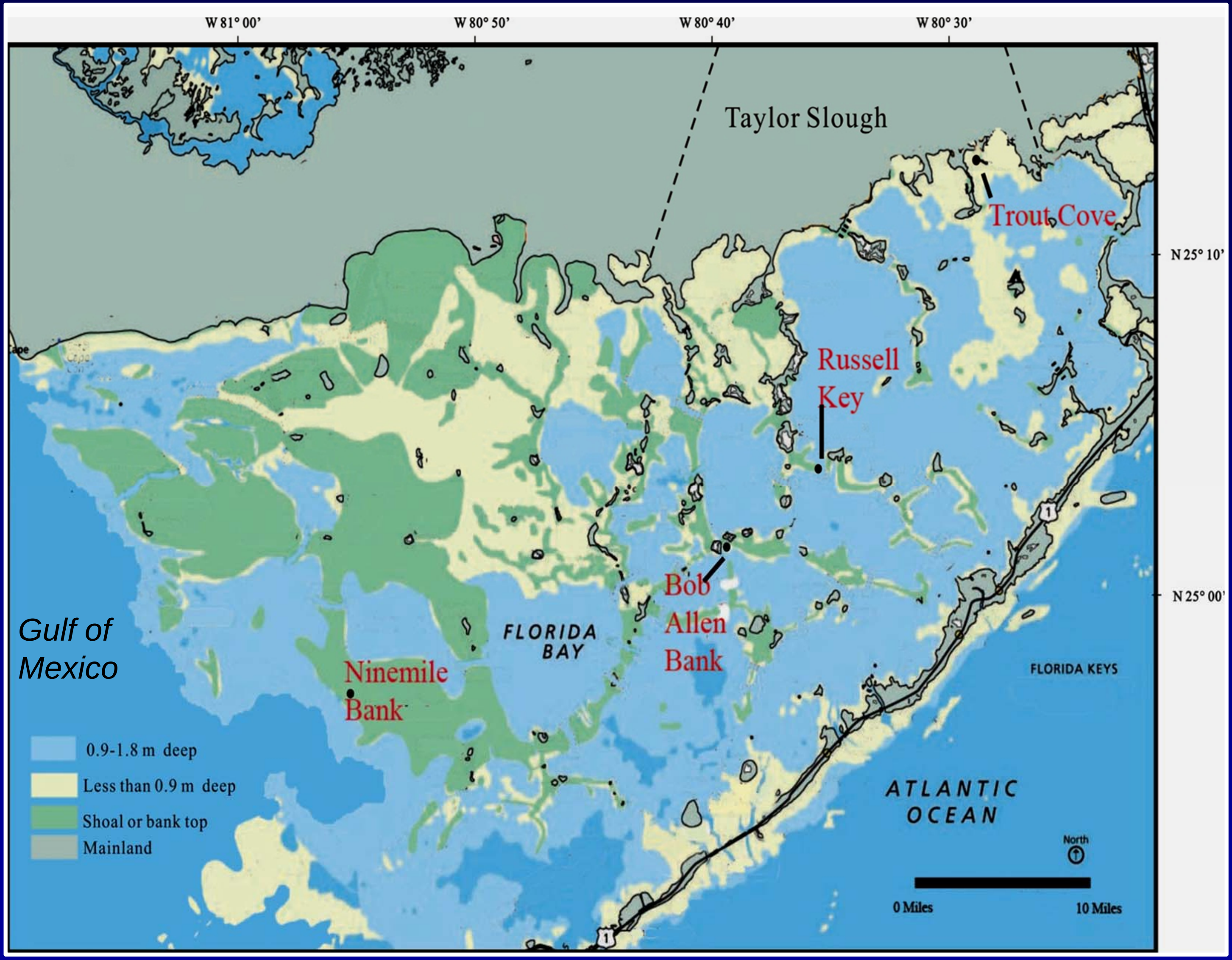
METHODS

- Collected sediment cores

Florida Bay Coring Sites



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METHODS

- Split 2-cm core slices among researchers
  - ½ for ^{210}Pb ages and bulk analyses
  - ¼ for stable isotopes, nutrients and organic chemistry
  - ¼ for foraminifera and diatoms

Slicing core extruded at top of core barrel, Key Largo

top slice of core

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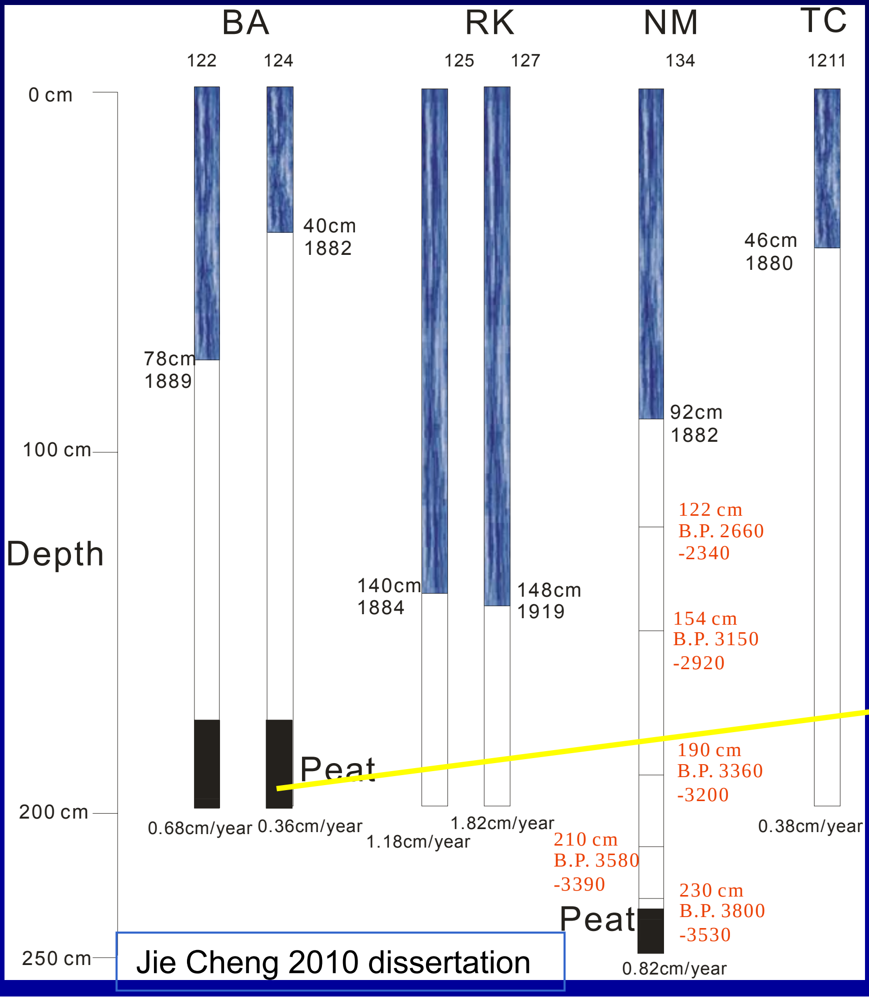
METHODS

- ages of sediment cores (USGS), last 120 years



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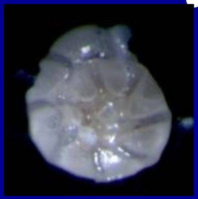
MATHEMATICAL METHODS

- Standard statistical techniques did not work due to massive assumption violations
- Signal processing: impulse-response (Dirac) functions and generalized irf for modeling equations, to identify when larger breaks and smaller perturbations for indicators occurred
- Physical variables produced no definitive responses but biotic variables (diatoms, foraminifera) worked
  - Species assemblages are variable systems that are hit with a disruption and we examine the response (the assemblage after the disruption).



MATHEMATICAL METHODS

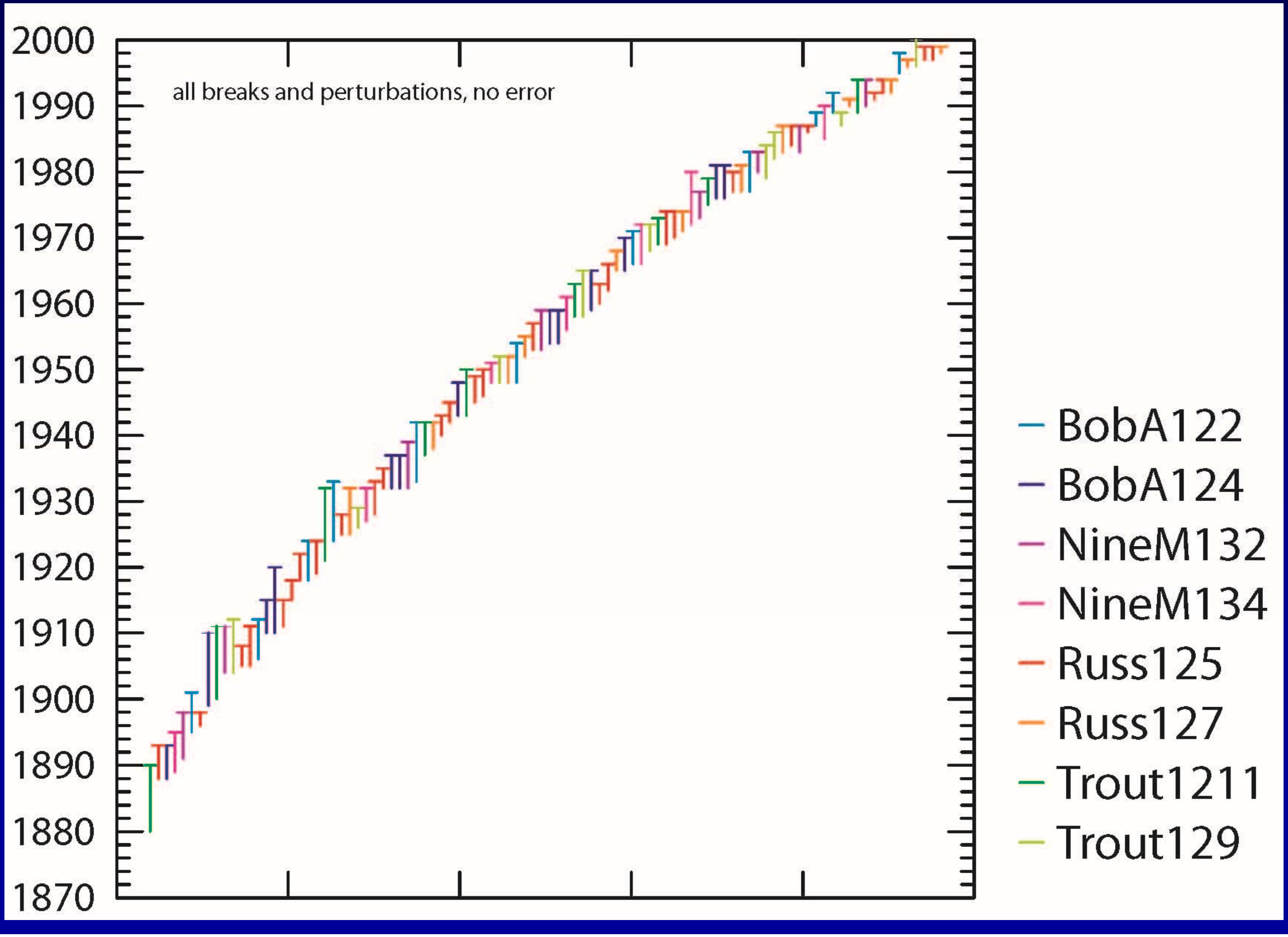
- Assemblage Turnover Index identifies species contributions to total assemblage turnover

  - Species' contributions to the turnover are determined as percentages of ATI or total assemblage change

  - If you know the ecology of the species, the change in proportion of each species in the assemblage indicates the type of change in habitat

RESULTS

All Breaks and Perturbations, no age error



RESULTS

Counts of Breaks & Perturbations Above Background, 1890 – 1940

Years	All breaks >4	All breaks & supp. perts w/in site, > 5,6,7	All breaks & all perts, >5,6,7	Events to be tested
1933			**x 7**	
1932		**x - 7**	**x - 9**	**<u>EVENT 2</u>: 1926-1935 hurricanes**
1928			**x - 7**	
1921	**x - 4**			**Lake Okee. levee 1921-1938**
1911	**x - 4**		**x -8**	
1910	**x - 4**	**x - 6**	**x - 8**	**<u>EVENT 1</u>: Flagler RR construction, start (1906) to completion (1911)**
1905-1909			**x - 6-7**	

RESULTS

Counts of Breaks & Perturbations Above Background, 1940 – 1970

Years	All breaks, >4	All breaks & supp. perts w/in site, > 5,6,7	All breaks & all perts, >5,6,7	Events to be tested
1970-1972			**x - 7**	**droughts 1961-63 & 1971-74; 1968 Everglades-S Dade Conv. syst.;**
1967	**x - 4**			**SFWMD Min. All. Plan 1965-70, Monthly All. Plan 1970-early 1980s**
1959			**x - 7**	**Everglades Ag Area and AMO warm, both 1954-59, drought 1955-57; vs Hurricane Donna 1960**
1948-1949	**x - 4**		**x - 7-8**	**Lake Okee. E levee 1952-54**

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RESULTS

Counts of Breaks & Perturbations Above Background, 1970 – 2001

Years	All breaks, >3/4*	All breaks & supp. perts w/in site, > 5,6,7	All breaks & perts, >5,6,7	Events to be tested
1998-1999	**x - 3**		**x - 4-5**	**<u>EVENT 6</u>: seagrass recovery, increased flow**
1997			**x - 5**	
1992			**x 6**	**<u>EVENT 5</u>: seagrass die-off 1987-1994**
1987			**x - 7**	
1980		**x - 8**	**x - 8**	**<u>EVENT 4</u>: droughts '71-'74, '80-'82; Monthly Allocation Plan**
1977-1979	**x - 4**	**x - 7-8**	**x - 7-8**	

*** fewer co-occurrences considered with fewer cores: 1987-1995 = 1 less core, 1995-2001 = 2 fewer cores**

TESTING THE RESULTS

1. Event 1, construction of Flagler Railroad
2. Event 2, 1926 – 1935 hurricanes
3. Event 3, Lake Okeechobee E levee construction
4. Event 4, droughts of '71-'74 and '80-'82; Monthly Allocation Plan
5. Event 5, seagrass die-off of 1987-1994
6. Event 6, seagrass recovery, increased flow

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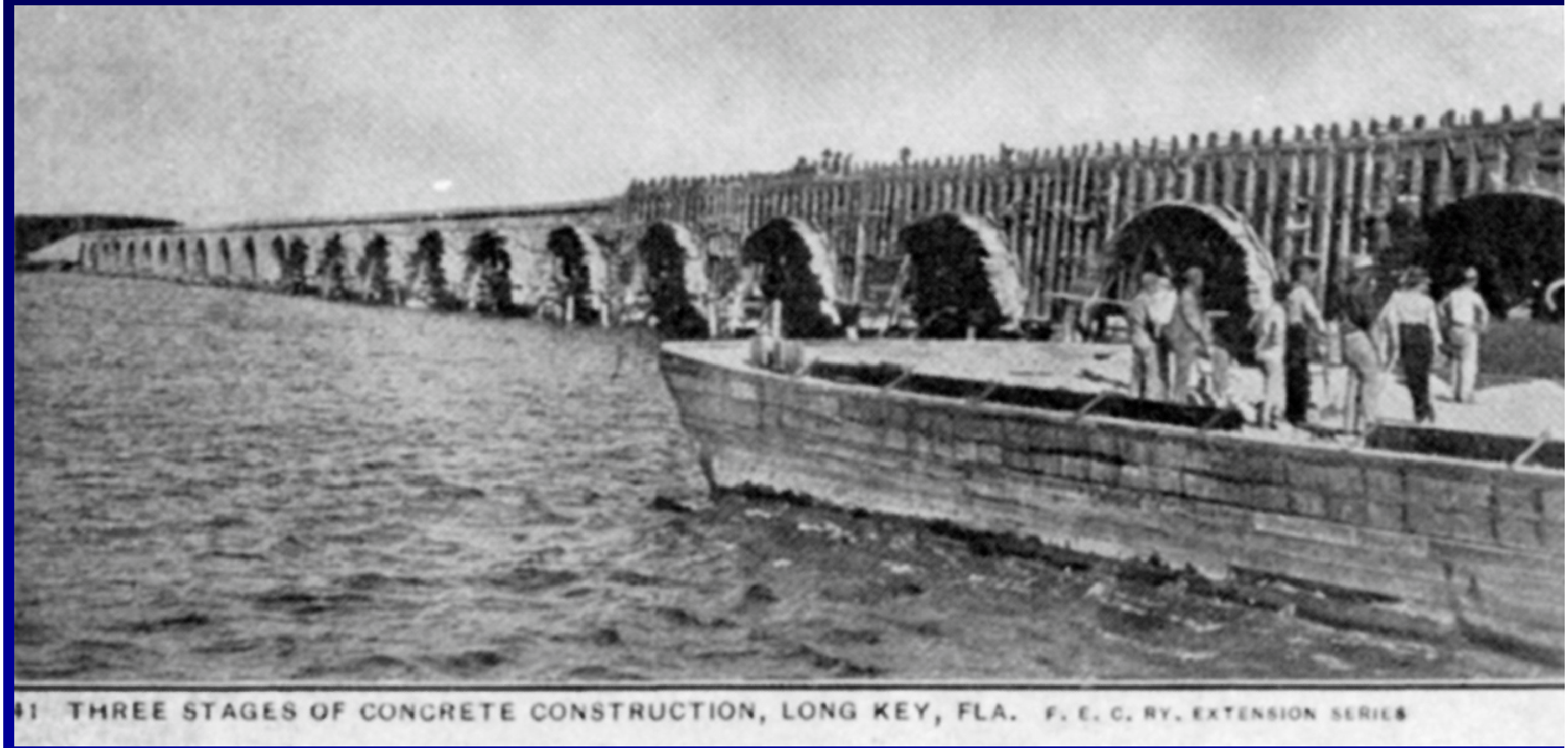
RESULTS

Event 1, Flagler RR construction

infill in Atlantic-Bay passages in 1907 reduced exchange



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RESULTS

Event 1: Flagler RR

Predictions of decreased circulation and less Atlantic inflow:

- Decrease in salinity with less normal-salinity input and more influence from runoff would increase low-salinity forams and diatoms
- Decrease of Atlantic inflow would affect planktic diatoms, which are most sensitive to nutrients
- Decrease in circulation would cause increased retention of organic materials, increasing the taxa associated with organic-rich sediments

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RESULTS

Event 1: Flagler RR

Prediction 1. Decrease in salinity would increase low-salinity-associated forams (F) and diatoms (D): **YES**

Large changes, BA122:

Increase in low-salinity F: *Ammonia tepida* (16%), *Elphidium galvestonense* (16%), *Elphidium poeyanum* (4%), normal-high-salinity miliolid taxa mostly decrease.

Large changes, BA 124:

Increase in low-salinity F: *Ammonia tepida* (8%) and *Elphidium galvestonense* (7%), but large decrease in low-salinity *Haynesina depressula* (20%), and miliolid taxa both increase and decrease. Increase in low-salinity-tolerant D: *Cyclotella distinguenda* (10%), *Mastogloia erythreae* (4%)

Large changes, RB125:

Increase in low-salinity F: *Elphidium poeyanum* (8%), *E. galvestonense* (3%); miliolids both increase and decrease. Increase in low-salinity D: *Cyclotella distinguenda* (4%), *Mastogloia erythreae* (2.3%), *Amphora coffeaeformis var. aponina* (2%), *Nitzschia sigma* (1%)

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RESULTS

Event 1: Flagler RR

Large changes, NM 134:

Low-salinity F: increase in *Ammonia tepida* (6%) but decrease in *Elphidium poeyanum* (6%) and *Haynesina depressula* (9%) - equivocal

Large changes, NM 132:

Low-salinity D: increase in only one - *Mastogloia erythreae* (2.3%).

Prediction 2. Decrease in throughflow would affect planktic diatoms, the ones most responsive to nutrient changes: **MAYBE**

BA124: decreases only, seen in planktic D: *Cyclotella litoralis* (7%), *Paralia sulcata* var. *genuina* f. *coronata* (1%), *Paralia sulcata* (1%).

RB125: large increase in planktic D *Cyclotella litoralis* (30%)

NM 132: decrease in *Paralia sulcata* var. *genuina* f. *radiata* (7%), increase in *P. sulcata* var. *genuina* f. *coronata* (1%)

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RESULTS

Event 1: Flagler RR

Prediction 3. Decrease in circulation would cause increased retention of organic materials, increasing the organic-associated foraminifera: **NO**

- None of the 27 diatom taxa associated with high amounts of total organic carbon changed $\geq$ 1%.
- Two foram taxa associated with org-C-rich sediments decreased 1%.

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Conclusions

- Six taxonomic turnovers, corresponding to:
  - 1906-1911 construction of Flagler RR, Florida Keys
  - 1926-1935 cat 4+ hurricanes
  - 1954-1959 strongly negative phases of ENSO and Pacific Decadal Oscillation, and associated droughts
  - 1977-1980 negative AMO and ENSO, strong drought, and start of Monthly Allocation Plan for water release
  - 1987-1994 seagrass die-off
  - 1997-1999 seagrass recovery, increased water flow
- Most were natural events
- Construction of Flagler RR caused permanent salinity decrease, indicated by biotic variables

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RESULTS

No physical variable produced a definitive irf response but some support by stable isotopes for large change

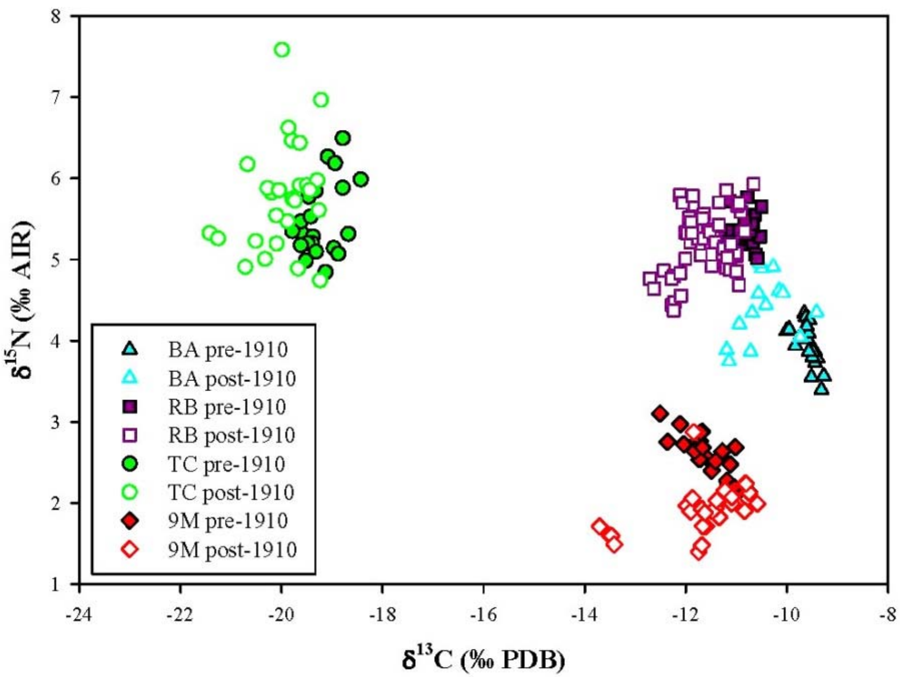

Figure 4.7 Carbon and nitrogen isotopic data from four Florida Bay cores: Bob Allen Bank (BA), Russell Bank (RB), Trout Creek (TC), and Ninemile Bank (9M). Closed symbols denote data from core stratigraphy between 1850 and 1910; open symbols denote data from 1910 to 2002.

S. Evans, 2009 dissertation (FIU)

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