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

Ben Fertig & Michael Kennish

May 27, 2015
Assessment of nutrient loading and eutrophication in Barnegat Bay-Little Egg Harbor, New Jersey in support of nutrient management planning
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
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 Averaged 1989 - 2009

- a) June - July
- b) August - September
- c) October - November
1989 to 2010: BB-LEH experienced:

- **Low dissolved oxygen**
  
  \[ (82x \leq 4 \text{ mgL}^{-1}) \]

- **High total suspended solids**
  
  \[ (\text{max} > 200 \text{ mgL}^{-1}) \]

- **High chlorophyll \( a \)**
  
  \[ (\text{max} > 40 \mu\text{gL}^{-1}) \]

- **Harmful algal blooms**
  
  \[ (\geq 200\text{K cells mL}^{-1}) \]

- **Epiphytic loading**
  
  \[ (\text{max} 38.3\% \text{ cover of seagrass}) \]
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 m² aboveground
  - 17.9 +/- 37.5 g per m² belowground
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.

<table>
<thead>
<tr>
<th>Method Name</th>
<th>Biological indicators</th>
<th>Physico-chemical indicators</th>
<th>Nutrient load related to impairments</th>
<th>Integrated final rating</th>
</tr>
</thead>
<tbody>
<tr>
<td>TRIX³</td>
<td>Chl</td>
<td>DO, DIN, TP, Water clarity, DO, DIN, DIP</td>
<td>no</td>
<td>yes</td>
</tr>
<tr>
<td>EPA NCA Water Quality Index¹</td>
<td>Chl</td>
<td>DO</td>
<td>no</td>
<td>yes</td>
</tr>
<tr>
<td>ASSETS⁵</td>
<td>Chl, macroalgae, seagrass, HAB</td>
<td>DO</td>
<td>yes</td>
<td>yes</td>
</tr>
<tr>
<td>TWQI/LWQI²</td>
<td>Chl, macroalgae, seagrass</td>
<td>DO, DIN, DIP</td>
<td>no</td>
<td>yes</td>
</tr>
<tr>
<td>OSPAR COMPP⁷</td>
<td>Chl, macroalgae, seagrass, phytoplankton indicator species</td>
<td>DO, TP, TN, DIN, DIP</td>
<td>yes</td>
<td>yes</td>
</tr>
<tr>
<td>WFD⁶</td>
<td>Phytoplankton, Chl, macroalgae, benthic invertebrates, seagrass,</td>
<td>DO, TP, TN, DIN, DIP, water clarity</td>
<td>no</td>
<td>yes</td>
</tr>
<tr>
<td>HEAT⁴</td>
<td>Chl, primary production, seagrass, benthic invertebrates, HAB, macroalgae</td>
<td>DIN, DIP, TN, TP, DOP, water clarity</td>
<td>no</td>
<td>yes</td>
</tr>
<tr>
<td>IFREMER⁹</td>
<td>Chl, seagrass, macrobenthos, HAB</td>
<td>DO water clarity, SRP, TP, TN, DIN, sediment organic matter, sediment TN, TP</td>
<td>no</td>
<td>yes</td>
</tr>
<tr>
<td>STI⁹</td>
<td>Chl, Primary Production</td>
<td>DIN, DIP</td>
<td>no</td>
<td>no</td>
</tr>
</tbody>
</table>


Ferreira J et al. ECSS 2011  
doi: 10.1016/j.ecss.2011.03014

6/15/2015
The Biotic Index builds on the NEEA approach (ASSETS)

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

**Influencing factors**
- Agriculture
- Animal farming
- Industry
- Development
- Waste water
- Shellfish (filtration)
- Plants (filtration)
- Freshwater input
- Nutrient inputs

**Eutrophic symptoms**
- Chlorophyll a (phytoplankton)
- Macroalgal growth
- Dissolved oxygen
- Loss of submerged aquatic vegetation
- Nuisance/toxic blooms
- Poor water clarity*

**Future outlook**

- **Worsening outlook**
  - Increased macroalgal growth and chlorophyll a
  - Decreased dissolved oxygen
  - Loss of submerged aquatic vegetation
  - Increased nuisance/toxic blooms
  - Decreased water clarity
  - Impaired human uses

- **Improving outlook**
  - Reduced macroalgal growth and chlorophyll a
  - Increased dissolved oxygen
  - Submerged aquatic vegetation abundance
  - Fewer nuisance/toxic blooms
  - Increased water clarity
  - Improved human uses

*A symptom not included in rating system
Eutrophic Condition considered
Primary & Secondary symptoms

**Primary symptoms**
- Chlorophyll $a$ (Phytoplankton)
- Macroalgal blooms

**Secondary symptoms**
- Dissolved oxygen
- Submerged aquatic vegetation
- Nuisance/toxic blooms
NEEA concluded that Barnegat Bay was ‘highly eutrophic’

- **Influencing factors:** ‘Bad’
- **Eutrophic condition:** ‘Bad’
- **Future outlook:** ‘Good’
- **ASSETS Rating:** ‘Bad’
This multimetric index builds on NEEA approach

**NEEA**

- **Primary symptoms**
  - Chlorophyll a (Phytoplankton)
  - Macroalgal blooms

- **Secondary symptoms**
  - Dissolved oxygen
  - Submerged aquatic vegetation
  - Nuisance/toxic blooms

**Biotic Index**

- 85 variables
- 20 indicators
- 74,400 observations
- 6 components
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
For Barnegat Bay, there are many data sets, many data gaps

- **Spatial, temporal mismatches**
- **Evaluate & address for each metric**
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
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
2004 to 2010: Seagrass declined

- Seagrass cover scores decreased from 34 to 14
- Seagrass length scores decreased from 30 to 18
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
Nutrient loading severely impacts eutrophication in BB-LEH

• Initial rapid declines highlight sensitivity to loading

• Suggests switch in dominant factors
Moderate to intense ecosystem stress from nutrient loadings

- Central: 65 (Moderate)
- South: 55 (Moderate)
- North: 7 (Highly Degraded)
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 & susceptible to nutrient loading.**
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**
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).
NEEA: Barnegat Bay ‘highly eutrophic’
2010: Eutrophication Index 45-50/100

NEEA, 2007

Fertig et al., 2014