Eutrophication Assessment in Coastal Waters
A Decade of Change

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New Jersey Water Quality Monitoring Council Meeting
September 6, 2007
NJDEP HQ - Public Hearing Room, Trenton, NJ

http://www.eutro.org
http://www.eutro.us
The Context and Guiding Legislation


- EU Water Framework Directive (2000/60/EC), EU UWWTD and Nitrates Directives – Definition of Sensitive Areas and Vulnerable Zones

- Eutrophication is a significant problem worldwide (US, EU, Baltic, Mediterranean, Japan, Australia and elsewhere)

http://www.eutro.org
http://www.eutro.us
http://ian.umces.edu/neea
Symptoms and Consequences of Nutrient Enrichment

<table>
<thead>
<tr>
<th>Nutrient Inputs and Processing</th>
<th>Primary Impacts</th>
<th>Secondary Impacts</th>
<th>Consequences of Symptoms</th>
</tr>
</thead>
<tbody>
<tr>
<td>Increased N and P concentration</td>
<td>High algal production (Chl)</td>
<td>Loss of SAV</td>
<td>Fish kills</td>
</tr>
<tr>
<td></td>
<td>Loss of water clarity</td>
<td>Low D.O</td>
<td>Loss of habitat</td>
</tr>
<tr>
<td></td>
<td>Epiphyte problems</td>
<td>Nuisance/Toxic blooms (HABs)</td>
<td>Human health risks</td>
</tr>
<tr>
<td></td>
<td>Macroalgal problems</td>
<td></td>
<td>Loss of tourism</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Closed fishing grounds</td>
</tr>
</tbody>
</table>

### NEEA/ASSETS: Pressure - State - Response

P: Influencing Factors – Natural processing + Human Nutrient Load
S: Overall Eutrophic Condition – Condition of waterbody
R: Future Outlook – What will happen in the future?

[http://www.eutro.org](http://www.eutro.org)  [http://ian.umces.edu/neea](http://ian.umces.edu/neea)  [http://www.eutro.us](http://www.eutro.us)
The NEEA approach may be divided into three parts:

- Division of estuaries into homogeneous areas
- Evaluation of data completeness and reliability
- Application of indices

Spatial and temporal quality of datasets (completeness) Confidence in results (sampling and analytical reliability)

**State:** Overall Eutrophic Condition index (Chl, macroalgae, HABs, DO, SAV loss)

**Pressure:** Overall Human Influence index (susceptibility + nutrient load)

**Response:** Future Outlook index (susceptibility + future nutrient load)

Guide for management, research, monitoring
Pressure: Influencing Factors

Susceptibility + Nutrient Inputs = Overall Human Influence

- Susceptibility: dilution & flushing
- Nutrient Inputs: land based or oceanic

Overall Human Influence
- High
- Moderate High
- Moderate
- Moderate Low
- Low

Nutrient Pressures
- Low
- Moderate
- High
State: Overall Eutrophic Condition

Overall Eutrophic Condition
- Moderate
- Moderate High
- High

Primary Symptoms
- Low
- Moderate Low
- Low

Secondary Symptoms
- Low
- Moderate
- High

Secondary Symptoms
- Moderate
- Moderate
- High

Primary Symptoms
- Low
- Moderate
- High
Future outlook is based on susceptibility and projected changes in nutrient pressures:

**Susceptibility** is the capacity of a system to dilute or flush nutrients.

**Nutrient pressure** changes are based on expected population changes, future treatment and remediation plans and changes in watershed use (particularly agricultural).
### Influencing Factors

<table>
<thead>
<tr>
<th>Region</th>
<th>Human Influence (M – H)</th>
<th>&gt;50% NPS</th>
<th>Primary NPS from Ag*</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. Atlantic (18)</td>
<td>33</td>
<td>78</td>
<td>0</td>
</tr>
<tr>
<td>Mid Atlantic (22)</td>
<td>100</td>
<td>91</td>
<td>60</td>
</tr>
<tr>
<td>So. Atlantic (22)</td>
<td>81</td>
<td>100</td>
<td>81</td>
</tr>
<tr>
<td>Gulf of Mexico (38)</td>
<td>95</td>
<td>100</td>
<td>85</td>
</tr>
<tr>
<td>Pacific (39)</td>
<td>82</td>
<td>89</td>
<td>50</td>
</tr>
<tr>
<td>US Total (139)**</td>
<td>68</td>
<td>92</td>
<td>56</td>
</tr>
<tr>
<td>Portugal (10)</td>
<td>30</td>
<td>89</td>
<td>67</td>
</tr>
<tr>
<td>China (4)</td>
<td>75</td>
<td>?</td>
<td>?</td>
</tr>
</tbody>
</table>

*as percentage of systems
US from SPARROW model estimates, PT from Ferreira et al 2003
*for US: >30% though most are >70% from ag, for PT: ag is most significant nonpt source
**Early 2000s: 44 of 64 (~70%) systems evaluated had moderate to high influencing factors
Overall Eutrophic Condition

1990s – 84 of 121 assessed systems M to H
17 systems unknown

2000s – 64 of 99 assessed systems M to H
42 systems unknown

http://ian.umces.edu/neea
http://www.eutro.us
Future Outlook

1990s – 71% assessed systems – worsen
7% assessed systems - improve

2000s – 65% assessed systems – worsen
20% assessed systems - improve
## ASSETS Synthesis

<table>
<thead>
<tr>
<th></th>
<th>US 1990s</th>
<th>US 2000s</th>
<th>EU</th>
<th>CN</th>
</tr>
</thead>
<tbody>
<tr>
<td>High</td>
<td>2</td>
<td>1</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Good</td>
<td>19</td>
<td>5</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Moderate</td>
<td>28</td>
<td>18</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Poor</td>
<td>53</td>
<td>11</td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>Bad</td>
<td>18</td>
<td>13</td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>Unknown</td>
<td>19</td>
<td>93</td>
<td>4</td>
<td></td>
</tr>
</tbody>
</table>

Management
Changes 1990s – 2000s

Analysis was possible for 58 of 141 systems

Improved: 13 systems (9%) assessed surface area

Worsened: 13 systems (14%) assessed area

Remained the same: 32 systems (77% assessed area)

Due to management efforts, primarily point source

Due to population increase and associated activities
Mid Atlantic Lagoon Systems

Overall eutrophic condition & eutrophic symptoms

<table>
<thead>
<tr>
<th>Estuary</th>
<th>Overall eutrophic condition</th>
<th>Overall confidence expression</th>
<th>Chlorophyll a</th>
<th>Macroalgae</th>
<th>Dissolved oxygen</th>
<th>Nuisance/toxic blooms</th>
<th>SAV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Barnegat Bay</td>
<td></td>
<td>***</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>New Jersey Inland Bays</td>
<td>Down</td>
<td>*</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Delaware Inland Bays</td>
<td>Yellow</td>
<td>***</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>N. Maryland Coastal Bays (Isle of Wight/Assawoman)</td>
<td>Yellow</td>
<td>***</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>S. Maryland Coastal Bays (Chincoteague/Sinepuxent)</td>
<td>Down</td>
<td>***</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Eutrophic condition in 2004

- High
- Moderate
- Low
- Insufficient data

Overall confidence expression in 2004

- *** High
- ** Moderate
- * Low

Change in eutrophic condition since 1999 assessment

- Improved
- No change
- Worsened
- Insufficient data

% assessed systems with Moderate & High symptom expression

<table>
<thead>
<tr>
<th>Mid Atlantic Region</th>
<th>1999</th>
<th>2004</th>
<th>% change</th>
</tr>
</thead>
<tbody>
<tr>
<td>HABs</td>
<td>50</td>
<td>63</td>
<td>13</td>
</tr>
<tr>
<td>Chl a</td>
<td>100</td>
<td>86</td>
<td>14</td>
</tr>
</tbody>
</table>
Classification based on physical and hydrologic characteristics – nutrients will be processed differently in systems that flush well or flush poorly and management strategies will be different.

A top-down classification resulted in 14 types. DISCO gives 10 types.

A top-down classification resulted in 7 types. DISCO gives 6 types but semi-enclosed lagoons were not included.
Eutrophication control

Phytoplankton removal
31000 kg C y⁻¹

Detritus removal
84540 kg C y⁻¹

Population equivalents
3237 PEQ y⁻¹

N removal (kg y⁻¹)
Algae -4822
POM -13151
Excretion 3745
Faeces 3545
Mass balance -10683

Shellfish filtration
Density of 500 oysters m⁻³
180 day cultivation period
11 μg L⁻¹ chl a initial
3.3 kg N y⁻¹ PEQ

ASSETS INCOME PARAMETERS
Chl a
O₂
Shellfish farming: 2300 k€ y⁻¹
Sewage treatment: 2000 k€ y⁻¹
Total income: 4300 k€ y⁻¹
Density of 500 oysters m⁻³
180 day cultivation period
11 μg L⁻¹ chl a initial
3.3 kg N y⁻¹ PEQ
National and International Partners

Thank You!