Why do I criticize MSY theory in ecosystem approach?

- Hiroyuki MATSUDA (Yokohama Nat’l Univ.)
  - Program Committee for 5th World Fisheries Congress 2008
  - Since 2004 Sci. Committee of Shiretoko World Heritage
  - Since 2003 Standing Committee of Ecol. Soc. of Japan
  - Since 2002, Committee for Stock Assessment, Fisheries Research Agency, Japan
  - Since 2002 Advisory Committee, WWF Japan
  - 2001-2003 IWC/SC, Japan deligate

Notes on Demystifying Ecosystem Approaches

- I still encourage adaptive population management.
- MSY theory is not based on EA
- Understand difficulty of EA (Indeterminacy in indirect effects; Mystifying approach)
- Target switching is robust and efficient
- Make a falsifiable prediction
- Adaptive management may not work in EA
Seek simplicity, but distrust it

— Begon, Harper & Townsend (1986) "Ecology: Individuals, Populations and Communities"

• Make a simple model that only includes statistically/biologically evident to obtain reasonable results.

• Include process- & measurement- errors.
  – Risk management is needed

• A simple model with errors can explain the data if it does not include wrong factors.

“Community (multispecies) model is needed when either…

• Species interactions (prey-predator, …) probably affect stock dynamics and coexistence…, and like to make a multispecies conservation or management plan; or

• Population dynamics of each species is mutually (positively or negatively) correlated;

• Myth #1: complex model including EA is always powerful.
Requiem to Maximum Sustainable Yield Theory

- Ecosystems are uncertain, non-equilibrium and complex.
- MSY theory ignores all the three.
- Myth #2 MSY theory guarantees species persistence…

Unconstrained MSY that maximizes the total yield from the community (Matsuda & Abrams 2006)

- We choose fishing effort $e_i$ independently;
- 6-species systems including 2 prey
- random matrix with 50% probabilities;
- we seek $r$ having a positive equilibrium;
- price $p$ is 0-1 for prey, 0-10 for predators
- Unconstrained MSY that may result in extinction;
Some resultant biological communities at MSY (Matsuda & Abrams 2006)

Solution maximizing total yield from community

MSY solution usually reduces species and links;

http://risk.kan.ynu.ac.jp/matsuda/2006/060612UN.ppt

Notes on Demystifying Ecosystem Approaches

- I still encourage adaptive population management.
- MSY theory is not based on EA
- Understand difficulty of EA (Indeterminacy in indirect effects; Mystifying approach)
- Target switching is robust and efficient
- Make a falsifiable prediction
- Adaptive management may not work in EA
Difficulties & hopelessness in ecosystem modeling

- We need many unverified assumptions and intuitive understanding is usually difficult
- “Ecosystem models without errors” often overfit observed data and predict a unique future.
- Indirect effects via the third species or adaptive change in traits is often counterintuitive and not negligible in the long-term effect (see Abrams, Polis…);
- Indeterminacy (Yodzis 1988): Results (+/-) vary with small change in parameter values

Catch of top predators may decrease its prey fish.

- Myth #3 Trophic cascade: decrease of predator always increases its prey.
Notes on Demystifying Ecosystem Approaches

- I still encourage adaptive population management.
- MSY theory is not based on EA
- Understand difficulty of EA (Indeterminacy in indirect effects; Mystifying approach)
- Target switching is robust and efficient
- Make a falsifiable prediction
- Adaptive management may not work in EA

Species Replacement of Pelagic Fishes

<table>
<thead>
<tr>
<th>Year</th>
<th>Anchovy</th>
<th>Horse mackerels</th>
<th>Pacific saury</th>
<th>Chub mackerel</th>
<th>Sardine</th>
</tr>
</thead>
<tbody>
<tr>
<td>1900</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>1910</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>1920</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>1930</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>1940</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>1950</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>1960</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>1970</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>1980</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

Catch in Japan (1000 mt)
Target switching of multispecies fisheries (Katsukawa & Matsuda, Fish.Res. 2002)

Policy 1 (no switching; NSF)
Fishing effort $E_i = e_i/3$ (constant)
Or $E_i = E_i(x_i)$ (independent of $x_j$)

Policy 2 (switching; SF)
$E_i = e_i x_i / (\Sigma x_i)$ (∝ stock abundance)
Fishers focus on relatively abundant fish species.

Switching increases & stabilizes total catch, save it at low levels

• If stock fluctuations of alternative fish are negatively correlated or independent
Cyclic Advantage Hypothesis based on ecosystem approach (species interaction)

The next dominant to sardine is anchovy – Yes! As I predicted
The second next is chub mackerel
Many people agree now


Large fluctuation of recruitment in chub mackerel (Kuroshio stock)

Strong year classes appeared twice
Immatures were heavily caught before the age at maturity

<table>
<thead>
<tr>
<th></th>
<th>1970s</th>
<th>1980s</th>
<th>1990s</th>
<th>1993-</th>
</tr>
</thead>
<tbody>
<tr>
<td>%immatures</td>
<td>65.0%</td>
<td>60.0%</td>
<td>87.0%</td>
<td>90.6%</td>
</tr>
</tbody>
</table>

Future of Pelagic Fish Populations in the north-western Pacific:

- If overfishing of immatures continues,
  - chub mackerel will not recover forever.
  - Fishers did not agree to my recommendation.
- If cyclic replacement hypothesis is true,
  - sardine will not recover forever either.
- Do not catch immatures too much!
  - The overfishing is an experiment for my hypothesis. (adaptive mismanagement)
  - In 2003, fishers agreed to stock recovery plan!
Notes on Demystifying Ecosystem Approaches

- I still encourage adaptive population management.
- MSY theory is not based on EA
- Understand difficulty of EA (Indeterminacy in indirect effects; Mystifying approach)
- Target switching is robust and efficient
- Make a falsifiable prediction
- Adaptive management may not work in EA

Feedback control in fishing effort is powerful...

Stock size:
\[ \frac{dN}{dt} = f(N) - qEN \]

Fishing effort:
\[ \frac{dE}{dt} = U(N - N^*) \]

Myth #4
- Even though the MSY level is unknown, the feedback control stabilizes a broad range of target stock level.

http://risk.kan.ynu.ac.jp/matsuda/2006/060612UN.ppt
If prey is exploited and fishing effort is feedback control, ...(Matsuda & Abrams in prep.)

\[
\begin{align*}
\frac{dP}{dt} &= 0 \\
\frac{dN}{dt} &= 0 \\
\end{align*}
\]

Fishing effort must be controlled by the predator density \( P \)

- \( dE/dt = U(P - \text{Target predator density}) \)
- \( E = E(N, P), \partial E/\partial N > 0, \partial E/\partial P > 0 \)
  
  \( e.g. \) \( E = E_{\text{target}} (1 + a \log N/P_{\text{target}}) \)

- In this case, feedback control guarantees persistence of the target stock and its predators.

- Adaptive *multi-species* management is sometimes needed (seek simplicity, but distrust it).
Conclusion of today’s my talk

1. Do not catch fishes that are at low stock levels;
2. Do not catch immature fishes but catch adult fishes;
3. Catch fishes that are temporally dominant;
4. In order to achieve Principles 1-3, improve the technology for selective fishing gear;
5. Monitor not only a target species, but its prey and predator and the ecosystem;
6. We must remind that our temporal decision may be wrong. (a key concept of adaptive management)

Seek simplicity, but distrust it

Thank you for attention!

• In Shiretoko World Natural Heritage inscribed in 2005, we try to include Ecosystem perspectives (esp. endangered species protection and material circulation) in coastal fisheries management;