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

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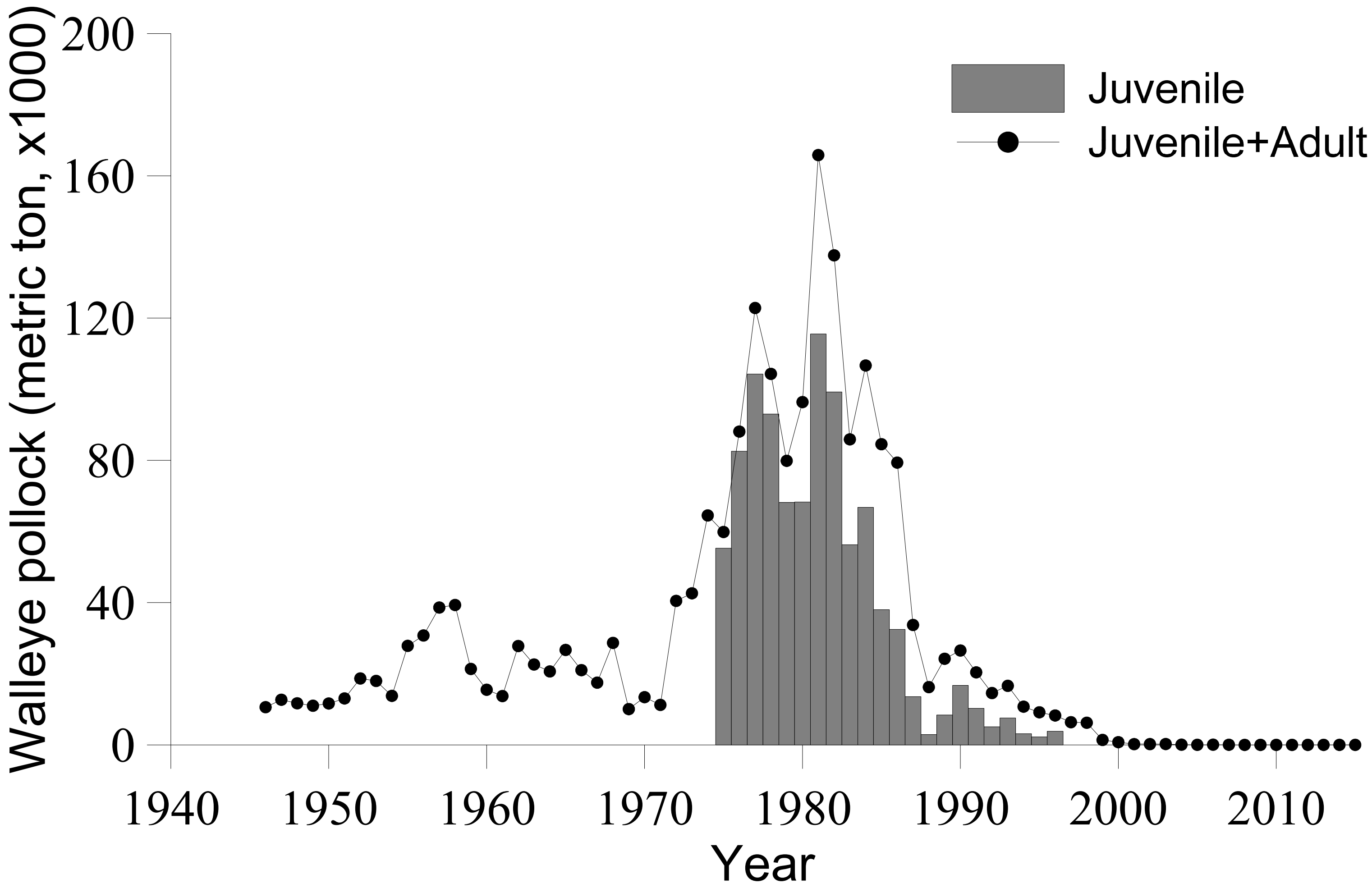
Contents

Background & Introduction

Biomass fluctuation of fisheries resources

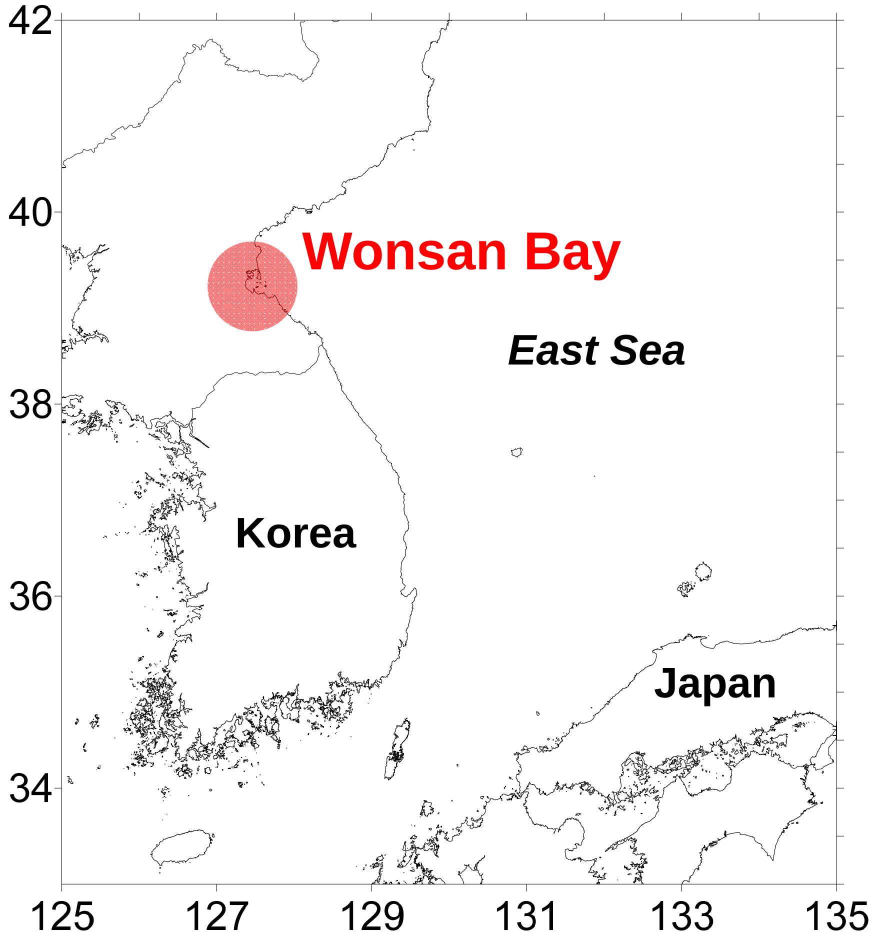
- Overfishing
- Ecological processes within foodweb
- Changes in Oceanographic conditions

Catch variability in walleye pollock in the East Sea (1946–2015)



Korea

walleye pollock?



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)

Purposes of this study

- 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

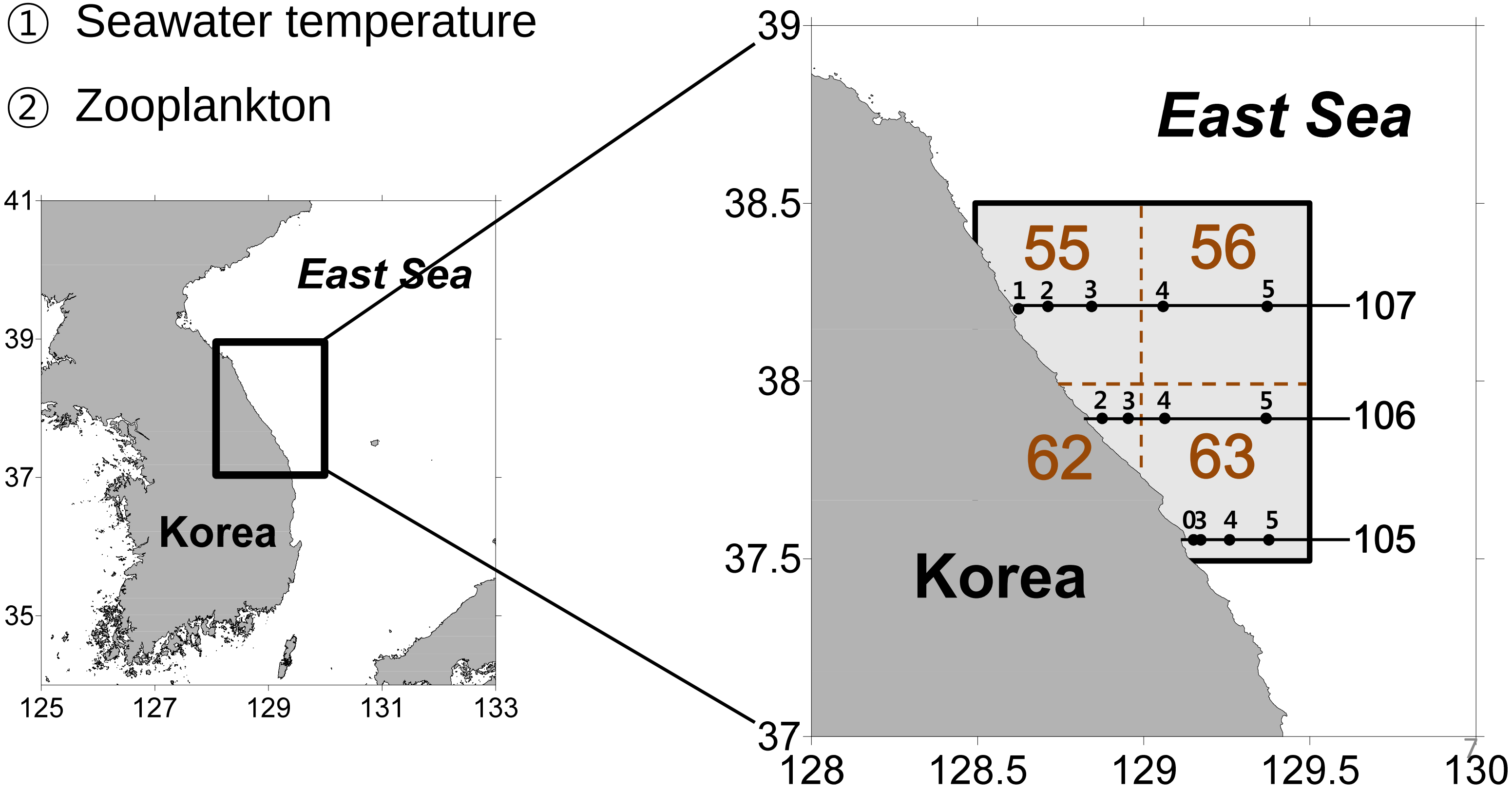
❖ Data set

1. Environmental data

– NIFS serial oceanographic observation data

① Seawater temperature

② Zooplankton



2. walleye pollock data

① Catch data

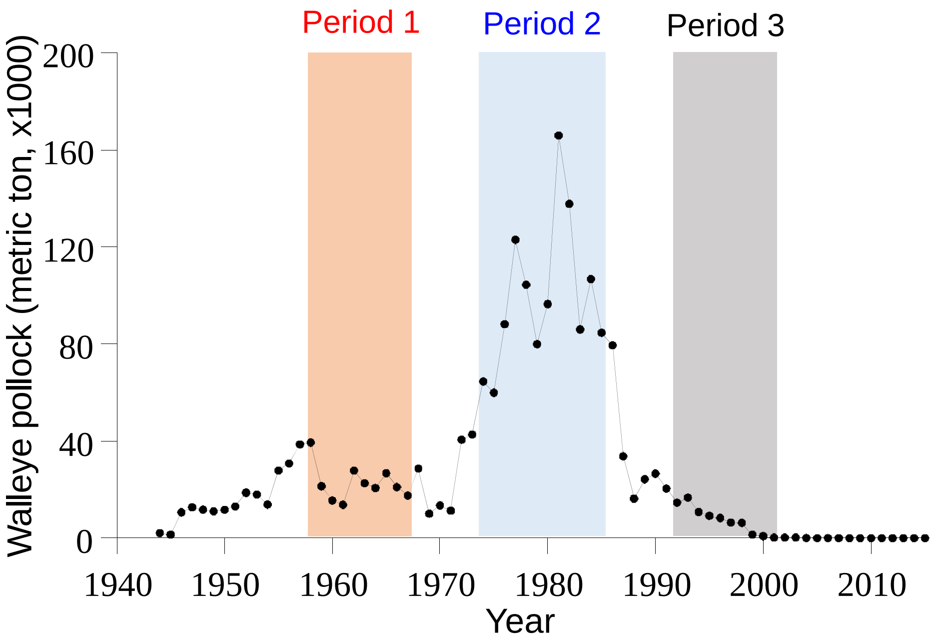
Yearbook of fisheries statistics (1965–2002, http://www.fips.co.kr)

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**

Weakening stage of fisheries (1991–2002)

❖ Data Analysis

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 = 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

$$P_i = \frac{1}{1 + e^{-K \times (X_i - L_{50})}}$$

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)

$$N_{ij} = N_{i+1,j+1}e^{M} + C_{ij}e^{\frac{M}{2}}$$

$$N_{ij} = C_{ij}\frac{F_{ij} + M}{F_{ij}(1 - e^{-(F_{ij}+M)})}$$

N_{ij} = the number of fish of age *j* in the population at time *i*

F_{ij} = the instantaneous rate of N of the fish of age *j* at time *i*

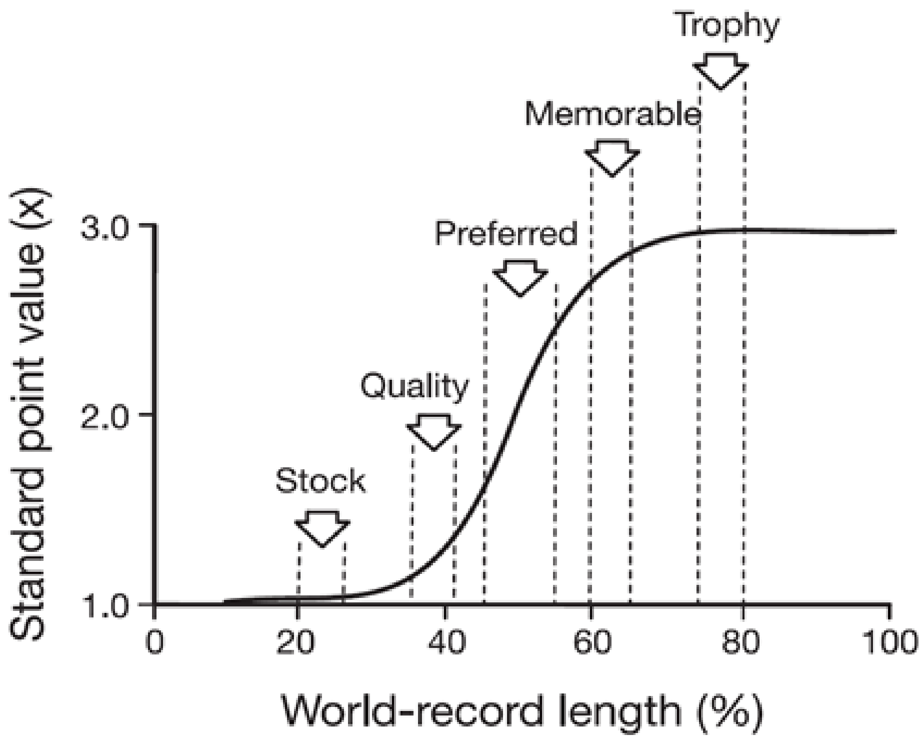
C_{ij} = the total catch in the number of fish of age *j* in the time *i*

M = natural mortality

③ Proportional size distribution (PSD)

: to differentiate size distribution of fish and to determine the level of recruitment

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



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

1. Seawater temperature in December (1965–2005)

(a) Period 1 (1958–1968)

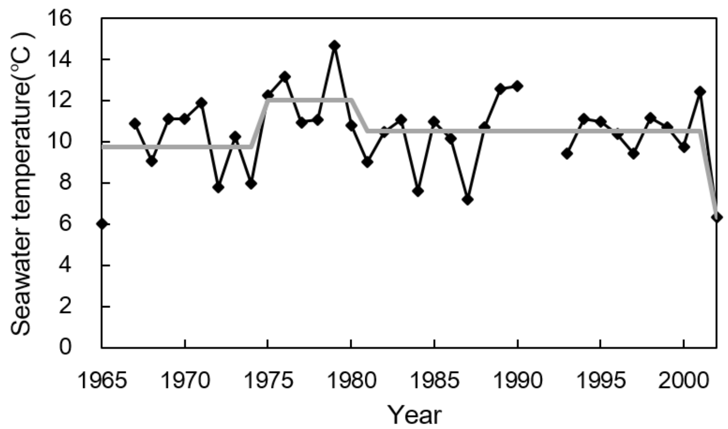
: Low temperature

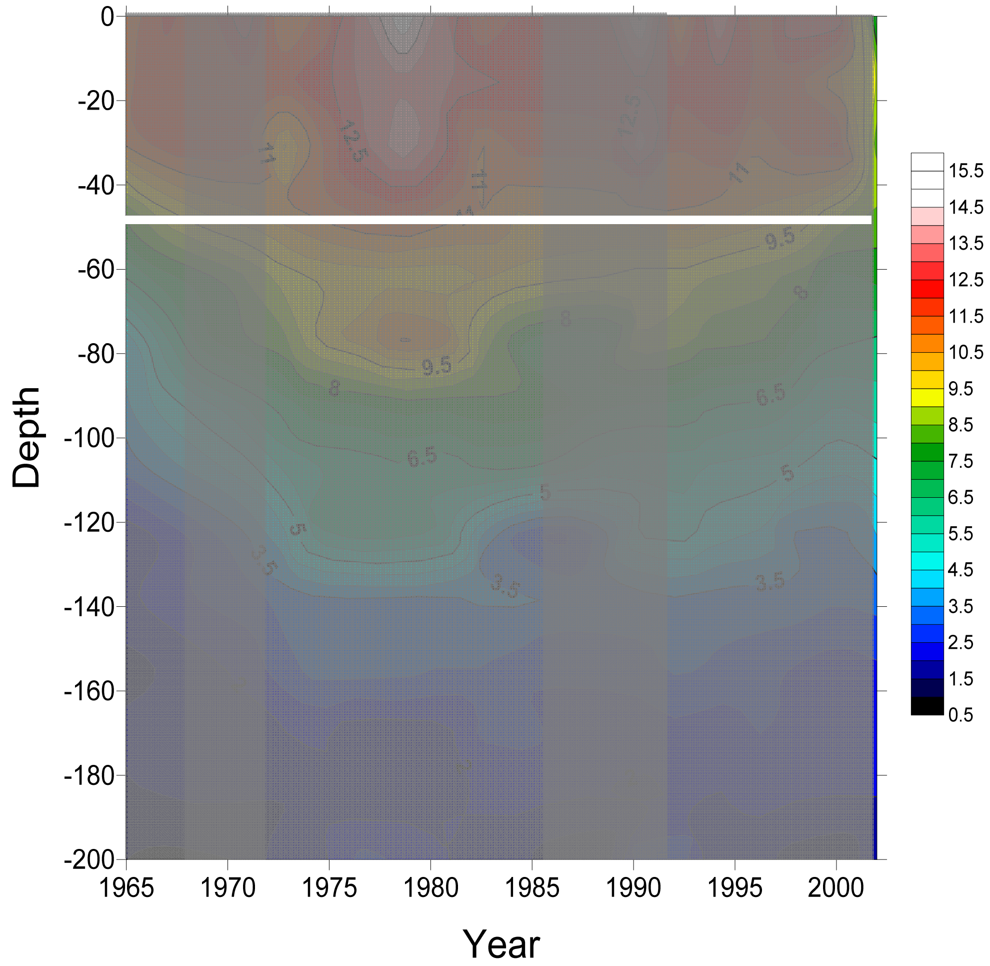
(b) Period 2 (1973–1985)

: High temperature

(c) Period 3 (1991–2002)

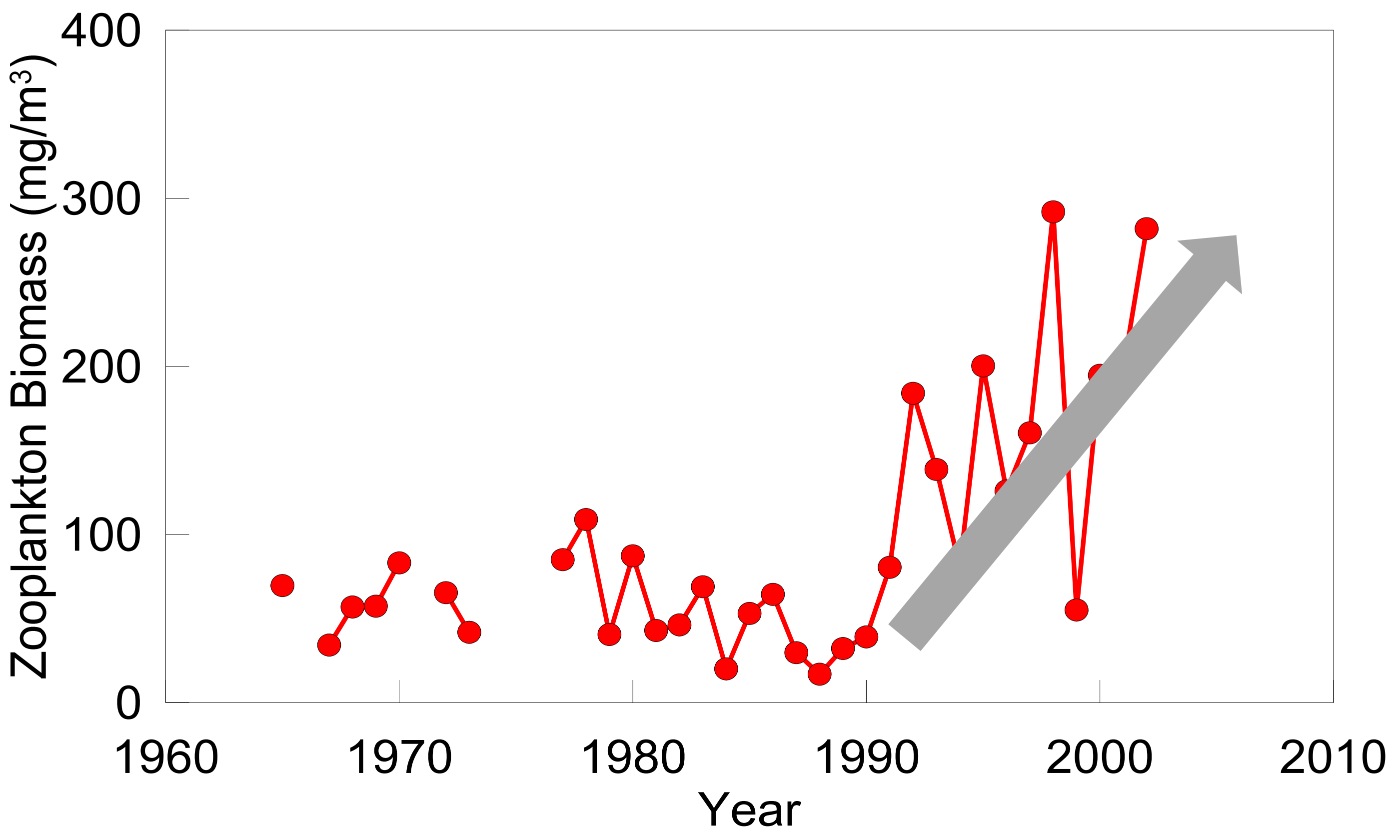
: Low temperature





2. Zooplankton in the main fishing area (1965–2002)

: increase in biomass since the early 1990s



3. Major zooplankton (1978–2002)

: Copepod, Euphausiid + Amphipod

(a) Annual change in density

– Copepod

: dramatically increased from 2000s

– Euphausiid + Amphipod

: increased since 1990s

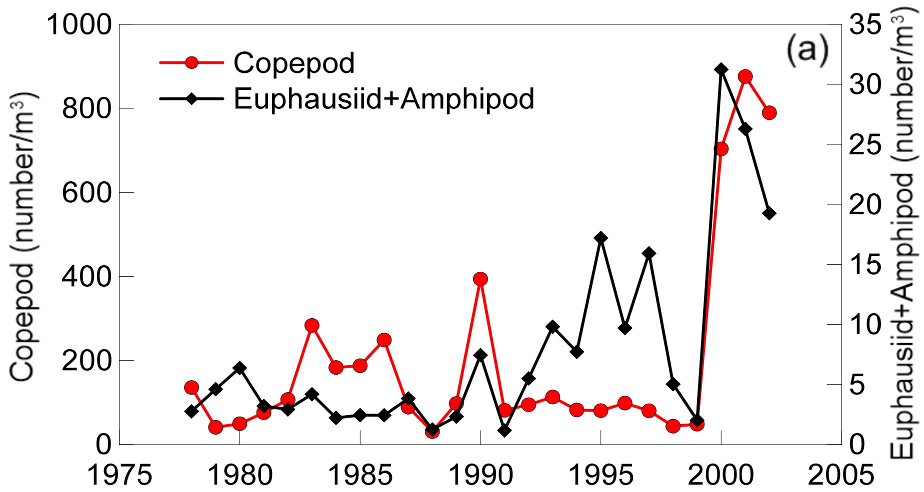
(b) Seasonal variation

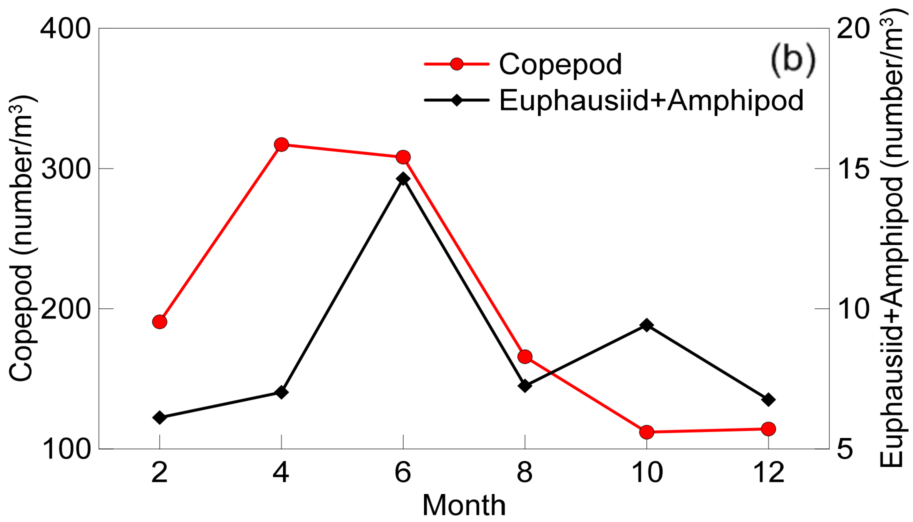
– Copepod

: peak season in April, June

– Euphausiid + Amphipod

: peak season in June, October





❖ Biological parameters of pollock population

Parameters		Estimated value		
		Period 1	Period 2	Period 3
Length-weight relationship	α	0.0065	0.0100	–
	β	2.958	2.843	–
von Bertalanffy equation	FL_{∞}	56.3 >	51.5	–
	K	0.341	0.418	–
	t_0	-0.06	0.1098	–
Mortality	M	0.28/yr	0.24/yr	–
	F	1.27/yr <	2.06/yr	–
	Z	0.98/yr	1.82/yr	–
Length at maturity	P_{50}	–	33 cm <	37 cm
Condition factor	Average	56.3	56.8 <	62.8

Density-dependent effect occurred in the East Sea

High/low walleye pollock biomass → high/low prey competition → slow/fast growth

❖ Recruitment variability

1. Relative Length Frequency

(a) Period 1 (1958–1968)

: high number of small and large size

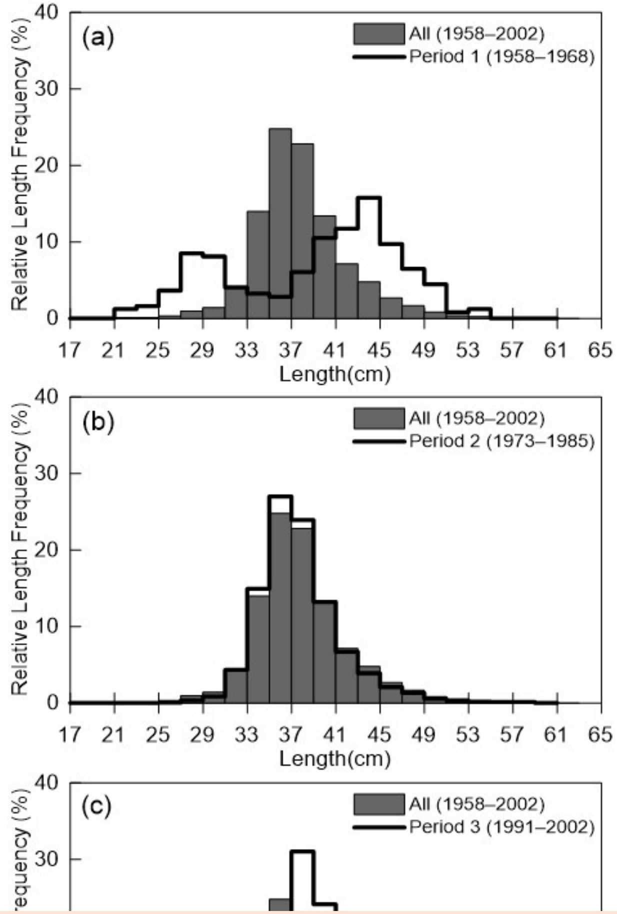
(b) Period 2 (1973–1985)

: 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

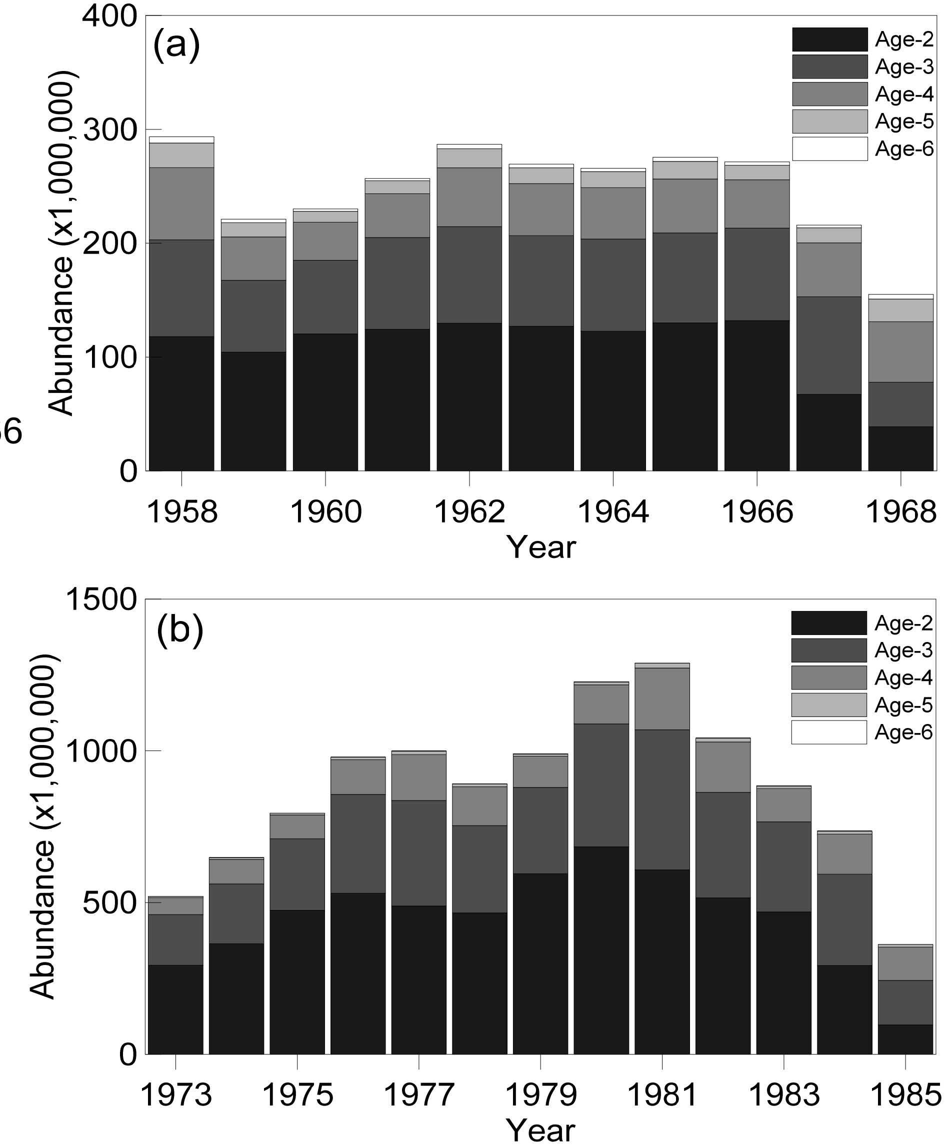
✓ Pope's cohort analysis

(a) Period 1 (1958–1968)

: decreased in abundance since 1966

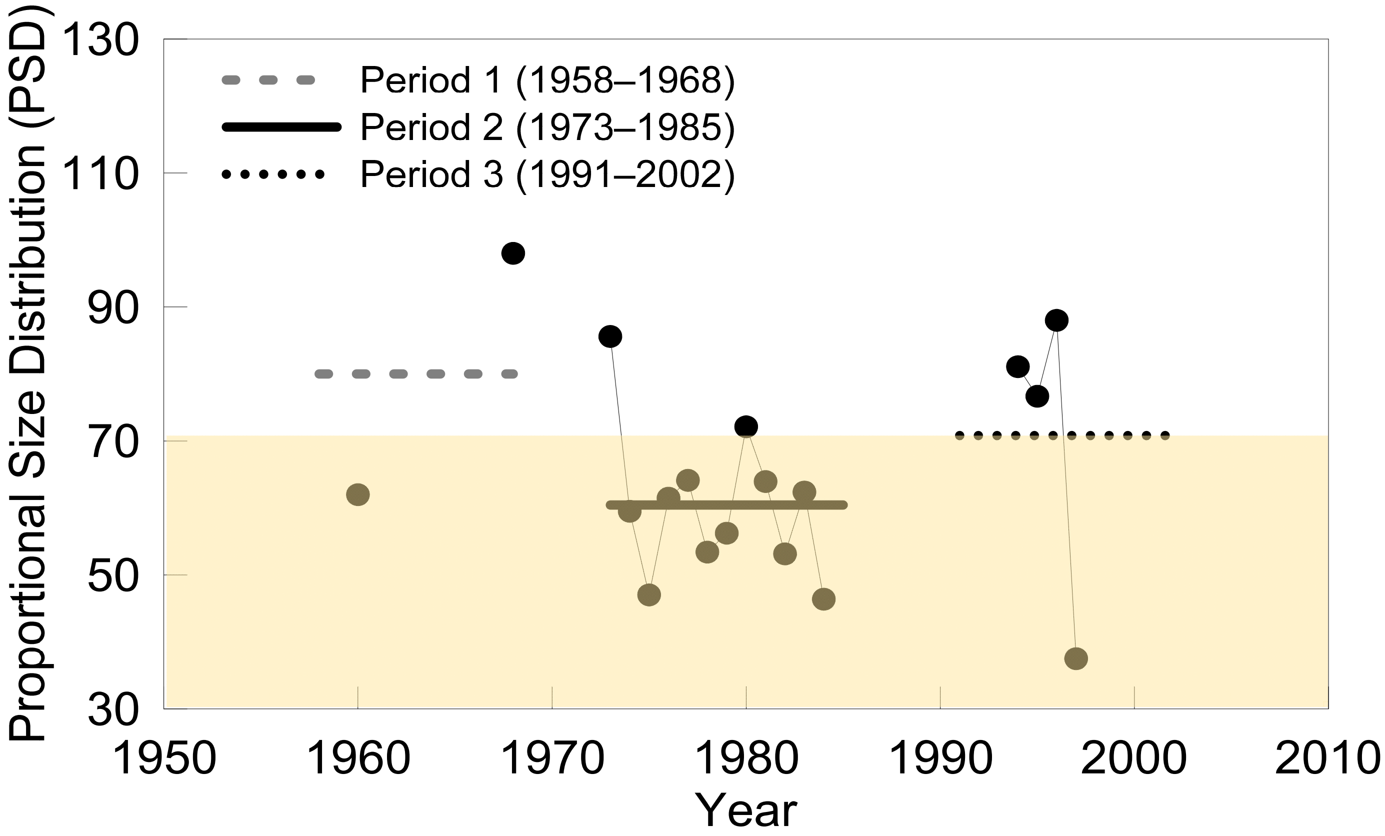
(b) Period 2 (1973–1985)

: high abundance in 1981



3. Proportional Size Distribution (PSD)

: stable recruitment variability in Period 2



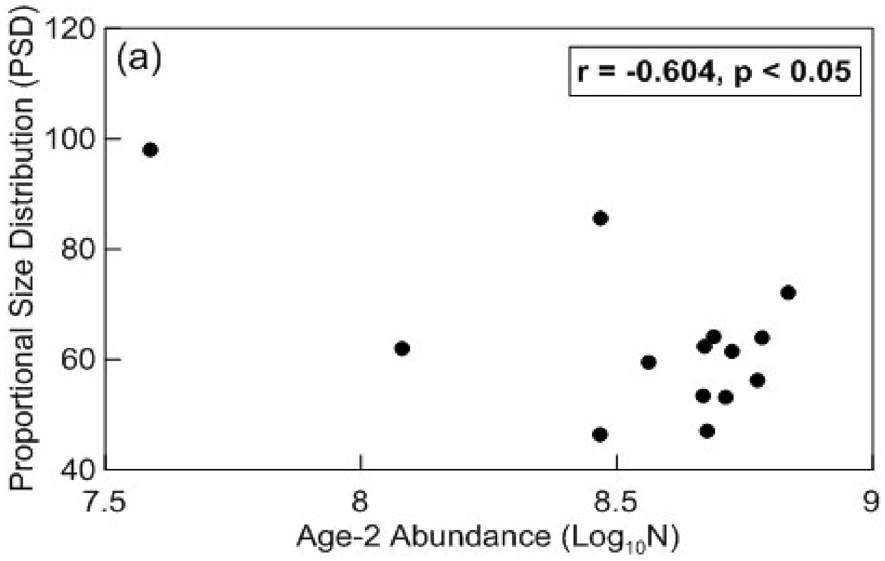
✓ Relationship between PSD and Age–2, 3 abundance in Period 1 and 2

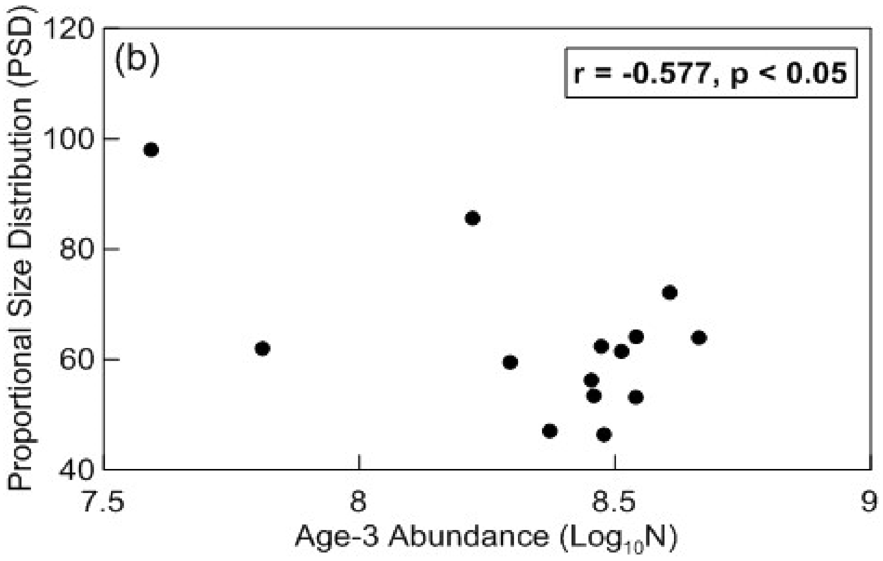
(a) PSD vs. age–2 abundance

: negative correlation

(b) PSD vs. age–3 abundance

: negative correlation

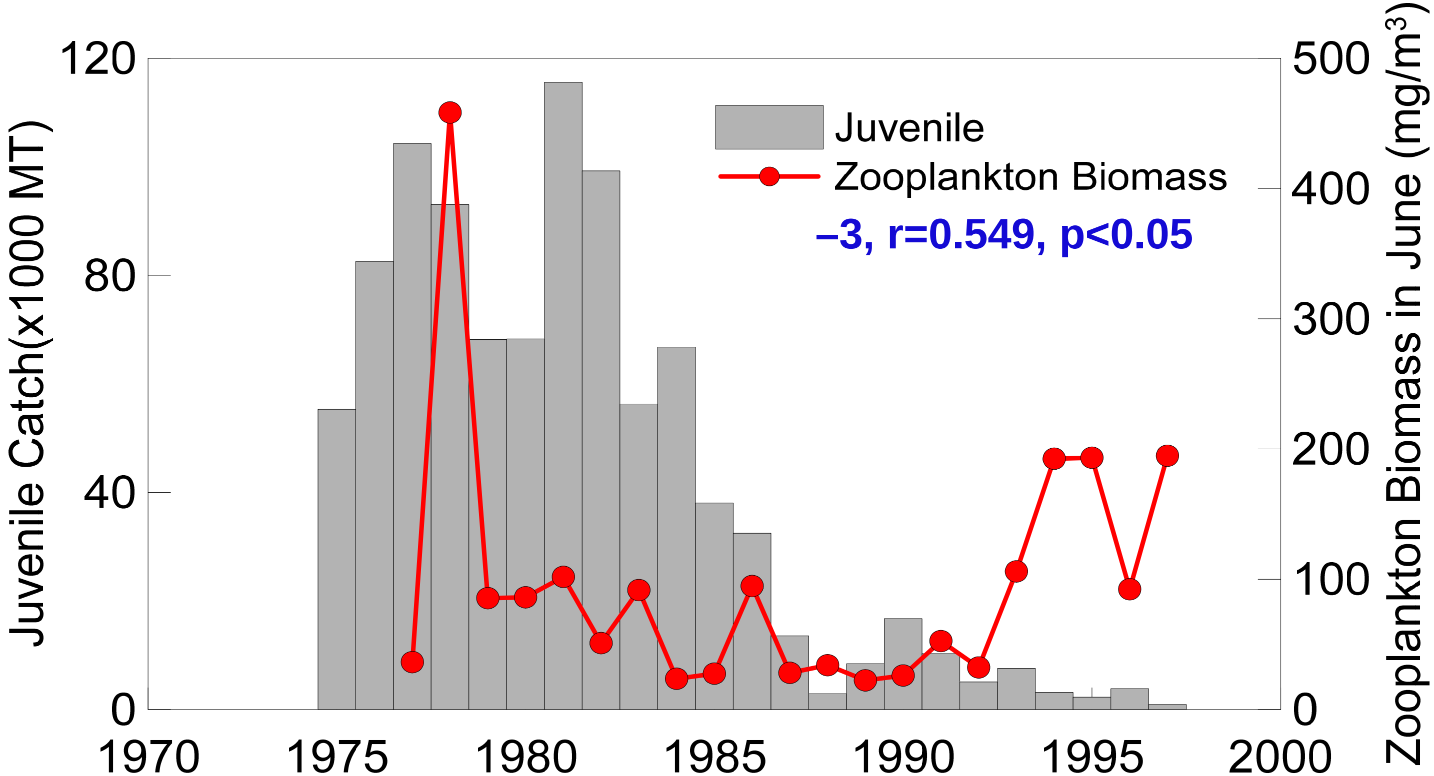




❖ Relationship between walleye pollock and environmental factors

1. Juvenile catch vs. Zooplankton biomass in June (1975–1997)

: positive correlation with a time lag of 3 years



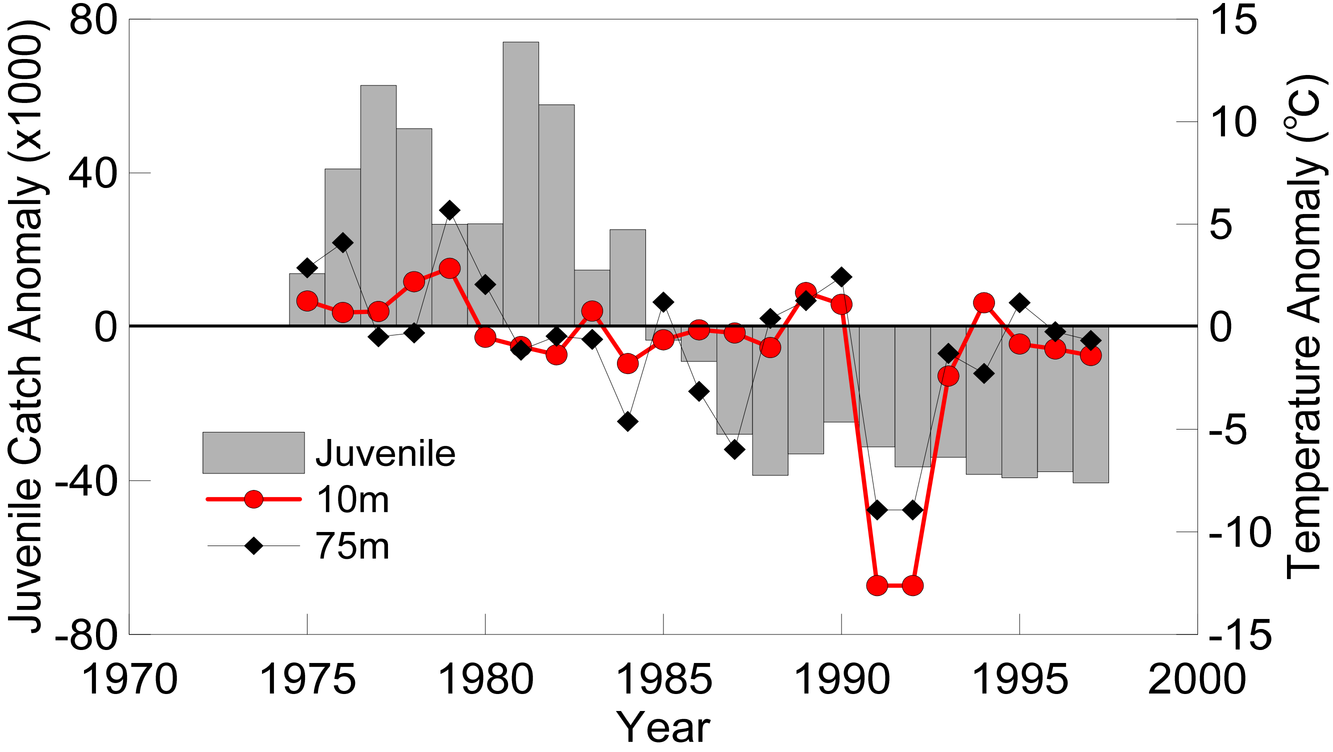
Zooplankton biomass affect change in walleye pollock catch

High/Low zooplankton biomass → High/Low walleye pollock catch

2. Juvenile catch vs. Seawater temperature in the spawning period

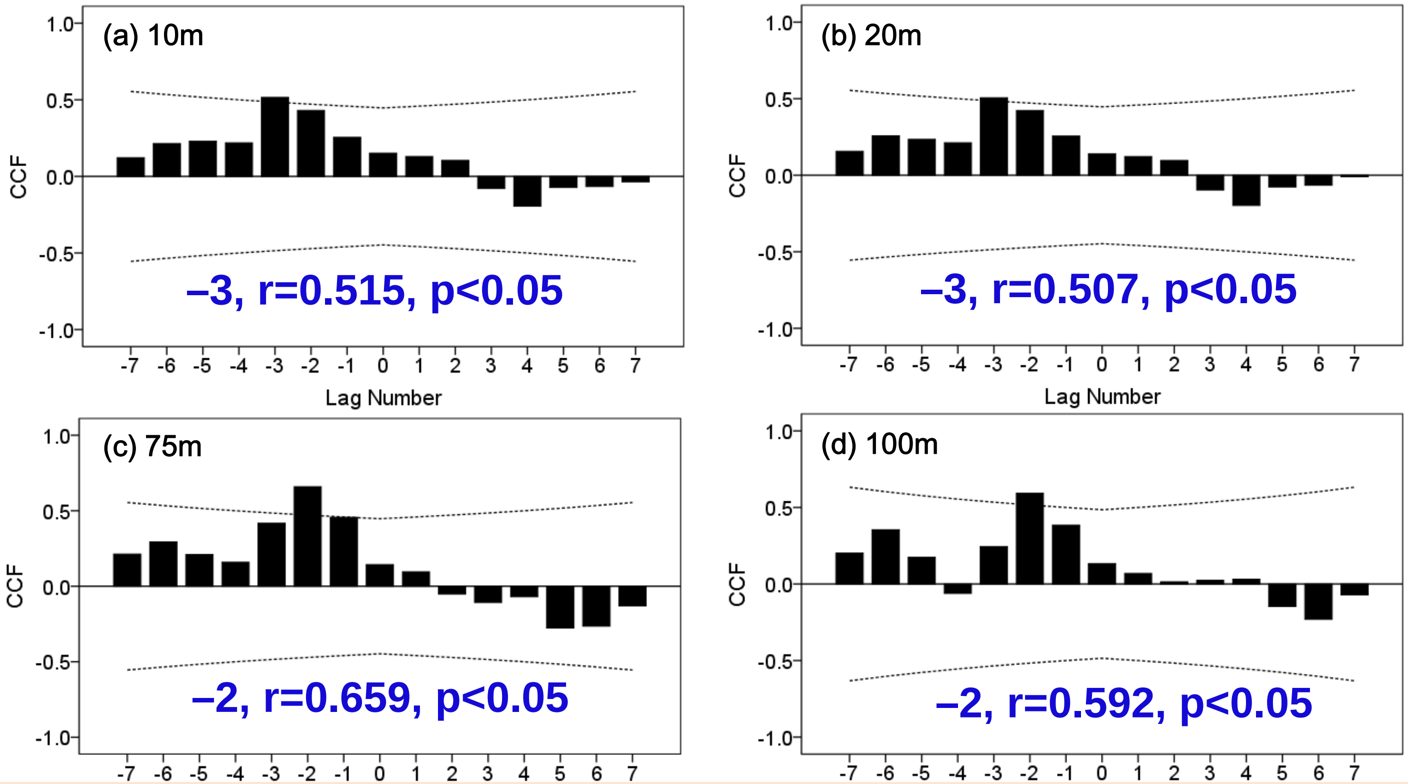
✓ Anomaly of juvenile catch and December temperature at 10m, 75m

: similar trend



2. Juvenile catch vs. Seawater temperature in December

: positive correlation with a time lag



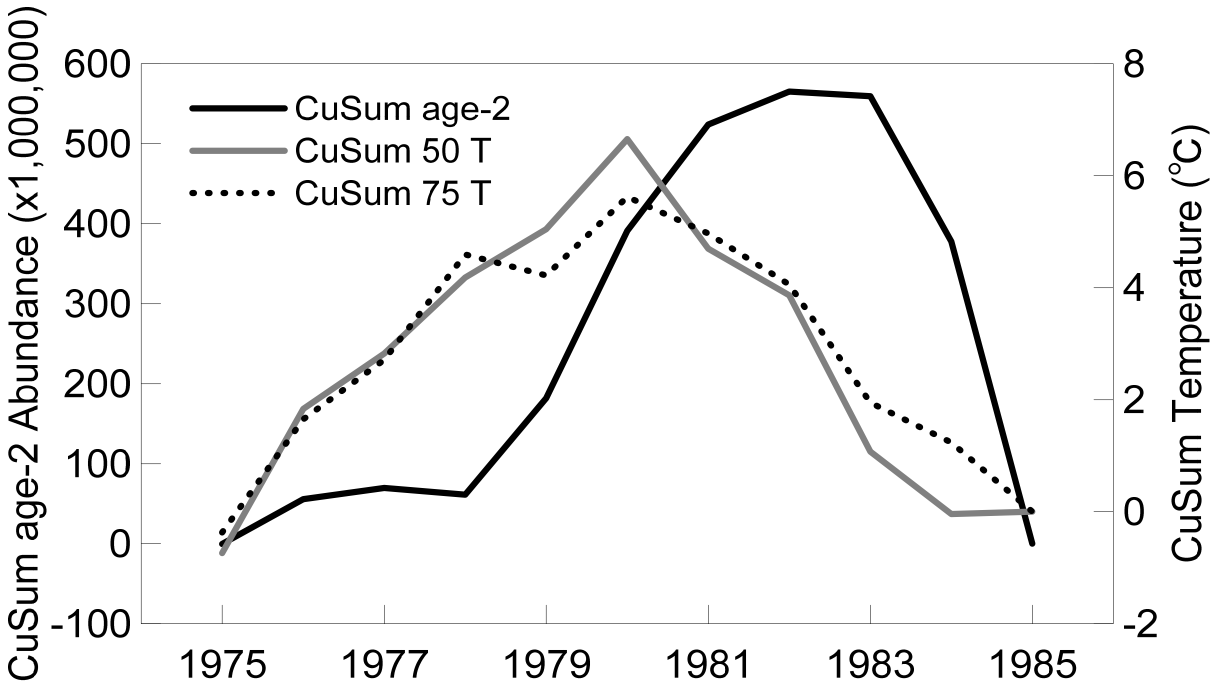
Seawater temperature affect change in walleye pollock catch

High/Low habitat temperature → High/Low walleye pollock catch in future

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

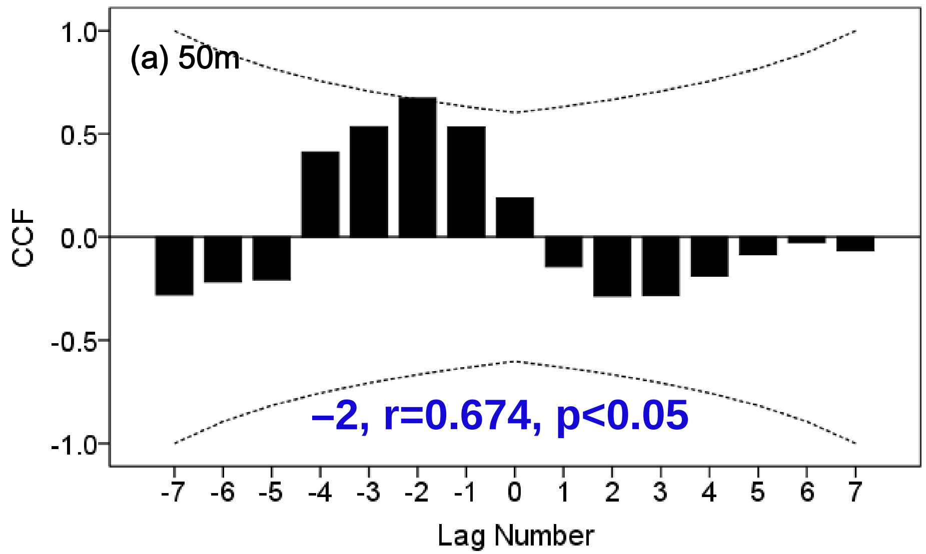
- ✓ Cumulative Sum (CuSum) curve of Age–2 abundance and April seawater temperature at 50 m, 75 m

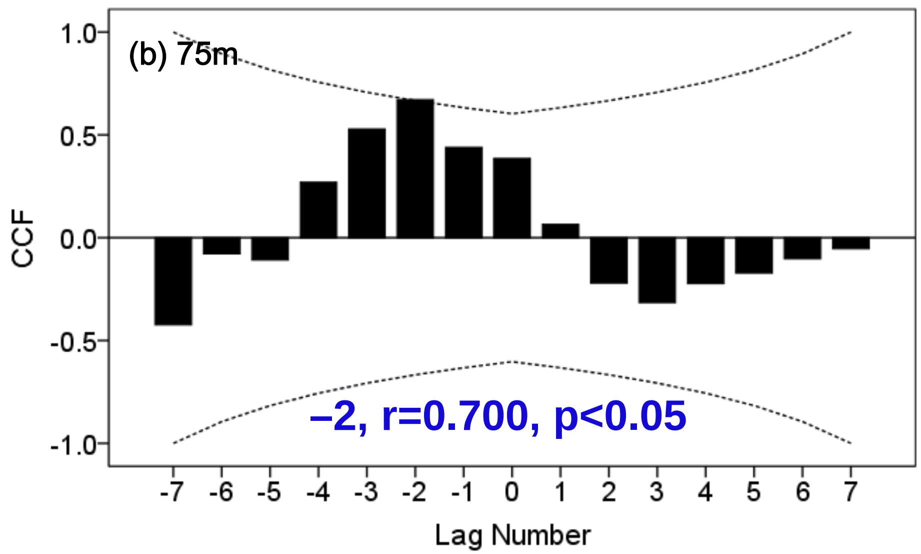
  : similar trend



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

: positive correlation with a time lag

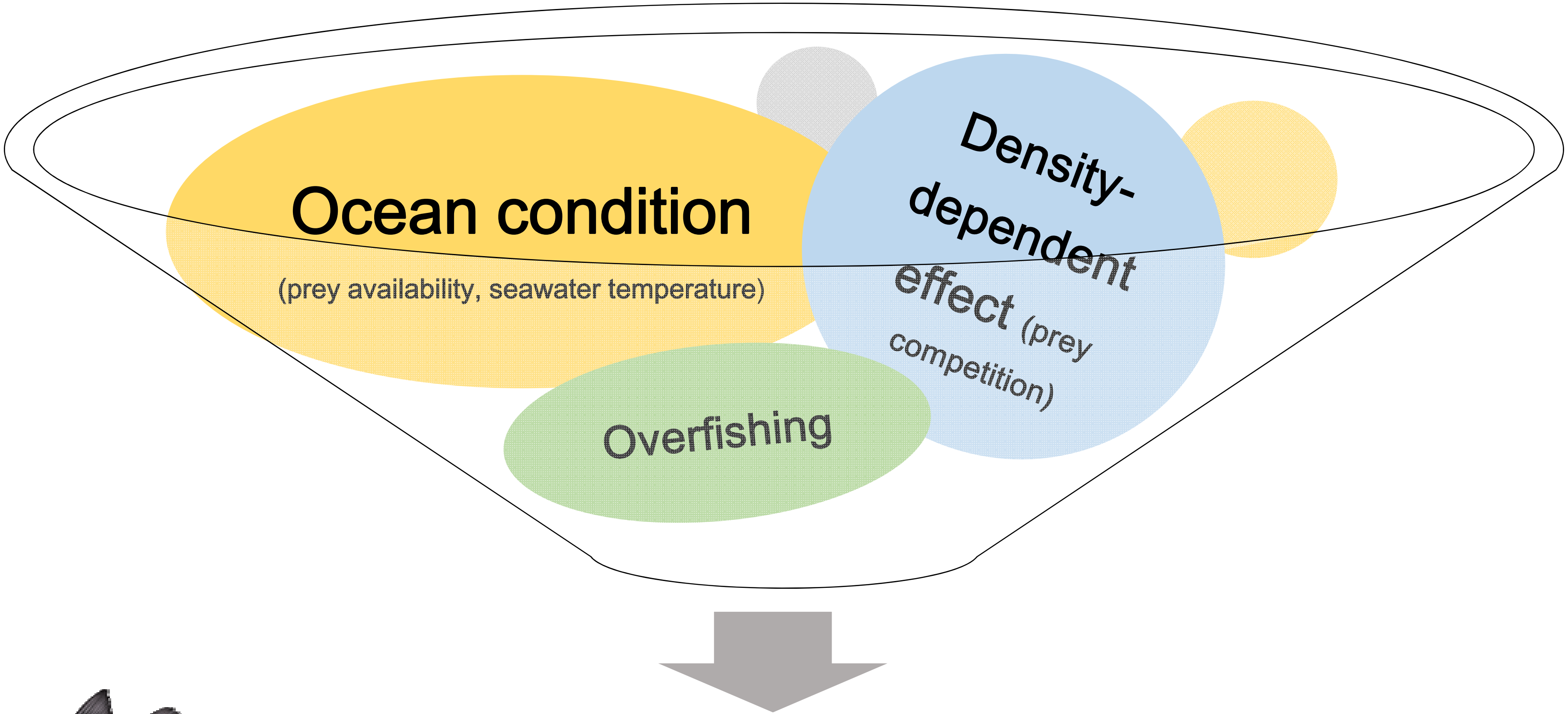




Seawater temperature affect age-2 abundance of walleye pollock

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

Conclusion



Variability in biological characteristics and recruitment