Assessing the influence of bottom-up and top-down processes in Tampa Bay using Ecopath with Ecosim

Dave Chagaris
FWRI
Outline

• Bottom-up and top down processes
• Recent trends in Tampa Bay
• Ecopath with Ecosim description
• Model Calibration: assessing the impacts
• Results (anchovy, blue crab, spotted seatrout)
Tampa Bay: historical nutrient loading

Total N Loading to Tampa Bay

Pribble et al. 2001; Poe et al. 2005; Janicki Environmental 2009
Tampa Bay: Changes in Fishing

**Gill Net Effort**

**Mullet Fishing Mortality**

**Recreational Effort**

**Total Landings**
Ecopath with Ecosim

www.ecopath.org

- Ecological/ecosystem modeling software
- used to study fisheries resources in an ecosystem context, for overall ecosystem analysis, and for exploring management policy options
- Combines trophic mass balance analysis with dynamic model for exploring impacts of fishing and environmental disturbances over time
- can include multiple stanzas to represent life history stages
- Describe all mortality components in Ecopath (fishing, predation, other mortality)
Model Overview

Ecopath
- Composed of biomass "pools"
- Multistanza groups for life stages
- Mass balanced
- Trace flow of energy via food web

Ecosim
- Time dynamic simulation
- Fit to historical time series data
- Policy exploration

Production ($P$)
Consumption ($Q$)
Diet ($DC_{ji}$)
Landings, discards
Foraging arena theory
Historical time series abundance, $F, f$
Environmental forcing fn.
Trophic mediations
Ecopath Mass Balance

Mass Balance of a group:
Production = catch + predation + other mortality

\[ P_t = Y_t + B_tM2_t + P_t(1 - EE_t) \]

production | removals

Mass Balance within a group:
consumption = prod. + resp. + unassim. food

\[ Q_t = P_t + R_t + U_t \]

energy in | energy out

production (Z) | predation

other mortality | consumption

bio mass production | respiration

excretion
Ecopath to Ecosim

- time-dynamic simulation module based on Ecopath model
- time series fitting to replicate historical trends in abundance and catch
- environmental forcing functions (bottom-up)
  - Nutrient uptake assumes Michaelis-Menten uptake kinetics
- fishing mortality forcing (top-down)
- Mediation effects
  - E.g. Seagrass as refuge habitat, water clarity and visual predation
- Biomass predicted by:
  \[
  \frac{dB_i}{dt} = g_i \sum_j Q_{ij} - \sum_j Q_{ij} - B_i(MO_i - F_i)
  \]
- Where pred-prey interactions \(Q_{ij}\) controlled by foraging arena theory (Walters et al. 1997)
Ecopath to Ecosim

\[
\frac{dB_i}{dt} = g_i \sum_j Q_{ij} - \sum_j Q_{ji} - B_i(MO_i - F_i)
\]

Foraging Arena Theory (Walters et al. 1997)

- Controls pred-prey consumption rates \(Q_{ij}\)
- Prey biomass divided into vulnerable and invulnerable states and prey move between these states
- Parameters: Vulnerability flow rate \(V\), foraging time, handling time, predator effect on foraging time, mediations
  - High \(V\) implies top-down control
  - Low \(V\) implies bottom-up control
- Type II & III functional response
Tampa Bay model structure

- 74 biomass pools
  - 2 detritus, 3 primary producers, 2 zooplankton
  - 13 invertebrate groups (juv & adult for shrimp and blue crab)
  - 51 fish pools
    - Multistanza: snook, red drum, black drum, spanish mackerel, jacks, pompano, spotted seatrout, sand seatrout, snappers, flounders, mullet, ladyfish
    - Large and small coastal sharks
    - Small pelagic baitfish: anchovies, silversides, clupeids, killifish, small carangids, menhaden
    - Demersal/other fishes: pinfish, mojarra, catfish, gobies, spot, rays, “small demersals”
  - Dolphins
  - Birds
- 8 fishing “fleets”: recreational, cast net, gill net, seines, hook & line, traps, trawl, roller trawl
Model Calibration:
measuring bottom-up vs. top down

- IOAs generated from FIM data or available in stock assessments
- Vs adjusted manually and/or optimized in Ecosim to reduce the sums of squared differences (SS) between observed and predicted values. (Foraging Arena Parameters)
- forced top-down by fishing mortality and bottom-up by nutrient loading
- 4 scenarios:
  - Baseline: no PP forcing, constant F (Ecopath F)
  - F only: forced fishing mortality only
  - PP only: nutrient loading forcing only
  - Full: fishing and primary productivity
  - Mediation: third party interactions on consumption rates (foraging arena)
- Assess the **relative** influence on the SS of each forcing scenario as a percentage of the baseline scenario
Bottom-up impacts on anchovies

Anchovies

- Baseline = 1.73
- F only = 1.65 (95%)
- PP only = 1.51 (87%)
- PP & F = 1.54 (89%)
- FIM
Other small, forage species

<table>
<thead>
<tr>
<th>Pinfish</th>
<th>Mojarra</th>
<th>Small Carangids</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image1.png" alt="Graph" /></td>
<td><img src="image2.png" alt="Graph" /></td>
<td><img src="image3.png" alt="Graph" /></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Clupeids</th>
<th>Silversides</th>
<th>Anchovy</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image4.png" alt="Graph" /></td>
<td><img src="image5.png" alt="Graph" /></td>
<td><img src="image6.png" alt="Graph" /></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Killifish</th>
<th>Gobies</th>
<th>Shrimp</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image7.png" alt="Graph" /></td>
<td><img src="image8.png" alt="Graph" /></td>
<td><img src="image9.png" alt="Graph" /></td>
</tr>
</tbody>
</table>
Combined top-down and bottom-up impacts on blue crab

- Baseline = 3.62
- F only = 2.63 (73%)
- PP only = 1.90 (53%)
- F,PP = 1.66 (45%)
- Assessment SRA
Mediation Effects

- used to modify feeding parameters in ecosim (vulnerabilities, search rate, etc.)
- a third party organism may either facilitate predation or provide protection from predation
- Quickly test hypothesis
- Example: high phytoplankton biomass reduces vulnerability of prey to spotted seatrout
Spotted seatrout and mediation effects

baseline = 3.59
F only = 2.06 (58%)
PP only = 2.90 (81%)
F, PP = 1.76 (49%)
Mediation = 1.38 (38%)
• Assessment B
Data Sources

And many more…
Conclusions

• Ecosim can be used to assess the relative influence of environmental and anthropogenic forcing factors on various species in Tampa Bay

• Mediation effects can impact consumption rates
  – *difficult to describe shape of relationships

• Results have implications on managed species
  – Ex. Blue crab response to drought years

• Baywide monitoring programs greatly improve our ability to move towards ecosystem based fishery management