Eutrophication Assessment of the Barnegat Bay-Little Egg Harbor Estuary Using a Multimetric Index

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Assessment of nutrient loading and eutrophication in Barnegat Bay-Little Egg Harbor, New Jersey in support of nutrient management planning

Project Goal & Anticipated Results

Quantify nutrient loading & relationship with bioindicators to develop biotic index for assessing estuarine condition.

1. Characterize & model land use impacts on nutrient fluxes

2. Determine if nutrient loading and biotic response are stable or temporally variable, quantified by subwatershed

3. **Develop and calculate overall index of eutrophic condition, as a tool to evaluate future assessments**

4. Apply a conceptual model of eutrophication to determine if ecosystem structure/function have been altered

5. **Develop threshold levels of biotic decline and numeric nutrient loading criteria for Barnegat Bay & discuss their integration into management plans**

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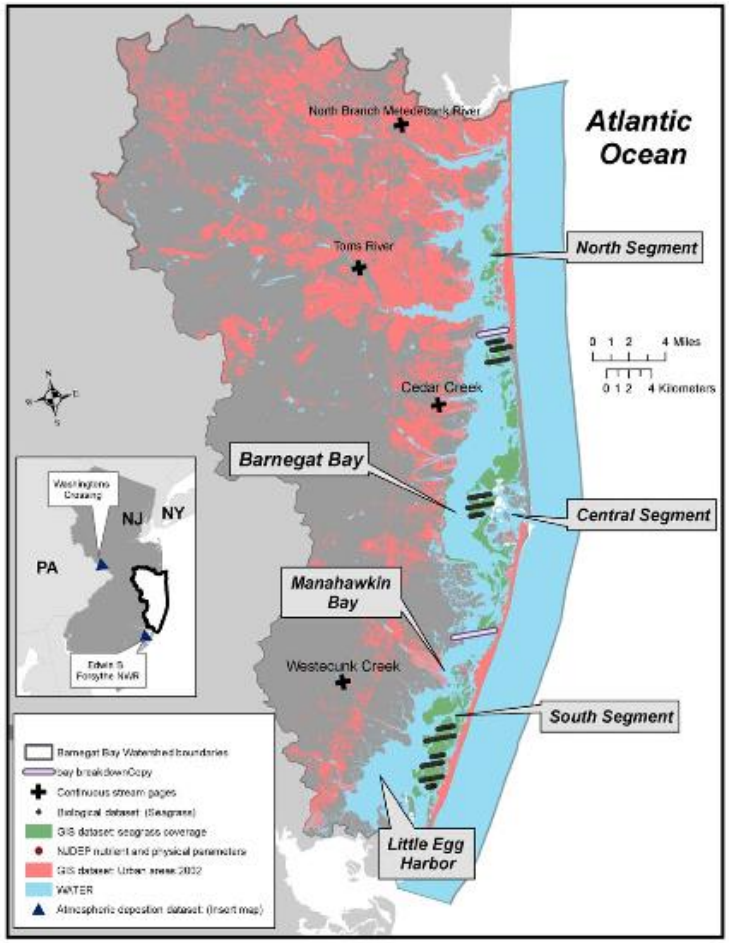
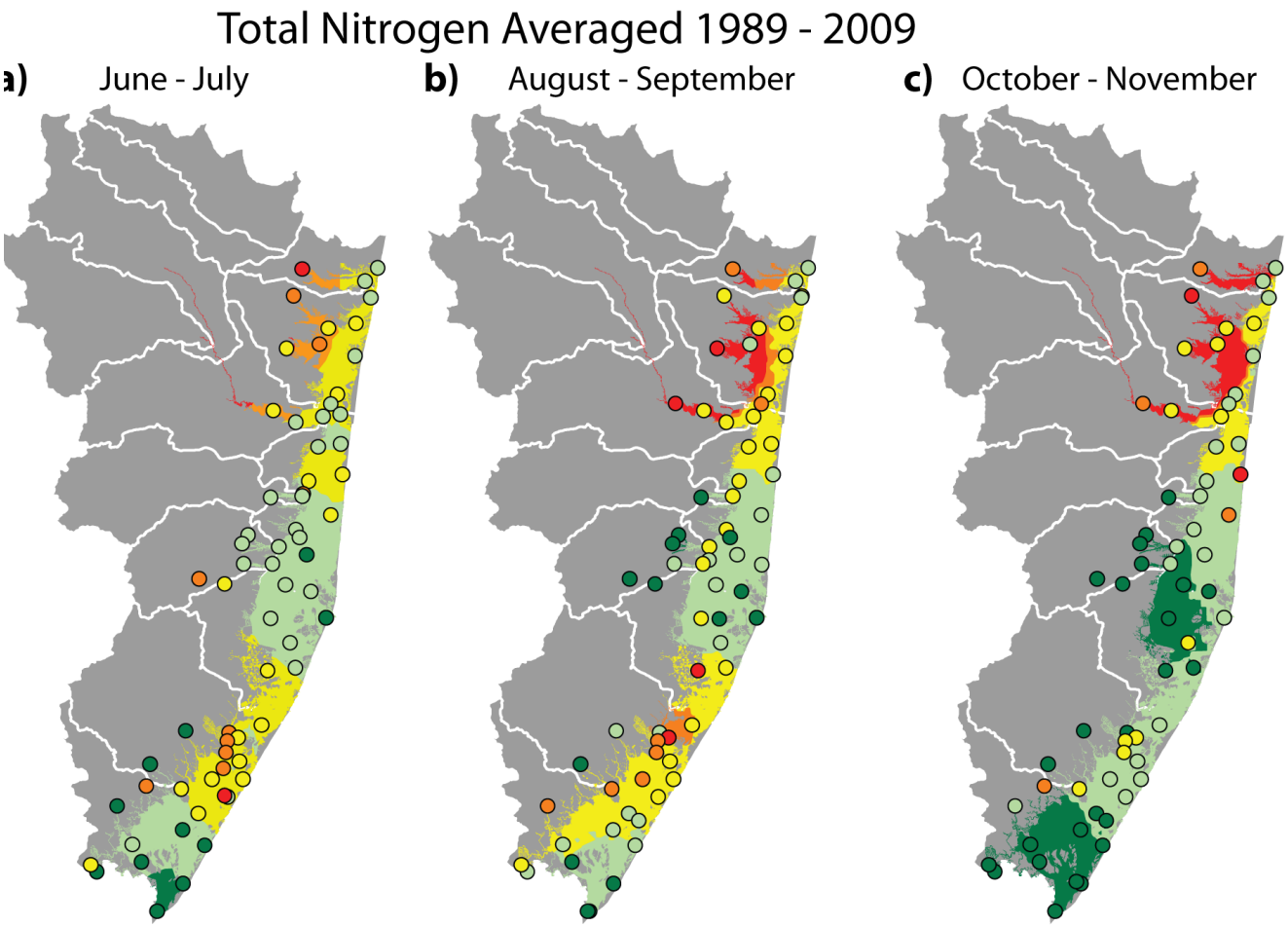
BB-LEH: shallow, poorly flushed, & affected by a developed watershed

- **~2 m deep**
- **~60 days for water flushing**
- **3 different segments**
- **448,000 to 851,000 kg N per year (USGS)**



Nutrient concentrations in surface water are strongly related to land use

TN & TP:
- highest where most urban & agriculture
- highest where least forested & undeveloped



Total Nitrogen µg L^{-1}	µM
> 840	> 60
701 - 840	51 - 60
561 - 700	41 - 50
421 - 560	31 - 40
< 421	< 31

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1989 to 2010: BB-LEH experienced:

- **Low dissolved oxygen**
  (82x <= 4 mgL^{-1})
- **High total suspended solids**
  (max >200 mgL^{-1})
- **High chlorophyll *a***
  (max >40μgL^{-1})
- **Harmful algal blooms**
  (>= 200K cells mL^{-1})
- **Epiphytic loading**
  (max 38.3% cover of seagrass)

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1989 to 2010: BB-LEH experienced:

- **Macroalgal blooms**

  80% to 100% 36x

  70% to 80% 19x

  60% to 70% 10x

- **Habitat loss (>67% fewer clams)**
- **Degraded seagrass biomass**

  2.7 +/- 8.0 g per m^2 aboveground

  17.9 +/- 37.5 g per m^2 belowground

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Many varieties of indices available

Table 2. Methods of eutrophication assessment, and examples of biological and physico-chemical indicators used, and integration capabilities (pressure-state, and overall; modified from Borja et al., 2012). Abbreviations explained throughout the text.

Method Name	Biological indicators	Physico-chemical indicators	Nutrient load related to impairments	Integrated final rating
TRIX[2]	Chl	DO, DIN, TP	no	yes
EPA NCA Water Quality Index[1]	Chl	Water clarity, DO, DIN, DIP	no	yes
ASSETS[5]	Chl, macroalgae, seagrass, HAB	DO	yes	yes
TWQI/LWQI[3]	Chl, macroalgae, seagrass	DO, DIN, DIP	no	yes
OSPAR COMPP[7]	Chl, macroalgae, seagrass, phytoplankton indicator species	DO, TP, TN, DIN, DIP	yes	yes
WFD[6]	Phytoplankton, Chl, macroalgae, benthic invertebrates, seagrass,	DO, TP, TN, DIN, DIP, water clarity	no	yes
HEAT[4]	Chl, primary production, seagrass, benthic invertebrates, HAB, macroalgae	DIN, DIP, TN, TP, DO, , water clarity	no	yes
IFREMER[8]	Chl, seagrass, macrobenthos, HAB	DO water clarity, SRP, TP, TN, DIN, sediment organic matter, sediment TN, TP	no	yes
STI[9]	Chl, Primary Production	DIN, DIP	no	no

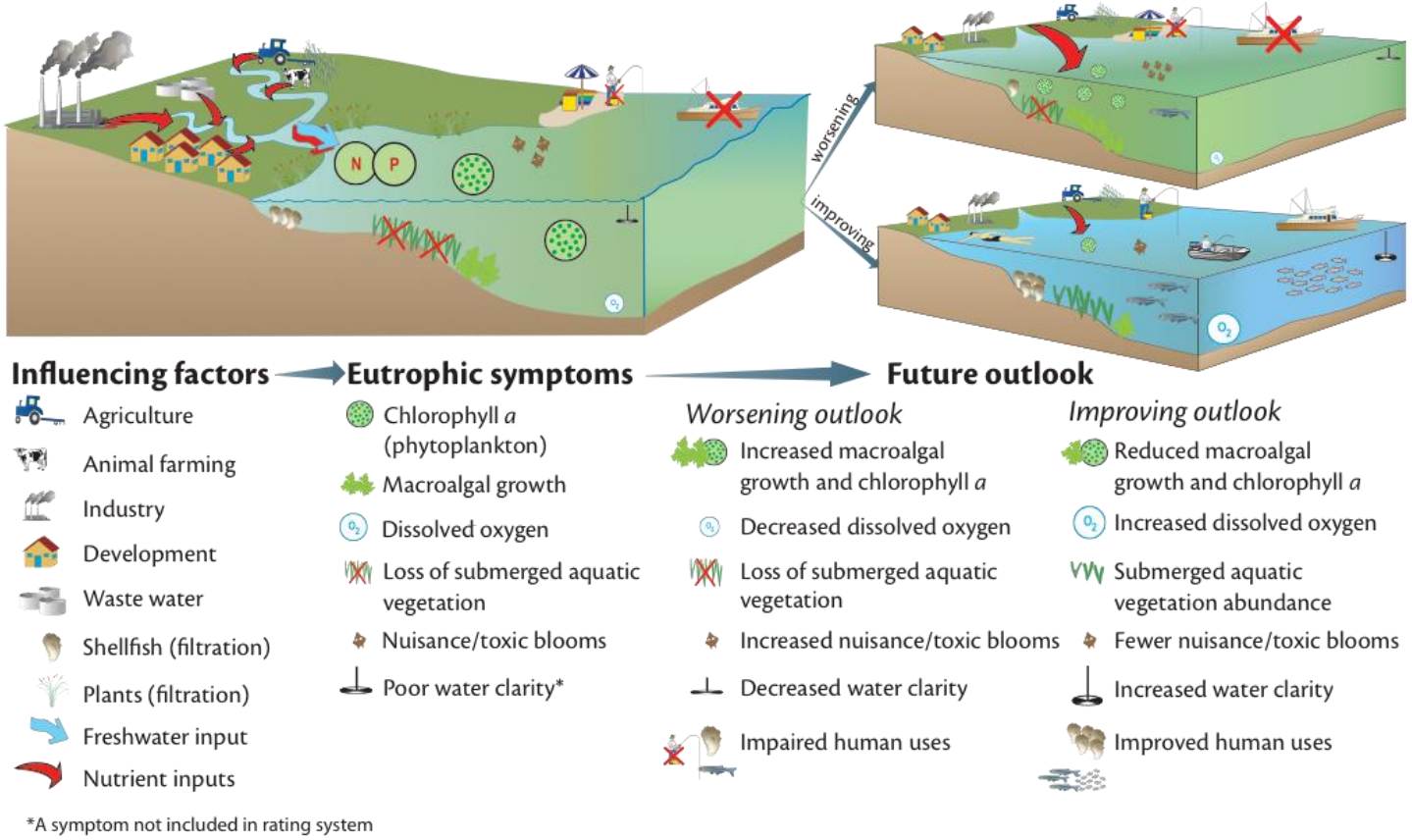
[1]USEPA, 2005, 2008. [2]Vollenweider *et al.*, 1998; [3]Giordani *et al.*, 2009; [4]HELCOM, 2009; [5]Bricker *et al.*, 1999, 2003, 2007; [6]Devlin, pers. Com.; [7]OSPAR, 2002, 2008; [8]Souchu *et al.*, 2000; [9]Ignatiades, 2005.

Ferreira J et al. ECSS 2011

doi: 10.1016/j.ecss.2011.03014

The Biotic Index builds on the NEEA approach (ASSETS)

- **ASSETS (ASSessment of Estuarine Trophic Status)**



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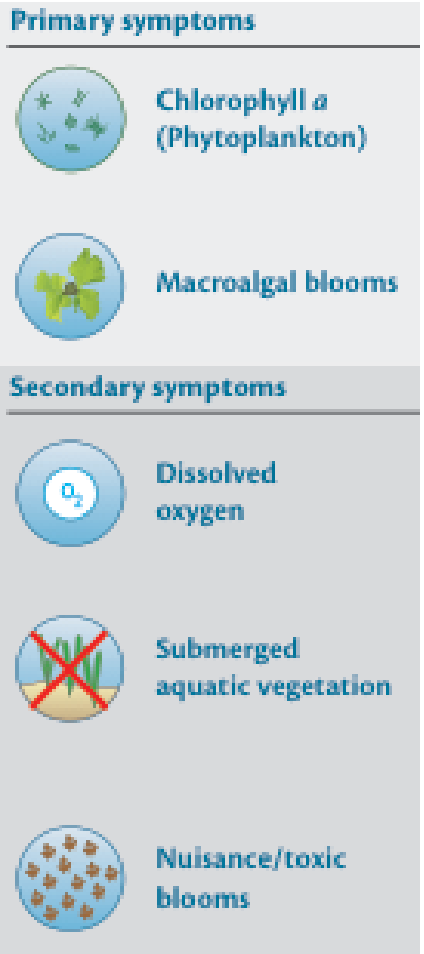
Eutrophic Condition considered Primary & Secondary symptoms



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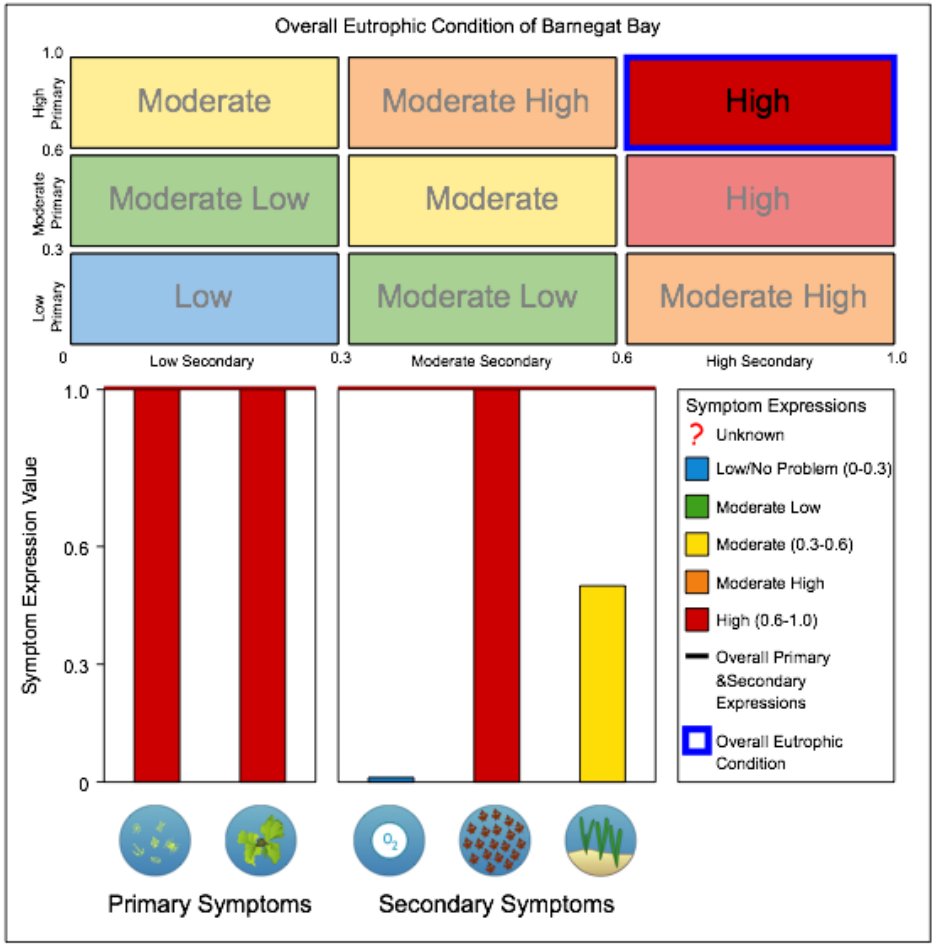
NEEA concluded that Barnegat Bay was 'highly eutrophic'

- **Influencing factors: 'Bad'**
- **Eutrophic condition: 'Bad'**
- **Future outlook: 'Good'**
- **ASSETS Rating: 'Bad'**



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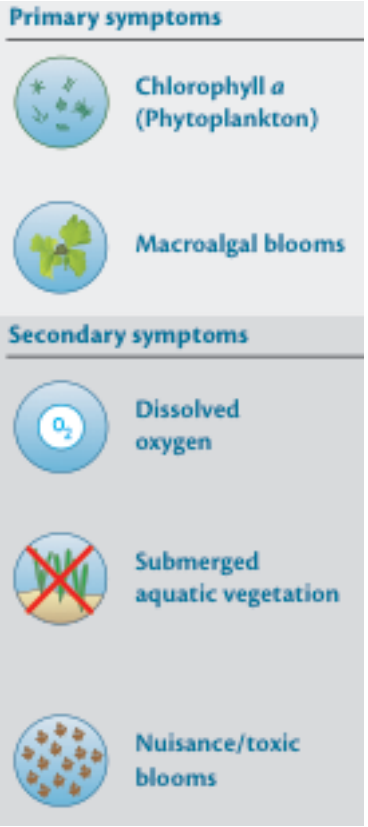
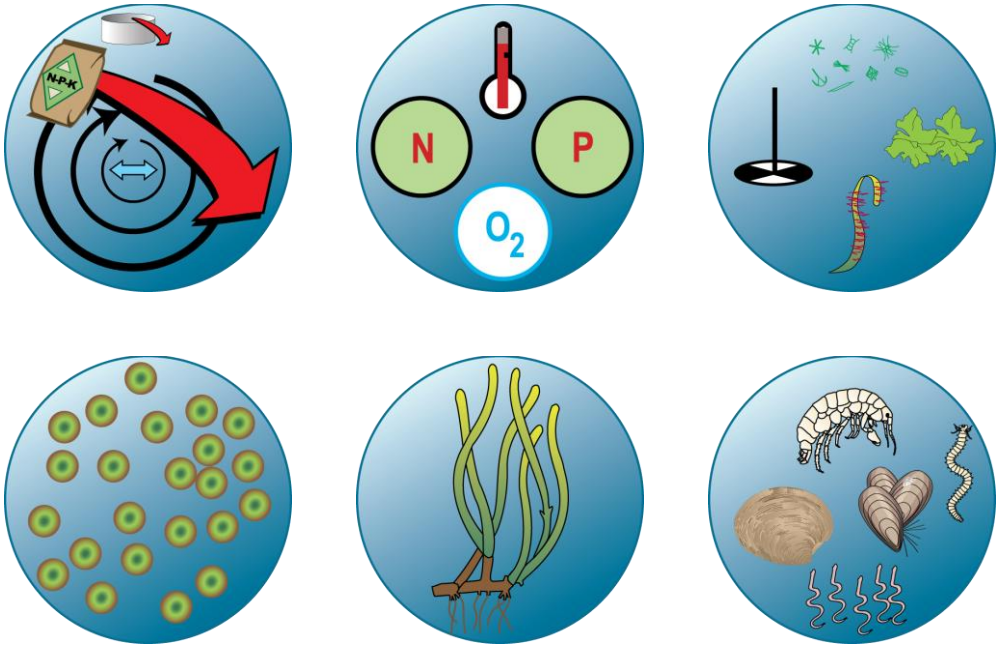
This multimetric index builds on NEEA approach

- **NEEA**



- **Biotic Index**
  - 85 variables
  - 20 indicators
  - 74,400 observations
  - 6 components



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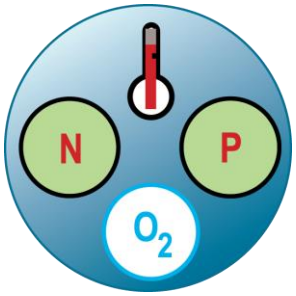
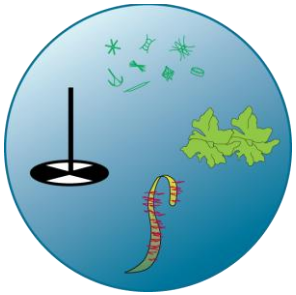
Organizing the Index

1. **Ecosystem Pressures**
   A. Residence Time
   B. Nutrient Loading
2. **Ecosystem State**
3. **Ecosystem Biotic Response**

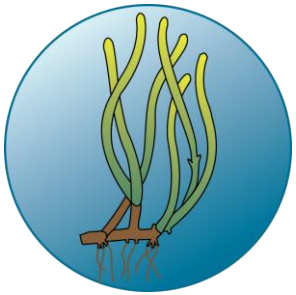
Organizing the Index

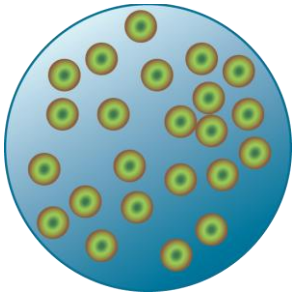


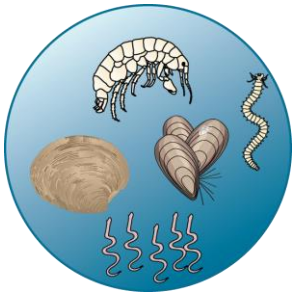


1. Ecosystem Pressures
2. **Ecosystem State**
   A. Water Quality
   B. Light Availability
3. Ecosystem Biotic Response

Organizing the Index







1. **Ecosystem Pressures**
2. **Ecosystem State**
3. **Ecosystem Biotic Response**
   A. Seagrass
   B. Harmful Algae Blooms
   C. Benthic Invertebrates

Project is most comprehensive and holistic assessment of BB-LEH

- **Annual assessment**
- **3 areas (North, Central, South)**
- **Scale of 0 to 100 (0 is Highly Degraded, 100 is Excellent)**
- **Assesses condition and consistency**
- **Increased data availability would improve resolution**
- **Monitoring intensified:**
  - over time
  - # of indicators
- **Space – time alignment of data collection and increased sampling frequency will improve future assessments**

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For Barnegat Bay, there are many data sets, many data gaps

- **Spatial, temporal mismatches**
- **Evaluate & address for each metric**

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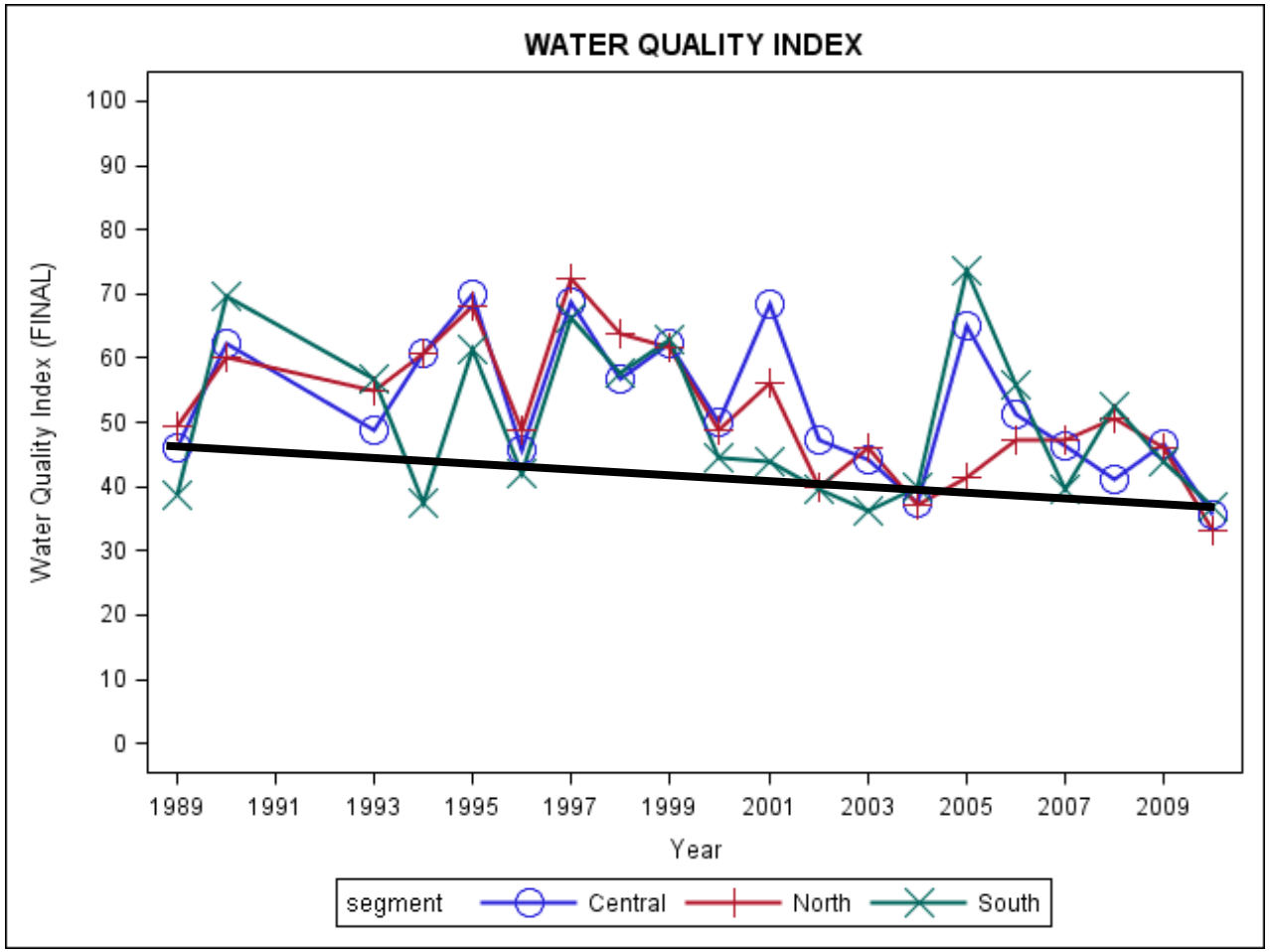
Overall water quality declined

- **1989 to 1997:**
  - Favorable temperatures but low DO → Water Quality Index of 57
- **1998-1999:**
  - Favorable temperatures continued
- **2000-2003**
  - TP increased



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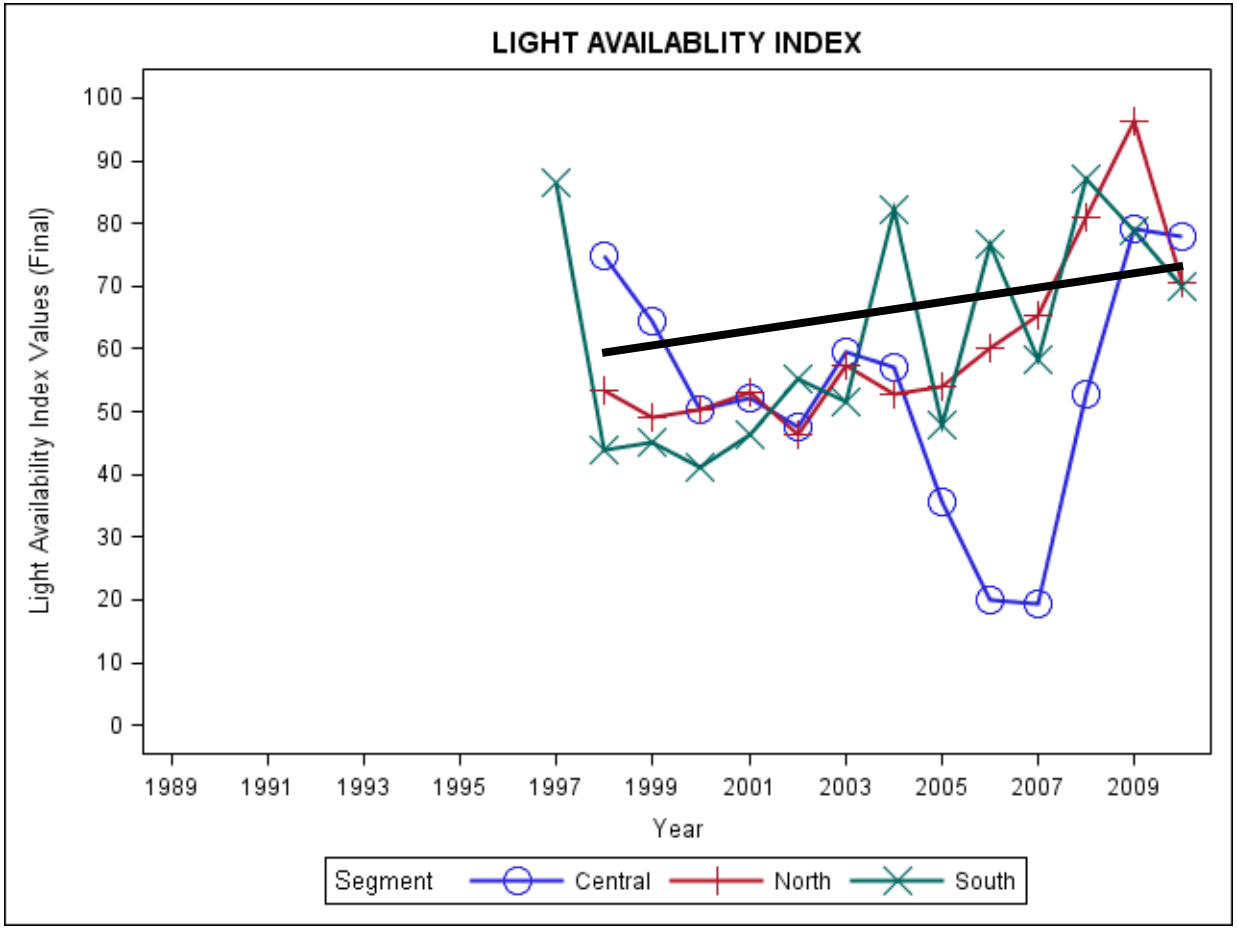
Overall light availability increased

- **TSS scores: 21 to 45**
- **Epiphyte scores: 16 to 40**
- **Available surface light scores: 7 to 32, declining in 1998-2002 in the North & South**



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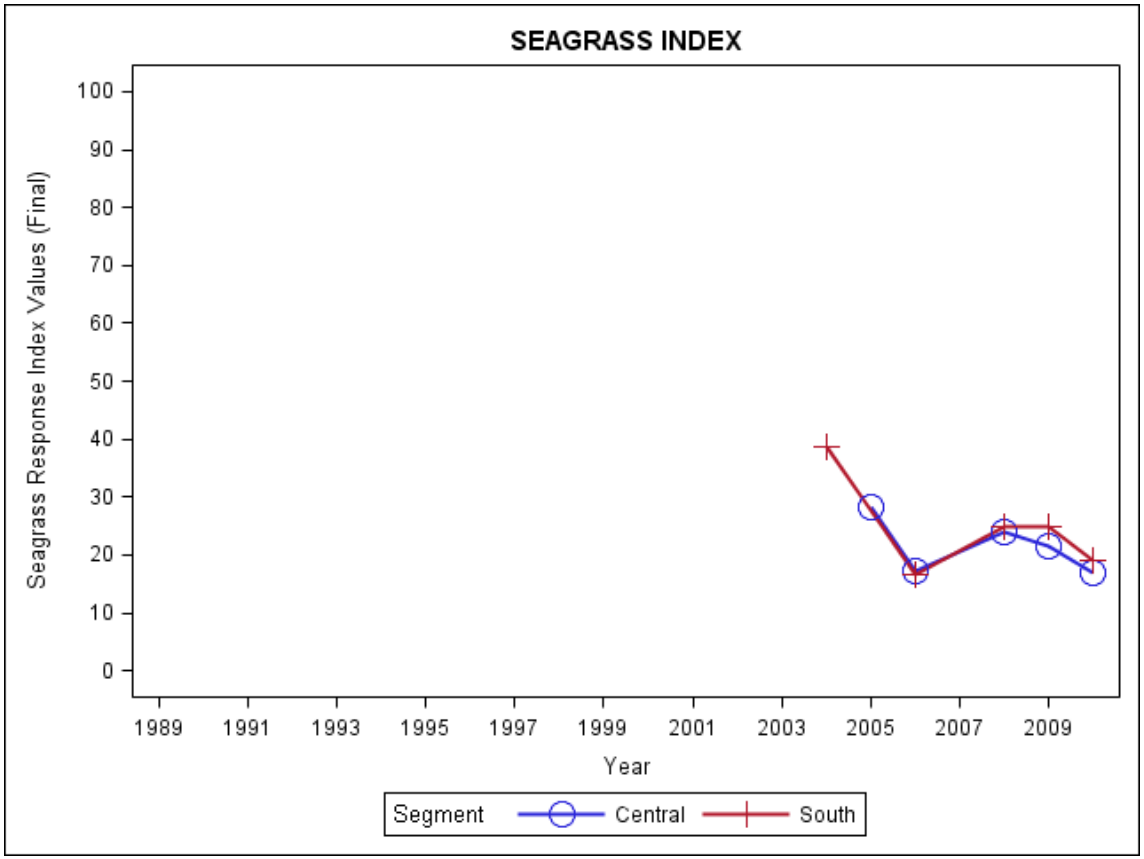
2004 to 2010: Seagrass declined

- **Seagrass cover scores decreased from 34 to 14**
- **Seagrass length scores decreased from 30 to 18**



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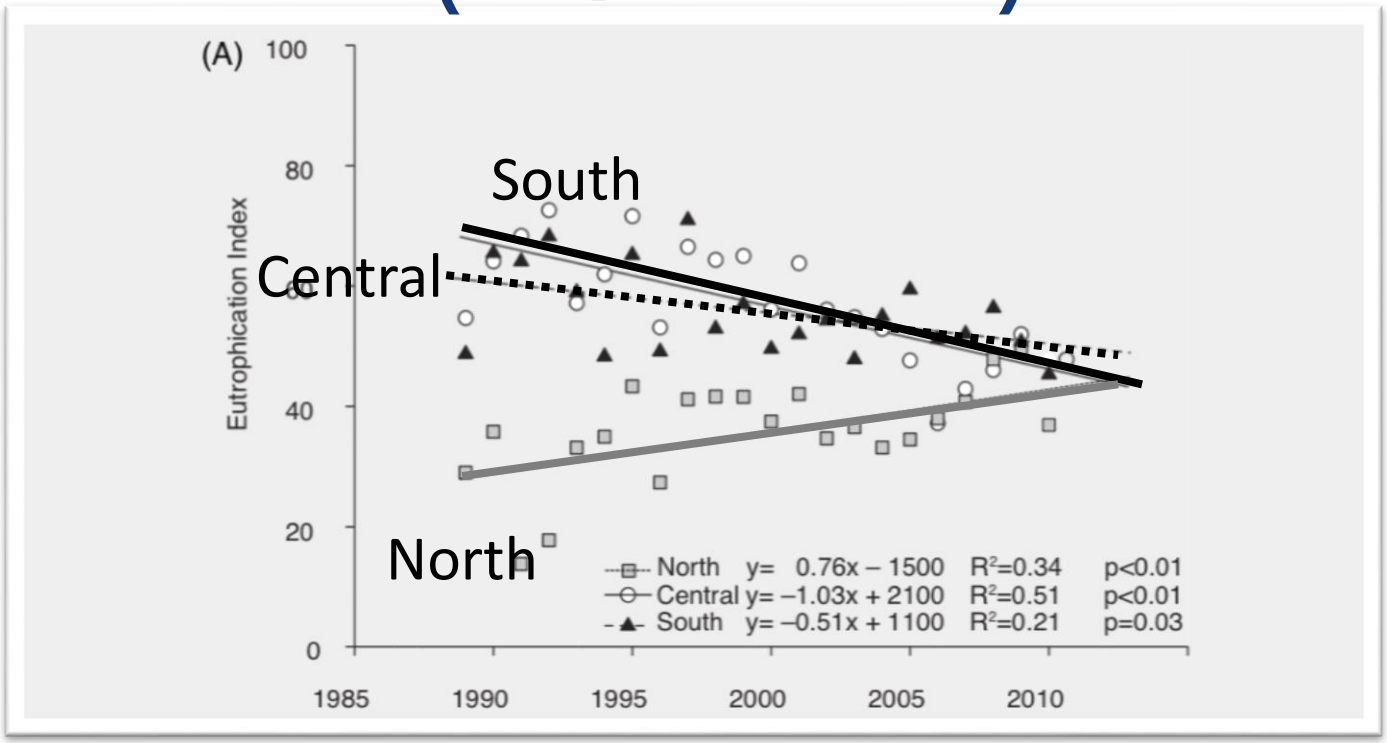
Central & South segments are currently undergoing eutrophication

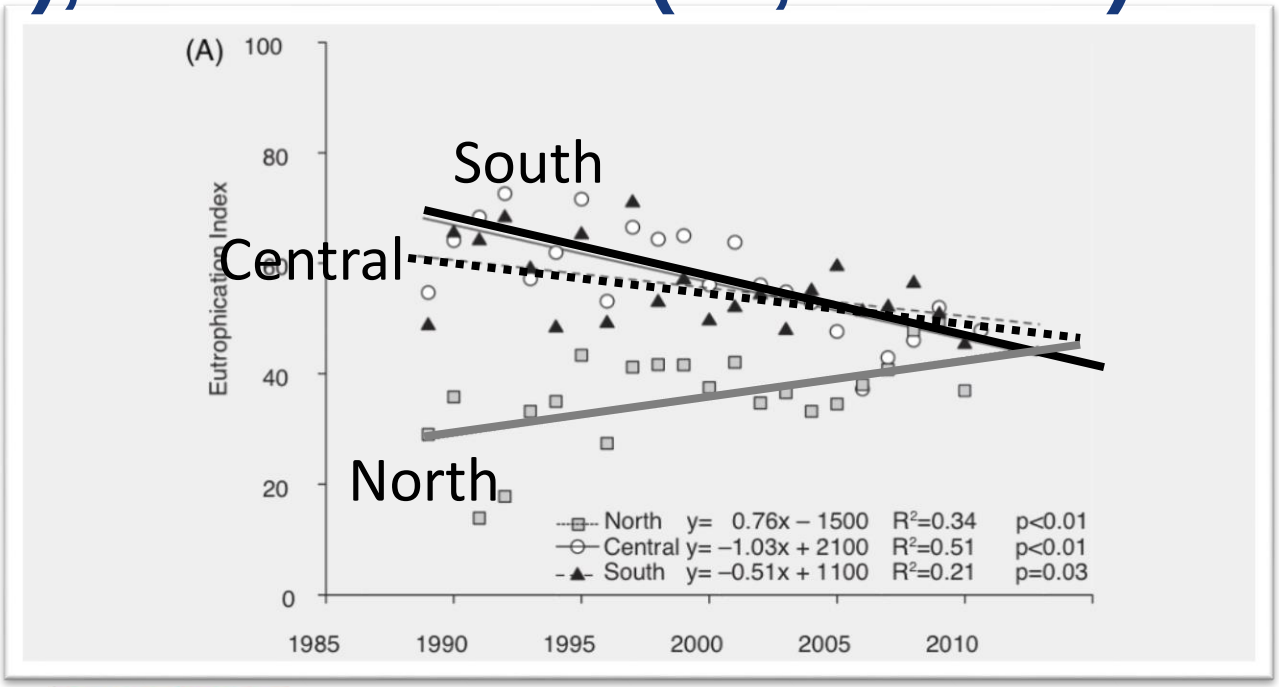
- **Central: Declined from 73 to 48 (34%)**
- **South: Declined from 71 to 45 (36%)**
- **2003-2010 (73 → 45 and 37).**



Fertig et al., 2014

North segment already underwent eutrophication; in worst condition

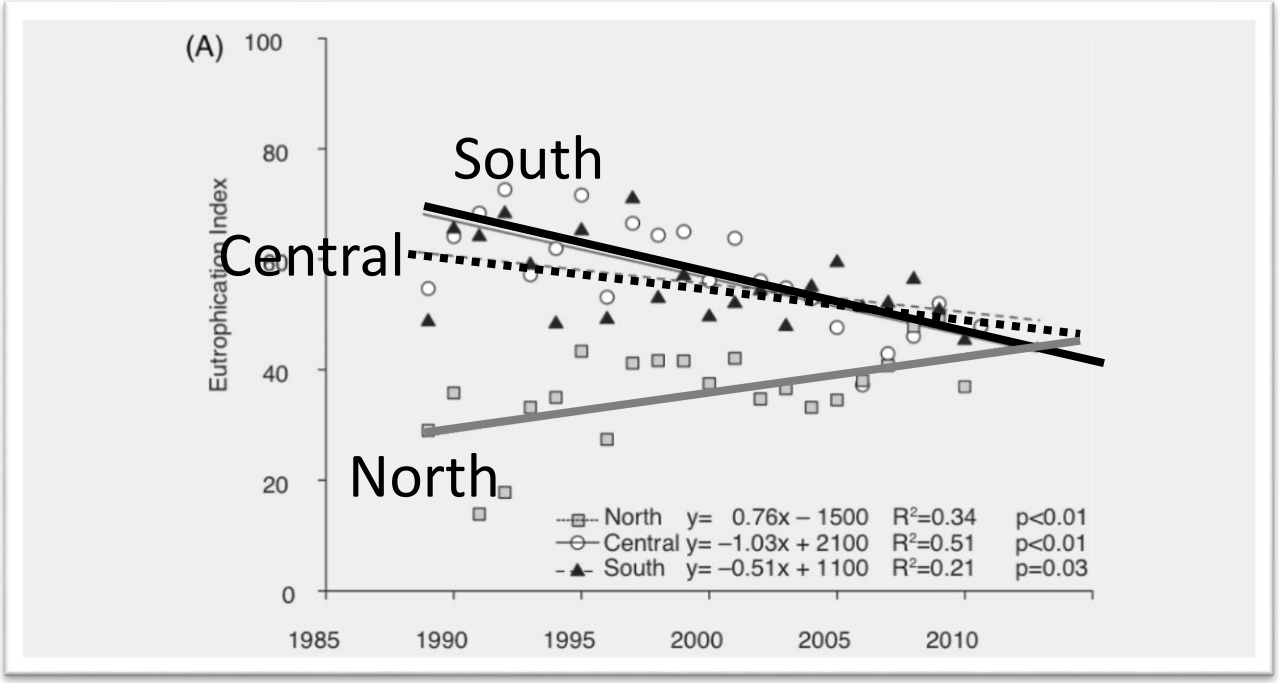
- **Declined sharply in 2010 (to 37)**
- **Improvement: Highest score in 2009 (50), lowest score (14, in 1991)**



Fertig et al., 2014

Overall since the 1990s:

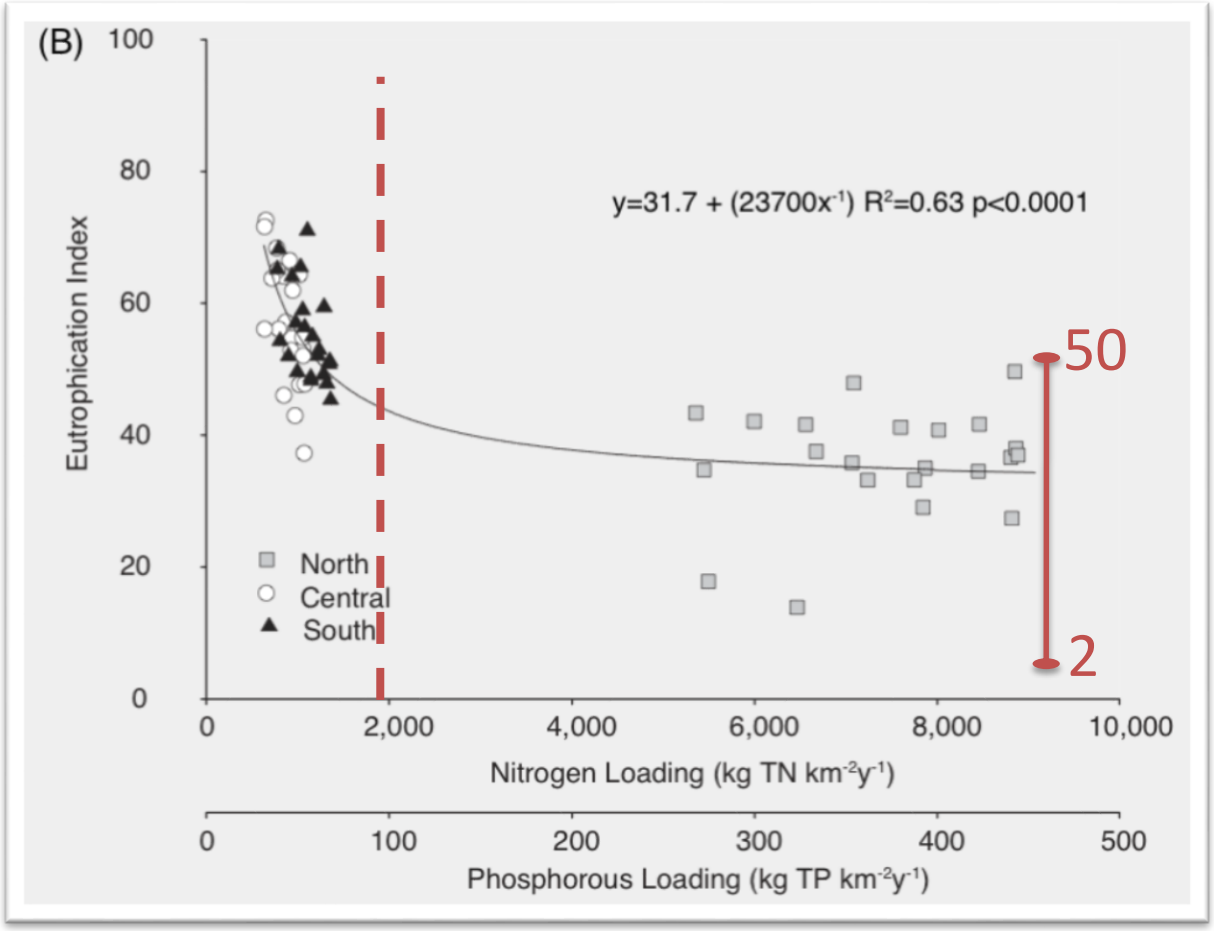
- **Increasing eutrophication in Central & South segments**
- **Condition worsened for N & P**
- **Periods of improvement did not outpace shorter but detrimental periods**



Fertig et al., 2014

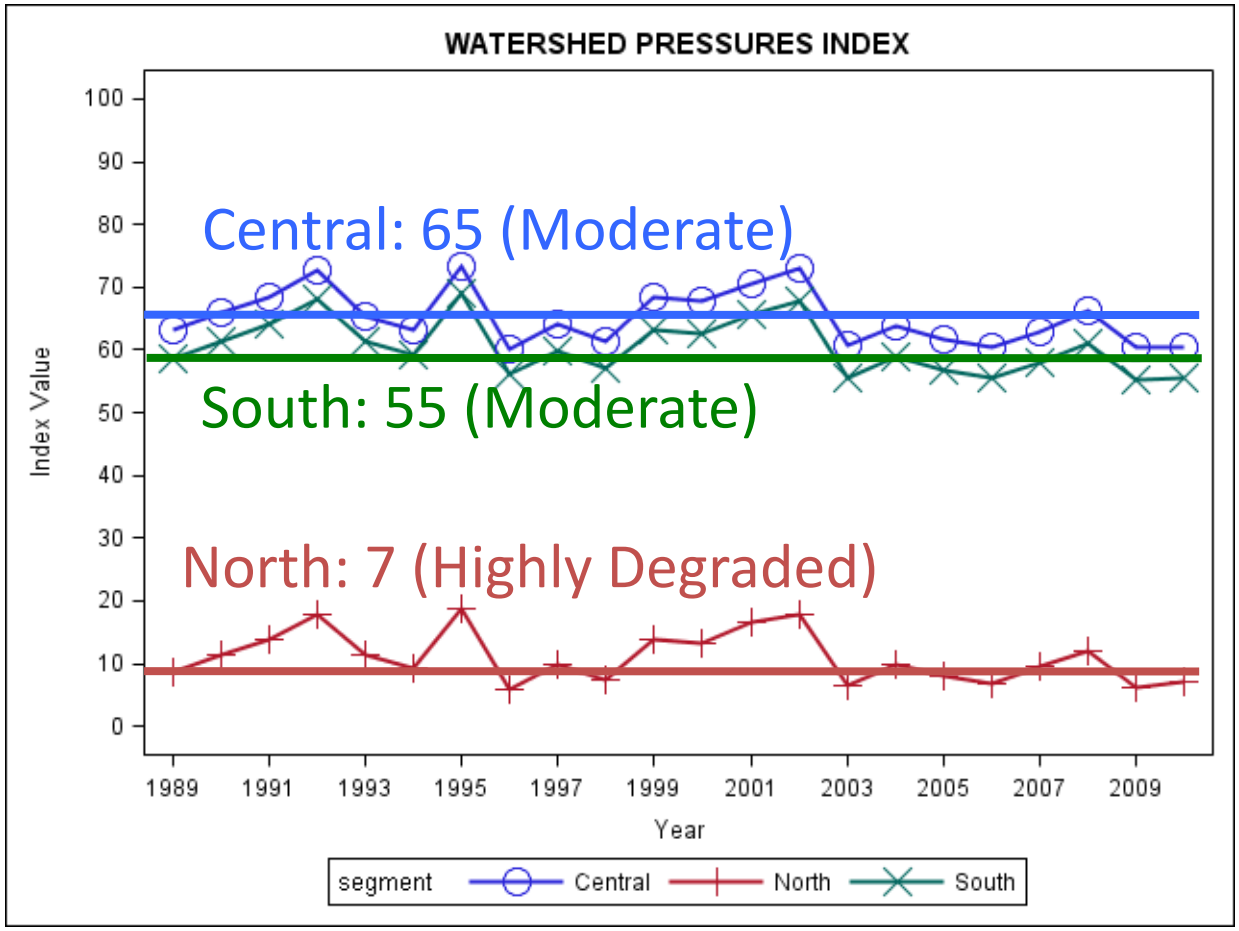
Nutrient loading severely impacts eutrophication in BB-LEH

- **Initial rapid declines highlight sensitivity to loading**
- **Suggests switch in dominant factors**



Fertig et al., 2014

Moderate to intense ecosystem stress from nutrient loadings



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Overall Conclusion

- Collectively, the direct relationship between nutrient loading from the watershed and estuarine nutrient concentrations, the degradation of an array of biotic indicators, and the relationship between nutrient loading and the Index of Eutrophication supports the conclusion that **BB-LEH is an estuary that has undergone significant ecological decline, is highly eutrophic & suceptible to nutrient loading.**

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Thank You

- **Rutgers:** Mike Kennish, Gregg Sakowicz
- **USGS:** Bob Nicholson, Ron Baker, Christine Wieben
- **NEWIPCC:** Susy King
- **EPA:** Darvene Adams
- **DEP:** Tom Belton, Bob Schuster
- **BBEP:** Stan Hales, Jim Vasselides

Benthic invertebrate datasets have limited spatial and temporal extent

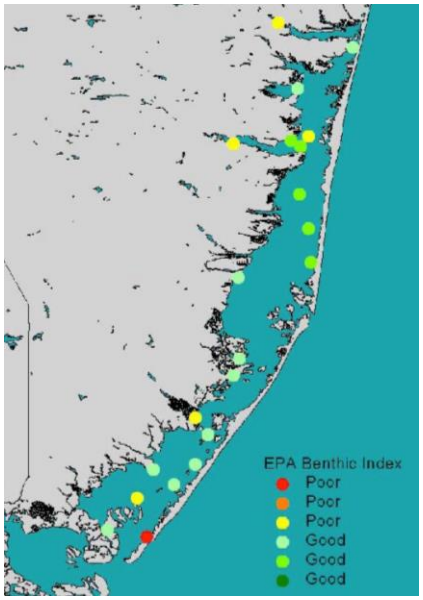
- **NCA**

Sampling:

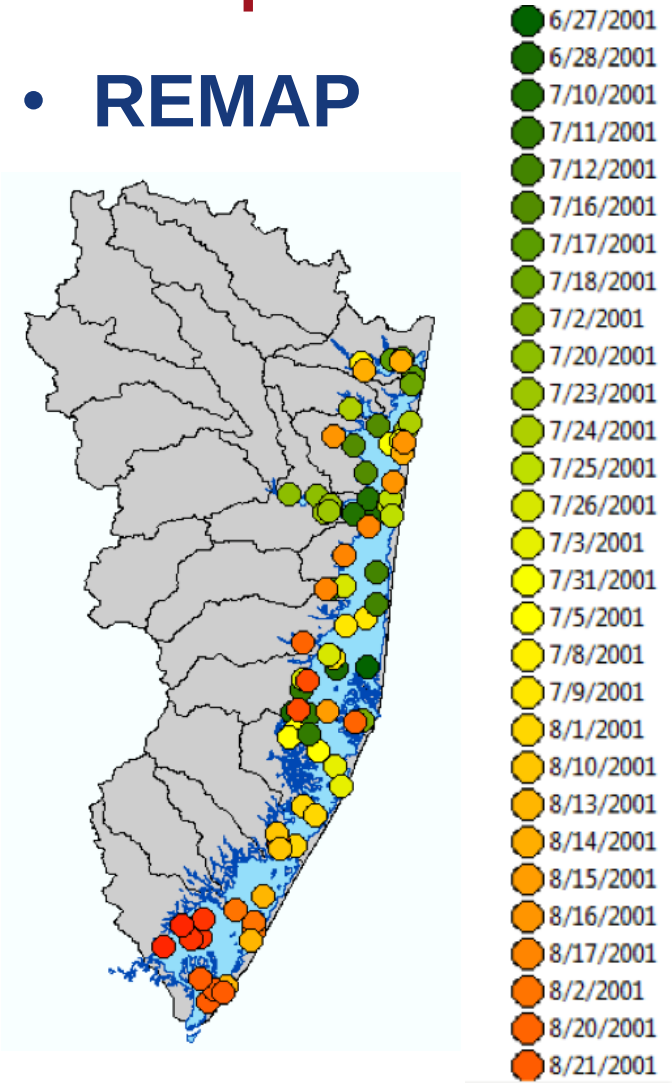
July-October

Years:

- 2000: 4
- 2001: 15
- 2002: 6
- 2003: 4
- 2004: 10
- 2005: 4
- 2006: 16



- **REMAP**



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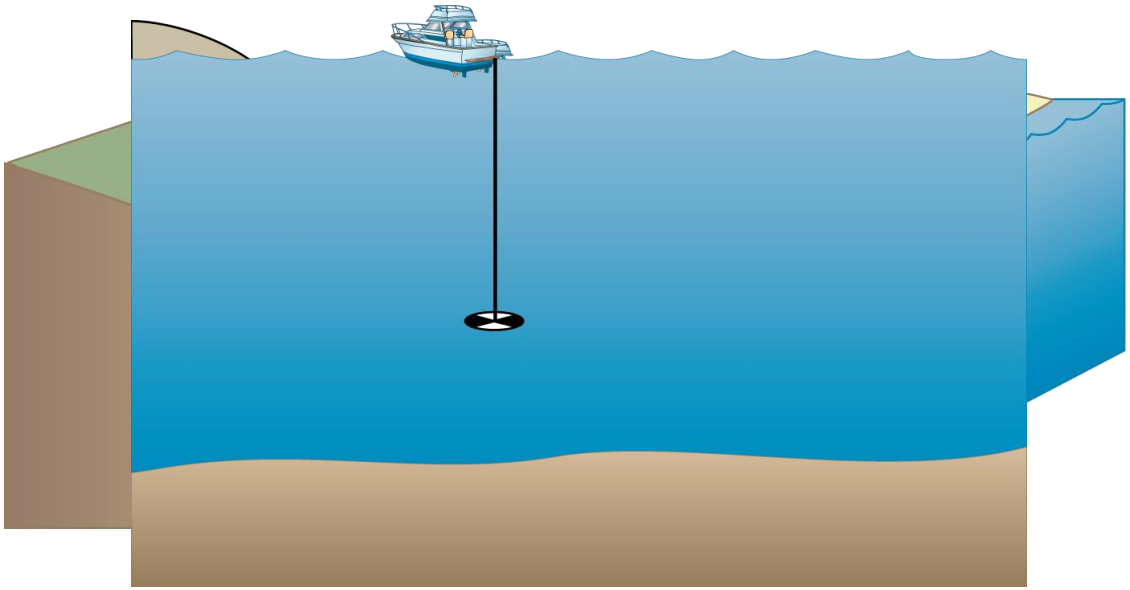
Data Challenges:

- Secchi Depth

- Open Ocean
- Drowned River Estuary
- Shallow Coastal Lagoon



Need for an integrated metric for light availability in Barnegat Bay

Also during 2004 to 2010:

- **TP scores ↓ 32 to 7**
- **TSS scores ↑ North, variable in South, & declined (2004-2007) in Central segment.**
- **Declines (2004-2009) in Central segment: epiphytic load scores (44 to 1) and available surface light scores (41 to 0).**

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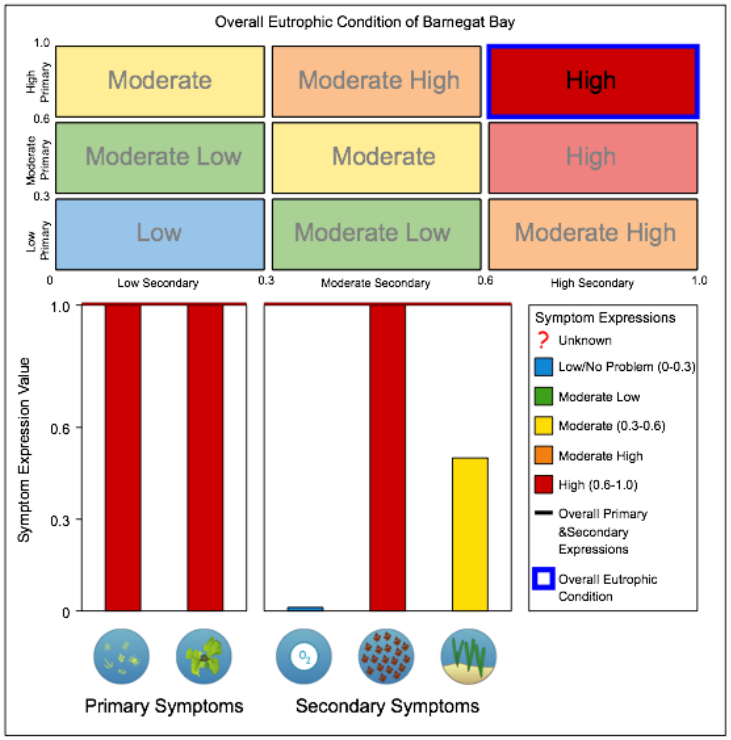
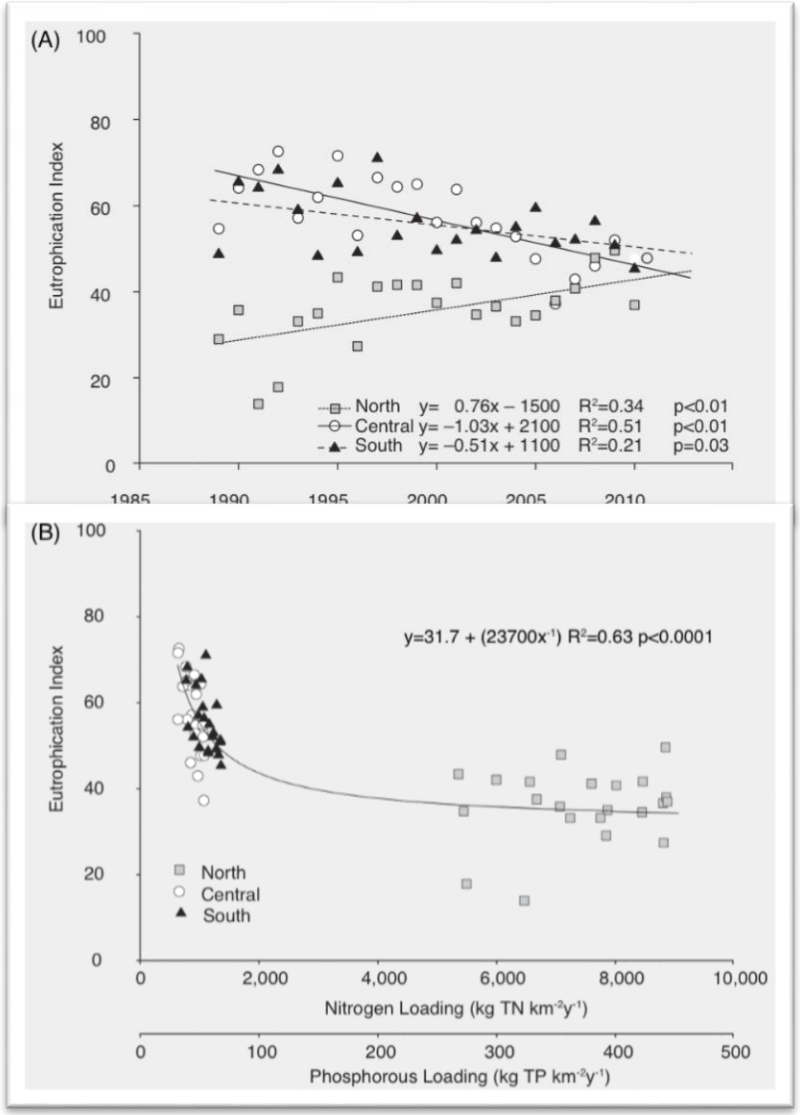
NEEA: Barnegat Bay 'highly eutrophic' 2010: Eutrophication Index 45-50/100



NEEA, 2007



Fertig et al., 2014

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