Fisheries Management and Ecosystem Regime Shifts: Lessons Learned from Kuroshio/Oyashio Current System

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Japanese catch of Japanese sardine, anchovy, and mackerels (chub and spotted) during 1905-2006

[Graph showing catch data with labels and time series for Sardine, Mackerels, Anchovy, and Regime shift, with Aleutian Low Pressure Index on the graph.

The graph includes data points from 1905 to 2006, with a focus on the catch in tons for sardine, mackerels, and anchovy, as well as the anomaly of the Aleutian Low Pressure Index.]
Regimes and regime shifts in stock-recruitment relations of the Japanese sardine and chub mackerel in the Kuroshio/Oyashio system (Tanaka 2003 Fish Sci)

Estimated Carrying Capacity ($K$, 1000 ton) for each “regime”

<table>
<thead>
<tr>
<th>Year Range</th>
<th>Sardine</th>
<th>Chub mackerel</th>
</tr>
</thead>
<tbody>
<tr>
<td>1950-61</td>
<td>258</td>
<td></td>
</tr>
<tr>
<td>1962-69</td>
<td>38</td>
<td></td>
</tr>
<tr>
<td>1970-87</td>
<td>44,490</td>
<td>786</td>
</tr>
<tr>
<td>1988-95</td>
<td></td>
<td>353</td>
</tr>
</tbody>
</table>
Fish lifecycle and fishing

Spawner per Recruits (SPR) = \( f \) (fishing, adult \( M \), growth, maturation)

Recruitment per Spawner (RPS) = \( f \) (adult biology, juvenile \( M \))

\( M \): Natural mortality rate
Sustainable use: A balance between RPS and fishing

NB1: Juvenile $M$ is affected by ecosystem regime shifts

RPS

$= f$ (adult biology, juvenile $M$)

SPR

$= f$ (fishing, adult $M$, growth, maturation)

NB2: Adult biology (age/size composition, fatness, etc.) are changed by fishing

NB3: Sustainable fishing pressure varies with RPS
Mismatch between investments and 1988 regime shift: example of Japanese purse-sein fishery

Late 1970s-1980s: increase of larger fleets for fish-meal production, to compensate for collapse of Peruvian anchovy

After 1988/89 RS: collapse of Japanese sardine and birth of excess fishing capacity, due to longer life of fleets and difficulties in reduction of fleets once established.
Outcome of excess fishing capacity: prevention of recovery of chub mackerel stock

Mid 1990s-: fishing pressure increased, due to collapse of sardine

1990s-: Excess fishing capacity and catch of immature fish (age 0 and 1) prevented recovery of chub mackerel despite the occurrences of strong year classes in 1992, and 1996

Also, reduced old fishes
How and when shall we change the fishing rates? - Results for 60-years simulation (Barange et al., in press)

“Anchovy”: lifespan = 5 yrs, age of maturity (AM) = 1 yr, \( M=1.2/yr \)

“Flatfish”: lifespan = 50 yrs, age of maturity (AM) = 5 yr, \( M=0.1/yr \)

Best balance: Regime-dependent \( F \) with a lag of years at AM
Target switching among 3 alternating stocks
(Katsukawa 2004, Katsukawa and Matsuda 2003 Fish Res)

Issue 1: Differences in fish price and catchability
Issue 2: How to determine multi-species $F_{msy}$ or optimum fishing effort?
Importance old/big spawners of Atlantic cod  
( Ottersen et al., 2006 FO )

**Mechanism:**  
Older > younger

- Spawning period
- Vertical range of egg distribution

**Mean age in spawners (weighted by biomass)**

**BOFFF (Big, Old, Fat, Fecund Female) hypothesis**
“Regime Concept” of fisheries management

- Regime Shift
  - Protection of biodiversity - e.g., by MPAs and selective gears
  - Change in productivity of stocks
  - Regime-dependent precautionary fishing rates with a time-lag
  - Non-parametric target switching
  - Species replacement
  - Best-mixtures of management measures
  - Communications among stakeholders
  - Monitoring and research

- Uncertainties
Co-management of sandlance in the Ise Bay

Life span: 3 years
Age of maturation: 1 yr
Fishery: pair trawl for larvae for human consumption and adult for aquaculture bait

Spawning Gr in winter
Estivation Gr in summer and autumn
Catch history of sandlance in the Ise Bay
(Tomiyama et al., 2008)

Unit: metric ton
In-season stock assessment, monitoring and constant escapement strategy (CES) for sandlance (Tomiyama 2000)
Pre-season monitoring of sandlance (Tomiyama 2000)

Pre-fishing monitoring gives a good estimate of initial stock

Under CES, good estimate of annual total catch

Optimum fishing plan
The fishing strategy is determined through consensus between local fisher's associations based on scientific information provided by fishery research stations.
Why co-management of sandlance succeeded?

✓ Fishing right: ownership of the stock by several autonomous fishers organizations

✓ Sandlance fishers can control fish price (to some extent) due to the limited market

✓ The local stock of sandlance was compact enough to manage by multiple fisheries: all fishers can feel effects of management simultaneously

✓ There were good relations among fishers, researchers and managers, to develop a management protocol based on scientific knowledge
Many of the Japanese fishery stocks are still bad

Why Japanese right-based management did not work?

- Race for fish
- Over-capitalization
- Degradation of habitat
- Insufficient scientific knowledge on population dynamics and uncertainties
- Insufficient mechanism for stock recovery or avoid severer management: misuse of “right”?

Stock level of 90 stocks assessed in 2007 around Japan
The “regime concept” of fishery management includes:
- Regime-dependent fishing rates with a time-lag after the year of regime shift
- Target switching
- Conservation of age/size diversity
- Precautionary approach
- Consider mismatches between life spans of fishing fleets and ecosystem regimes
- CAVEAT: RS is not a mare reversal to previous state

Co-management of fishery stocks needs:
- Incentives for management (economic and social)
- Studies for explanations on stock depletion
- Good relations among fishes, researchers and managers to develop a science-based management
- Seek alternative stocks when the target stock is depleted
PDO, Victoria, AO and SST regime shifts
(regime shift years: after Yasunaka and Hanawa, 2002)

Every six regimes has different combinations of PDO, Victoria and AO anomalies
Conceptual Model Diagram for Japanese Sardine
(Japanese Pacific Stock, Yatsu et al. 2008 PiO)

Aleutian Low Intensification

Winter MLD Deepening in Kuroshio, Expansion of Oyashio area

Other Forcing

Lower SST of Kuroshio and Oyashio

Improved Early Growth

Improved Early Survival

Accumulation of Biomass and Alternate to Anchovy

Less Arrival of Predators (Skipjack, Common Squid)

Improved Primary Production, Altered Zooplankton compositions
Higher SST would enhance arrival of skipjack and biomass of Japanese common squid.
Growth, fishing and aestivation of sandlance in the Ise Bay (Tomiyama et al. 2008)
In-season stock assessment, monitoring and constant escapement strategy (CES) (Tomiyama 2000)

- End of fishing for human consumption
- Resume fishing for fish bait

Date (March to May, 1995)

Fish value (JPY/box)

Small area, limited number of fishers, and good relation between fishers and scientists

The fishing strategy is determined through consensus between local fisher's associations based on scientific information provided by fishery research institutes.