Using Moored Arrays and Hyperspectral Aerial Imagery to Develop Eelgrass-based Nutrient Criteria for New Hampshire's Great Bay Estuary

John RU Morrison  
*University of New Hampshire, Durham*

Shachak Pe'eri  
*University of New Hampshire, Durham, shachak.peeri@unh.edu*

Phil Trowbridge  
*NH Department of Environmental Sciences*

Frederick T. Short  
*University of New Hampshire, Jackson Estuarine Laboratory*

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Coastal GeoTools
March 4, 2009
Motivation – Long term trends

- Eelgrass a critical habitat in Great Bay
- Trends mirror those in seagrass globally – declining
- PREP nutrient criteria development focused on eelgrass habitat protection
Motivation – Long term trends

1974-1981 Data recovered as part of the buoy data discovery process

Dissolved inorganic nitrogen concentrations measured at Adams Point at low tide (Figure 6)

Data Source: UNH Jackson Estuarine Laboratory

Suspended solids concentrations measured at Adams Point at low tide (Figure 7)

Data Source: UNH Jackson Estuarine Laboratory
Conceptual Model of Eutrophication (Bricker et al. 2007)
Minimum Water Clarity for Eelgrass Survival

Zmin = 1 meter for the Great Bay Estuary due to tidal amplitude

Zmax should be >1 m below Zmin for viable eelgrass beds (i.e., Zmax>2 m)

22% of surface light at depth for eelgrass survival

For Zmax=2 and Iz/Io=0.22, Kd should be 0.75 1/m.

From Koch (2001)
What attenuates light?

CDOM
Solution – Grab samples

Great Bay NERR SWMP Grab sample data

Combined $r^2 = 0.62$
Solution – Buoy Measurements

- Surface Irradiance (Hyperspectral 350 nm – 800 nm)
- Subsurface Irradiance (1.1 m)
- FLNTUS – Chlorophyll and Turbidity
- FLCDS – CDOM

And much more……
Buoy relationship – PAR

\[
\frac{K_d(PAR)}{D_o} = 0.2449 + 0.0188 \cdot [Chl] + 0.0101 \cdot [CDOM] + 0.0784 \cdot [NAP]
\]

\[ r^2 > 0.95 \]
Contributions to $K_d$(PAR)

- Water: 31%
- Chlorophyll (chl): 8%
- CDOM: 29%
- Turbidity (turb): 32%

But just one location
Solution
HS imagery

- EPA grant with PREP
- Expand results from Great Bay Buoy with hyperspectral imagery
- SpecTIR collected imagery (2 flights between end of July and end of October)
- Grab samples and spatial survey underneath with multiple partners
Summary

• Well coordinated in-situ validation campaign
• Near-perfect conditions on August 29
• Imagery collection exactly as planned
• Atmospheric correction achieved with TAFKAA
• Algorithm developed
Remote Sensing Algorithm 101

- $\text{Rrs} = f\left(\frac{b_b}{a+b_b}\right)$ and $K_d = f\left(b_b + a\right)$
  - $a$ – absorption, $b_b$ – backscattering
- CDOM, phytoplankton, non-agal particles
- Started with 708 nm and assumed water-dominated absorption
- Calculated $b_{bp}$ at 708 nm
  - Turbidity = $f[b_{bp}(708)]$
  - Used this to calculate $b_{bp}$ at 555 nm
  - Calculated $a$ at 555 nm
- Calculated $K_d$ at 555 nm
- $K_d(\text{PAR}) = f[K_d(555)]$

Based on Sound Bio-optical principles
Figure 8.16 Comparison between the attenuation coefficient measured in-situ and that derived from the HS imagery. For this comparison data from GRBAP, GRBGB, GRBLR, GRBOR, collected by LeClair and GB4A, and GRBGB collected by Morrison et al. were used. Also included are the $K_d$(PAR) estimate from the 0900 local time at the Great Bay Coastal Buoy. Information from the Squamoscott River and those collected by Edwards were excluded from this analysis as in situ measurements were either collected in close proximity to shading structures or later than other measurements. An initial linear regression analysis indicated that the intercept was not significantly different from zero giving that the HS $K_d$(PAR) = 0.78 in situ $K_d$(PAR) ($r^2 = 0.88$).
Absorption at 555 nm in the Great Bay Estuary on August 29, 2007

Turbidity in the Great Bay Estuary on August 29, 2007
## Results Analyzed by Zone

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<th>Assessment Zone</th>
<th>BLM</th>
<th>CCH</th>
<th>GB</th>
<th>LB</th>
<th>LMP</th>
<th>LPR</th>
<th>NMP</th>
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<td>0.74</td>
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<td>$a$(555)</td>
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<td>0.361</td>
<td>0.516</td>
<td>0.588</td>
<td>0.990</td>
<td>1.244</td>
<td>0.740</td>
<td>0.589</td>
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<tr>
<td>Stdev</td>
<td>0.051</td>
<td>0.092</td>
<td>0.187</td>
<td>0.066</td>
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<td>0.081</td>
<td>0.086</td>
<td>0.226</td>
<td>0.239</td>
<td>0.114</td>
<td>0.063</td>
<td>0.146</td>
</tr>
</tbody>
</table>
Eelgrass Survival Depth.

\[ z_{\text{survive}} = \frac{\ln(22/100)}{K_d(PAR)} \]
SAV mapping - Expert Defined Test Areas
Test area – Spectral Signatures

- 0.67 µm
- 0.71 µm
- 0.56 µm
- 0.63 µm

Spectral Library Plots

Value

Wavelength

NERACOOS
Northeastern Regional Association of Coastal Ocean Observing Systems

UNH Coastal Observing Center

Coastal GeoTools
March 4, 2009
Great Bay Eelgrass & Macroalgae

Macroalgae are beginning to proliferate in Great Bay
What do we know now?

• Now know what decreases water quality
• Now have some idea of its temporal and spatial distribution
• Now know where eelgrass and macroalgae are
• Need to pull it all together to develop criteria
Water Clarity Decreases with Increasing Nitrogen Concentrations

Median Nitrogen (mg N/L)

Median Kd (1/m)

- **y = 9.4223x - 0.145**  
  \( R^2 = 0.5594 \)

- **y = 7.0838x - 1.0553**  
  \( R^2 = 0.7957 \)

- **y = 4.843x - 0.8035**  
  \( R^2 = 0.8736 \)

TN Threshold = 0.32 mg N/L

N>12 ex. six TDN points with N=9-10, one Kd point with N=7
Eelgrass and Macroalgae in Great Bay in 2007

Median TN in Great Bay = 0.42 mg N/L

An Area with Obvious Macroalgae Proliferation

From Pe’eri et al. (2008)
Nutrient Criteria to Prevent Eelgrass Loss

- Maximum light attenuation coefficient to maintain eelgrass
  - $K_d = 0.75$ (1/m)
- TN associated with $K_d$ threshold from regressions
  - $TN = 0.32$ mg N/L
- Macroalgae proliferation
  - No problems for $TN < 0.40$ mg N/L
- Ocean background
  - $TN = 0.24$ mg N/L
- Reference concentration where eelgrass still exists (Portsmouth Hbr)
  - $TN = 0.32$ mg N/L (75th percentile)
- TN thresholds set for other estuaries in NE
  - $TN = 0.35-0.38$ mg N/L (Mass. Estuaries Project, Nantucket Sound)
- Weight of evidence threshold
  - TN threshold for eelgrass in GBE = 0.32 mg N/L
# Proposed Numeric Nutrient Criteria for the Great Bay Estuary

<table>
<thead>
<tr>
<th>Designated Use / Regulatory Authority</th>
<th>Parameter</th>
<th>Threshold</th>
<th>Statistic</th>
<th>Comments</th>
</tr>
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<tbody>
<tr>
<td>Primary Contact Recreation (^1)</td>
<td>Chlorophyll-a</td>
<td>20 (\mu)g/L</td>
<td>90(^{th}) percentile during summer</td>
<td>Applies to all areas of the Great Bay Estuary</td>
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<td>(Env-Wq 1703.14)</td>
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<tr>
<td>Aquatic Life Use Support – to protect</td>
<td>Total Nitrogen</td>
<td>0.45 mg N/L</td>
<td>Median</td>
<td>Applies to all areas of the Great Bay Estuary</td>
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<tr>
<td>Dissolved Oxygen (^1)</td>
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<tr>
<td>(RSA 485-A.8)</td>
<td>Chlorophyll-a</td>
<td>12 (\mu)g/L</td>
<td>90(^{th}) percentile during summer</td>
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<tr>
<td><strong>Aquatic Life Use Support – to protect</strong></td>
<td><strong>Total Nitrogen</strong></td>
<td>0.32 mg N/L</td>
<td>Median</td>
<td>Portsmouth Harbor, Little Harbor, Piscataqua River, Great Bay, Little Bay, and areas of tidal tributaries where eelgrass has existed in the past</td>
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<tr>
<td>Eelgrass (^1,2)</td>
<td>Light Attenuation Coefficient (Water Clarity)</td>
<td>0.75 m(^{-1})</td>
<td>Median</td>
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<tr>
<td>(Env-Wq 1703.14)</td>
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</table>
Management Implications for Nitrogen Impairments

- NPDES permitted sources for nitrogen must hold their loadings at the existing levels (e.g., WWTFs, MS4s).
- New permitted sources (e.g., AoT or CGP permittees) within the upstream watershed of an impaired waterbody would have to demonstrate zero additional loads of nitrogen or arrange for trading within the watershed.
- The “hold the load” restriction would continue until a TMDL is completed, at which point the load allocations from the TMDL would become effective. The TMDL allocations will likely require reductions in loading.
Acknowledgements

Thanks to:

- Mike Novak, Anna Brook, Tom Gregory, Paul Currier
- All those who collected the historical data
- Dave Shay and the faculty and staff of Jackson Estuarine Laboratory
- Chris Hunt and Shawn Shelito for help with the flow through measurements
- The captain and crew of the R/V Gulf Challenger
- Rich Lagan and Jon Pennock, University of New Hampshire
- Darrell Adams, Cyril Dempsey, and all at Satlantic Inc.
- Andrew Barnard, Ian Walsh, Alex Derr, Ron Zaneveld and all at WET Labs, Inc.
- EPA and NOAA for the funding
- NHEP and NHDES
- SpecTIR who flew the HS mission