Eastern Oysters (*Crassostrea virginica*) as an Indicator for Restoration of Everglades Ecosystems

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Historic Flow

Current Flow
Getting The Water Right

Quantity

Quality

Timing

Distribution
Northern Estuaries
Applicability of the oyster indicator species to CERP

- Oyster life cycle is typical of other estuarine species.
- Oyster reefs provide habitat, shelter, and food for over 300 species.
- Oyster reefs contribute to benthic-pelagic coupling.
- Oysters are primary consumers.
- Productivity and community structure are directly linked to hydrology.
- Secondary habitat and food source for 2 and 3 carnivores.
- Oyster-reef survival, distribution, and aerial extent are key indicators (performance measures) in most RECOVER Conceptual Ecological Models and in CERP Interim Goals;
Advantages of the oyster indicator

- The indicator is feasible to implement and is scientifically defensible
- The indicator is sensitive to System Drivers (Stressors)
- The indicator is integrative
- Goals and Performance measures are established in the RECOVER MAP for the indicator and the following metrics are being monitored
Conceptual model – Eastern oyster

- Adult Density
- Salinity
- Sedimentation (muck and rate)
- Hydrodynamics
- Temperature
- Substrate
- Predation
- Reproduction
- Larval Recruitment
- Disease
- Food
- DO

Oyster Abundance and Health
Performance measures

- Number of live oysters per square meter;
- Number of acres of oyster reefs;
- Condition index of live oysters;
- Disease prevalence and intensity of *Perkinsus marinus* in oysters;
- Larval / spat recruitment
- Reproduction.
- Growth and survival
STUDY SITES

1. Piney Point
2. Cattle Dock
3. Bird Island
4. Kitchel Key
5. Tarpon Bay
Parameters measured

- Temperature, salinity, D. O.
- Flow (CFS; SFWMD)
- Condition Index
- *Perkinsus marinus* intensity and prevalence
- Gonadal Index
- Spat Recruitment
- Growth
- Survival (including predation)
- Living density
Salinity vs. Flow (1999-2007 data)
Condition Index Growth and Survival

Quantify the ability of an area to support oyster growth (i.e., suitable water quality, food availability). CI quantifies the overall health.

Juvenile survival and growth analyses yield results related to short-term survival and long-term potential to support oyster reefs.
Condition Index
Juvenile Growth – closed bag

![Graph showing growth of juvenile fish over time]

**Length (mm)** vs **Month**

- Iona Cove
- Cattle Dock
- Bird Island
- Kitchel Key
- Tarpon Bay
- PepperTree
Juvenile growth - closed
Juvenile survival – closed bag

![Graph showing the number of living oysters over time for different locations.](image-url)

- Iona Cove
- Cattle Dock
- Bird Island
- Kitchel Key
- Tarpon Bay
- PepperTree
Juvenile survival – open bag
Survival: Disease

Juvenile survival and disease analyses yield results related to short-term survival
P. marinus intensity

The graph shows the infection intensity of P. marinus over time at various locations: Piney Point, Cattle Dock, Bird Island, Kitchel Key, and Tarpon Bay. The y-axis represents infection intensity, while the x-axis represents sampling time from September 2000 to November 2007.
**P. marinus** prevalence

Figure 1: Perkinsus marinus infection prevalence (% infected oysters) in oysters from Caloosahatchee River to Tarpon Bay are from upstream to downstream. Ten oysters per location are analyzed monthly using Ray's fluid thiofascollate medium.
Reproduction

- Effects of water quality and substrate on long-term viability of reef
- Gonadal index: reproductive stage and qualitative estimate of fecundity
- Recruitment: estimates for next year class
- Management implications: timing of freshwater inflows
Oysters spawn between May – October.

Large freshwater releases flush larvae downstream or create unfavorable salinity conditions.
Spat Recruitment
Reproduction

- Effects of water quality and substrate on long-term viability of reef
- Gonadal index: reproductive stage and qualitative estimate of fecundity
- Recruitment: estimates for next year class
- Management implications: timing of freshwater inflows
Living Density

Dry Season

Wet Season
Living Density (2008)

Caloosha 2008 Density Data
(Average # oysters per square meter) Dry
Approach

- What do we do with the data?
- The measurements we make will answer why and not just what is happening.
- Enables us to engage in adaptive management.
- In addition to scientific evaluation of the cause and effect relationship, we need to communicate the results with resource managers and public
- Stoplight Indicator (Success (Green), Caution (Yellow) and Failure (Red)).
- Caloosahatchee Estuary as an example
Stoplight Indicator

- A communication tool that uses MAP performance measures to grade an estuary’s response to anthropogenic or restoration inputs (Average of component score + trend score).
- Questions or decision rules are developed for each performance measure and translated as suitability curves.
- Suitability curve address:
  - (1) Have we reached the restoration target, and
  - (2) are we making progress toward targets?
- Finally, results are translated into a stoplight display (red, yellow, green)
**Component Scores – Decision rules**

1. What is the current living density, in individuals per meter square, of oysters in the Caloosahatchee estuary.
   a. 0 - 200 Score: 0 Red
   b. > 200 - 800 Score: 0.5 Yellow
   c. > 800 - 4000 Score: 1.0 Green

2. What is the current condition index of the oysters in the Caloosahatchee estuary? Use the yearly average.
   a. 0 – 1.5 Score: 0 Red
   b. > 1.5 – 3.0 Score: 0.5 Yellow
   c. > 3.0 - 6.0 Score: 1.0 Green

3. What is the current gonadal condition of oysters in the Caloosahatchee estuary? Use the yearly average.
   a. 0 – 1 Score: 0 Red
   b. >1 - 2 Score: 0.5 Yellow
   c. >2 - 4 Score: 1 Green
Component Scores – decision rules

4. What is the current spat recruitment of oysters (spat / shell) in the Caloosahatchee estuary?
   a. 0 - 5 Score: 0 Red
   b. > 5 - 20 Score: 0.5 Yellow
   c. > 20 – 200 Score: 1.0 Green

5. What is the current growth of juvenile oysters in mm/month?
   a. 0 – 1 Score: 0 Red
   b. > 1.0 - 2.5 Score: 0.5 Yellow
   c. > 2.5 - 5 Score: 1.0 Green

6. What is the prevalence of *Perkinsus marinus* (% of infected oysters) in oysters from the Caloosahatchee estuary? Use the yearly average.
   a. 0 - 20 Score: 1 Green
   b. > 20 – 50 Score: 0.5 Yellow
   c. > 50 - 100 Score: 0 Red

7. What is the intensity of *Perkinsus marinus* (scale 0-5) in oysters from the Caloosahatchee estuary? Use the yearly average.
   a. 0 - 1 Score: 1 Green
   b. > 1 - 3 Score: 0.5 Yellow
   c. > 3 – 5 Score: 0 Red
Trend score
Trend score – decision rule

Trend question
a. - slope          Score: 0           Red
b. no slope         Score: 0.5       Yellow
c. + slope          Score: 1.0       Green

Translation of component score and trend score into an index score

<table>
<thead>
<tr>
<th>Index Score</th>
<th>Stoplight Color</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.0-0.3</td>
<td>Red</td>
</tr>
<tr>
<td>&gt;0.3-0.6</td>
<td>Yellow</td>
</tr>
<tr>
<td>&gt;0.6-1.0</td>
<td>Green</td>
</tr>
<tr>
<td>Component</td>
<td>Parameter Value</td>
</tr>
<tr>
<td>----------------------------</td>
<td>------------------</td>
</tr>
<tr>
<td><strong>Oysters</strong></td>
<td></td>
</tr>
<tr>
<td>Living Density (per sq. m.)</td>
<td>1029</td>
</tr>
<tr>
<td>Condition Index</td>
<td>2.96</td>
</tr>
<tr>
<td>Spat Recruitment per shell</td>
<td>6.43</td>
</tr>
<tr>
<td>Juvenile growth (mm/month)</td>
<td>2</td>
</tr>
<tr>
<td><em>Perkinsus marinus</em> prevalence</td>
<td>49.5</td>
</tr>
<tr>
<td><em>Perkinsus marinus</em> intensity</td>
<td>0.83</td>
</tr>
</tbody>
</table>

Geometric mean of oyster component scores 

\((0.75 \times 0.5 \times 0.5 \times 0.25 \times 0.5)^{1/6} = 0.477\)

Final Eastern Oyster Index score = 0.5
### St. Lucie Estuary

<table>
<thead>
<tr>
<th>Component</th>
<th>Parameter Value</th>
<th>Parameter Value Stoplight</th>
<th>Index Score</th>
<th>Trend</th>
<th>Trend Stop Light</th>
<th>Trend Score</th>
<th>Average Component Score</th>
<th>Component Stoplight</th>
</tr>
</thead>
<tbody>
<tr>
<td>Living Density (per sq. m.)</td>
<td>95.3</td>
<td>0</td>
<td>+</td>
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<td>1</td>
<td>(1+0)/2=0.5</td>
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<td></td>
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<tr>
<td>Condition Index</td>
<td>2.7</td>
<td>0.5</td>
<td>±</td>
<td></td>
<td>0.5</td>
<td>(0.5+0.5)/2=0.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Spat Recruitment per shell</td>
<td>1.4</td>
<td>0</td>
<td>-</td>
<td></td>
<td>0</td>
<td>(0+0)/2=0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Juvenile growth (mm/month)</td>
<td>3.2</td>
<td>1</td>
<td>±</td>
<td></td>
<td>0.5</td>
<td>(1+0.5)/2=0.75</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Perkinsus marinus prevalence</td>
<td>5.7</td>
<td>1</td>
<td>+</td>
<td></td>
<td>0</td>
<td>(1+0)/2=0.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Perkinsus marinus intensity</td>
<td>0.04</td>
<td>1</td>
<td>±</td>
<td></td>
<td>0.5</td>
<td>(1+0.5)/2=0.75</td>
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<td></td>
</tr>
</tbody>
</table>

Geometric mean of oyster component scores \( (0.5*0.5*0^1*0.5^1)^{1/6} = 0 \)

Final Eastern Oyster Index Score = 0
## Loxahatchee Estuary

<table>
<thead>
<tr>
<th>Component</th>
<th>Parameter Value</th>
<th>Parameter Value Stoplight</th>
<th>Index Score</th>
<th>Trend</th>
<th>Trend Stop Light</th>
<th>Trend Score</th>
<th>Average Component Score</th>
<th>Component Stoplight</th>
</tr>
</thead>
<tbody>
<tr>
<td>Living Density (per sq. m.)</td>
<td>168</td>
<td>0</td>
<td>+</td>
<td></td>
<td></td>
<td>1</td>
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<tr>
<td>Condition Index</td>
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<td>1</td>
<td>+</td>
<td></td>
<td></td>
<td>0.5</td>
<td>(1+0.5)/2=0.75</td>
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<tr>
<td>Spat Recruitment per shell</td>
<td>3.8</td>
<td>0</td>
<td>+</td>
<td></td>
<td></td>
<td>1</td>
<td>(0+1)/2=0.5</td>
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<tr>
<td>Juvenile growth (mm/month)</td>
<td>2.8</td>
<td>1</td>
<td>+</td>
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<td></td>
<td>0.5</td>
<td>(1+0.5)/2=0.75</td>
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<tr>
<td><em>Perkinsus marinus</em> prevalence</td>
<td>28.7</td>
<td>0.5</td>
<td>+</td>
<td></td>
<td></td>
<td>0</td>
<td>(0.5+0)/2=0.25</td>
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<tr>
<td><em>Perkinsus marinus</em> intensity</td>
<td>0.22</td>
<td>1</td>
<td>+</td>
<td></td>
<td></td>
<td>0</td>
<td>(1+0)/2=0.5</td>
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</tbody>
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Geometric mean of oyster component scores \((0.5*0.75*0.5*0.75*0.25*0.5)^{1/6}\)=0.03

Final Eastern Oyster Index Score = 0.03
# Lake Worth Lagoon

<table>
<thead>
<tr>
<th>Component</th>
<th>Parameter Value</th>
<th>Parameter Value Stoplight</th>
<th>Index Score</th>
<th>Trend</th>
<th>Trend Stop Light</th>
<th>Trend Score</th>
<th>Average Component Score</th>
<th>Component Stoplight</th>
</tr>
</thead>
<tbody>
<tr>
<td>Living Density (per sq. m.)</td>
<td>172</td>
<td>0</td>
<td>-</td>
<td></td>
<td>0</td>
<td>0</td>
<td>(0+0)/2=0</td>
<td>0</td>
</tr>
<tr>
<td>Condition Index</td>
<td>3.4</td>
<td>1</td>
<td>+</td>
<td></td>
<td>1</td>
<td>1</td>
<td>(1+1)/2=1</td>
<td>1</td>
</tr>
<tr>
<td>Spat Recruitment per shell</td>
<td>3.1</td>
<td>0</td>
<td>±</td>
<td></td>
<td>0.5</td>
<td>0.5</td>
<td>(0+0.5)/2=0.25</td>
<td>0.5</td>
</tr>
<tr>
<td>Juvenile growth (mm/month)</td>
<td>2.5</td>
<td>0.5</td>
<td>±</td>
<td></td>
<td>0.5</td>
<td>0.5</td>
<td>(0.5+0.5)/2=0.5</td>
<td>0.5</td>
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<tr>
<td><em>Perkinsus marinus</em> prevalence</td>
<td>41.6</td>
<td>0.5</td>
<td>+</td>
<td></td>
<td>0</td>
<td>0</td>
<td>(0.5+0)/2=0.25</td>
<td>0.5</td>
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<tr>
<td><em>Perkinsus marinus</em> intensity</td>
<td>0.32</td>
<td>1</td>
<td>+</td>
<td></td>
<td>0</td>
<td>0</td>
<td>(1+0)/2=0.5</td>
<td>0.5</td>
</tr>
</tbody>
</table>

Geometric mean of oyster component scores \((0*1*0.25*0.5*0.25*0.5)^{1/6}=0.0\)

Final Eastern Oyster Index Score = 0.0
Summary

- Freshwater releases from Lake Okeechobee decrease salinities at the samples sites by 3-6 ppt.

- Juvenile oysters at upstream locations with intermediate salinities showed higher growth, with the exception of Cattle Dock, a location that receives output from Cape Coral (water quality?)
Summary

- Oysters in the Caloosahatchee Estuary spawn continuously between April – October.

- High levels of freshwater flows during summer (spawning) months may flush out oyster larvae or reduce salinities to unfavorable levels.

- High salinities in 2007 resulted in poor spat recruitment and higher disease levels (as well as low survival due to predation?)
Summary

- Flows between 500 – 3000 CFS from Lake Okeechobee will result in optimum salinities at sampling locations (15 – 25 ppt).

- Stoplight indicator communication toll was developed. Can be adapted for other estuaries

- Caloosahatchee estuary is at “Caution”
Future directions

- Integration of the data with HSI
- Inclusion of other factors influencing oyster responses
- Newer techniques that will enhance the sample size and power of analyses
- Addition / changing sampling locations
- Looking at why the indicator species is responding and not what it is doing.
- Adaptive management
Acknowledgements

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