Long-term changes in fisheries production of the Japan Sea with an emphasis on the impacts of fishing and climate regime shift during the last three decades

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last 46 years: 1958-2003
Subtropical Circulation

Warm Water Species
- Tunas, yellow tail, Jack mackerel, common squid, etc.

Cold Water Species
- Atka mackerel, walleye pollock, Pacific cod, etc.

Asian Monsoon

Subarctic Circulation

Decadal

Aleutian Low

ENSO

ENSO-scale?
Fish Community and Environment

Fish Community

- Human Impacts
  - with complex trophic dynamics and interspecific interactions

- Environmental/ climate changes

- Oceanic Ecosystem
  - Fishing

- Human Impacts
TWO OBJECTIVES

1. To identify the long-term variability in the fish community.
2. To unravel the mechanisms whereby oceanic and climate changes are linked to the dynamics in the community structure.

Final Goal
To understand the function and structure of the ecosystem toward ecosystem-based fisheries management.
Data Sources

   58 species items, 91% of total catches
   Fishing effort for three major fisheries (1971-2001)

   SST for Japan Sea: $1^\circ \times 1^\circ$ grid data set from JMA
   50 m depth water temperature: Tsushima Current

   PDO, NPI, SOI, AOI, MOI
Methods

1. Community Indices
   1) Diversity Index (DI)
   \[ DI = 1 - \sum_{i}^{n} \frac{Y_i (Y_i-1)}{Y (Y-1)} \]
   2) Mean Trophic Level (MTL)
   \[ MTL = \sum_{i}^{n} \frac{TL_i Y_i}{Y} \]
   3) Piscivores / Zooplanktivores ratio

2. Principal Component Analysis (PCA)
   To identify the common variation pattern between various time series
Five Climate Indices

(a) NPI
- Year: 1950 to 2000
- Winter NPI (hPa)
- 1987/88

(b) PDO
- Year: 1950 to 2000
- Winter PDO
- 1987/88

(c) SOI
- Year: 1950 to 2000
- SOI
- 1987/88

(d) AOI
- Year: 1950 to 2000
- Winter AO
- 1987/88

(e) MOI
- Year: 1950 to 2000
- Winter MOI (hPa)
- 1987/88
Indicator of Tsushima Warm Current

50 m depth water temperature (winter)

Late 1980s regime shift is evident

Mid-1970s global regime shift is not evident

Late 1980s regime shift is evident
Catches Trend of 58 Species Items in the Japan Sea during 1958-2003

- piscivores
- pelagic species
- sardine
- demersal fishes
- invertebrates


Catch (thousand metric tons)
Three major fisheries in the Japan Sea

- **Purse seine**: small pelagic fishes
- **Bottom trawl**: demersal fishes and invertebrates
- **Set net**: coastal and migratory fishes

**Graph**:
- **X-axis**: Year from 1970 to 2000
- **Y-axis**: Catch in thousand ton
- **Legend**:
  - Purple: Purse seine
  - Yellow: Trawl
  - Light green: Set net
  - Orange: Ratio

The graph shows the catch trends and ratio for each method over the years.
Fishing Effort and CPUE: 1970-2001

Cumulative fishing days

CPUE

Year
Community Structure in the Japan Sea

- **58 species items**
- **Piscivores**
  - 20 items
- **Herbivores and Detritivores**
  - 11 items
- **Zooplanktivores**
  - 23 items
- **Seaweeds**
  - 3 items
- **Marine mammals**
- **Large predatory fishes:** Tuna, sword fish, yellow tail, etc.
- **Small pelagic fishes:** sardine, anchovy, etc.
- **Demersal fishes:** invertebrates,
Changes in Community Indices

Biomass Diversity Index

Year | Diversity index
---|---
1958 | 0.4
1963 | 0.5
1968 | 0.6
1973 | 0.7
1978 | 0.8
1983 | 0.9
1993 | 1.0

Mean Trophic Level

Year | Mean trophic level without sardine | Mean trophic level with sardine
---|---|---
1958 | 2.6 | 2.6
1963 | 2.8 | 2.8
1968 | 3.0 | 3.0
1973 | 3.2 | 3.2
1978 | 3.4 | 3.4
1983 | 3.6 | 3.6
1988 | 3.8 | 3.8

Effect of sardine
Impacts on Community

Mean trophic level

Year

-1960s
Slow increase

1970s-1980s
Sharp decline

1990s-
Rapid recovery

Exploitation + Warm water

Fishing effort

Warm water

Intense fishing? +
Sardine dominant +
Cold water

Warm water
The First Four Principal Components

- **PC1**: 36.1%
  - Mid-1960s

- **PC2**: 18.8%
  - Late-1980s

- **PC3**: 11.7%
  - Mid-1970s

- **PC4**: 6.1%
  - Early-1990s

**ENSO pattern**
Large Predatory Warm Water Species

50 m depth water temperature (winter)

Anomalies (winter)

regime mean

Tuna
Demersal Cold Water Species

Cold regime
Increase in abundance
Expansion of distribution

Warm regime
Decrease in abundance
Reduction of distribution
Response to climatic regime shifts

Fish community in the Japan Sea

- ENSO, (Winter Monsoon)
  - Interannual

- Mid-1970s Regime Shift: Primary Production
  - Interdecadal ?

- Late 1980s Regime Shift: Water Temperature
  - Decadal
CONCLUSIONS

• The fish community structure is forced by oceanic conditions; Large decline in community indices during 1980s is resulted from dominant sardine.

• No fishing down food web

• Mid-1970s and late 1980s regime shifts largely associated with the variability in the fisheries resources.
Piscivores/zooplanktivores (PS/ZP) ratio

![Graph showing the PS/ZP ratio for Northern and Southern regions from 1958 to 2003. The Northern region shows a steady increase in the PS/ZP ratio from 1958 to 2003, whereas the Southern region shows a decrease and then an increase around 1998.](image-url)
Outline of This Work

1. Climatic and oceanographic conditions in the Japan Sea

2. Features of fisheries production trend

3. Change in community indices

4. Response to climate regime shift