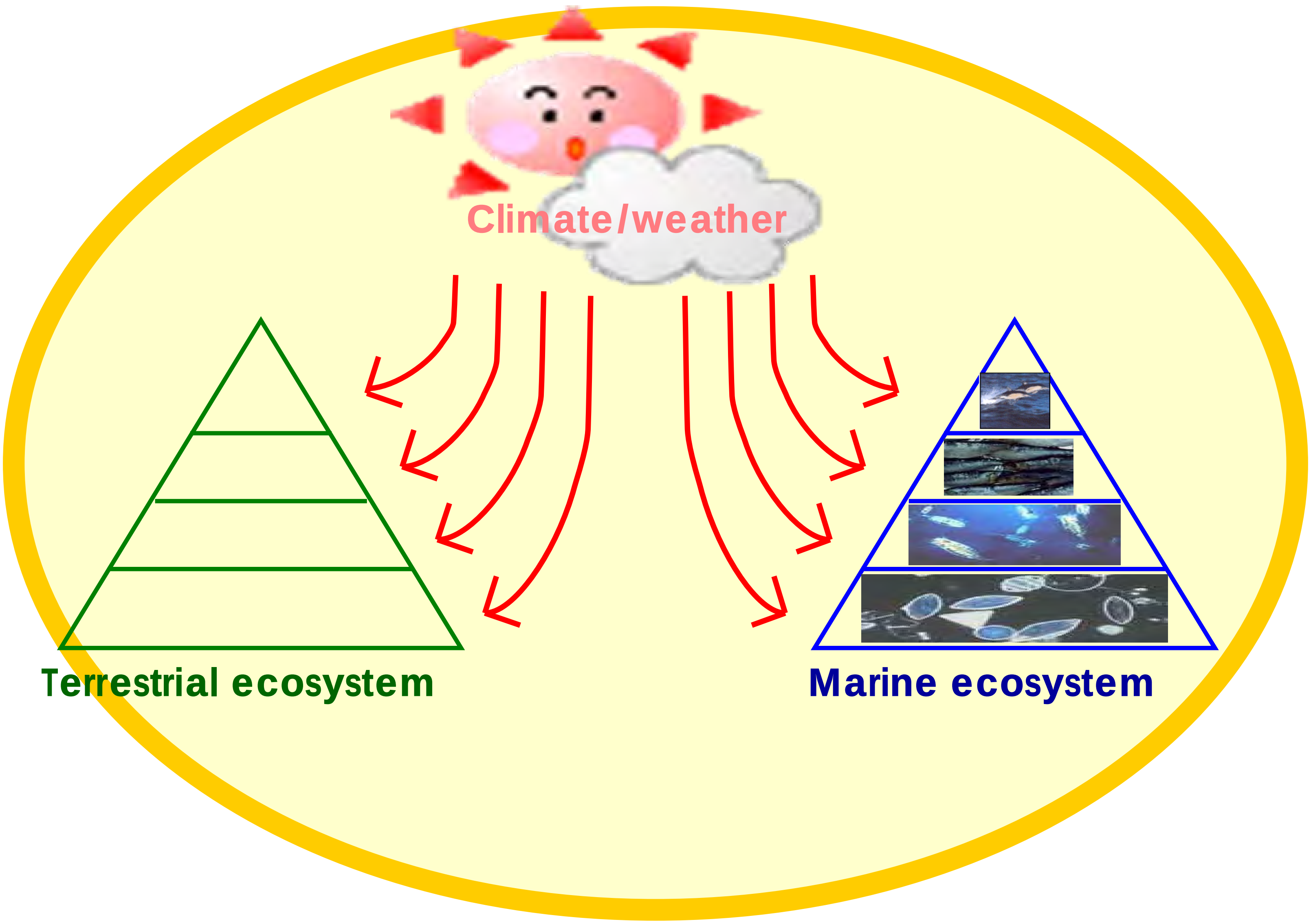
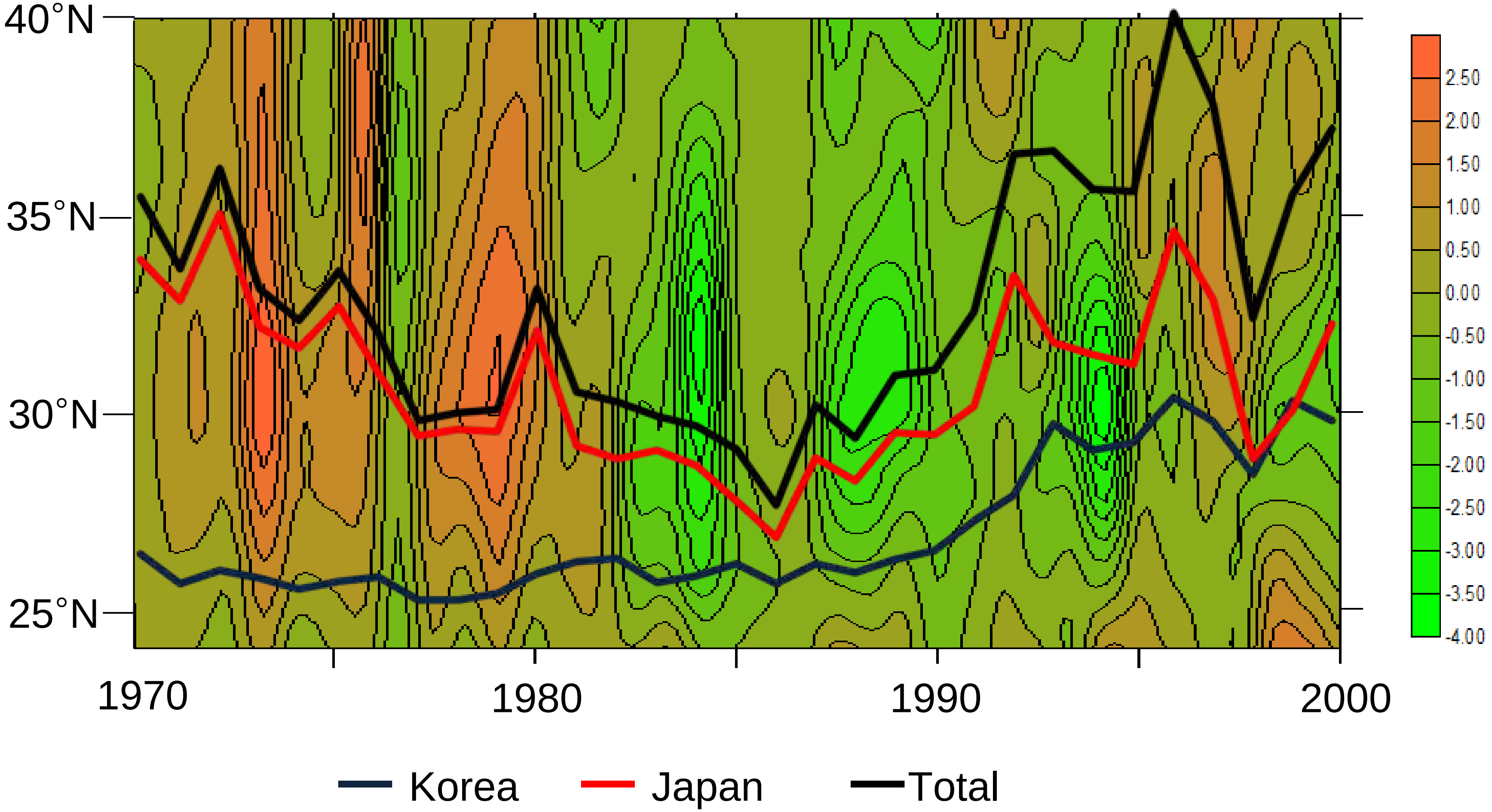

Climate/weather
Terrestrial ecosystem
Marine ecosystem

Effects of atmospheric and oceanographic variability on the common squid in Korean and Japanese waters

Suam Kim, Ana L. Rosa,
Sangwook Yeh, Chung-Il Lee,
Sukyung Kang, Sinjae Yoo,
Hyoun-woo Kang and Yasunori Sakurai

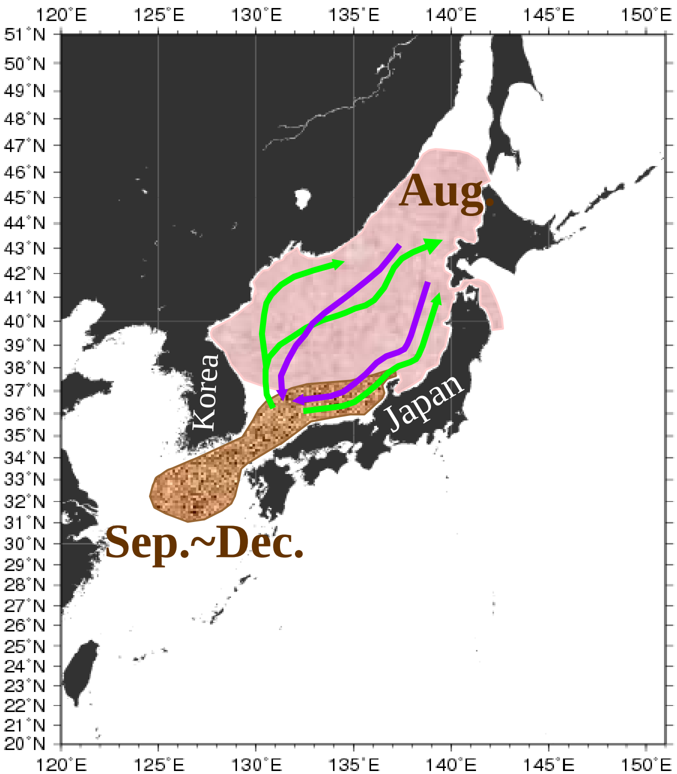
Distribution of common squid, *Todarodes pacificus*

Annual fluctuation in *Todarodes pacificus* catches of Korea and Japan during the last three decades

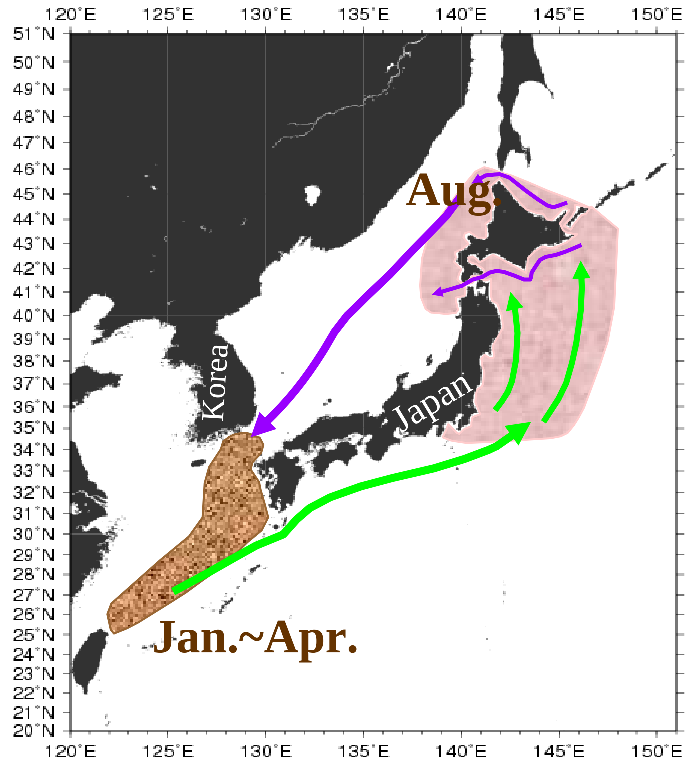


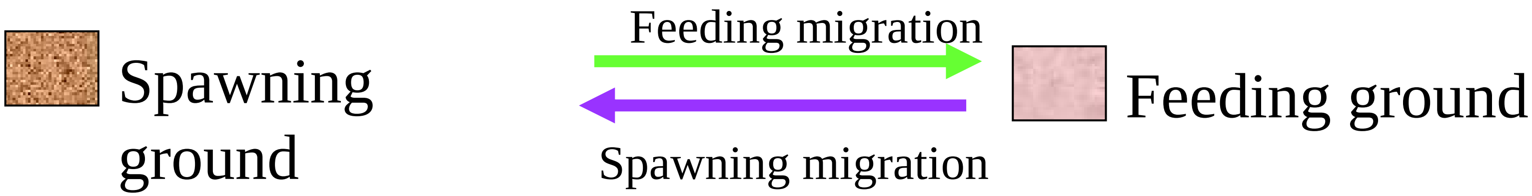
Annual cohorts: autumn, winter and summer

Autumn

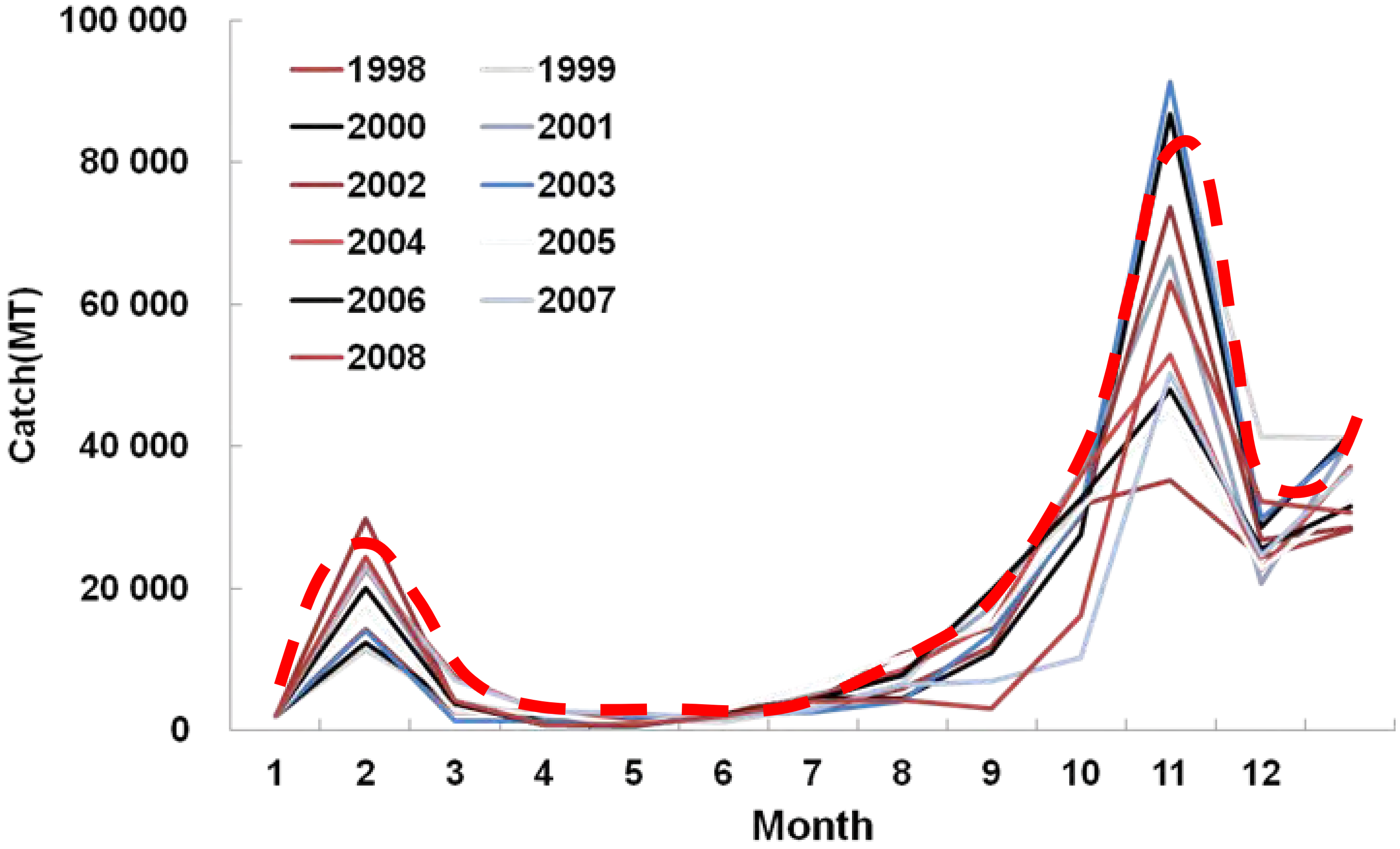


Winter

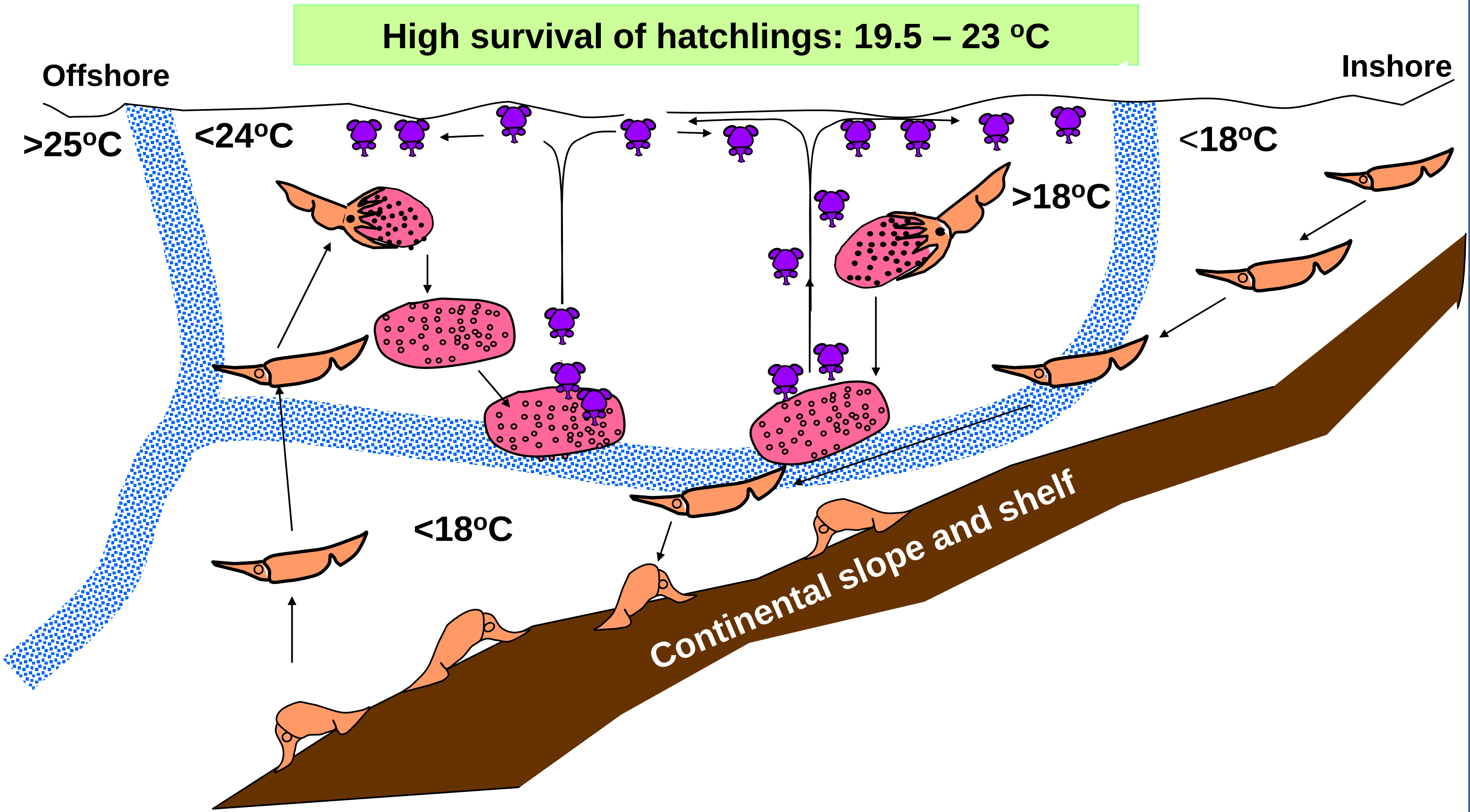




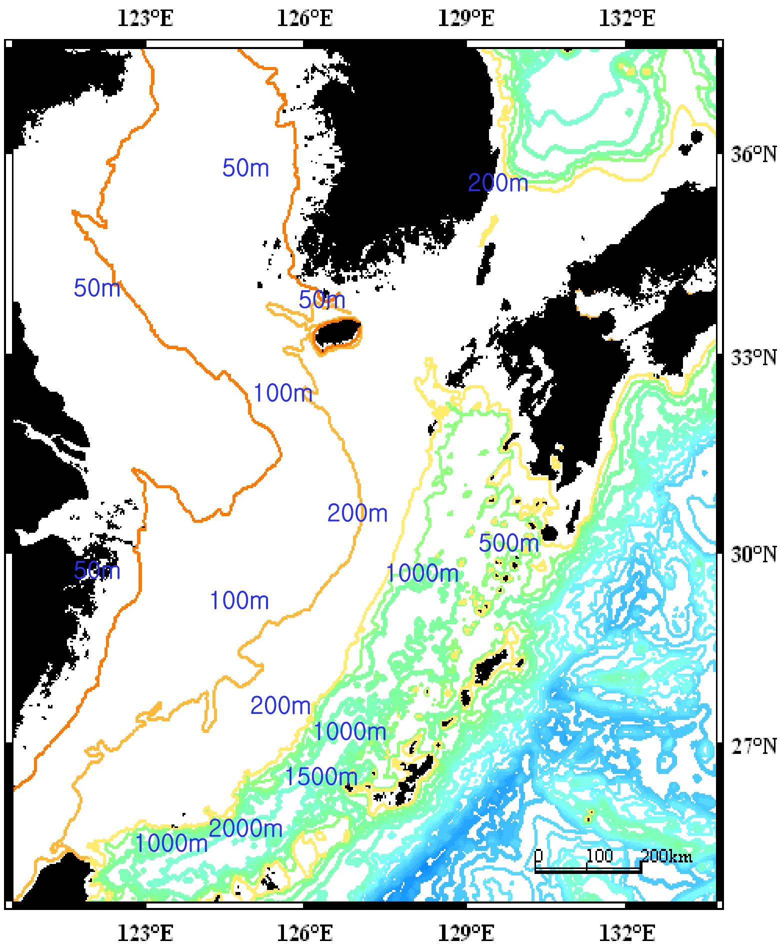
Monthly catch of common squid by Korean fishery

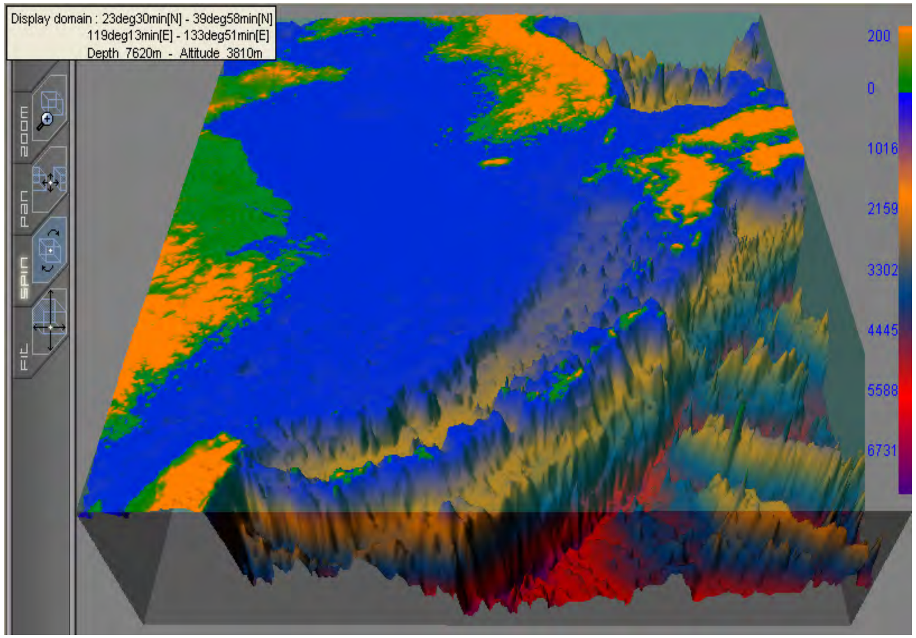


Schematic diagram of EHL common squid



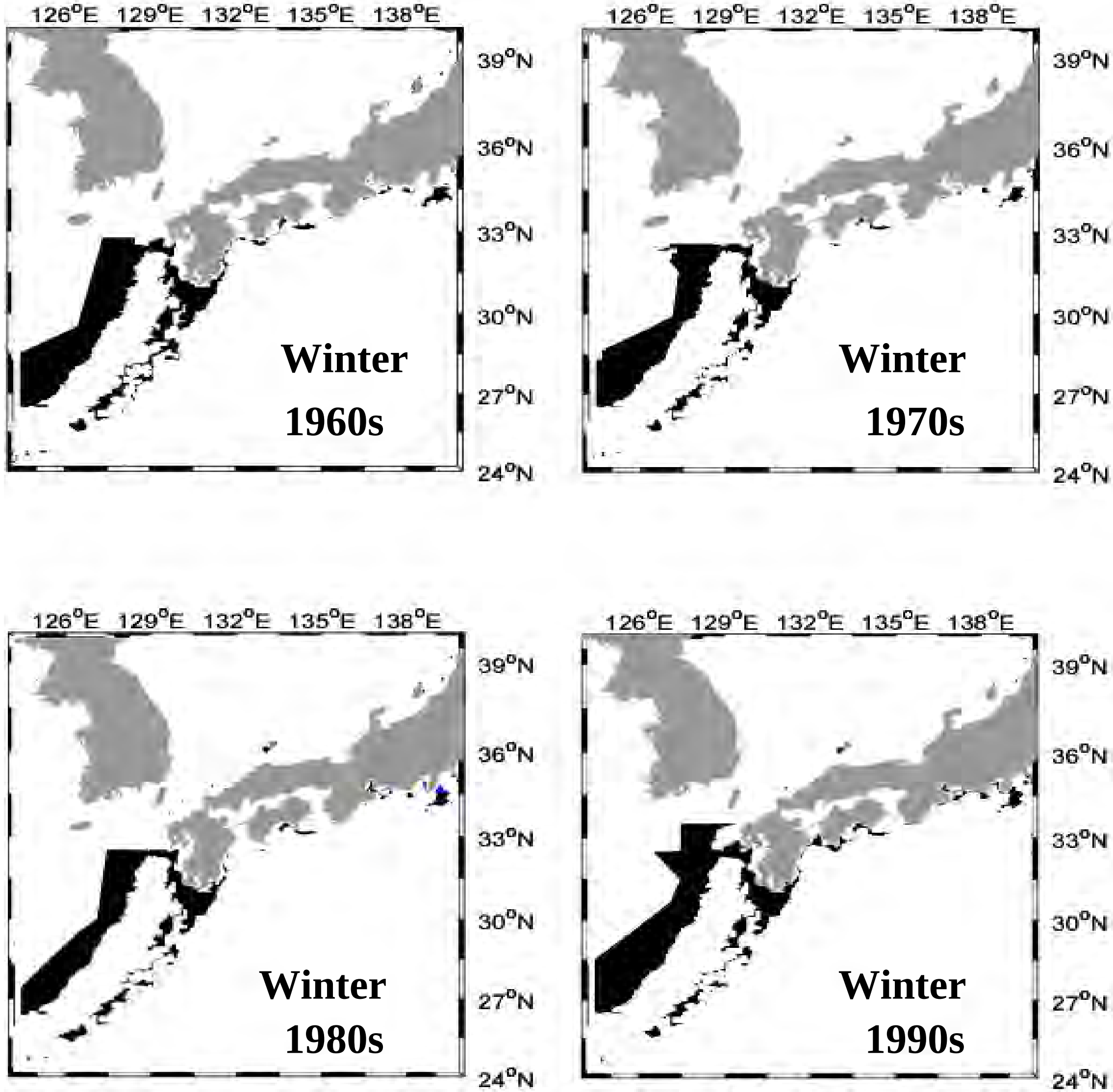
Topography





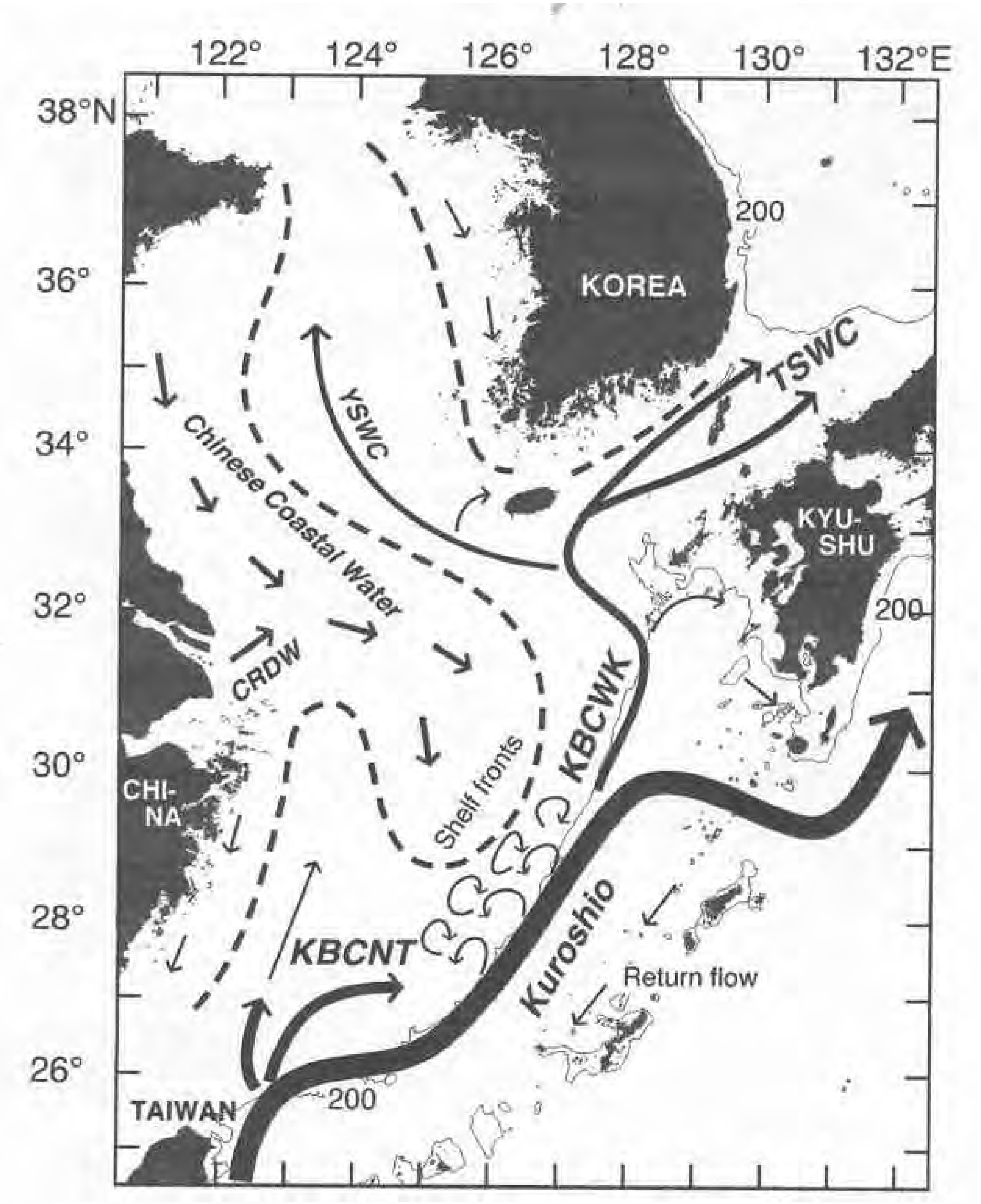
Bathymetry data from MIRINE GIS (ESL)

We assumed that appropriate depth of spawning is 100-500m (from Sakurai *et al.*, 2000).



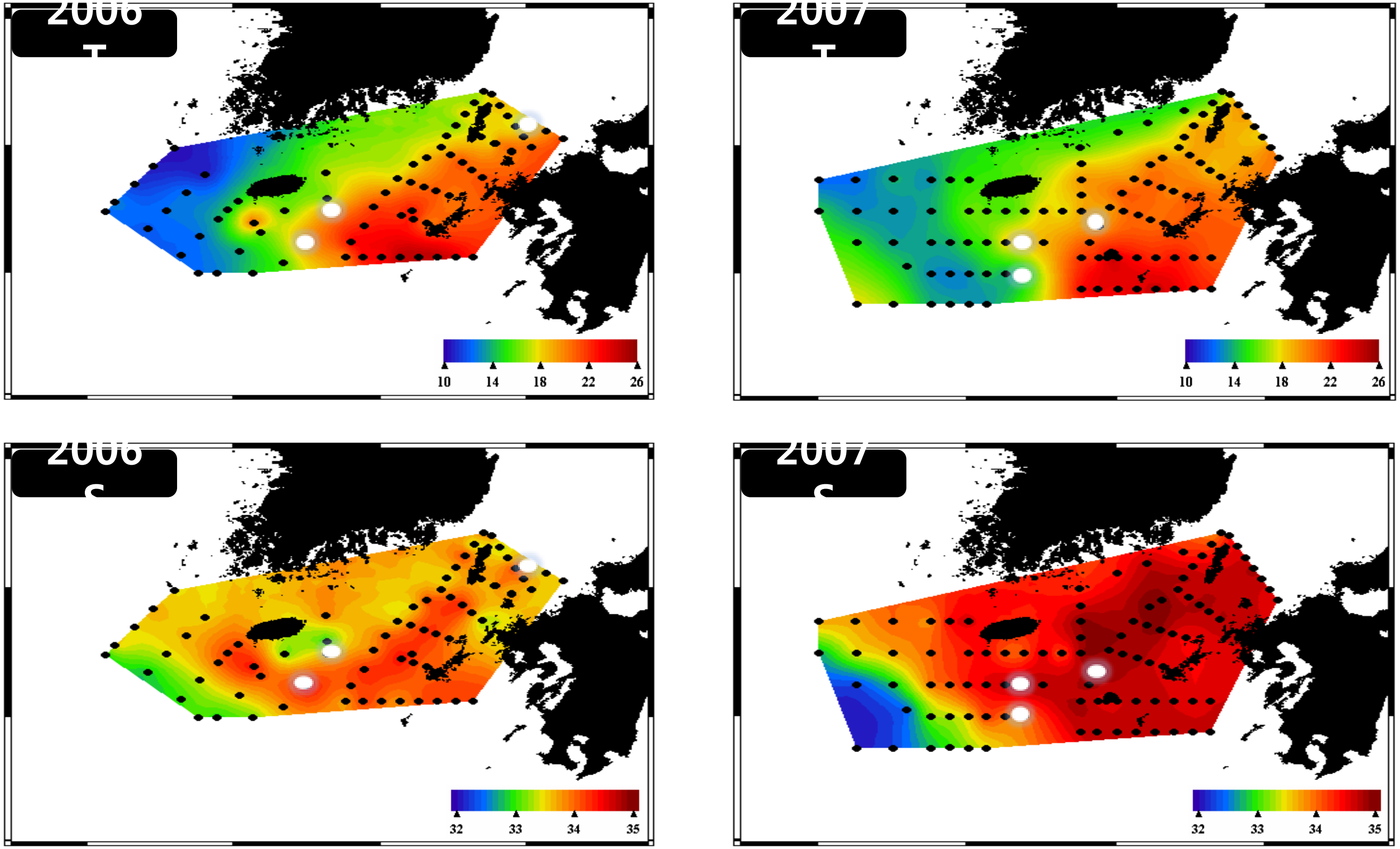
Example of inferred winter spawning areas of *Todarodes pacificus* around the Korean Peninsula based on mean water temperature (15-23℃) over the continental shelf and slope ranging 100-500 m (Sakurai, 2000).

Currents in the East China Sea



Horizontal circulation patterns after Kondo (1985), Ichikawa and Beardsley (2002), and Lie and Cho (2002).

Temperature & salinity at high larval stations



What factors control the recruitment of common squid?

1. **Global-scale climate change**
2. **Seawater properties as well as physical characteristics in spawning area**
3. **Wind and current pattern during the drift period**
4. **Plankton productivity in nursery area**

Objectives and implication

This research aims to identify the most influential controlling factors for squid recruitment.

The output of this research will be used to

1) understand the mechanism and effects of atmospheric and oceanographic variability on the common squid, and

2) make the basis for the proper management in conjunction with climate/ecosystem variability.

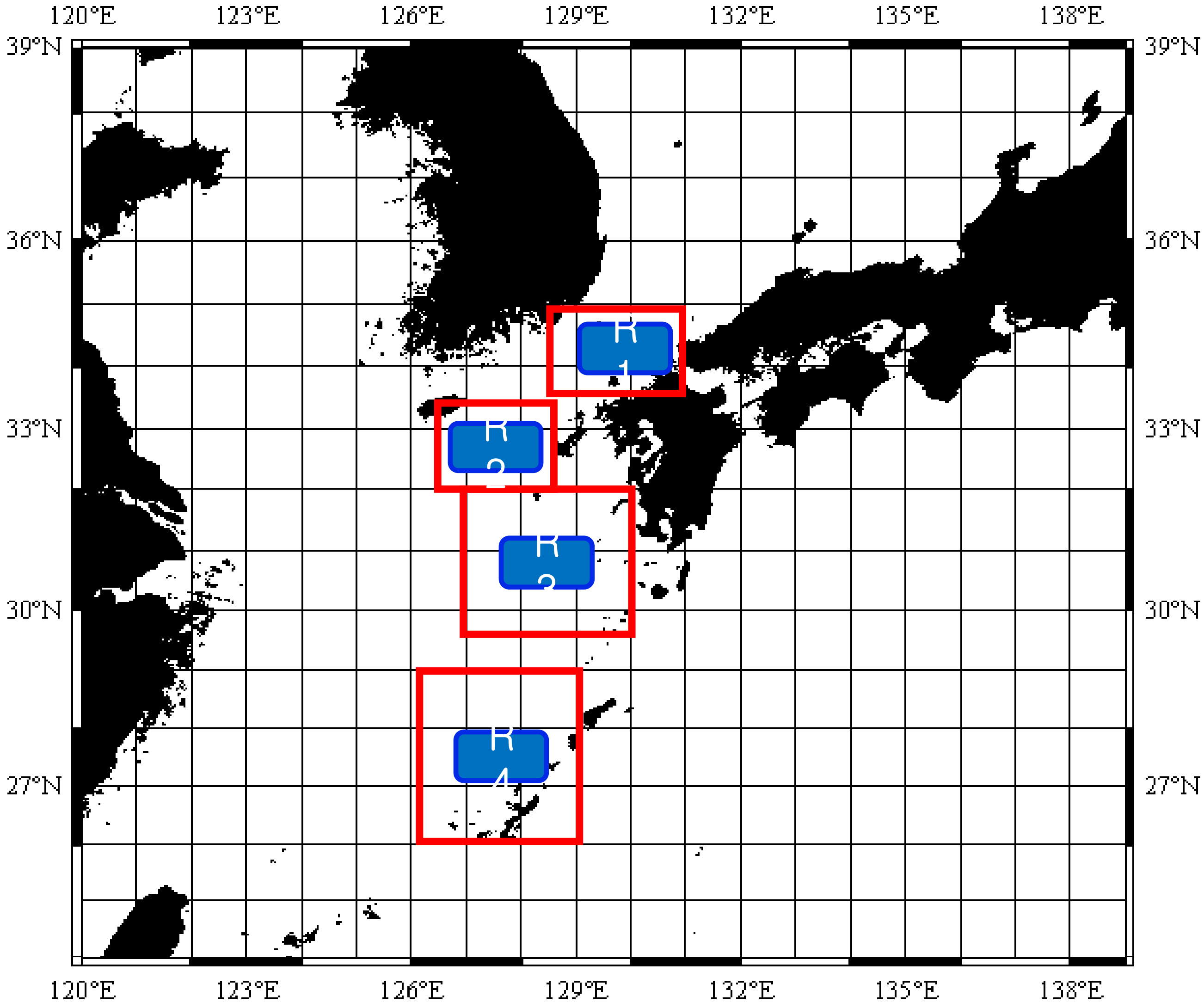
Data

1) Environmental data: observed (KODC, JODC, Hadley) and assimilated data (SODA data)

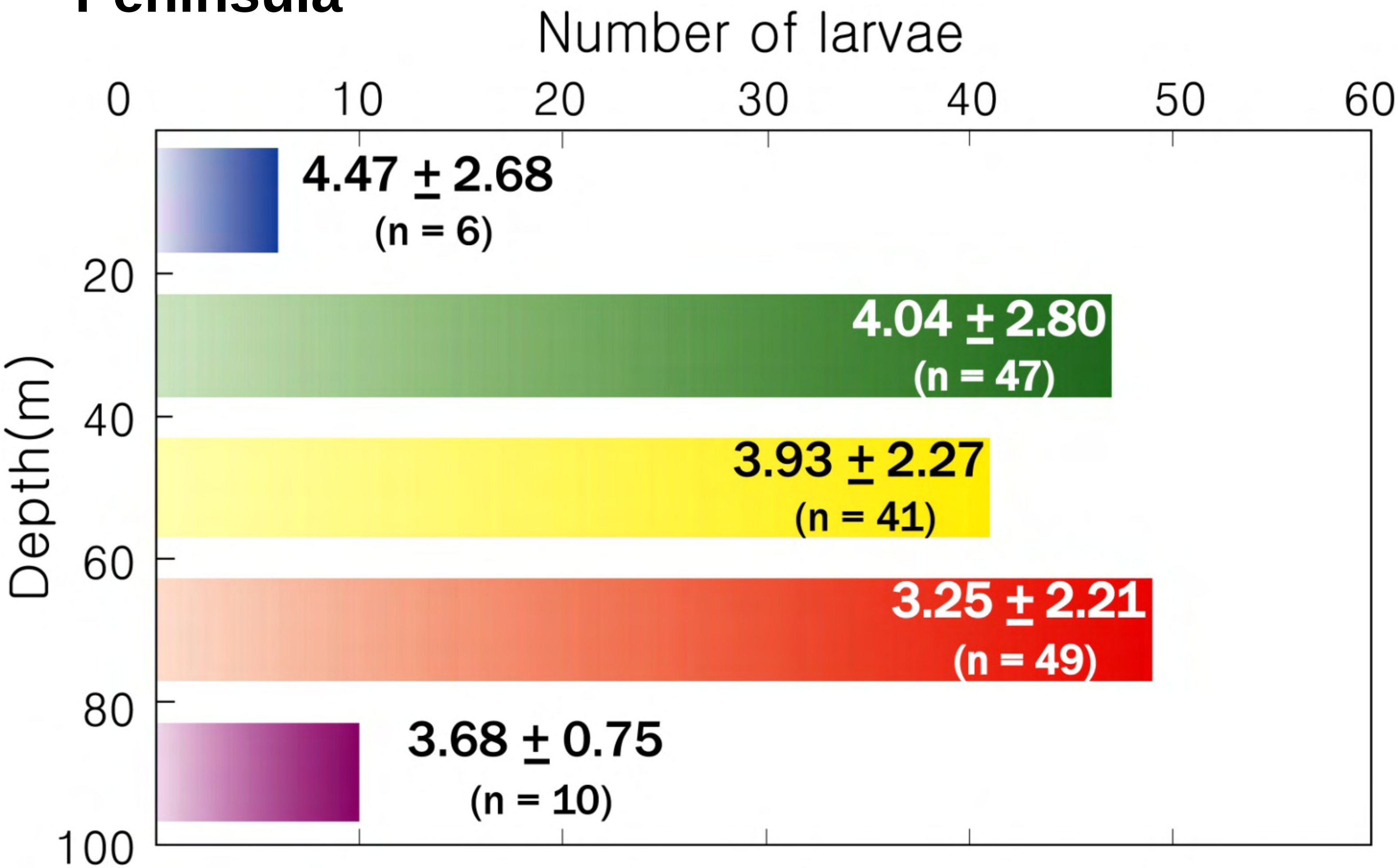
2) Biological information: satellite, net sampling

3) Fisheries information: FAO data bank, and domestic statistic book

Study areas

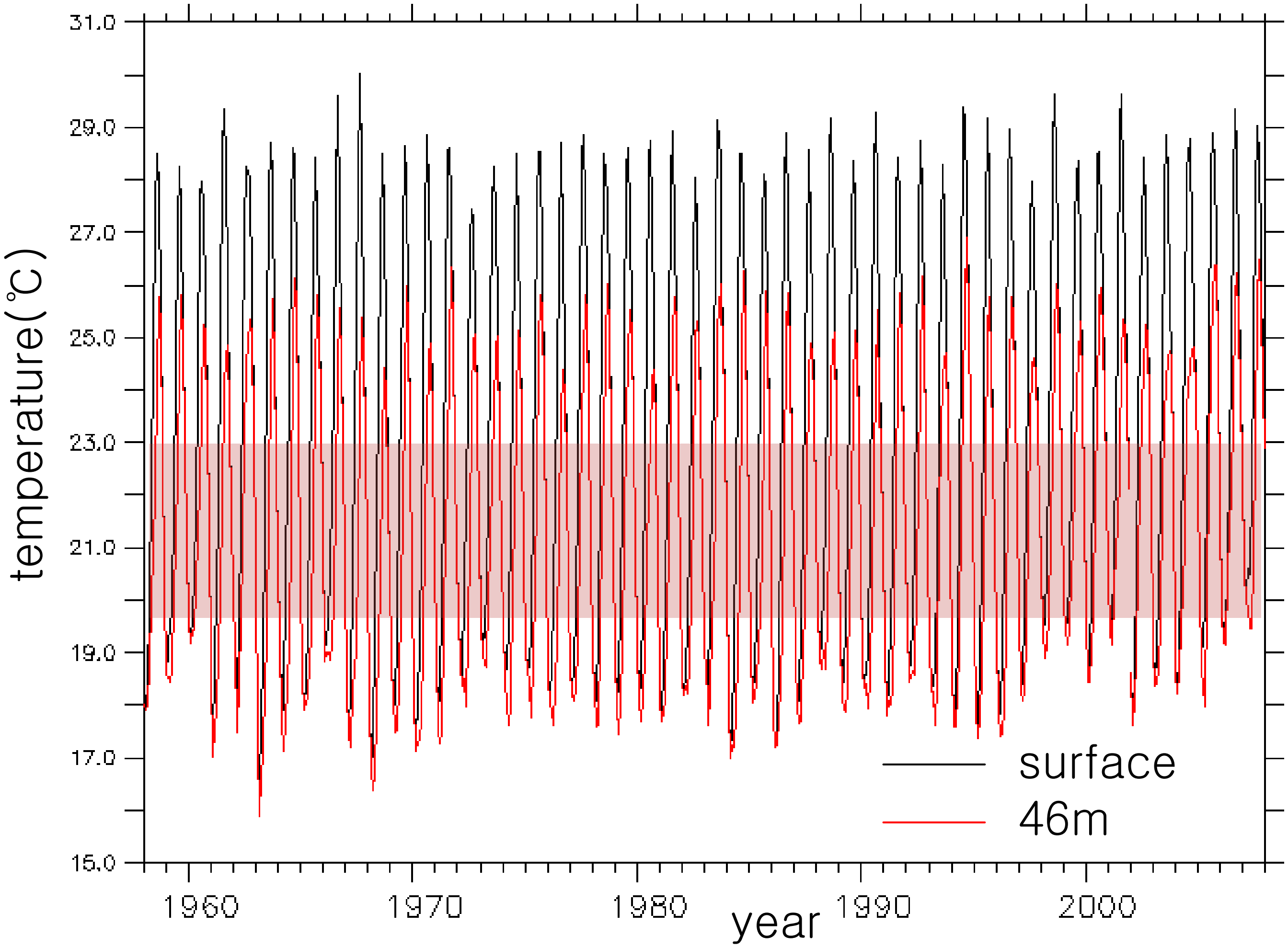

120°E
123°E
126°E
129°E
132°E
135°E
138°E
39°N
36°N
33°N
30°N
27°N
R1
R2
R3
R4

Vertical distribution of common squid paralarvae off the southern coast of Korean Peninsula



Larval length at each layer was shown

SODA temperature at surface and 46 m

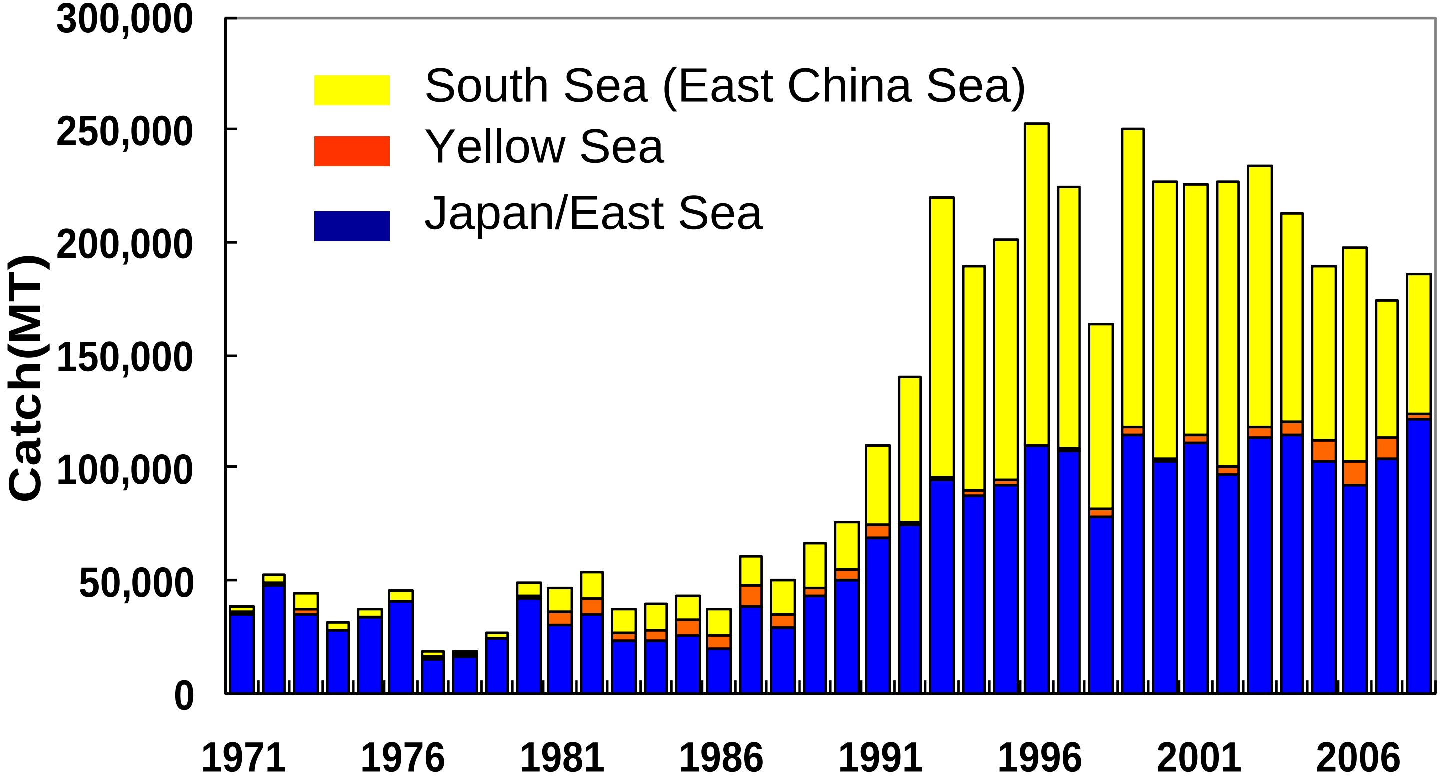


Data source: Simple Ocean Data Assimilation (SODA)

Question 1

Do the large- and meso-scale changes in climate and ocean effect on the fluctuation of squid populations in the northwestern Pacific?

Trend of squid catch in Korea

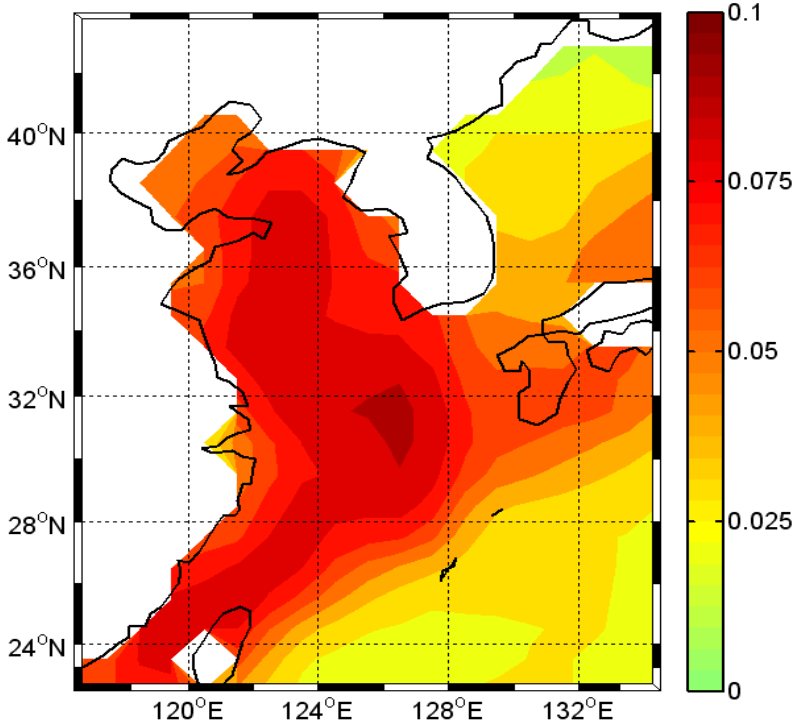


%	Japan/East Sea	Yellow Sea	East China Sea
71-90	72.4	7.6	19.9
90-'08	49.2	2.1	48.7

Correlation between climate indices and squid catch

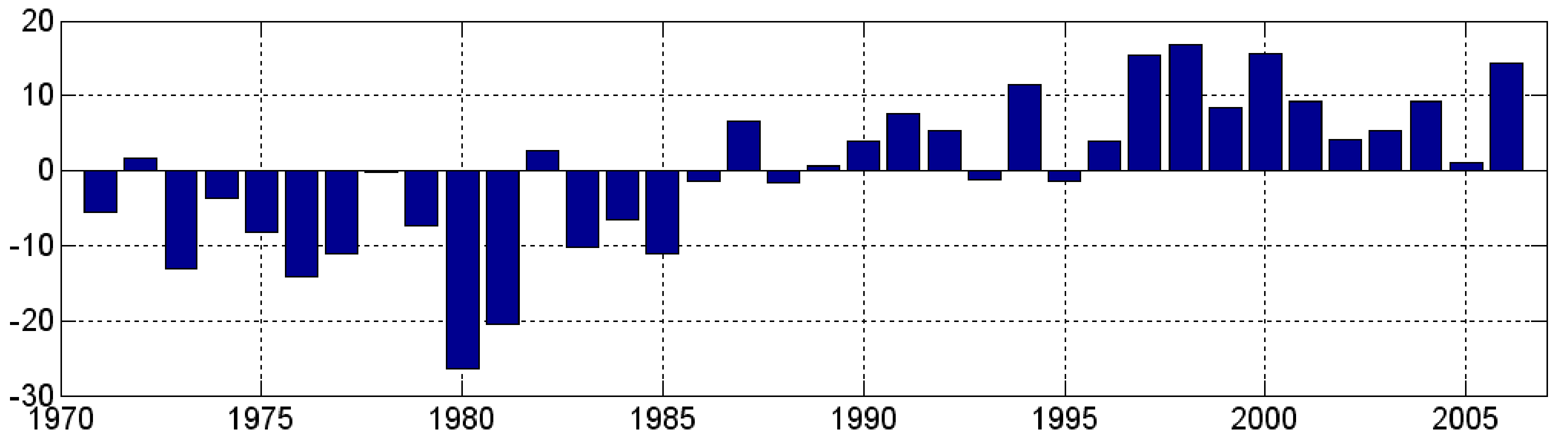
	PDO	AOI	NPI	ALPI	AFI	SOI
Korea	.061	.116	-.159	.177	.112	-.121
Japan	-.528**	.089	.195	-.258	-.467**	.291
Total	-.294	.126	.026	-.55	-.225	.110

EOF analysis with SST

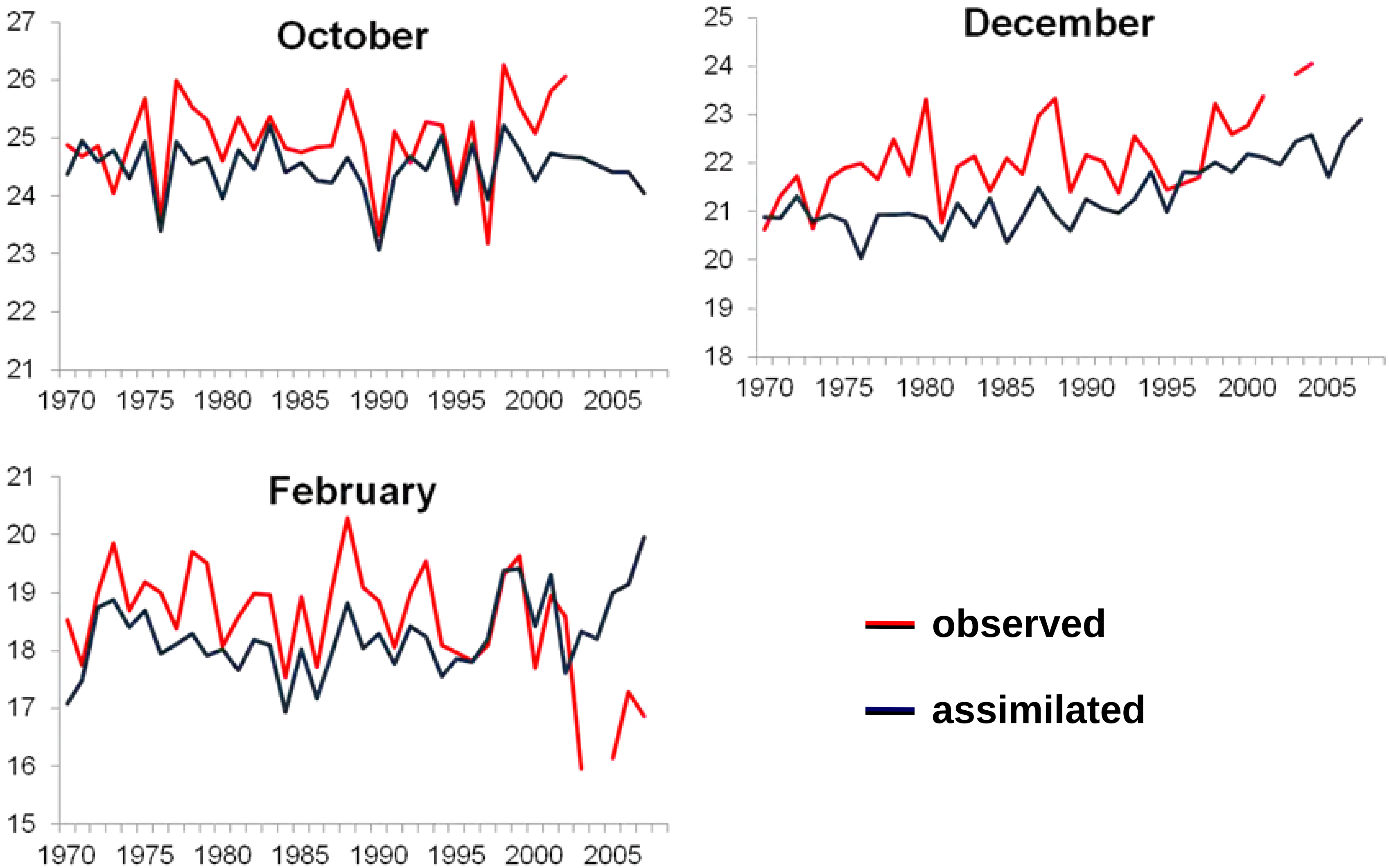


Leading EOF

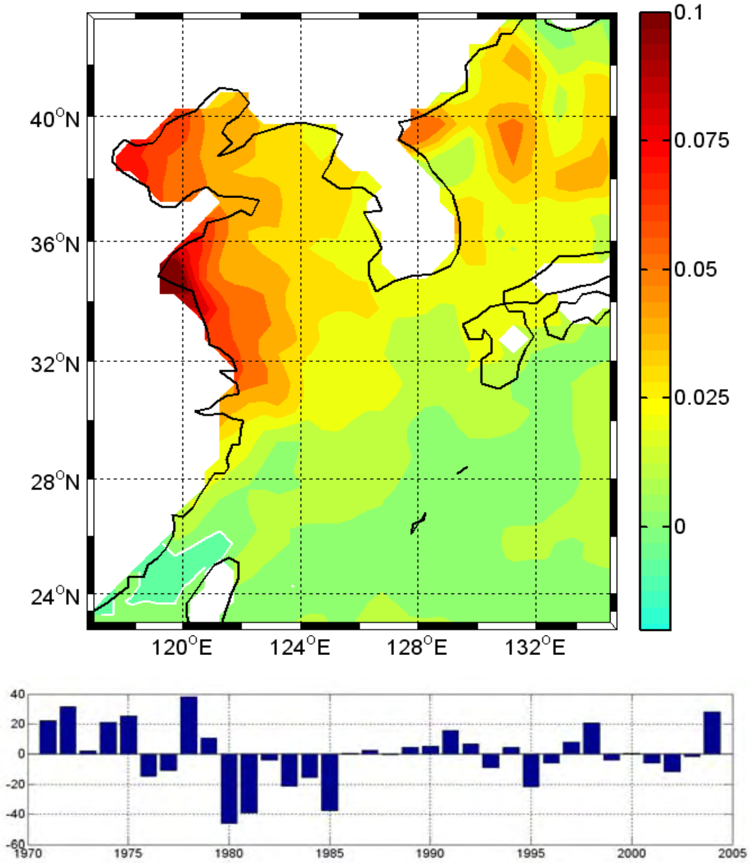
- **HadSST**
- **117-134.5˚E, 23-43˚N**
- **1971-2006 (DJF)**

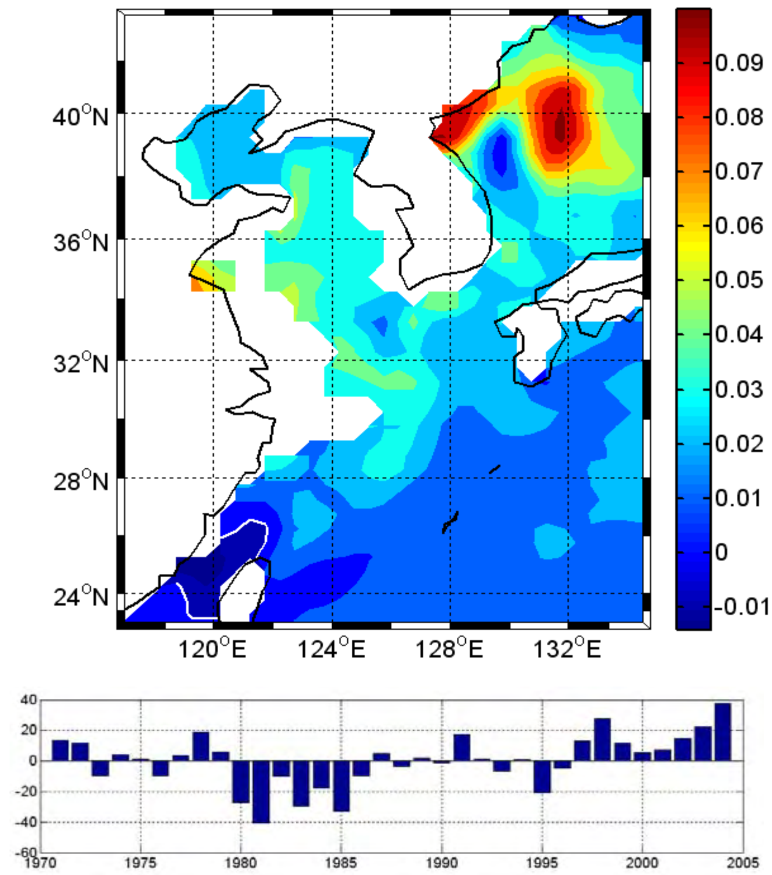


Comparison of observed and assimilated SODA Temperatures at 50 m in R3



EOF analysis with SODA temperatures





Leading EOF

- SODA, SST

- 117-134.5˚E, 23-43˚N

- 1971-2004 (DJF)

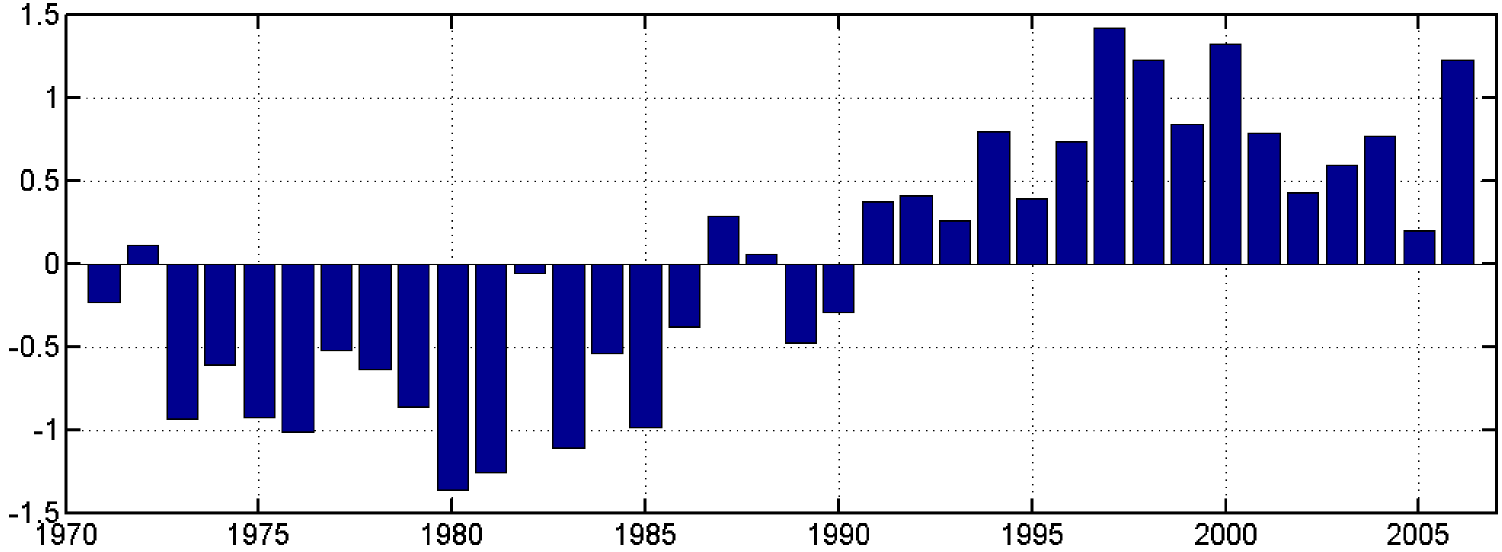
Leading EOF

- SODA, 50 m

- 117-134.5˚E, 23-43˚N

- 1971-2004 (DJF)

Leading EOF with SODA monthly temperature at 46.6 m in R3



- R3 (127-130˚E, 29.5-32˚N)

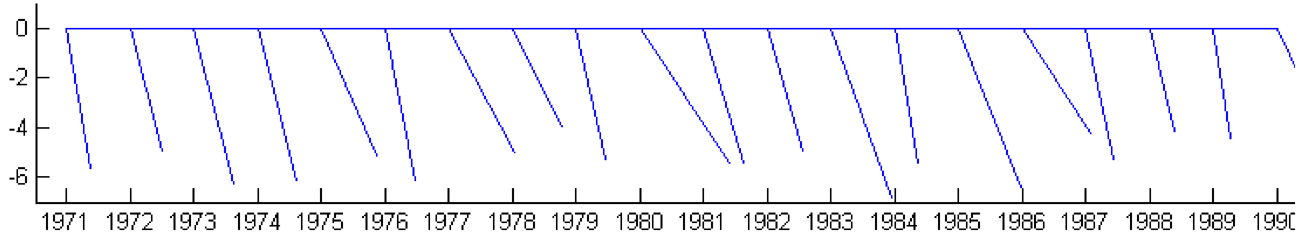
- 1971-2008 (DJF)

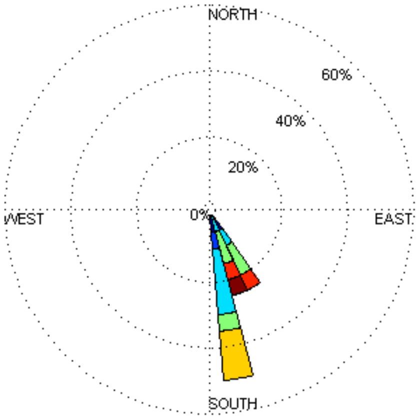
Question 2

Does the recruitment of common squid have a significantly negative correlation with wind velocity and Mixed Layer Depth (MLD) in spawning ground?

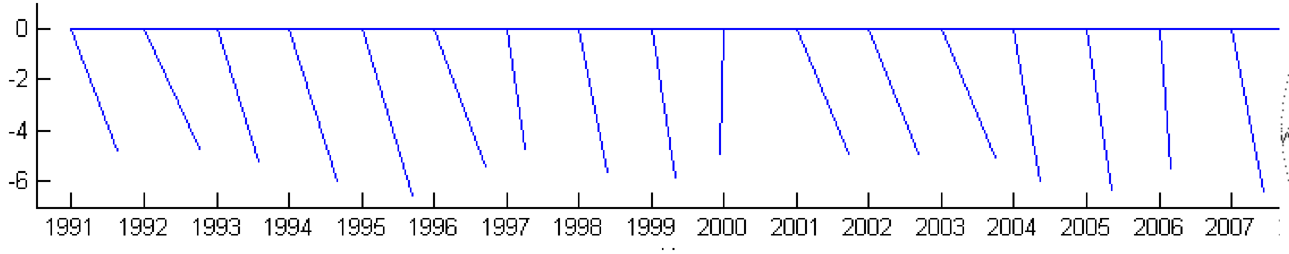
Monthly winter wind at 1000 hPa during 1971-2008

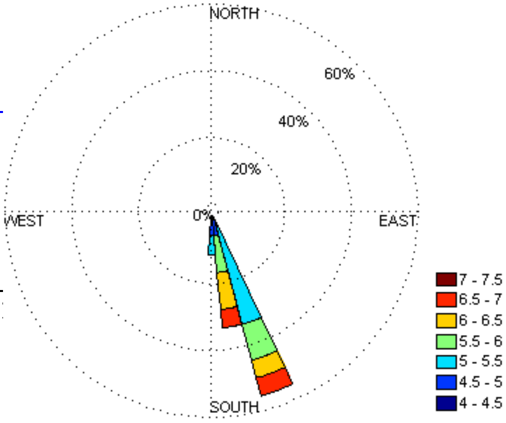
1971-1990:



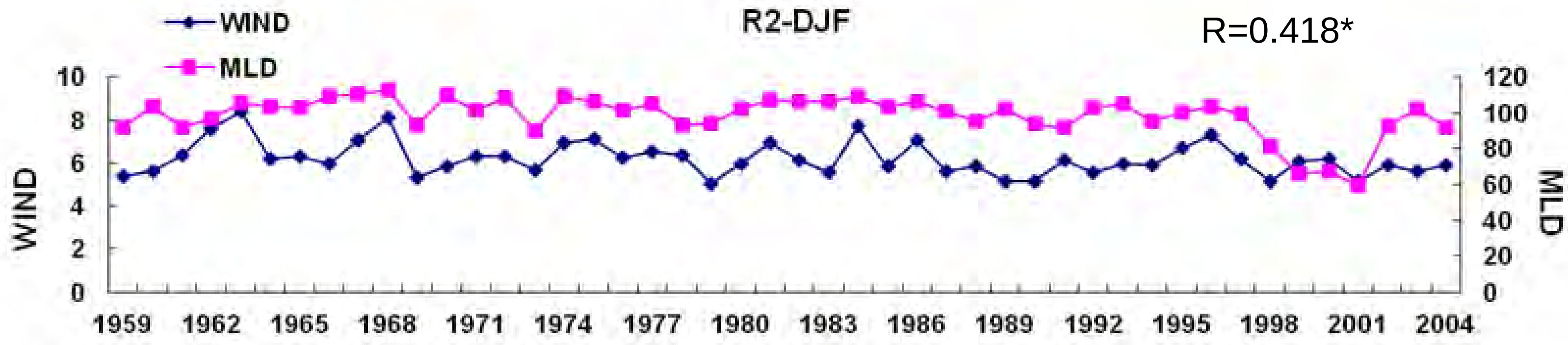


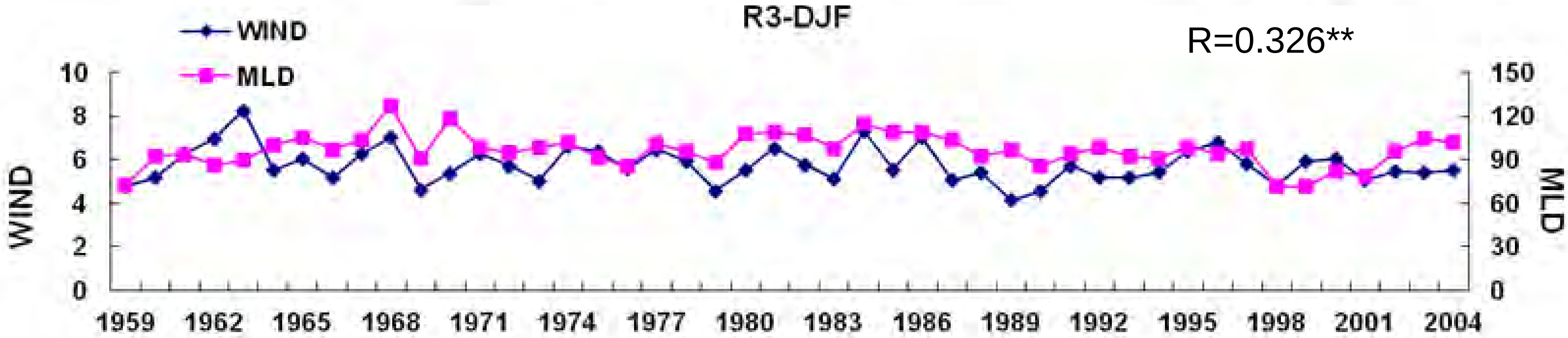
1991-2008:

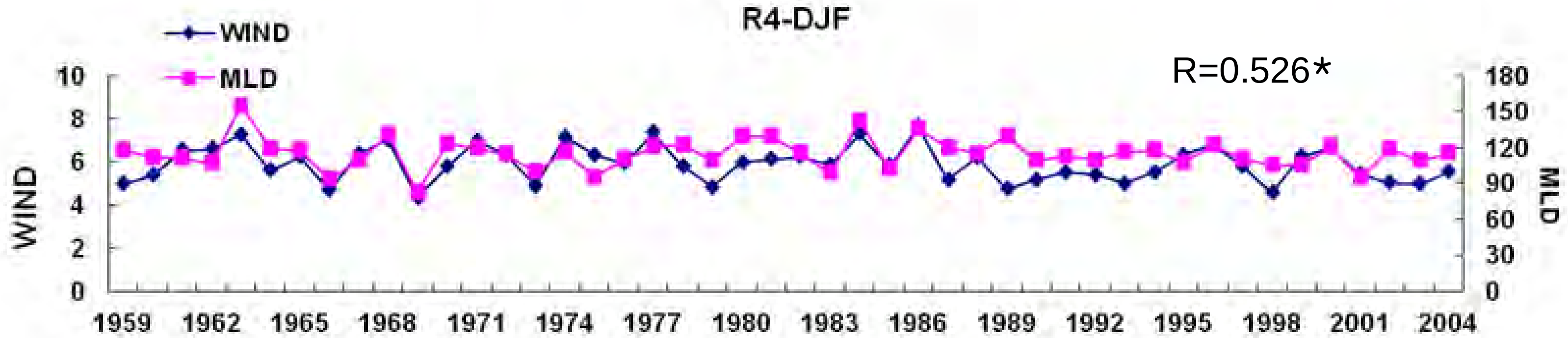




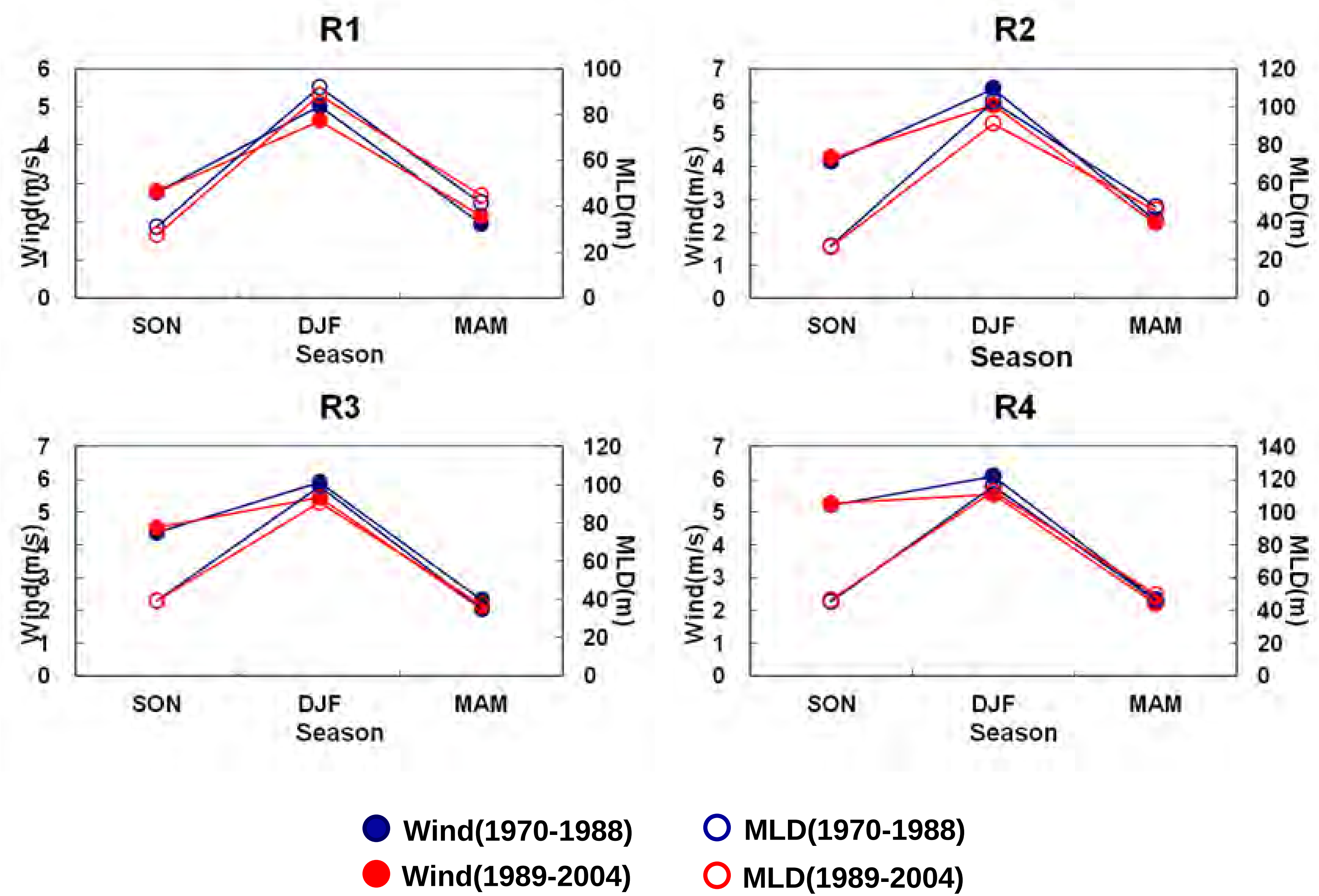
Relationship between wind strength and MLD



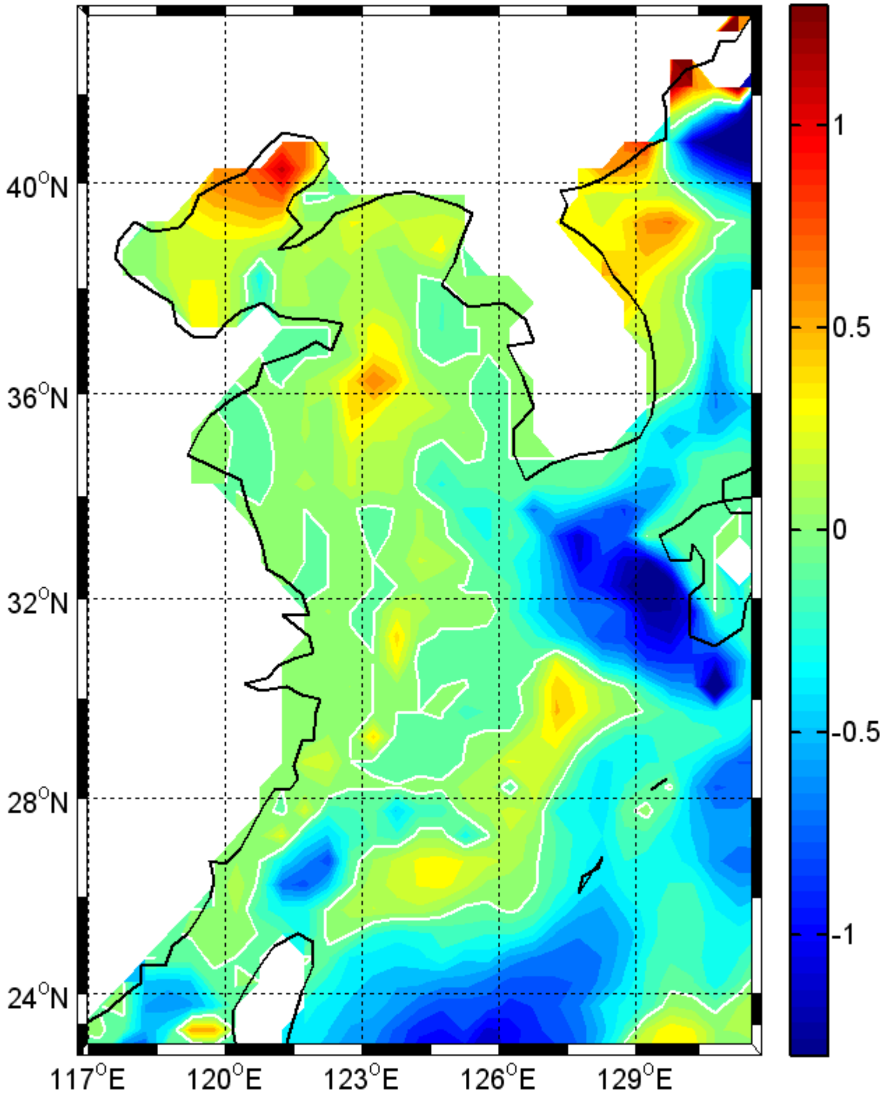




Variations in wind strength and MLD



Linear trend of MLD



Linear trend of MLD

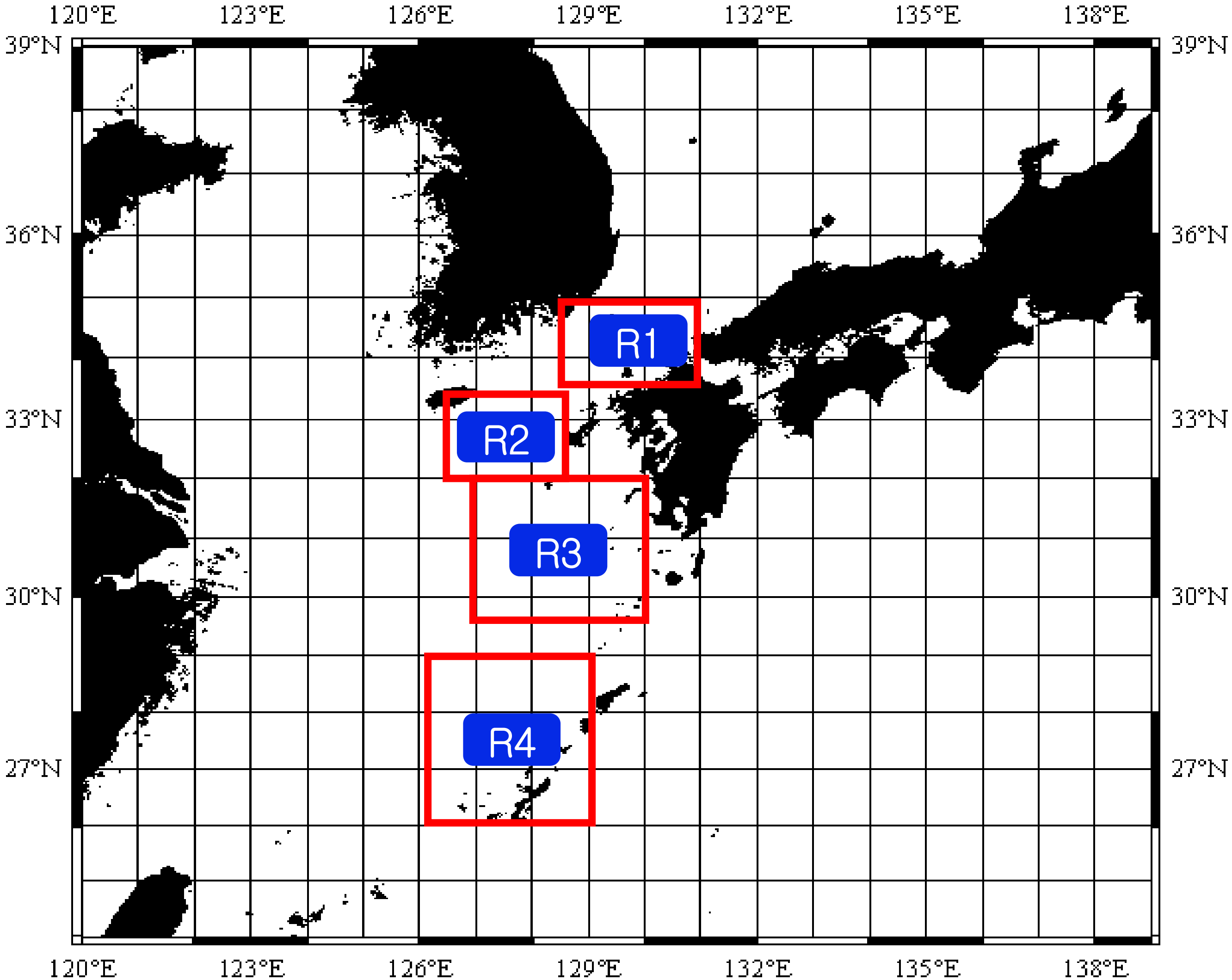
DJF 1971-2003

Unit: m/yr

Question 3

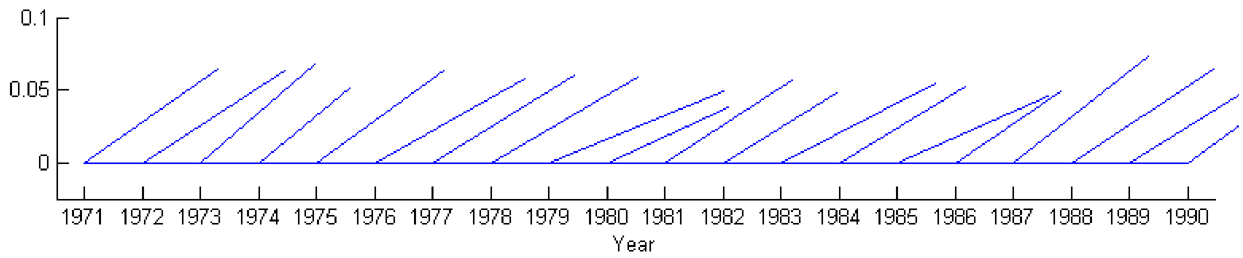
Does the recruitment of common squid be influenced by current strength and transport in nursery ground during larval drifting period?

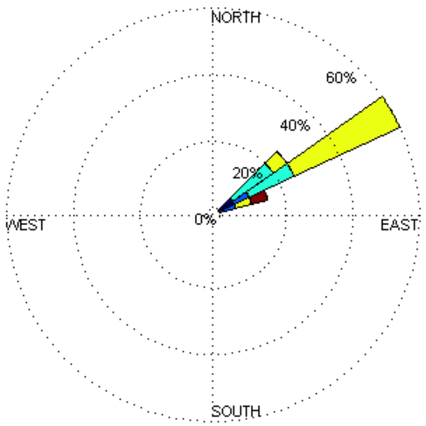
Study areas


120°E
123°E
126°E
129°E
132°E
135°E
138°E
39°N
36°N
33°N
30°N
27°N
R1
R2
R3
R4

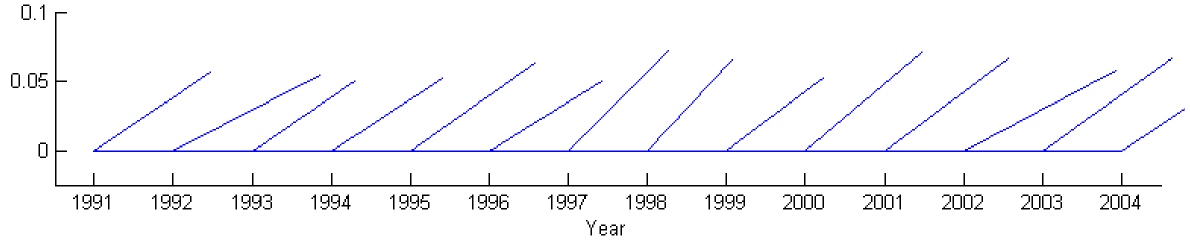
Simulated winter (DJF) current at 50 m of R3 during 1971-2004

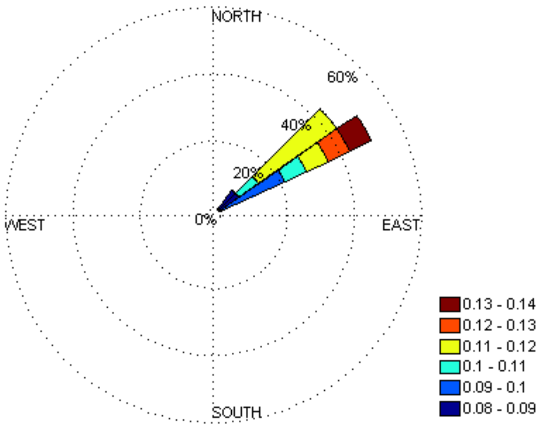
1971-1990:





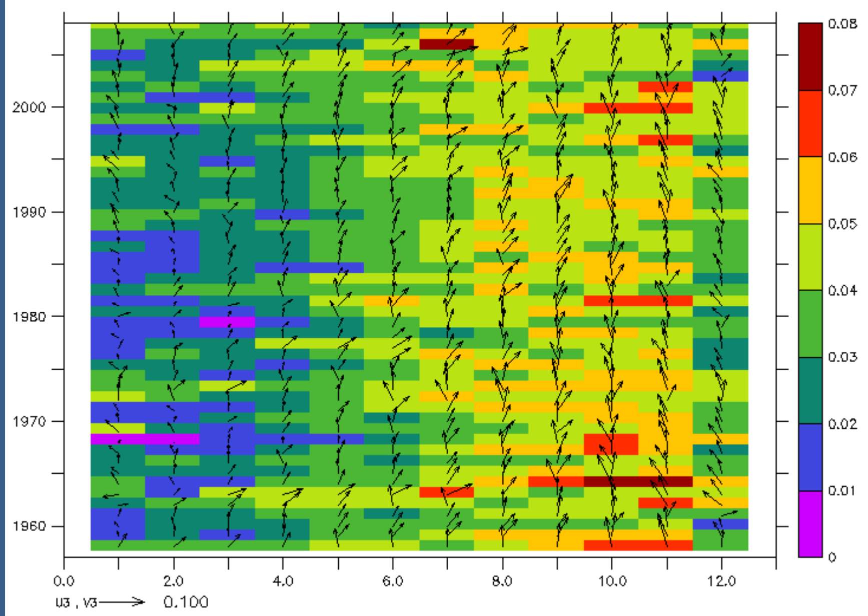
1991-2004:



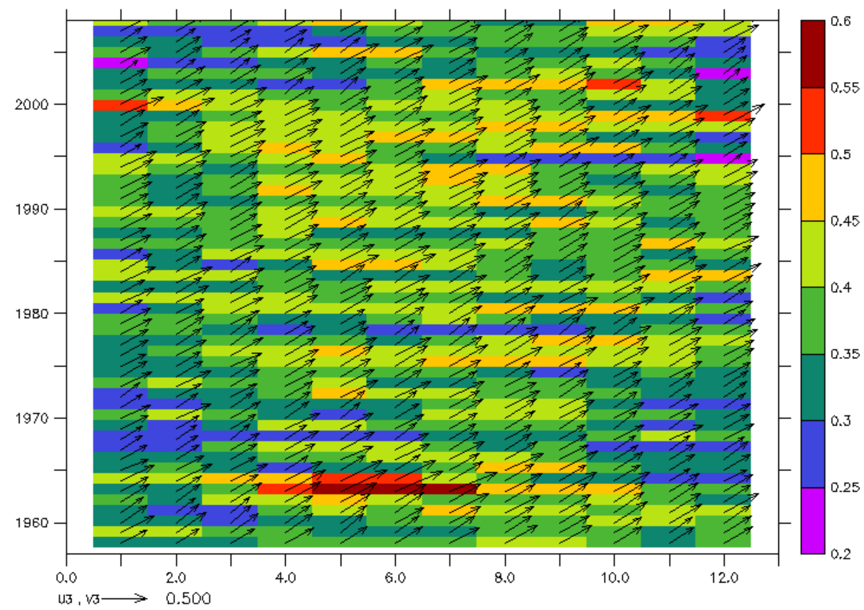


Flow at 46m (R3 northern & southern boundary)

northern



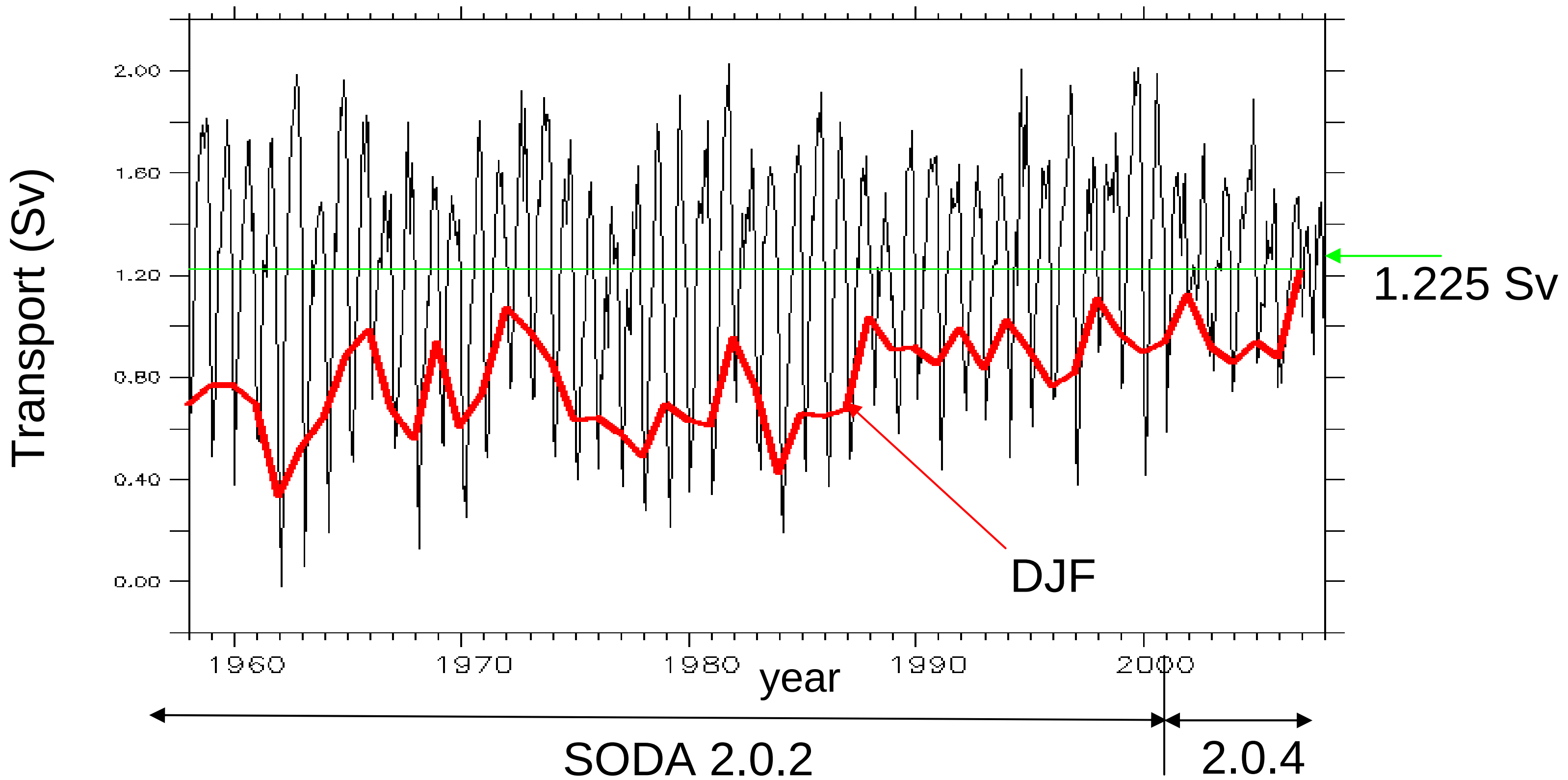
southern



Mean = 0.03 m/sec
Strong in fall

Mean = 0.35 m/sec
Strong in summer and
weak in winter

East Sea Throughflow Transport (Sv) in Korea Strait (R1)



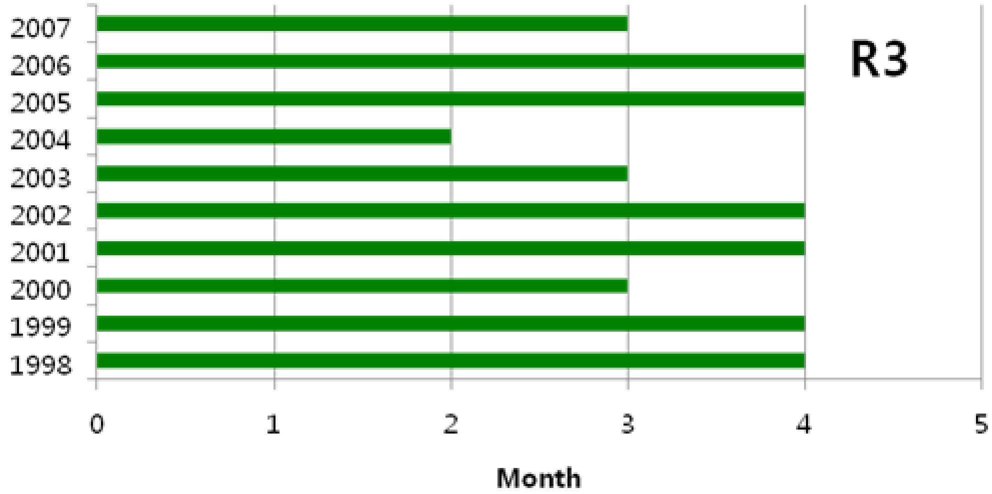
Correlation between current/transport and squid catch

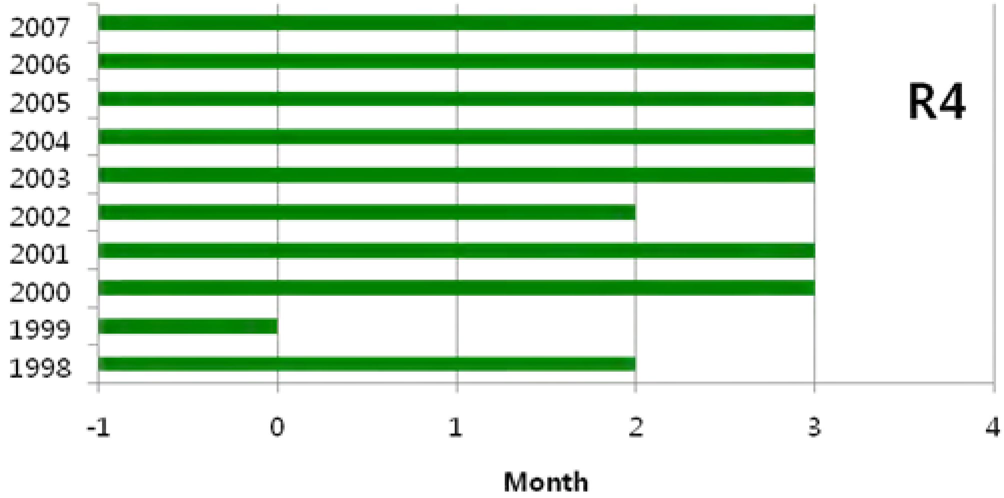
	Northern R3	Southern R3	Transport R1
Korea	0	0.37	0.51
Japan	-0.26	0.30	0.19
Total	-0.17	0.42	0.43

Question 4

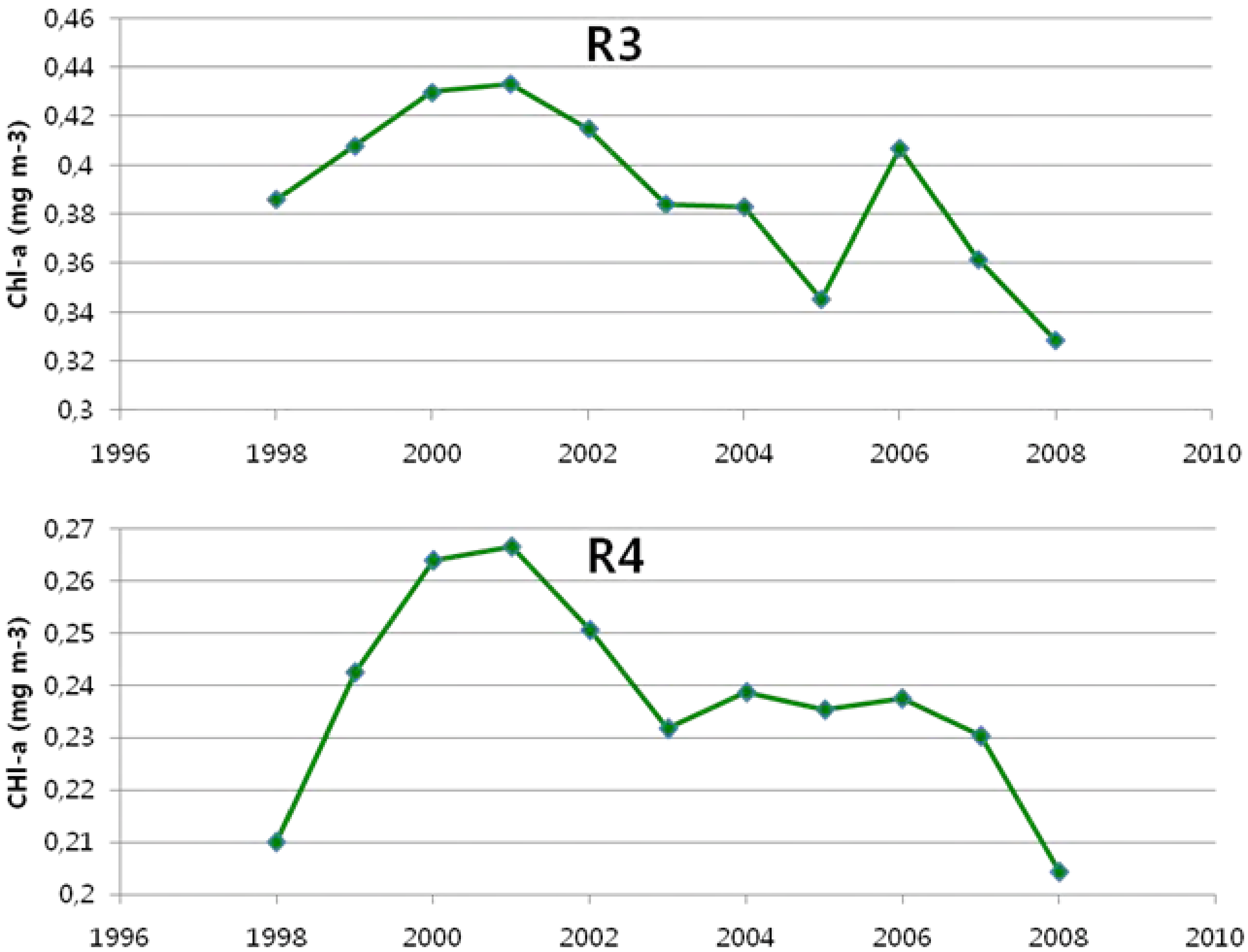
Does the zooplankton biomass in nursery grounds effect on the recruitment of common squid population?

Timing of Max CHL-a

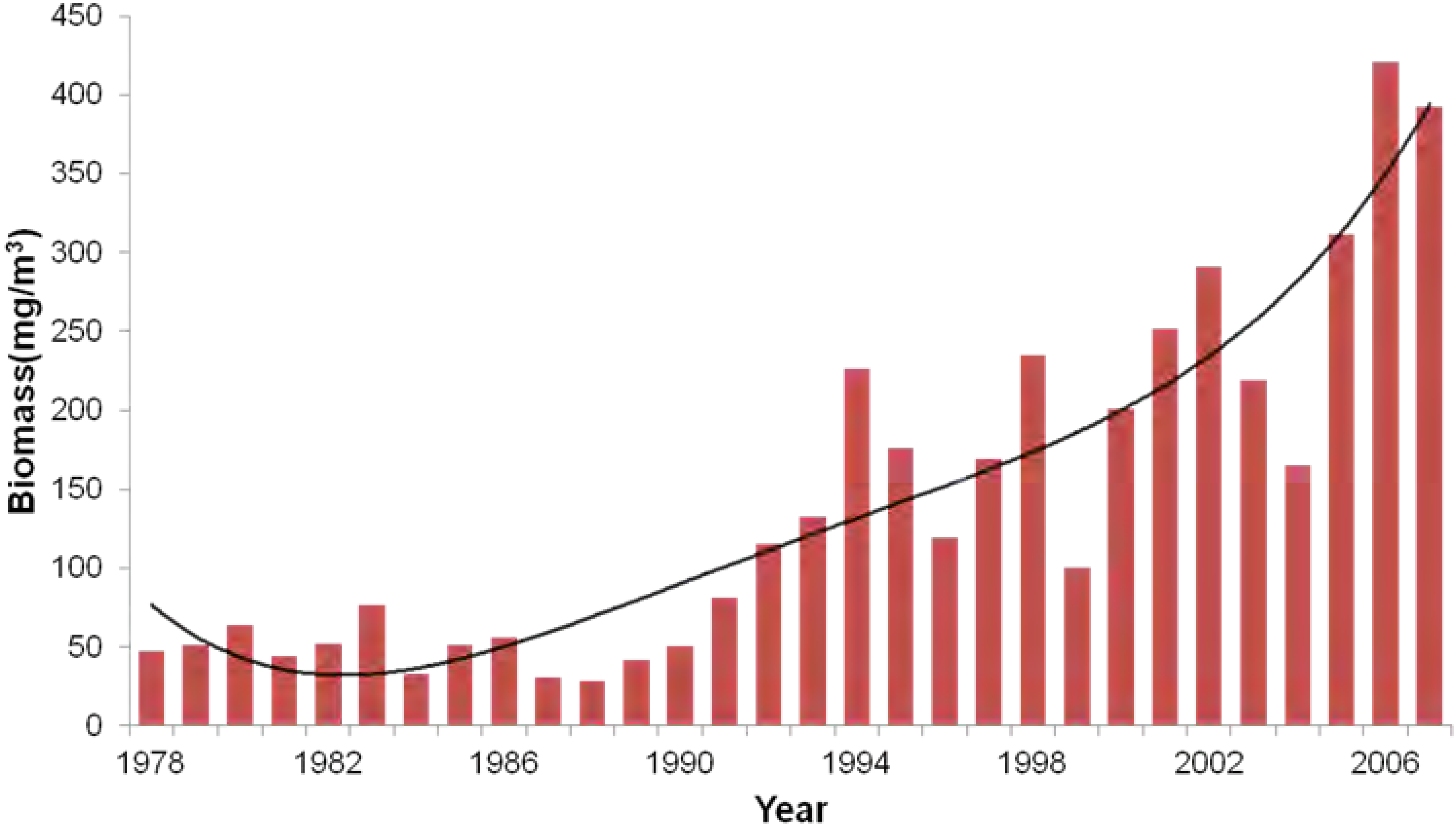




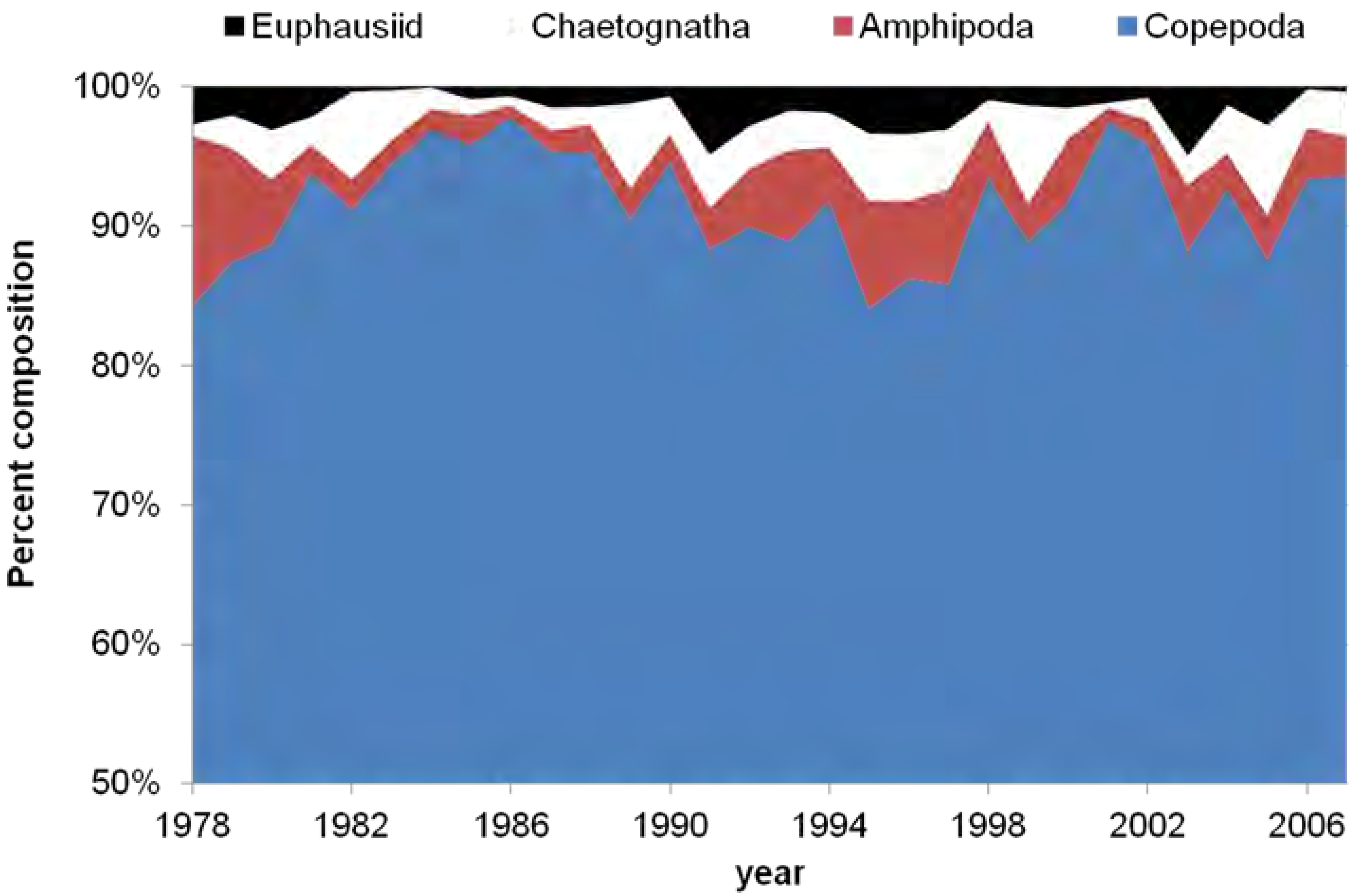
Autumn-winter-spring average CHL-a (Oct-Apr)



Long-term changes in annual mean biomass of the zooplankton in the Japan/East Sea, 1978-2007



Percent composition of major four zooplankton groups in the Japan/East Sea



Correlation coefficients between squid catches in year n and zooplankton biomass

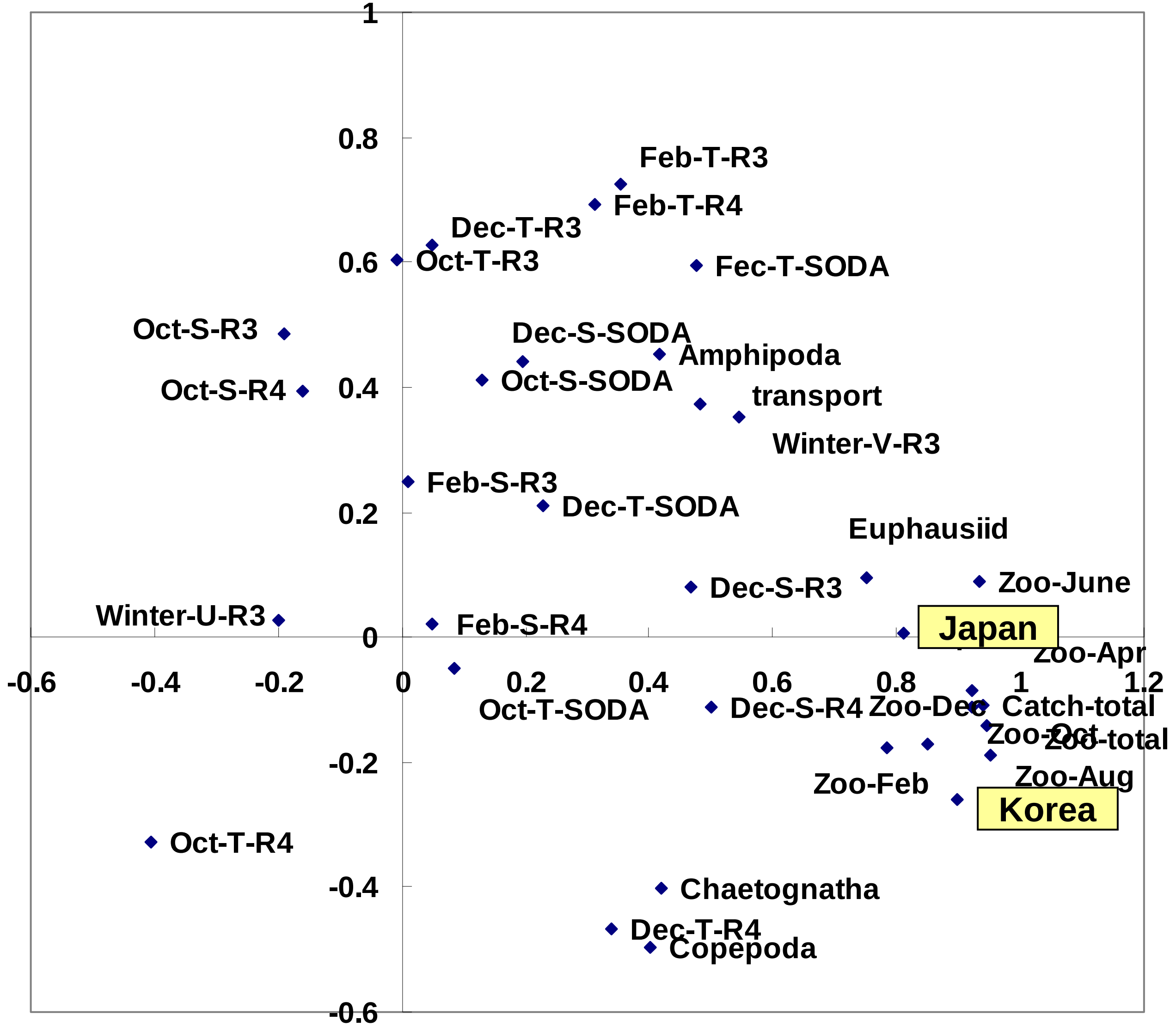
Variable of zooplankton biomass	
Sum of October and December (n-1 years)	0.927**
Sum of December (n-1 years) and February (n year)	0.693**
Sum of February and April (n year)	0.670**
Sum of April and June (n year)	0.735**
Sum of June and August (n year)	0.653**

** P<0.01

Correlation coefficients between squid catches in year n and abundance of major four Zooplankton assemblages

	Copepoda	Amphipoda	Chaetognata	Euphausiid
Oct.- Dec. (n-1 years)	0.49*	0.48*	0.38	0.36
Dec.(n-1)-Feb.(n year)	0.48*	0.39	0.43*	0.42*
Feb.-Apr. (n year)	0.42*	0.41*	0.38	0.63**
Apr.- Jun. (n year)	0.44*	0.72**	0.39	0.48*
June-Aug. (n year)	0.47*	0.59**	0.44*	0.35

* P<0.05, ** P<0.01



1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.6
-0.4
-0.2
0
0.2
0.4
0.6
0.8
1
1.2
Feb-T-R3
Feb-T-R4
Dec-T-R3
Oct-T-R3
Fec-T-SODA
Oct-S-R3
Dec-S-SODA
Amphipoda
Oct-S-R4
Oct-S-SODA
transport
Winter-V-R3
Feb-S-R3
Dec-T-SODA
Euphausiid
Zoo-June
Dec-S-R3
Winter-U-R3
Feb-S-R4
Japan
Zoo-Apr
Oct-T-SODA
Dec-S-R4
Zoo-Dec
Catch-total
Zoo-Oct
Zoo-total
Zoo-Aug
Zoo-Feb
Korea
Oct-T-R4
Chaetognatha
Dec-T-R4
Copepoda

Summary

- Large-scale climate indices do not provide significant correlation with squid catch in the northwestern Pacific.
- Wind is significantly correlated with MLD. Low catch in 1970~1990 matched with higher MLD and stronger wind speed in spawning area during winter spawning period.
- We could not find strong evidence that larval drift in nursery area is crucial to the recruitment. High catch in Korean waters, however, seems to be correlated by high winter transport through the Korea Strait.
- Squid spawning seems to adjust with phytoplankton production, and recruitment of squid has a significant correlation with zooplankton biomass in nursery areas.

Future Study

- Develop modeling work on larval distribution and transport processes that determine the size of regional populations
- Seek for ocean processes on growth and survival of squid larvae, and the range of seawater properties for high larval survival
- Examine the effects of Three Gorge Dam on East China Sea ecosystem
- Develop the refined estimation of inferred spawning areas to predict catch
- Forecast the prediction of common squid populations under changing climate