Wind off Hawaii and fisheries in Japan: Expected benefit from marine science to society

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Why forecasting marine ecosystem is important?
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Human society expects stable ecosystem services

- One of advantages of agriculture is “large amount” and “scheduled” supply of products compared with hunting/gathering. The productivity per man x day is much larger than hunting/gathering.
- Based on the “schedule”, it is possible to manage the use of redundant man power for infrastructure, warfare, art, religion, etc.
- Stable climate in Holocene is one of important factors of the development of strong regimes and empires under scheduled supply of food through agriculture.
- To minimize unexpected variability in agricultural production, human society has been developed stabilizers, such as bank, irrigation system, pesticide, fertilizer, etc.
Fisheries: still unstable production

- Recent studies revealed the collapses of ancient regimes were related to long-term climate variability (100s years) which induced starvation, riot, invasion of different ethnic groups, etc.

- Fisheries are targeting natural resources which supply is from ecosystem service.

- Fishermen know seasonal timing of fish migration, fishing point, fish behavior, etc. from their experience, but are unable to predict whether big or poor catch in next fishing season.......*Mother nature only knows*
Natural science and society

- Marine scientists are preparing obtained knowledge to fishermen, managers and society such as stock size, recruitment success/failure, ocean circulation status, expected migration route, etc. However, forecasting the degree of recruitment success and landing (and many others) are still difficult.
- Most drastic change in fisheries production is induced by fish species alternation observed in small pelagic fishes such as sardine, anchovy.
Sardine landing in Japan:
1960s: $10^4 - 10^5$ ton
mid 1980s: $>4 \times 10^6$ ton
1988: start declining
2000-: $\sim 10^5$ ton (<5% of peak landing)
Migration route of Japanese sardine

Sardine landing
> $10^6$ ton mid-1980s
0 after 1994
Impact of the sardine collapse to regional economy in Kushiro for 3-yeas (1990-92)

Direct impact to purse seiners is not included (all the officers/crews are based in other regions)

Kaneko et al. 2012
Impacts of FSA

- 11 billion yen  -339 jobs in Kushiro during 1990-92

24 fleets were disbanded

Sudden and unpredictable FSA induces economical and social problems
Fishery: highly variable production

- “Mizu-shohbai” in Japanese means unstable (like water “mizu”) business (shohbai) such as fisheries......not really respectful word.
- Unpredictability and high variability in fisheries production prevents direct (boats, nets, gears, etc.) and indirect (e.g., branding, developing new market) investment to the industry. This also prevents investment to infrastructure for value addition (e.g., cold store, transporting system of high quality fresh fish from harbor to market).

Scientists’ efforts to understand the mechanism of FSA and the forecast contribute stable fishers housekeeping, more effective investment and easier application of fisheries management policy (based on fishers’ confidence in manager and scientists)
Sardine landing in Japan:
1960s: $10^4$-$10^5$ ton
mid 1980s: $>4 \times 10^6$ ton
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2000-: $\sim 10^5$ ton (<5% of peak landing)
Anchovy landing increased after the sardine stock collapse
Juvenile sardine did not grow to age+1 after 1988

- Sudden increase in aged fish & decrease in recruitment from 1988
- No. of eggs spawned were $>10^{15}$ during 1988-1992

**Juvenile sardine did not grow to age+1 after 1988**
What is the trigger of the FSA?

SST anomaly

Correlation between SST anomaly and larval mortality rate

1987

1988

Noto & Yasuda 1999
Juvenile sardine (distribute in KEX region) did not grow to age+1 after 1988
Correlation

Mechanisms

Climate Variability & Change

Dynamics

Ecosystem response to Climate
We carried out retrospective analysis of KEX physical status by means of eddy resolving GOCM OFES to understand the mechanisms of the change in SST and sardine recruitment variability responded to the SST change.
Strengthened eastrnary wind induced high SSH anomaly in eastern N. Pac.

SSH anomaly induced Rossby wave and propagated to west.

SSH anomaly reached to KEX in 4 years (1988)

The arrival in SSH anomaly in KEX region induced KEX acceleration and SST increase
Annual variations in MLD, SST in the KEX (OFES) and RPS

Recruitment per spawner

Recruitment failure in the years of shallow MLD and high SST

(Nishikawa, Yasuda & Itoh, FO, 2011)
Seasonal change in phytopl. (model)

1988-91, 93 (blue): years of MLD < 170m

Early initiation, low magnitude, early termination (except for 1991)

(Nishikawa, Yasuda 2008)
In the years of shallow MLD:
• Low growth rate due to low food conc.
• Resultant increase in mortality

“Mismatch” induced by the change in wind curl anomaly in the central N. Pacific
Wind off Hawaii influence fisheries and fisheries-related industry in Japan

+4~6 years time lag
Monitoring precursor of FSA

- Climate change
  - Climate obs. system/satellite
  - Time (year): 0
- SSH anomaly
  - Satellite/RV/Argo
  - Time (year): 0-1
- Propagation
  - Model
  - Time (year): ~4
- SST/WML in KEX
  - Model
  - Time (year): ~4
- Ecosystem change
  - RV
  - Model
  - Time (year): ~4
- Decline in fish growth
  - Egg/larvae survey
  - Time (year): 4+
- Decline in recruitment
  - Pre-fishing season survey
  - Time (year): 4+
- Stock decline
  - Resource assessment survey
  - Time (year): 5-7
Conclusions

• Innate problem of fishery as a modern industry is that the production is not based on planning by human being. Human society and economics expect stable or scheduled supply. Fishery is often unable to response to the request due to the high variability.

• Forecasting future change in stock is most useful to enable stable fishers’ housekeeping and wise use of ecosystem fisheries production.

• Based on SUPRFISH findings, monitoring the change in ocean status to forecast the FSA is one of the ways to utilize natural scientific knowledge to societal benefits.

• Our understanding on the mechanisms of ecosystem variation is still limited. Further scientists’ efforts on “understand the mechanisms” and “forecasting future” are essential way of science contribution to society.