Ecosystem-based fisheries assessment and management: A step towards 'FUTURE' implementation of EAM

Chang Ik Zhang

Pukyong National University

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Contents

- Marine ecosystems, habitats, & fisheries
- Ecosystem-based fisheries assessment, forecasting & management
- ‘FUTURE’ and future plans for EAM
YS, ECS (D): very highly impacted, EBS is also highly impacted

Global map of human impact on marine ecosystems based on 17 anthropogenic drivers (Halpen et al., 2008, Science)
Half of world's population could face climate-induced food crisis by 2100
(Vince Battisti 2009, Science)

... warming climate is likely to seriously alter crop yields ... by the end of this century and, without adaptation, will leave half the world's population facing serious food shortages
By 2050, large numbers of marine species (1,066 spp.) will migrate towards cooler waters – specifically the Arctic and Southern Ocean – at an average rate of 40 to 45 km per decades. (Cheung et al., 2009)
World capture fisheries production including freshwater (FAO, 2009)
Catch by FAO marine fishing area

( ) : catch per unit area (t/km²)
Chlorophyll-based annual net primary production (2003). NW Pacific, not higher than other areas!

(Elena-Carr et al., 2006)
Catch proportions of NE & NW Pacific

Catch per unit area in NE & NW Pacific
Out of 584 monitored stocks, 441 stocks (76%) were assessed.

Of the 441 stocks, 77% fully- or over-exploited, depleted or recovering (85% in NW Pacific; 82% in NE Pacific).

Increasing trend in % over-exploited stocks since 1974.

(FAO, 2005)
Declining Biomass of Southern Bluefin Tuna

✓ Current SSB is 4.6% of the unfished level

(CCSBT, 2009)

- Distinct difference among N Pacific countries
Percentage of seafood as the source of animal protein

- Japan 45.4%
- Korea 39.9%
- China 18.0%
- NW Pacific 34.4%
- Russia 12.7%
- Canada 9.9%
- NE Pacific 9.7%
- USA 6.4%

World Average 15.0%

(Data Source: FAO Food Balance Sheet)
General Patterns of Ocean Usage in the N Pacific

- **Western N Pacific side**
  - having greater coastal populations with long history of full exploitation of fishery resources
  - focusing on minimizing existing impacts and rebuilding depleted stocks

- **Eastern N Pacific side**
  - coastal populations and development were much less with fishing impact
  - challenging how to maintain their resources and habitats while permitting appropriate economic activity

(Jamieson and Zhang, 2005)
Disaster due to climate changes and improper fisheries management!!
Shortcomings of a single species management
- Lead to over-fishing in many areas
  (77% fully-, over-fished: FAO (2005))
- Limited management: focuses only on sustainability, ignoring habitat and ecological interactions

Reykjavik Declaration (2002) and FAO (2003) stressed implementation of ecosystem approach to fisheries (EAF)

WSSD (2002) encouraged the application of the ecosystem-based approach of fishery by 2010
EAM-related Products by PICES

PICES SCIENTIFIC REPORT No. 29 2005
Report of the Study Group on Ecosystem-Based Management Science and its Application to the North Pacific

PICES, 2005

PICES SCIENTIFIC REPORT No. 33 2006
Report of the PICES/NPRB Workshop on Integration of Ecological Indicators of the North Pacific with Emphasis on the Bering Sea

PICES, 2006

Fisheries Research
An international journal on fisheries science, fishing technology and fisheries management

Fisheries Research, 2009
Working Group on Ecosystem-based management science and its application to the North Pacific (Oct. 2004 - )

Acronym: WG-19

Parent Committees: MEQ, FIS

Co-Chairman: Glen Jamieson  <jamiesonG@pac.dfo-mpo.gc.ca>

Co-Chairman: Chang-Ik Zhang  <cizhang@pknu.ac.kr>

Co-Chairman: Patricia Livingston  <Pat.Livingston@noaa.gov>

Mailing List (WGEBM Members only)

Terms of reference:

1. Describe and implement a standard reporting format for EBM initiatives (including more than fishery management) in each PICES country, including a listing of the ecosystem based management objectives of each country.

2. Describe relevant national marine ecosystem monitoring approaches and plans and types of models for predicting human and environmental influences on ecosystems. Identify key information gaps and research and implementation challenges.

3. Evaluate the indicators from the 2004 Symposium on "Quantitative Ecosystem Indicators for Fisheries Management" for usefulness and application to the North Pacific.

4. Review existing definitions of "eco-regions" and identify criteria that could be used for defining ecological boundaries relevant to PICES.
Spectrum of Ecosystem-based Management Approaches
(Modified from Sainsbury)

- Traditional fishery management
- Ecosystem-based fishery management
- Ecosystem-based multi-sector management

- Target species
- Start with the target species
- Add issues of ecosystem impact on fishery resources

EBFA approach
Numerous studies on ecosystem indicators carried out (Fulton et al. 2004; Jennings 2005; Kruse et al. 2006)

However, few approaches exist, synthesizing indicators to obtain an integrated assessment (ERAEF by Australia, MSC’s FAM, EBFA by Korea)

The speed of policy adoption has necessitated equally rapid development of scientific and management tools to support practical implementation (Smith et al. 2007)
Ecosystem-based Fisheries Assessment Approaches

- ERAEF by Australia
- Marine Stewardship Council’s FAM
- EBFA by Korea
ERAEEF Approach

Evaluates 5 ecological components:

- Target species
- Bycatch species
- Threatened, Endangered and Protected species (TEP)
- Habitats
- Communities (including food chains)
ERAEF: Hierarchical approach

- Level 1: Qualitative SICA analysis
- Level 2: Semi-quantitative PSA analysis
- Level 3: Quantitative stock or Eco-family assessment

(Tony Smith, S2-5696)
Three MSC Principles for Sustainable Fishing

1. Sustainability of the stock
2. Impact on ecosystem
3. Management systems

*based on international guides and FAO Code of Conduct for Responsible Fisheries
Assessment Tree Structure with Performance Indicators

MSC Principles & Criteria For Sustainable Fishing (MSC Standard)

**Principle 1**
- Outcome
  - Pi: Stock Status
  - Pi: Reference Points
  - Pi: Stock Rebuilding
  - Pi: Harvest Strategy
  - Pi: Harvest Control Rules and Tools
  - Pi: Information / Monitoring
  - Pi: Assessment of Stock Status

**Principle 2**
- Retained Species
  - Pi: Outcome (O)
  - Pi: Management (M)
  - Pi: Information (I)
- Bynatch
  - Pi: O
  - Pi: M
  - Pi: I
- ETP Species
  - Pi: O
  - Pi: M
  - Pi: I
- Habitats
  - Pi: O
  - Pi: M
  - Pi: I
- Ecosystems
  - Pi: O
  - Pi: M
  - Pi: I

**Principle 3**
- Governance and Policy
  - Pi: Legal and/or Customary Framework
  - Pi: Consultation,roles and Responsibilities
  - Pi: Long Term Objectives
  - Pi: Incentives for Sustainable Fishing
- Fishery Specific Management System
  - Pi: Fishery Specific Objectives
  - Pi: Decision Making Processes
  - Pi: Compliance and Enforcement
  - Pi: Research Plan
  - Pi: Management Performance Evaluation

(MSC, 2009)
Certified fisheries can attach this MSC logo on their products.

(Tony Smith, S2-5976; Yukimasa Ishida, S2-5696)
Ecosystem-based Fisheries Assessment Approach (EBFA) for Korean Fisheries

(Zhang et al., 2009. Fish. Res.)
An ecosystem-based fisheries assessment approach for Korean fisheries

Chang Ik Zhang, Suam Kim, Donald Gunderson, Richard Marasco, Jae Bong Lee, Hee Won Park, Jong Hee Lee

A comprehensive ecosystem-based approach is required to holistically assess and manage fisheries resources and their associated habitats by considering ecological interactions of target species with predators, competitors, and prey species, interactions between fishes and their habitats, and the effects of fishing on these processes. A pragmatic ecosystem-based approach was developed for the assessment of fisheries resources in Korean waters involving three management objectives: sustainability, biodiversity, and habitat quality. A two-tier analytical method was employed. Tier 1 was designed for situations where sufficient information is available to allow for a quantitative evaluation of the status of the system, while Tier 2 was designed for situations where available information necessitated a semi-quantitative or qualitative assessment. A total of 20 Tier 1 indicators and 24 Tier 2 indicators were developed for assessment of ecosystem status. Both target and limit reference points were chosen for each indicator to assess the status of species, fisheries and ecosystems. Nested risk indices, such as objectives risk index (ORI), species risk index (SRI), fishery risk index (FRI), and ecosystem risk index (ERI), were developed to assess the ecosystem status at the management unit level. A risk assessment diagram was developed and found to be useful in quickly displaying results. A management status index (MSI) was also developed to evaluate the level of management improvement in species, fisheries, or ecosystems among different time periods or different areas. The method was demonstrated by applying it to the Tongyeong marine ranch and the Korean large purse seine fishery. It was found that this approach can be used to compare the status of species, fisheries and ecosystems spatially and temporally using an ecosystem perspective.
<table>
<thead>
<tr>
<th>Tier</th>
<th>Method</th>
<th>Level of information</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Quantitative analysis</td>
<td>High</td>
</tr>
<tr>
<td>2</td>
<td>Semi-quantitative or</td>
<td>Low</td>
</tr>
<tr>
<td></td>
<td>Qualitative Analysis</td>
<td></td>
</tr>
</tbody>
</table>
Elements of the EBFA approach

- Management objectives and attributes
- Indicators and reference points
- Nested risk indices and management status indices

(Inja Yeon, S2-5993; Jung Hyun Lim, S2-5833; Chang Seung, S2-5653; Dohoon Kim, S2-5630; Hyeok Chan Kwon, S2-5666; Jae Bong Lee, S2-5966; Hee Won Park, FIS-P-5832)
Management objectives, attributes & indicators

Sustainability
- Biomass
- Fishing intensity
- Size/age at first capture
- Habitat size
- Community structure

Habitat
- Habitat damage
- Discarded wastes
- Habitat protection

Socio-Economy
- Economic production
- Revenue
- Market
- Employment

Biodiversity
- Incidental catch
- Discards
- Trophic level
- Diversity
- Integrity of functional group
Reference Points (RP) and Risks

Increased anthropogenic impact

Green zone  Yellow zone  Red zone

Undisturbed  Target RP  Limit RP

Risk

Undisturbed: 0
Target RP: 0 - 2
Limit RP: 2

Improved by proper management

\[ RS_x = RS_{\text{max}} \left( \frac{X_{\text{target}} - X}{X_{\text{target}} - X_{\text{limit}}} \right) \]
Risk assessment diagram for the EBS trawl fishery

FRI_{97} = 0.665, \quad FRI_{07} = 0.291

(Anne Hollowed, S1-5830)
Ecosystem risk indices (ERI) for Korean fisheries in three marine ecosystems

(Jae Bong Lee, S1-5965)
From a practical standpoint, the ecosystem-based fisheries assessment approach (Zhang et al., 2009) is very appealing for its ability to incorporate a large number of quantitative ........

....Yet, even this approach should be further refined, sensitivity analyses conducted, the forecasting version of this approach further developed, and future applications tested in other ecosystems.....

(Kruse et al., 2009, Fish. Res.)
Integrated Fisheries Risk Assessment, Forecasting and Management for Ecosystems (IFRAME)

An extension of EBFA (Zhang et al., 2009. Fish. Res.)
IFRAME: in the developing stages
1) SOM (Self-Organizing Mapping): species grouping by swimming ability, size, bone, depth, shape, habitat, feeding, food type and longevity

2) Estimation of biomass and production of LTL groups, i.e., phyto- and zooplankton

3) Biomass, catch, P/B, Q/B, DC

4) Ecosystem structure model

5) Ecological Process Studies on relevant physical, chemical and biological oceanographic processes

6) Fisheries and Socio-economic Assessment

7) Integrated Fisheries Risk Assessment, Forecasting, and Management for Ecosystems
8) Ecosystem simulation model for biomass

9) Based on management index analysis

\[
MI = \left( \frac{ERI_{i+1} - ERI_i}{ERI_i} \right) \times 100
\]
10) Translate objectives to strategies, ‘what it will be done’

11) Translate strategies to tactics, ‘how it will be done’

12) Management tactic evaluation

13) Management strategy evaluation
Target species: Common mackerel (*Scomber japonicus*)

Scenarios

- Reference year: 2008
- Forecasted year: 2013 (5 years later)
- Forecasting risks by altering TAC of common mackerel based on 9 options:
  - no fishing, 40,000, 80,000, 120,000, 160,000 (current level), 200,000, 240,000, 280,000, 320,000 mt
2008

**TAC = 160,000mt**

Biomass of exploited species:
- Increase: Common mackerel, Yellowtail, Spanish mackerel
- No change: Common squid, Hairtail
- Decrease: Jack mackerel

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2013

**TAC = 320,000mt**

Biomass of exploited species:
- Increase: Jack mackerel
- No change: Common squid, Hairtail, Spanish mackerel
- Decrease: Common mackerel, Yellowtail
Forecasted ORIs for common mackerel by changing TAC in 2013

![Graph showing the effect of TAC on objective risk indices (Sustainability, Biodiversity, Habitat quality, and Socio-economic benefit)]
Forecasted SRI for common mackerel by changing TAC

<table>
<thead>
<tr>
<th>Objective</th>
<th>No fishing</th>
<th>40,000</th>
<th>80,000</th>
<th>120,000</th>
<th>160,000</th>
<th>200,000</th>
<th>240,000</th>
<th>280,000</th>
<th>320,000</th>
</tr>
</thead>
<tbody>
<tr>
<td>SRI</td>
<td>0.53</td>
<td>0.46</td>
<td>0.45</td>
<td><strong>0.23</strong></td>
<td>0.30</td>
<td>0.45</td>
<td>0.71</td>
<td>0.90</td>
<td>0.95</td>
</tr>
</tbody>
</table>
Preliminary results indicate that this approach has potential as a tool for forecasting risk indices of objectives, species and fisheries.

However, it is still far from practical applications due to lack of knowledge for assessing risks of a number of indicators.

Further research on indicators and reference points is required, and more ecological process studies, such as ecological interactions with physical factors, impacts on climate changes, are essential.

(You Jung Kwon, FIS-P-5797)
To understand and forecast responses of North Pacific marine ecosystems to climate change and human activities at basin and regional scales,

and to broadly communicate this scientific information to stakeholders and the public.
1. **Understanding Critical Processes in the North Pacific (Obj.1)**

Three key questions were adopted as priorities for FUTURE research activities:

- What determines an *ecosystem’s intrinsic resilience and vulnerability* to natural and anthropogenic forcing? *(Q1)*
- How do *ecosystems respond* to natural and anthropogenic forcing, and how might they *change in the future*? *(Q2)*
- How do *human activities affect coastal ecosystems* and how are *societies affected by changes in these ecosystems*? *(Q3)*

2. **Status, Outlooks, Forecasts and Engagement (Obj.2)**

---→ **Basic knowledge for implementing EAM**
IFRAME approach reflects FUTURE objectives

Assessment

- Ecosystem structure and risk assessment
  - Identifying species
    - SOM
  - Grouping species, species groups
    - NEMURO
    - Other input

- Constructing ecosystem structure
  - FSA

- Risk assessment

Forecast

- Forecasting ecosystem structure and risk
  - Set scenarios on climate changes or management options
    - NEMURO
    - Other input parameters

- Forecasting ecosystem structure
  - FSA

- Risk analysis by scenario

Management

- Evaluating and implementing management
  - Set management objectives
    - Strategies
    - Tactics

- Monitoring

------ AI CE, COVE
------ Status Reports (SOFE)
------ Outlooks & Forecasts (SOFE)
------ Engagement (SOFE)
------ COVE, AI CE
------ COVE, AI CE for feedback and evaluation

----- FUTURE Obj.s & Qs

----- FUTURE AP

Obj.1-Q1-Q3
Obj.2
Obj.1-Q2
Obj.2
Obj.1-Q1-Q3
Obj.2
“The scientific needs for an ecosystem approach to management (EAM) are an overarching motive for ICES Science Plan. EAM has application to fisheries, other industrial sectors and ecosystem as a whole. …”
Strategies to achieve EAM

1. Data compilation
2. Retrospective studies & Monitoring
3. Model development & process studies
4. Assessment, outlook & forecasting
5. Management implementation
We need strengthen links among

Meteorological & environmental sciences

Physical, chemical & biological oceanography

Fisheries sciences

Socio-economic sciences

Integrated multidisciplinary programs

PICES
It would be much desirable to include Okhotsk Sea, Kuroshio-Oyashio region, Eastern/Western Bering Sea, Gulf of Alaska and Strait of Georgia.
In conclusion

- Under the current situation of changing climate, degraded ecosystems and depleted stocks, a management system for holistic ecosystem approaches needs to be properly established.

- Since EAM requires multi-disciplinary cooperative research, our 10-year FUTURE program is timely and essential, and it should be successfully conducted by active participation of member countries.
N Pacific ecosystems by FUTURE in future

Towards healthy and wealthy marine ecosystems thru EAM
Thank you!