Fisheries (and Coasts) as Systems

Anthony Charles
Saint Mary’s University, Halifax Canada
AnthonyCharles.ca

(I) Fisheries as Systems at Multiple Scales
Fishery Systems

Fishery science: the study of fishery systems
Anthony T. Charles

A Systems Approach

A Systems Approach:
- Incorporates the approach of Ecosystem-Based Management
- Adds human dimensions
- Incorporates a ‘bigger picture’ around fish and fishers, which combines both ecosystem- and human-centred thinking...
Human dimensions of the ecosystem approach to fisheries: an overview of context, concepts, tools and methods

Workshop on Social Simulation of Fisheries and Coastal Management June 6-7 2016

Source: Garcia et al. (2003)
Workshop on Social Simulation of Fisheries and Coastal Management June 6-7 2016

Multi-Sectoral Systems

Tourism  Fishing
Shipping  Agriculture
Reefish  Coral reef
Mangrove  Seagrass

HUMAN SYSTEM
CARIBBEAN MARINE SES
COASTAL RESOURCE SYSTEM

by Serge Garcia

Complex System  Adaptive System
Models Scenarios  Mental models Perceptions
Facts, Data  Options  Expectations  Values, Knowledge
Analytical process  Participatory process
Experts  Stakeholders
Integrated model & Assessment
Validation
Communication  Advice  Public / Stakeholders
Issues Goals  Policy makers

Science community

CARIBBEAN (with P. McConney, UWI Barbados)

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Scale

<table>
<thead>
<tr>
<th>Time Scale</th>
<th>Daily</th>
<th>In-Season</th>
<th>Annual</th>
<th>Multi-Year</th>
<th>Long Term</th>
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<tr>
<td>Management</td>
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<td>Catch</td>
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<td>Management Portfolio</td>
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<td>Objectives and Policy</td>
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Spatial Scale

<table>
<thead>
<tr>
<th>Spatial Scale</th>
<th>Local</th>
<th>Fishing Ground</th>
<th>Ecosystem</th>
<th>Multiple Ecosystems</th>
<th>Large-scale</th>
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<td>Fishing Community</td>
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<td>National Jurisdiction</td>
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<tr>
<td>Multiple Nations</td>
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Organizational Scales

- Local-Level Systems
- Regional Systems
- Large-Scale Systems
- Global System

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Northwest Atlantic

Gulf of Maine

Gulf of Maine

Bay of Fundy
Bay of Fundy

Annapolis Basin

Annapolis Basin, Nova Scotia
Annapolis Basin, Nova Scotia

(II) Ingredients of a Systems Approach

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Workshop on Social Simulation of Fisheries and Coastal Management June 6-7 2016

A Systems Perspective

1. Values

- Intergenerational respect
- Importance of place
- Building consensus
- Valuing community
- Respect for human rights
- Food security
- Healthy & safe ecosystems and communities
- Ecological sustainability
- Resilience & diversity
2. Objectives

Bio-Socio-Economic Fishery Models: Labour Dynamics and Multi-Objective Management

\[
\text{Max} \int_0^\infty e^{-\delta t} \left[ a_1 [\pi \pm \lambda G (L - L^*)] + a_2 \left( \frac{\pi}{L} - \hat{Y} \right) + a_3 \left( \frac{E}{L} \right) + a_4 \left( \frac{dL}{dt} \right) \right] dt
\]

(1) \[ \frac{dx}{dt} = F(x) - h \]

(2) \[ \frac{dL}{dt} = \rho L \left( 1 - \frac{L}{f(\pi, L, E) \cdot M} \right). \]

3. Pillars of Sustainability

Ecological Sustainability

Institutional Sustainability

Social Sustainability

Economic Sustainability
4. System Drivers

- Climate Change
- Demand Shifts
- Globalization of Markets
- Technological Change
- Urbanization
- Evolving Governance

5. Governance
5a. Participation

The Triangle of Co-Management

Government Participation
Community Participation
Fisher Participation

5b. Some Ingredients of Good Governance

1. Get the Rights Right
2. Support Local Communities
3. Deal with Equity & Power Issues
4. See the Bigger Picture

6. Coping with Uncertainty

Illusion of Certainty  Fallacy of Controllability

The solution is Robust Management which seeks ‘reasonable’ success in meeting fishery objectives, even when faced with:
- faulty understanding of the fishery system;
- highly imperfect capability to control resource use.

Approaches for Robust Management

- Incorporate a precautionary approach within policy
- Mutually-reinforcing management ‘portfolio’
- Mechanisms to facilitate adaptation/learning
- Use all sources of knowledge
- Promote local management and stewardship
- Self-regulatory institutions, appropriate use rights
- Diversity: Multiple species, multiple livelihoods
7. Monitoring

Integrated Indicator Frameworks
- Ecological Indicators
- Social Indicators
- Economic Indicators
- Community Indicators
- Institutional Indicators

A Broad Range of Indicators

**Economic**
- Total Landed Value
- Total Processed Value
- Fishery Gross Domestic Product
- Value of Fishery Exports
- Profit per Fisher
- Return on Investment
- Depreciation in Natural Capital
- Value of Ecosystem Services
- Diversity of Employment Sources
- Economic Diversity
- Debt Levels of Fishers

**Social**
- Employment
- Equity
- Community well-being
- Diversity of employment

**Institutional**
- Acceptability of governance
- Robustness of management
- Management portfolio
- Participation in decision-making
- Effectiveness of incentives
Novel Indicators

Mean trophic level in fishery, 1972–2007 (weighted by landed weight)

Age distribution of fishers in Nova Scotia, 1931–2006 (in three age classes)

(III) Local Fishery/Coastal Systems
Successful community environmental stewardship, sustainable livelihoods, and government engagement.

www.CommunityConservation.net
(IV) Addressing a Global Policy Issue through a Spatial Bioeconomic Model
Global Policy: Protected Areas

- Through the Convention on Biological Diversity (CBD), the world has agreed on increasing the amount of protected areas globally, to reach certain targets.
- This target is treated on a country by country basis, so signatory countries are now working to reach this target.
- In the ocean, the target is 10% of ocean space by 2020, using Marine Protected Areas (MPAs), ocean areas designated for protection, e.g., in fishery closures, no-take areas, zoning.

What are the Impacts of this Global Policy & Creation of MPAs?

- MPAs may have benefits e.g. protecting spawning/juvenile fish; consumptive and non-consumptive uses; existence/option values.
- There are also costs. In particular, an MPA can cause winners and losers… notably if the MPA is ‘no-take’, no fishing is allowed, so what happens to those who traditionally fished inside the area?
  - compensate for loss of livelihood or provide alternative employment
  - allow continued fishing within the no-take zone
  - provide fishing rights to nearest stock outside MPA
- All of these can cause negative impacts on the fishing people!
A Bioeconomic Model


- multiple fish stocks \( \{S_i\} \) self-reproducing but intermingling
- multiple fishing communities \( \{C_i\} \) arrayed along a coastline

The Model: Implementing an MPA

Note: If the MPA includes stock \( S_i \), then the set of communities most directly affected includes corresponding community \( C_i \).
Population Dynamics

Next year’s stock = survival from last year + in-migration from adjoining areas + recruitment into stock

$s = \text{survival rate}; \ r = \text{intrinsic growth rate}; \ K = \text{carrying capacity}$

$m = \text{fraction of post-fishery fish migrating in each direction}$

$k = \text{fractional increase in carrying capacity inside the MPA}$

(Ability to produce new fish depends on ecosystem health)

$X_{i,n+1} = (1-2m)s(X_{i,n}-h_{i,n}) + ms(X_{i-1,n}-h_{i-1,n}) + ms(X_{i+1,n}-h_{i+1,n}) + r(X_{i,n}-h_{i,n})(1-(X_{i,n}-h_{i,n})/K(1+k\delta_{\text{MPA}}))$

Fishing Process

• Assume fishery regulated / limited by effort (time)
• Assume $N$ fishers per community, $f$ trips each per year
• Assume time $T$ is available per trip
• $t_{\text{travel}}(j) = \text{time required to and from fishing ground}$
• Annual fishing effort per capita $\propto N \cdot f \cdot [T-t_{\text{travel}}(j)]$
• Harvest of the $i^{\text{th}}$ stock by community $j$ in year $n$:

$h_{i,j,n} = q \cdot X_{i,n} \cdot N \cdot f \cdot [T-t_{\text{travel}}(j)]$

where $X_{i,n} = \text{size of } i^{\text{th}} \text{ stock } S_i \text{ in year } n$
Fisher Economics

\[ \Pi_{j,n} = p \cdot h - c_{\text{travel}} \cdot N \cdot f \cdot t_{\text{travel}} - c_{\text{fishing}} \cdot N \cdot f \cdot [T-t_{\text{travel}}] - N \cdot c_{\text{fixed}} \]

Profit for each fisher in community \( j \) in year \( n \)

- Gross revenue - ‘Steaming Costs’ - Fishing Costs - Fixed Costs

Negative impacts on fishery profits due to:

- extra costs to travel further to their new fishing grounds;
- less time available for fishing due to greater travel time;
- crowding on the fishing grounds outside the MPA
- (also possible opposition to those entering new fishing areas)

Results: No MPA

Profit 'Inside' vs Outside MPA

PV, Profits and Stock Size

\[ \text{PV}/25 \quad \text{Average Profit} \quad \text{Fin Stock Size} \]
Results: Typical Scenario

Profits 'Inside' vs Outside MPA

PV, Profits and Stock Size

Results: Displaced can be Winners with Sufficient Ecosystem Benefits

Profits 'Inside' vs Outside MPA

PV, Profits and Stock Size
Results: Displaced can be Winners with High Migration

Policy Impacts of MPAs: Conclusions

- The design of an MPA can affect its acceptance - especially if an MPA is mis-placed or mis-sized.
- Acceptance issues can arise through the distribution of benefits and costs arising from an MPA.
- This model helps to identify factors leading to distributional issues in creation of MPAs, relating to impacts on fishers.
- Unless ecosystem benefits of a no-take MPA are large, those displaced will be disadvantaged more than others.
- Possible remedies: avoid no-take MPAs, provide suitable compensation measures, or ensure that displaced fishers explicitly gain in other ways from the MPA.
Thank You!