Ecological Carrying Capacity of RI Aquaculture

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Coastal Institute IGERT Project
30 April 2008
Oyster Aquaculture

Oyster production = 97% RI aquaculture
RI Aquaculture Growth

<table>
<thead>
<tr>
<th>Year</th>
<th>Industry</th>
<th>Number of Farms</th>
</tr>
</thead>
<tbody>
<tr>
<td>2001</td>
<td>$300,000</td>
<td>18</td>
</tr>
<tr>
<td>2006</td>
<td>$1.3 million</td>
<td>28</td>
</tr>
</tbody>
</table>
Wild harvest clams
Limit aquaculture to 5 percent of R.I. waters, experts say

Providence Journal Sunday, March 2, 2008

Journal file photo / Bill Murphy
Carrying Capacity

- **Physical**: total area of marine farms that can be accommodated in the available physical space
- **Production**: the stocking density of bivalves at which harvests are maximized
- **Ecological**: the stocking or farm density which causes unacceptable ecological impacts
- **Social**: the level of farm development that causes unacceptable social impacts

Inglis *et al.* 2000
Carrying Capacity

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- **Ecological**: the stocking or farm density which causes unacceptable ecological impacts
- **Social**: the level of farm development that causes unacceptable social impacts
No fish is an Island

It signifies that all living organisms are linked together. In the oceans, for example, despite our great impact, we are only one of many predators. We must learn to behave responsibly in a realm where we are the intruders.
Fig. 1. Map showing Golden and Tasman Bays, northern end of the South Island of New Zealand.
Determine ecological carrying capacity using Ecopath model

What do we know & need to know to build the model?
White Paper

Adapt Existing Model for Narragansett Bay

- Permission to use model
- Outline steps
White Paper

Adapt Existing Model for Narragansett Bay

- Permission to use model
- Outline steps

Build New Model of RI salt ponds

- Outline steps using Ecopath
- Report parameter estimates
Fig. 2. Average annual energy flow (mg C m\(^{-2}\) yr\(^{-1}\)) and compartmental biomass (mg C m\(^{-2}\)) in Narragansett Bay.
Fig. 2. Average annual energy flow (mg C m⁻² yr⁻¹) and compartmental biomass (mg C m⁻²) in Narragansett Bay
Calculate Carrying Capacity
Calculate Carrying Capacity

Fig. 2. Average annual energy flow (mg C m$^{-3}$ yr$^{-1}$) and compartmental biomass (mg C m$^{-3}$) in Narragansett Bay
Procedure

1. Identify Groups
2. Estimate Parameters
3. Estimate Confidence Intervals
4. Balance Equations
5. Ecosim: Solve Equations
6. Ecospace: Design Spatial Grid
7. Determine parameters at each grid point
8. Solve Ecosim equations at each grid point

Pfeiffer-Herbert 2007
Christensen & Walters 2004
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<table>
<thead>
<tr>
<th><strong>Functional Group</strong></th>
<th><strong>Species Common Name</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Detritus</td>
<td></td>
</tr>
<tr>
<td>Benthic Microalgae</td>
<td>Diatoms, dianoflagellates, cyanobacteria</td>
</tr>
<tr>
<td>Benthic Bacteria</td>
<td></td>
</tr>
<tr>
<td>Deposit Feeders</td>
<td>Polychaete Worms</td>
</tr>
<tr>
<td></td>
<td>Benthic copepods</td>
</tr>
<tr>
<td>Eelgrass &amp; Macroalgae</td>
<td>Eelgrass</td>
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<tr>
<td></td>
<td>Red algae</td>
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<tr>
<td></td>
<td>Green algae</td>
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<tr>
<td>Epibenthic Invertebrates</td>
<td>Crabs</td>
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<td></td>
<td>Grass shrimp</td>
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<td></td>
<td>Amphipods</td>
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<td></td>
<td>Juvenile lobster</td>
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<td>Mud snail</td>
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<td>Benthic Feeding Fish</td>
<td>Tautog</td>
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<td>Cunner</td>
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<td></td>
<td>Black Sea Bass</td>
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<td>Scup</td>
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<td>Winter Flounder</td>
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<td>Filter Feeders</td>
<td>Oysters</td>
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<td>--------------------------------------</td>
<td>------------------------------</td>
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<tr>
<td></td>
<td>Clam</td>
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<tr>
<td></td>
<td>Slipper limpet</td>
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<tr>
<td></td>
<td>Ascidians, Tunicates, Sea Squirts</td>
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<td></td>
<td>Clam</td>
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<tr>
<td></td>
<td>Annelid worms</td>
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<tr>
<td>Cultured Oysters</td>
<td>Oysters</td>
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<tr>
<td>Phytoplankton</td>
<td>Oysters</td>
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<tr>
<td></td>
<td>Pelagic Copepods</td>
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<tr>
<td>Halozooplankton</td>
<td>Pelagic Copepods</td>
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<tr>
<td></td>
<td>Crustacean larvae (Nauplii)</td>
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<tr>
<td>Merozooplankton</td>
<td>Crustacean larvae (Nauplii)</td>
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<tr>
<td></td>
<td>Bivalve larvae</td>
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<tr>
<td></td>
<td>Fish larvae</td>
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<tr>
<td>Planktivorous Fish</td>
<td>Silversides</td>
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<td>Menhaden</td>
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<td>Mummichog</td>
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<tr>
<td></td>
<td>Striped Kilifish</td>
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<td>Sheepshead Minnows</td>
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<td></td>
<td>Ctenophores</td>
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<td></td>
<td>Lions Mane Jelly</td>
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<tr>
<td>Piscivorous Fish</td>
<td>Bluefish</td>
</tr>
<tr>
<td></td>
<td>Striped bass</td>
</tr>
</tbody>
</table>
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4. Balance Equations
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6. Ecospace: Design Spatial Grid
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2. Parameters

1. Biomass

2. 

3. 

4. 

5. 

6. 

7. 

8. 

9. 

2. Parameters

1. Biomass
2. Production/biomass ratio
3.
4.
5.
6.
7.
8.
9.
2. Parameters

1. Biomass
2. Production/biomass ratio
3. Consumption/biomass ratio
2. Parameters

1. Biomass
2. Production/biomass ratio
3. Consumption/biomass ratio
4. Ecotrophic efficiency
5. 
6. 
7. 
8. 
9. 
2. Parameters

1. Biomass
2. Production/biomass ratio
3. Consumption/biomass ratio
4. Ecotrophic efficiency
5. Catch rate
6. 
7. 
8. 
9. 
10. 
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3. Consumption/biomass ratio
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5. Catch rate
6. Net migration rate into pond
7. 
8. 
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9. Diet composition
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6. Net migration rate into pond
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8. Food assimilation rate
9. Diet composition
Pond Data

- Peer Review Literature
  - Macro-algae
  - Eelgrass
  - Productivity
  - Physical
  - Flushing rates

www.pubs.usgs.gov
www.horta.uac.pt
www.cybercolloids.net
www.solpugid.com/cabiota/ulva_lobata.jpg
Pond Data

- **DEM**
  - Larval fish: Quonnie, Pt. Judith, Ninigret, Winnapaug
  - Finfish: Quonnie, Pt. Judith & Potters
  - Shellfish: RI aquaculture, Narr Bay Quohogs
- **Pond Watchers**
  - Productivity
- **RI South Shore Sea Grant Project**
  - Physical
- **MapCoast**
  - Habitat
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4. Balance Equations

\[ \text{Production} = \text{predation} + \text{fishery} + \text{other mortality} + \text{biomass accum.} + \text{net migration} \]
4. Balance Equations

**Production** = predation + fishery + other mortality + biomass accum. + net migration

**Consumption** = production + unassimilated food + respiration
Calculate Carrying Capacity
Calculate Carrying Capacity
Procedure

- Identify Groups
- Estimate Parameters
- Estimate Confidence Intervals
- Balance Equations

5. **Ecosim: Solve Equations**
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5. Ecosim

- Temporal variability in biomass
  - Repeated simulations
  - Forcing functions
    - Seasonal or 100+ years
Procedure

✓ Identify Groups
✓ Estimate Parameters
✓ Estimate Confidence Intervals
✓ Balance Equations
✓ Ecosim: Solve Equations

6. Ecospace: Design Spatial Grid
7. Determine parameters at each grid point
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Ecospace
3D-gaming engine driven by EwE
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Recommendations

Narragansett Bay

1. Add ‘cultured oysters’ group

Salt Ponds

1. Rescale Narr Bay model

2. Build new model
   - Limited data in ponds
   - Infer parameters from other locations
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