Assessing impacts of climate changes on fisheries: An EAF perspective

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Outline

- Impacts of climate changes on fish and fisheries
- IFRAME approach as an EAF
- Application of the approach
- Management implications under changing climate condition
Examples of potential impacts of climate changes (Revised from UNEP (2007))

<table>
<thead>
<tr>
<th>State changes</th>
<th>Mediating environmental/ ecosystem impacts</th>
<th>Human well-being impacts</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Human health</td>
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<tr>
<td></td>
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<td>Food security</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Socio-economy</td>
</tr>
<tr>
<td>Sea surface temperature ↑</td>
<td>Trophic structure and food web ↔</td>
<td>Food safety ↓</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Fishery species distribution ↔</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Aquaculture production ↓</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Cost ↑</td>
</tr>
<tr>
<td>Coral Bleaching ↑</td>
<td>Disruption of utility services ↑</td>
<td>Artisanal fishers ↔</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Risk in fisheries and agriculture ↑</td>
</tr>
<tr>
<td>Sea-level rise ↑</td>
<td></td>
<td>Aquaculture facilities ↔</td>
</tr>
<tr>
<td>Trophical storm and hurricane frequency and intensity ↑</td>
<td></td>
<td>Aquaculture damage ↑</td>
</tr>
</tbody>
</table>
Fish migrating to cooler waters
(IPCC SRES A1B scenario)

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).
Impacts of climate changes

An example of catch proportions in Korean waters of the Japan/East Sea: shifts in dominant species

![Graph showing catch proportions over time with shifts in dominant species]
Impacts of climate changes

Catch of bluefin tuna in Korea

- Continuous increase since mid-1980s

\[ y = 129.89x - 739.26 \]

\[ r^2 = 0.7813 \]
Studies on impacts of climate changes

- Biodiversity: Roessig et al. (2004), Harley et al. (2006), Munday et al. (2008), ....
- Species richness: Hiddink and Hofsted (2008), ....
- Productivity of fish populations: Zhang et al. (1999), Hollowed et al. (2009), ....
- Distribution of fish populations: Park et al. (2000), Nye et al. (2009), Cheung et al. (2009), ....

But, still limited knowledge and poor understandings on the relevant mechanisms of key ecological processes !!!
Why ecosystem-based fisheries management?

- Shortcomings of a single species management
  - lead to over-fishing in many areas
    (77% fully-, over-fished: FAO (2005))
- Limited management only on sustainability
  - ignoring habitat quality, biodiversity and socio-economic benefits
- 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
Spectrum of Ecosystem-based Management Approaches

Traditional fishery management
- target species

Ecosystem-based fishery management
- start with the target species
- add issues of ecosystem impact on fishery resources

Ecosystem-based multi-sector management
- integrated multi-sector management

(Revised from Sainsbury)
Ecosystem-based fisheries assessment

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

- However, only a few approaches synthesized indicators to obtain an integrated assessment (ERAEF by Australia, MSC’s FAM, IFRAME by Korea)
Integrated Fisheries Risk Analysis Method for Ecosystems: in the developing stages
## IFRAME: 2 tier system

<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 Qualitative Analysis</td>
<td>Low</td>
</tr>
</tbody>
</table>
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 and Risks

Increased anthropogenic impact

Green zone
Target RP
Limit RP
Undisturbed
Risk

RS_x = RS_{max} \left( \frac{X_{target} - X}{X_{target} - X_{limit}} \right)

Improved by proper management
Nested risk indices of IFRAME

Ecosystem
Fishery A
Species 1
Objective S … ORI
Objective B … ORI
Objective H … ORI
Objective E … ORI
Species 2
Objective S … ORI
Objective B … ORI
Objective H … ORI
Objective E … ORI
Fishery B
Species 1
Objective S … ORI
Objective B … ORI
Objective H … ORI
Objective E … ORI
Species 2
Objective S … ORI
Objective B … ORI
Objective H … ORI
Objective E … ORI

\[
ORI = \frac{\sum_{i=1}^{n} I_i W_i}{\sum_{i=1}^{n} W_i}
\]

\[SRI = \lambda_S ORI_S + \lambda_B ORI_B + \lambda_H ORI_H + \lambda_E ORI_E\]

\[FRI = \frac{\sum B_i SRI_i}{\sum B_i}\]

\[ERI = \frac{\sum C_i FRI_i}{\sum C_i}\]

\(I_i\) : Score of i
\(W_i\) : Weighting factor of indicator i
\(n\) : Number of indicators

\(\lambda_S, \lambda_H, \lambda_B, \lambda_E\) : Weighting value for objectives
\[\sum \lambda = 1.0\]

\(ORI_S\) : Sustainability risk index
\(ORI_B\) : Biodiversity risk index
\(ORI_H\) : Habitat risk index
\(ORI_E\) : Socio-economic risk index

\(B_i\) : Biomass or biomass index of species i

\(C_i\) : Catch of fishery
Application to the Korean large purse seine fishery (Preliminary)

- **Korean large purse seine fishery**
  - Main species: chub mackerel (*Scomber japonicus*)
  - Bycatch species: bluefin tuna, horse mackerel, Spanish mackerel, squids, etc.
  - Annual catch: around 250,000 mt

- **Catch and CPUE data**
  - 30’x30’ blocks
  - 1980-2008 (29 years)
Warming of fishing ground

- IPCC SRES A2 scenario (Kim et al., 2007)
  - Increasing rate: 0.062°C/year

- SST in northern East China Sea
  - Main fishing ground of the Korean large purse seine
  - Warming rate of SST: 0.086°C/year
    (higher than 0.062°C/year of IPCC rate)
Methods

• Predictions for habitat areas
  - Warming rate of 0.06°C/year (SST)
  - Reference year 2008, predicted habitat areas for 2033, 2058, 2083, and 2108

• Predictions for biomass and risk indices
  – Using SOM, NEMURO, ECOPATH with ECOSIM
  – Predicting biomass altering F-values ranging from zero to 2.0xF_{ABC}, based on the changes in habitat areas of chub mackerel due to warming
  – IFRAME, Tier 1 for chub mackerel
Changes in fishing grounds of chub mackerel

- Northward movements of fishing grounds for 1980s-2000s (19 years):
  - Cheung’s method
    - 81.5km northward movement
    - 42.9km/decade
  - Equal-frequency ellipse method
    - 81.2km northward movement
    - 42.7km/decade
  - Fish movement rate similar with Cheung et al. (2009)’s prediction of 40-45km/decade
Prediction of habitat areas of chub mackerel

- SST range: 14.4-22.5°C
- Faster northward movement in the Japan/East Sea than that in the Yellow Sea
- The main habitat area of chub mackerel will be outside of the South Korean EFZ in Japan/East Sea in 2108
<table>
<thead>
<tr>
<th>Sustainability</th>
<th>Biodiversity</th>
<th>Habitat</th>
<th>Socio-economic benefit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Biomass (B)</td>
<td>Bycatch rate (BC/C)</td>
<td>Critical habitat damage rate (DH/H)</td>
<td>Landings</td>
</tr>
<tr>
<td>Fishing mortality (F)</td>
<td>Discards rate (D/C)</td>
<td>Pollution rate of spawning and nursery ground (PG/G)</td>
<td>Revenue (per vessel or person, etc.)</td>
</tr>
<tr>
<td>Age (or length) at first capture (t or L)</td>
<td>Mean trophic level of the community (TL&lt;sub&gt;c&lt;/sub&gt;)</td>
<td>Lost fishing gear (frequency, FR)</td>
<td>Return on Investment (ROI)</td>
</tr>
<tr>
<td>Habitat size (H)</td>
<td>Diversity index (DI)</td>
<td>Discarded wastes (DW)</td>
<td>% ratio of landing to total supply</td>
</tr>
<tr>
<td>Mean trophic level in catch (TL)</td>
<td>Pelagic sp./ Benthic sp. (P/B)</td>
<td></td>
<td>Employment rate</td>
</tr>
<tr>
<td>Rate of mature fish (MR)</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Slope of size spectra</td>
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</tbody>
</table>

A total of 16 indicators used for IFRAME (Revised from Zhang et al., 2010)
ORIs of chub mackerel for 2058

- Sustainability: risk index began to increase as F increased from $0.25F_{ABC}$
- Biodiversity and Habitat: risk index increased moderately as F increased
- Socio-economy: W-shaped risk indices lower at $0.75F_{ABC}$ and $1.5F_{ABC}$
Species Risk Indices of chub mackerel

- SRI for 2058: higher than that of 2008 from zero $F$ to $1.25F_{ABC}$
- SRI: lowest with $0.75F_{ABC}$ in 2008 and 2058
- Fishing with population-based $F_{ABC}$ level will cause ecological overfishing, suggesting to reduce the $F$ level to $0.75F_{ABC}$
IFRAME is still in the developing stages

- 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.
- Especially, specific ecological process studies on the indicators and reference points under a changing climate are required.
### Management implications from the preliminary analysis

<table>
<thead>
<tr>
<th>Management Objectives</th>
<th>Strategies</th>
<th>Tactics</th>
</tr>
</thead>
</table>
| **Sustainability**    | - Increasing biomass  
- Reducing fishing capacity  
- Maintaining community structure | - TAC reduction (by $0.75F_{ABC}$)  
- Reducing number of licenses or permits  
- Limiting number of trips and/or fishing days  
- Developing new fishing gears and methods |
| **Habitat**           | - Preventing habitat damage  
- Restricting discarded wastes | - Establishing marine protected area (MPA)  
- Modifying closed season and areas  
- Restricting use of harmful fishing gears |
| **Biodiversity**      | - Preventing incidental catches and discards  
- Preserving diversity and trophic level | - Adopting temporary fishing recession  
- Modifying stock enhancement programs |
| **Socio-economy**     | - Increasing revenues  
- Maintaining viable production  
- Supporting employment | - Enhancing community-based management  
- Government supports due to shifted fisheries  
- Predicting supply and demand of shifted fish species  
- Predicting employment due to shifted fisheries  
- Strengthening international cooperation for EAF management |
### Legal systems and relevant policies in fisheries management under climate changes: A Korean case

#### Two major acts for fisheries legal systems and policies

("Fishery Resources Management Act" and "Marine Ecosystem Conservation and Management Act")

<table>
<thead>
<tr>
<th>Objectives</th>
<th>To establish a comprehensive plan for fisheries resources and ecosystem management, and to contribute to a sustainable fisheries and marine ecosystems</th>
</tr>
</thead>
<tbody>
<tr>
<td>Contents</td>
<td>- Conducting assessment of fisheries resources every year</td>
</tr>
<tr>
<td></td>
<td>- Establishing a master plan for fisheries management every 5 years and for ecosystem conservation and management every 10 years</td>
</tr>
<tr>
<td></td>
<td>- Building up an institutional foundation for self-management of fisheries resources</td>
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<tr>
<td></td>
<td>- Embracing international regulations and encouraging international cooperation</td>
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<td></td>
<td>- Using eco-friendly fishing gears and methods</td>
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<tr>
<td></td>
<td>- Applying a precautionary approach</td>
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<td></td>
<td>- Stipulating management of habitats and ecological environments</td>
</tr>
<tr>
<td>Limitations</td>
<td>- Lack of scientific data and research for EAF</td>
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<tr>
<td></td>
<td>- No clear explicit provisions on EAF and climate changes</td>
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## Suggested policies and measures responding climate changes

<table>
<thead>
<tr>
<th>Current management</th>
<th>EAF management</th>
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</thead>
<tbody>
<tr>
<td><strong>Goal</strong></td>
<td>Managing and protecting species, fisheries and their ecosystems responding to climate changes</td>
</tr>
<tr>
<td>Managing and rebuilding species</td>
<td>Sustainability, habitat quality, biodiversity, socio-economic benefits, responding to climate changes</td>
</tr>
<tr>
<td><strong>Objective</strong></td>
<td>Scientific research, fishery data, non-scientific knowledge and information from fishers and other stakeholders</td>
</tr>
<tr>
<td>Sustainability of species itself</td>
<td>Central and local governments, and all relevant stakeholders including fishers, by establishing Fishery Management Councils</td>
</tr>
<tr>
<td><strong>Information</strong></td>
<td>Scientific research and fishery data</td>
</tr>
<tr>
<td>Scientific research and fishery data</td>
<td>Central and local governments</td>
</tr>
<tr>
<td><strong>Bodies</strong></td>
<td>Central and local governments</td>
</tr>
<tr>
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</tr>
<tr>
<td><strong>Flexibility</strong></td>
<td>Restricted</td>
</tr>
<tr>
<td>Flexible</td>
<td>Flexible</td>
</tr>
<tr>
<td><strong>Range of areas</strong></td>
<td>Areas within and beyond one nation’s EEZ, cooperating with neighboring nations, possibly by establishing a Regional Management Body</td>
</tr>
<tr>
<td>Areas within one nation’s EEZ</td>
<td>Flexible</td>
</tr>
<tr>
<td><strong>Period</strong></td>
<td>Short-term</td>
</tr>
<tr>
<td>Short-term</td>
<td>Short-term, and mid- and long-terms as well</td>
</tr>
</tbody>
</table>
Thank you very much!