Biotic and abiotic impacts on pollock (Gadus chalcogrammus) population off the east coast of Korea over the last 5 decades

Moojin Kim¹, Sukyung Kang², and Suam Kim¹

1 Pukyong National University, Korea
2 National Institute of Fisheries Science, Korea
Background & Introduction

Materials & Methods
- Data set
- Estimation of Biological parameter & Recruitment variability
- Statistical analysis

Results & Discussion
- Habitat environment
- Biological parameters of pollock population
- Recruitment variability
- Relationship between walleye pollock and environmental factors

Conclusion
Background & Introduction

Biomass fluctuation of fisheries resources

- Overfishing
- Ecological processes within foodweb
- Changes in Oceanographic conditions
Spawning season
- Dec.-Mar.
  (Park and Ok, 1986)

Habitat depth
- Juvenile:
  - Shallow water
- Adult:
  - 200-350 m
  (NIFS, 2010)

Habitat temperature
- Adult:
  - 2-10℃ (most preferable 3-5℃)
  (NFRDI, 2010)

Prey
- Larva&Juvenile:
  - copepod
  - amphipod
  - euphausiid
  (Lee, 1986)
- Adult:
  - euphausiid
  - shrimp
  - cephalopod
  - fish
  (NFRDI, 2010)
To reveal the change in biological characteristic and recruitment variability of pollock over the last 5 decades

To investigate the relationship between environmental change and its impacts on recruitment
Data & Methods

Data set

1. Environmental data

- NIFS serial oceanographic observation data
  ① Seawater temperature
  ② Zooplankton
2. Walleye pollock data

① Catch data


② Biological data

National Institute of Fisheries Science (NIFS) scientists subsampled biological parameters (length, weight, maturity, etc.) since the late 1950s

Data extracted:

- fishing gear (gillnet, longline), winter season (Nov.-Feb.), sex (female)

Three stages of fisheries

1) **Period 1**

   Beginning of fisheries (1958–1968)

2) **Period 2**

   Active stage of fisheries (1973–1985)

3) **Period 3**

1. Estimation of Biological Parameter

① von Bertalanffy growth curve

\[ L_t = L_\infty \left(1 - e^{-K(t-t_0)}\right) \]

- \( L_t \) = length at age \( t \)
- \( L_\infty \) = theoretical maximum length (asymptotic)
- \( K \) = growth coefficient, proportional to rate at which \( L \) is reached
- \( t_0 \) = theoretical age at \( L = 0 \) (often negative, or zero)

② Length at maturity curve

\[ P_i = \frac{1}{1 + e^{-K \times (X_i - L_\infty)}} \]

- \( P_i \) = proportion of the mature fish at length \( X_i \)
- \( K \) = instantaneous rate of fish maturation

③ Fulton Condition factor

\[ CF = \frac{BW}{FL^3} \times 10^4 \]

- \( BW \) = Body Weight (gram)
- \( FL \) = Fork Length (cm)
2. Recruitment variability

① Relative Length Frequency

a simple method to assess the size structure of a fish population quickly by comparing its sampled length frequency with an average developed for the particular geographic region.

We applied this method for data collected in the same geographical region during different periods

② Cohort Analysis

✓ Mortality estimation
   – Total mortality (Z) by catch curve (Pauly, 1984)
   – Natural mortality (M) by Zhang and Megrey (2006) equation
   – Fishing mortality (F) = Total mortality (Z) – Natural mortality (M)

✓ Age–length key

FSA package (alkIndivAge) in R

✓ Pope’s cohort analysis (Pope, 1972)

\[
N_{ij} = N_{i+1,j+1} e^M + C_{ij} \frac{M}{2} \\
N_{ij} = C_{ij} \frac{F_{ij} + M}{F_{ij}(1 - e^{-(F_{ij}+M)})}
\]

\(N_i\) = the number of fish of age \(j\) in the population at time \(i\)
\(F_i\) = the instantaneous rate of \(N\) of the fish of age \(j\) at time \(i\)
\(C_{ij}\) = the total catch in the number of fish of age \(j\) in the time \(i\)
\(M\) = natural mortality
③ Proportional size distribution (PSD)

To differentiate size distribution of fish and to determine the level of recruitment.

\[ PSD = \frac{\text{Number of fish} \geq \text{minimum quality length}}{\text{Number of fish} \geq \text{minimum stock length}} \times 100 \]

We defined:

**Stock Length**

- Mean length of first maturity: 25cm
- (Kang et al, 2013)

**Quality Length**

- Length at 50% maturity: 37cm
Statistical Analysis

- **Cross–Correlation Function (CCF) analysis (IBM SPSS Statistic)**
  : to examine the time-lag effect in correlation between environment variables and pollock data

- **Sequential Regime Shift Detector (SRSD)**
  : to detect changing phase of seawater temperature

- **Cumulative Sum (CuSum)**
  : to detect the timing of environmental change as well as to diagnose change in resource conditions
Results & Discussion

Habitat environments


(a) Period 1 (1958–1968)
   : Low temperature
(b) Period 2 (1973–1985)
   : High temperature
(c) Period 3 (1991–2002)
   : Low temperature
2. Zooplankton in the main fishing area (1965–2002)

- Increase in biomass since the early 1990s

: Copepod, Euphausiid + Amphipod

(a) Annual change in density

– Copepod
  : dramatically increased from 2000s
– Euphausiid + Amphipod
  : increased since 1990s

(b) Seasonal variation

– Copepod
  : peak season in April, June
– Euphausiid + Amphipod
  : peak season in June, October
## Biological parameters of pollock population

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Estimated value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Period 1</td>
</tr>
<tr>
<td><strong>Length-weight relationship</strong></td>
<td></td>
</tr>
<tr>
<td>$\alpha$</td>
<td>0.0065</td>
</tr>
<tr>
<td>$\beta$</td>
<td>2.958</td>
</tr>
<tr>
<td><strong>von Bertalanffy equation</strong></td>
<td></td>
</tr>
<tr>
<td>$FL_{\infty}$</td>
<td>56.3</td>
</tr>
<tr>
<td>$K$</td>
<td>0.341</td>
</tr>
<tr>
<td>$t_o$</td>
<td>-0.06</td>
</tr>
<tr>
<td><strong>Mortality</strong></td>
<td></td>
</tr>
<tr>
<td>$M$</td>
<td>0.28/yr</td>
</tr>
<tr>
<td>$F$</td>
<td>1.27/yr</td>
</tr>
<tr>
<td>$Z$</td>
<td>0.98/yr</td>
</tr>
<tr>
<td><strong>Length at maturity</strong></td>
<td></td>
</tr>
<tr>
<td>$L_{50}$</td>
<td>–</td>
</tr>
<tr>
<td><strong>Condition factor</strong></td>
<td></td>
</tr>
<tr>
<td>Average</td>
<td>56.3</td>
</tr>
</tbody>
</table>

Density-dependent effect occurred in the East Sea
High/low walleye pollock biomass $\rightarrow$ high/low prey competition $\rightarrow$ slow/fast growth
Recruitment variability

1. Relative Length Frequency

(a) Period 1 (1958–1968)
   : high number of small and large size

(b) Period 2 (1973–1985)
   : high number of middle size

(c) Period 3 (1991–2002)
   : narrow range of length and bigger size than Period 2

Changes in length frequency caused by overfishing

Strong/weak fishing effort → decrease/increase in size range
→ low/high recruitment
2. Cohort analysis

✓ Pope’s cohort analysis

(a) Period 1 (1958–1968)
  : decreased in abundance since 1966

(b) Period 2 (1973–1985)
  : high abundance in 1981
3. Proportional Size Distribution (PSD)

: **stable** recruitment variability in Period 2
✓ Relationship between PSD and Age–2, 3 abundance in Period 1 and 2

(a) PSD vs. age–2 abundance
   : negative correlation

(b) PSD vs. age–3 abundance
   : negative correlation

: positive correlation with a time lag of 3 years

Zooplankton biomass affect change in walleye pollock catch

High/Low zooplankton biomass → High/Low walleye pollock catch
2. Juvenile catch vs. Seawater temperature in the spawning period

- Anomaly of juvenile catch and December temperature at 10m, 75m

: similar trend
2. Juvenile catch vs. Seawater temperature in December

- Positive correlation with a time lag

Seawater temperature affect change in walleye pollock catch

High/Low habitat temperature → High/Low walleye pollock catch in future
3. Age–2 abundance vs. seawater temperature in April (1975–1985)

- Cumulative Sum (CuSum) curve of Age–2 abundance and April seawater temperature at 50 m, 75 m

: similar trend
3. Age–2 abundance vs. seawater temperature in April (1975–1985)

: positive correlation with a time lag

Seawater temperature affects age-2 abundance of walleye pollock

High/Low seawater temperature → High/Low walleye pollock age-2 abundance
Conclusion

Variability in biological characteristics and recruitment