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Climate-driven ecosystem shifts in Korean waters during the past 40 years

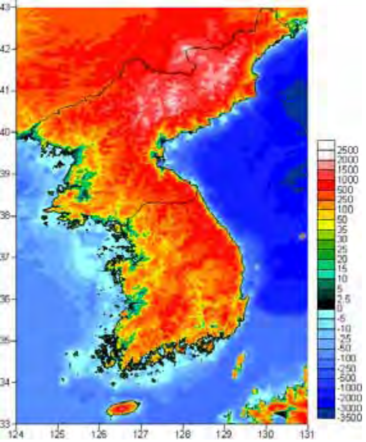
Sukgeun Jung[1] and Il Su Choi

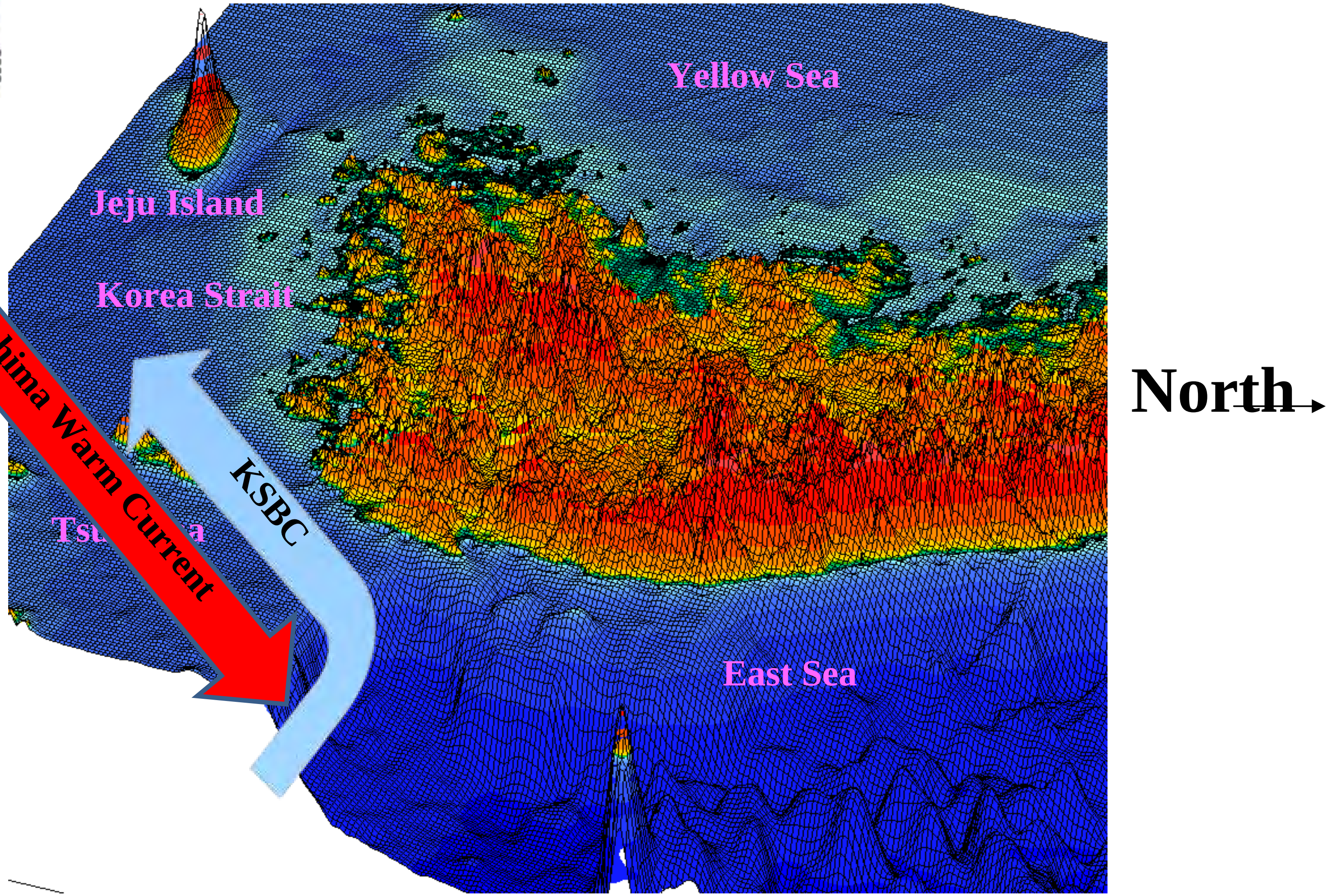
1. School of Marine Biomedical Sciences
Jeju National University, Korea
pices@korea.kr

Objective of Study

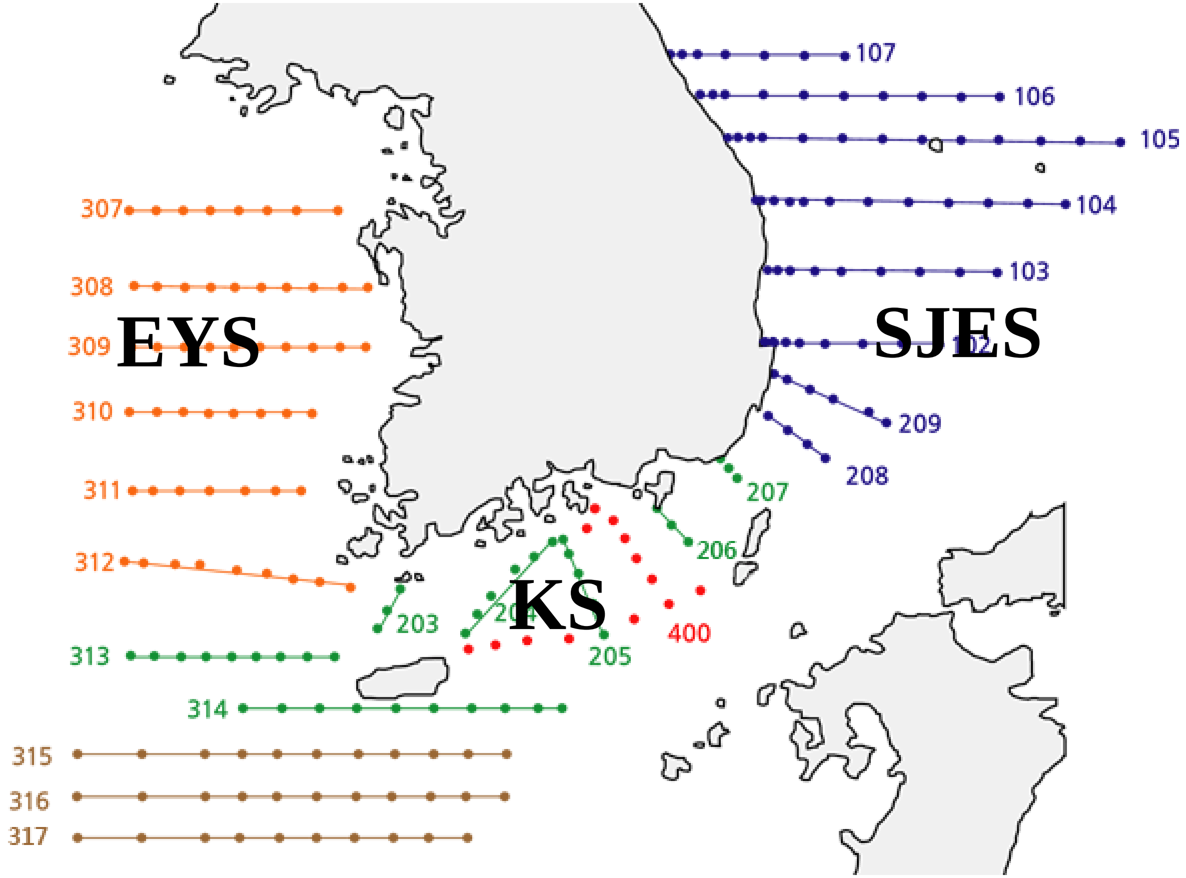
- The reported past regime shifts in the North Pacific
  - 1977, 1989, 1998
- How did the ecosystems of the Korean waters responded to these basin-wide regime shifts?
- Regional differences
  - Japan/East Sea: deep basin
  - Korea Strait: intermediate
  - Yellow Sea: shallow

Topography




Yellow Sea
Jeju Island
Korea Strait
Tsushima Warm Current
KSBC
East Sea
North

Study Area for Env, Zooplankton and Fish
Latitude: 32-39^{o}N
Longitude: 124-133^{o}E



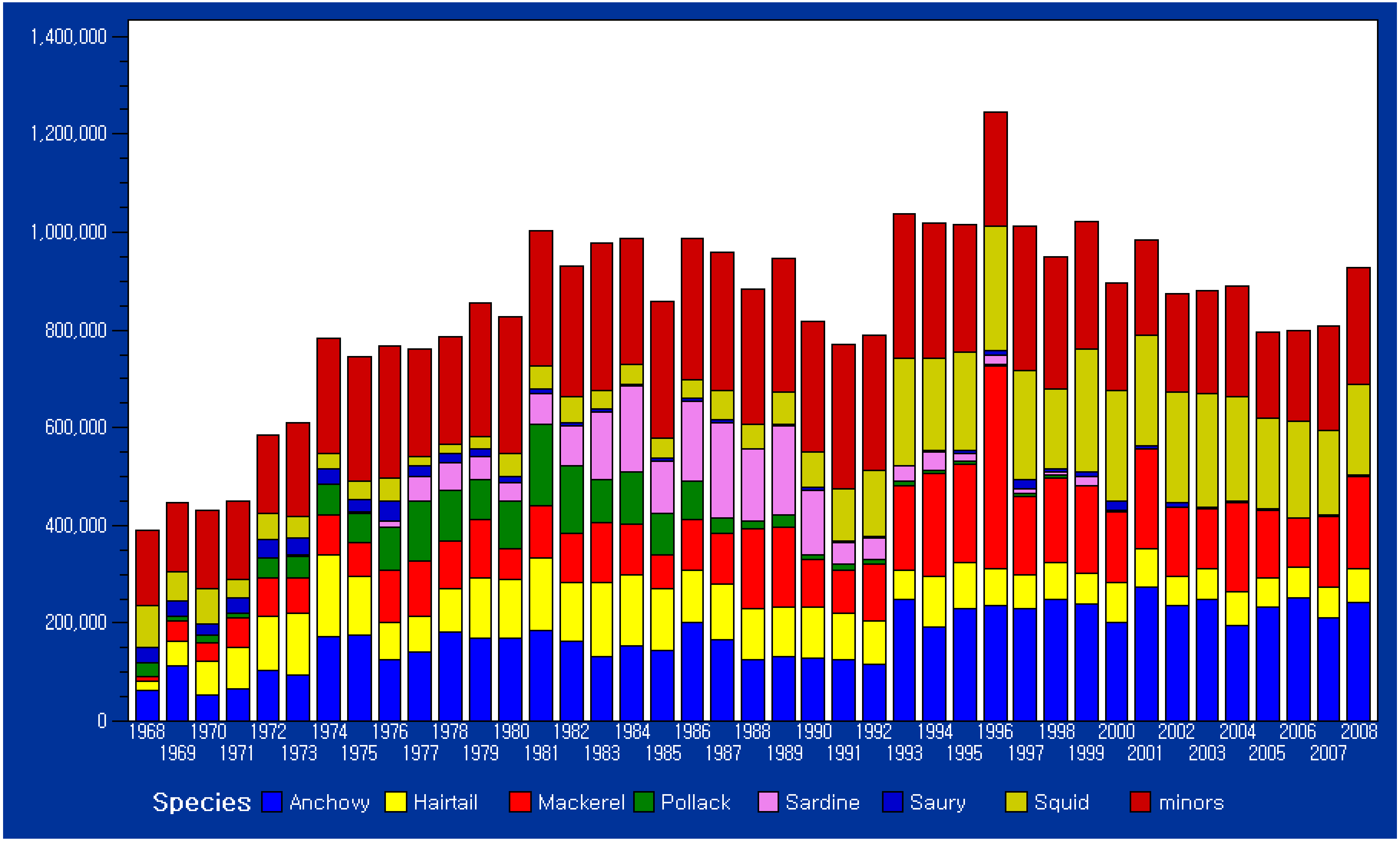
Time-series Data

- Korea Meteorological Administration
  - Air surface temperature 1968-2009
- MIFAFF-NFRDI
  - Depth-specific T, S, DO (0~100 m) 1968-2010
  - Meso- and Macro-zooplankton 1965-2006
  - Fisheries Data 1968-2010
- Seoul National University
  - Volume Transport of TWC and KSBCW 1968-2007

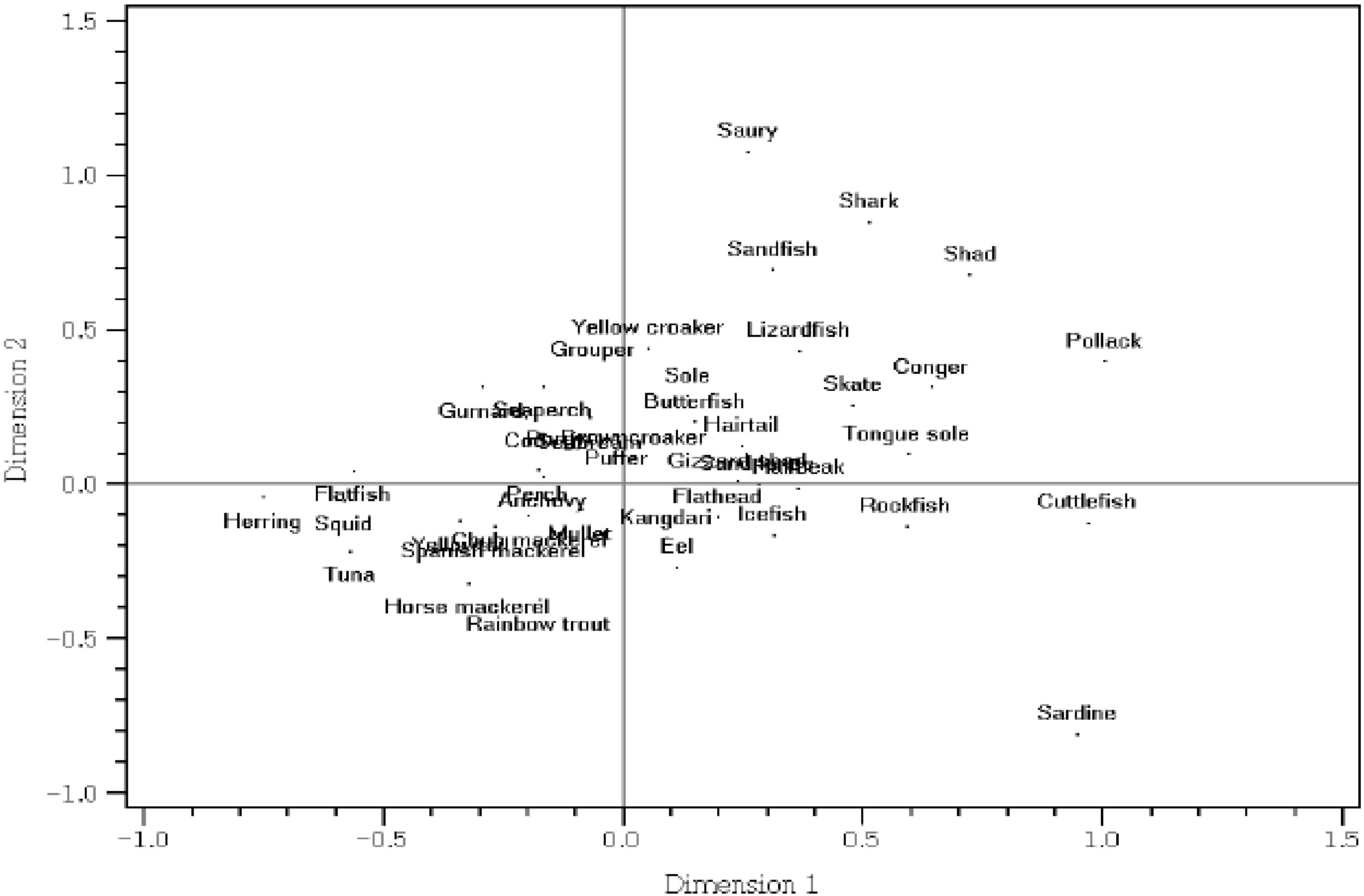
Methods

- Canonical Correspondence Analysis
  - To summarize annual changes in fish community structure
  - Biomass composition of major fisheries species
  - Environmental variables
    - Only those of $p<0.05$ were selected to display in the biplot
- Regime-shift detection
  - STARS 2
  - Bayesian Markov-chain switching model

Annual Catch from Korean Sea Waters by Species
(marine capture fisheries, metric tons, 1968-2008)

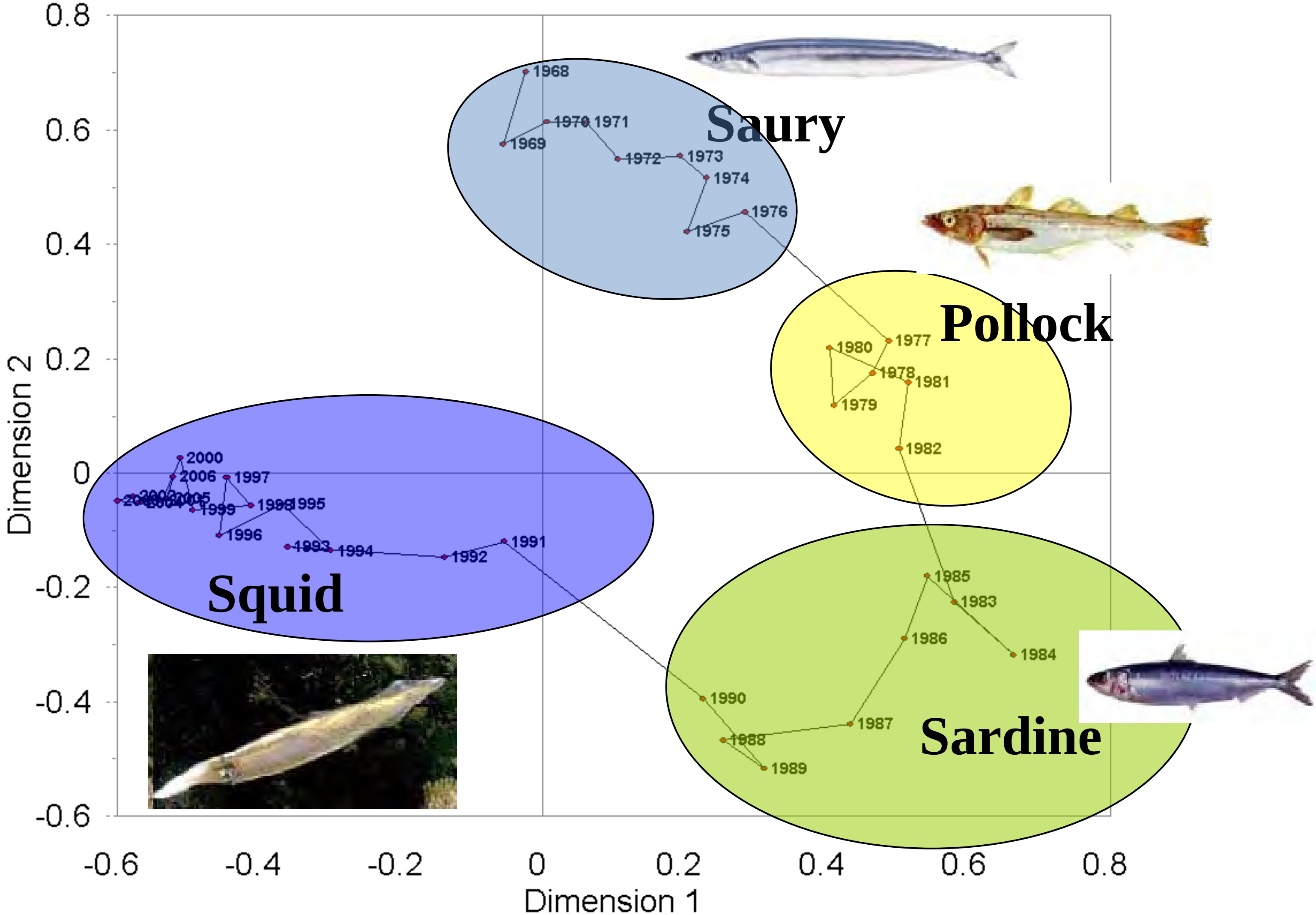


Correspondence Analysis on Biomass composition of Fishes



Correspondence Analysis

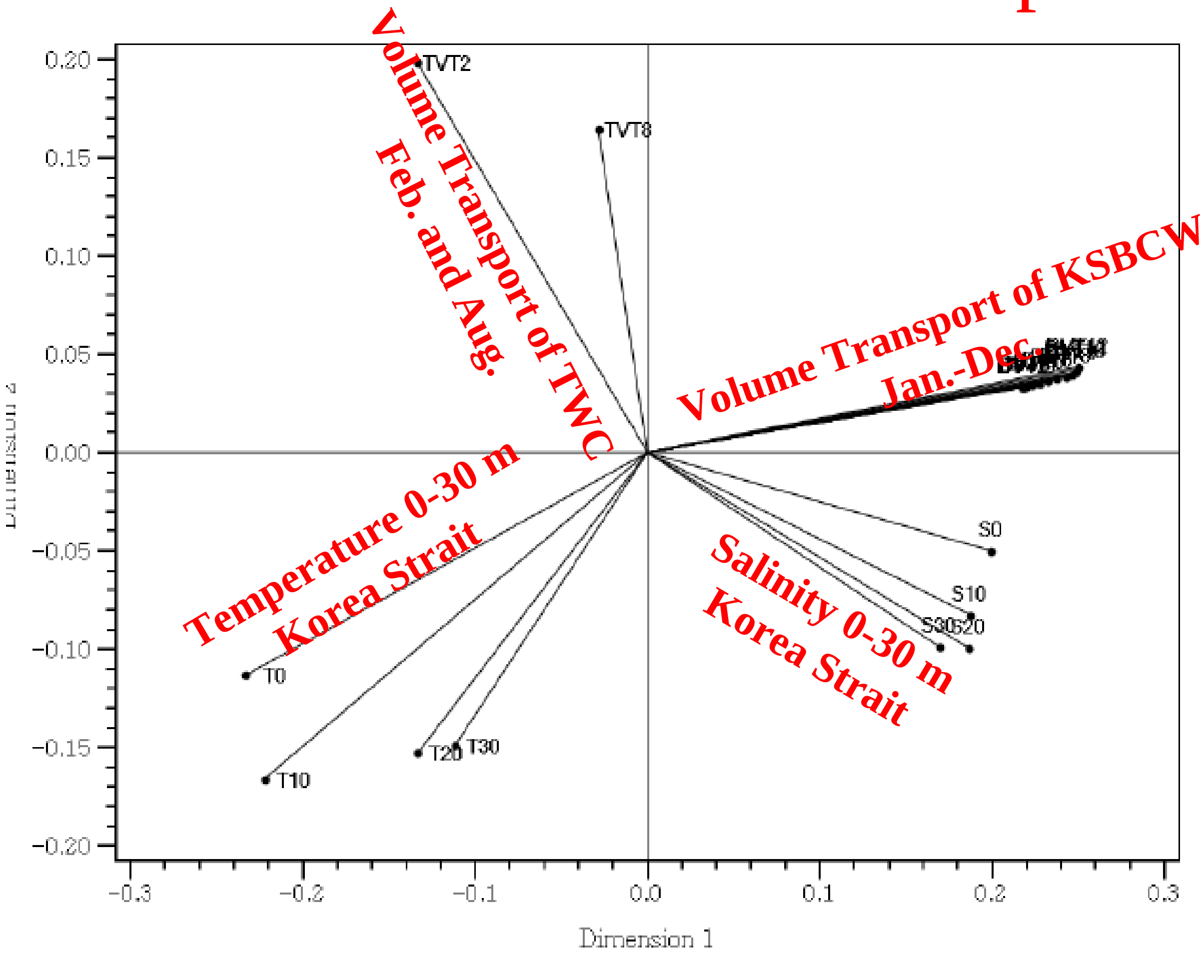
on species composition of Korean fishery catch



- **Reported Regime Shifts: 1976-1977, 1988-1989, 1997-1998**

Canonical Correspondence Analysis 1

Environmental Variables of p<0.05



Temperature and salinity in the mixed layer were correlated significantly.

Canonical Correspondence Analysis 2

Means for the entire Korean water

Monthly ENSO index

Variable	Corr. With Dim1	p-value
Air Temp	-0.53	0.000289
Salin 0 m	0.52	0.000356
Wtemp 10 m	-0.51	0.00055
SST	-0.47	0.001331
Salin 10 m	0.47	0.001658
Salin 20 m	0.43	0.003756
Salin 30 m	0.39	0.010301
Salin 50 m	0.32	0.034465
Disoxy 75 m	0.34	0.036871
Wtemp 20 m	-0.31	0.045795

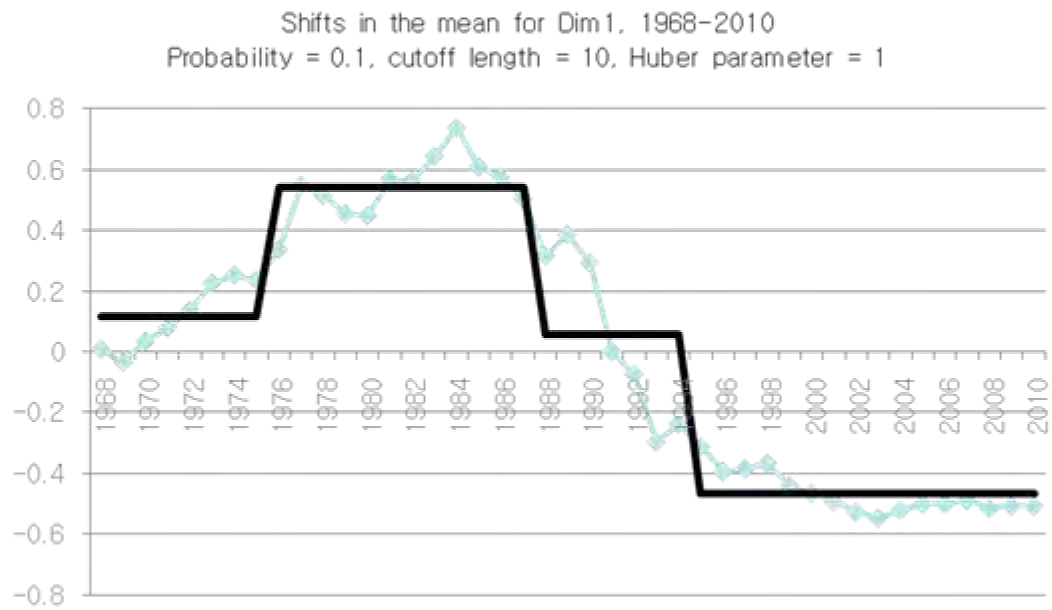
Variable	Corr with Dim2	p-value
disoxy 100 m	0.54	0.000413
dosat 100 m	0.51	0.001066
ENSO May	-0.44	0.003485
Air Temp.	-0.43	0.004796
ENSO Apr	-0.38	0.011862
SST	-0.38	0.011947
ENSO Jun	-0.36	0.016729
disoxy 75 m	0.38	0.021614
ENSO Mar	-0.32	0.036395
wtemp 10 m	-0.31	0.043796
dosat 30 m	0.32	0.047241

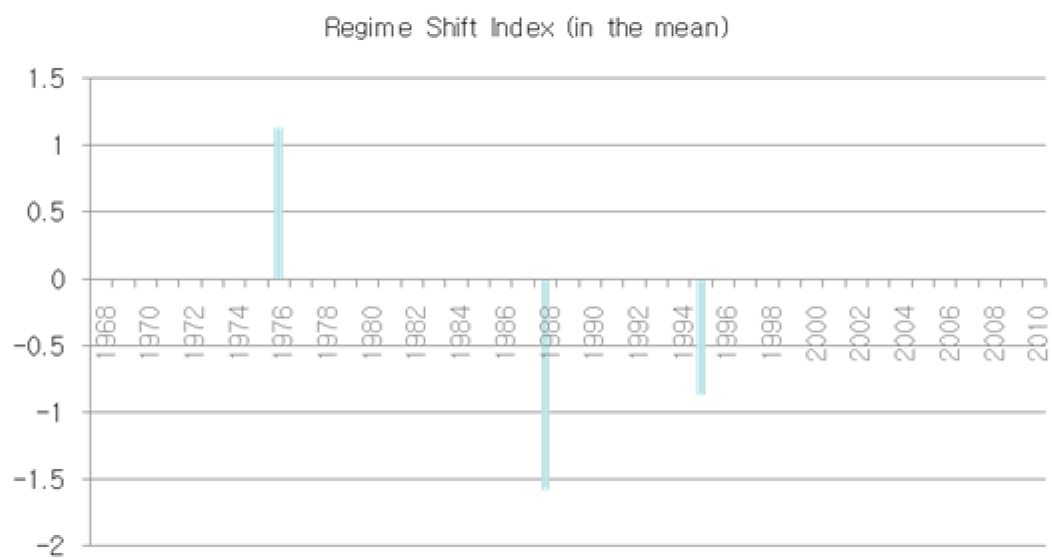
Dim 1 Stars2

1976

1988

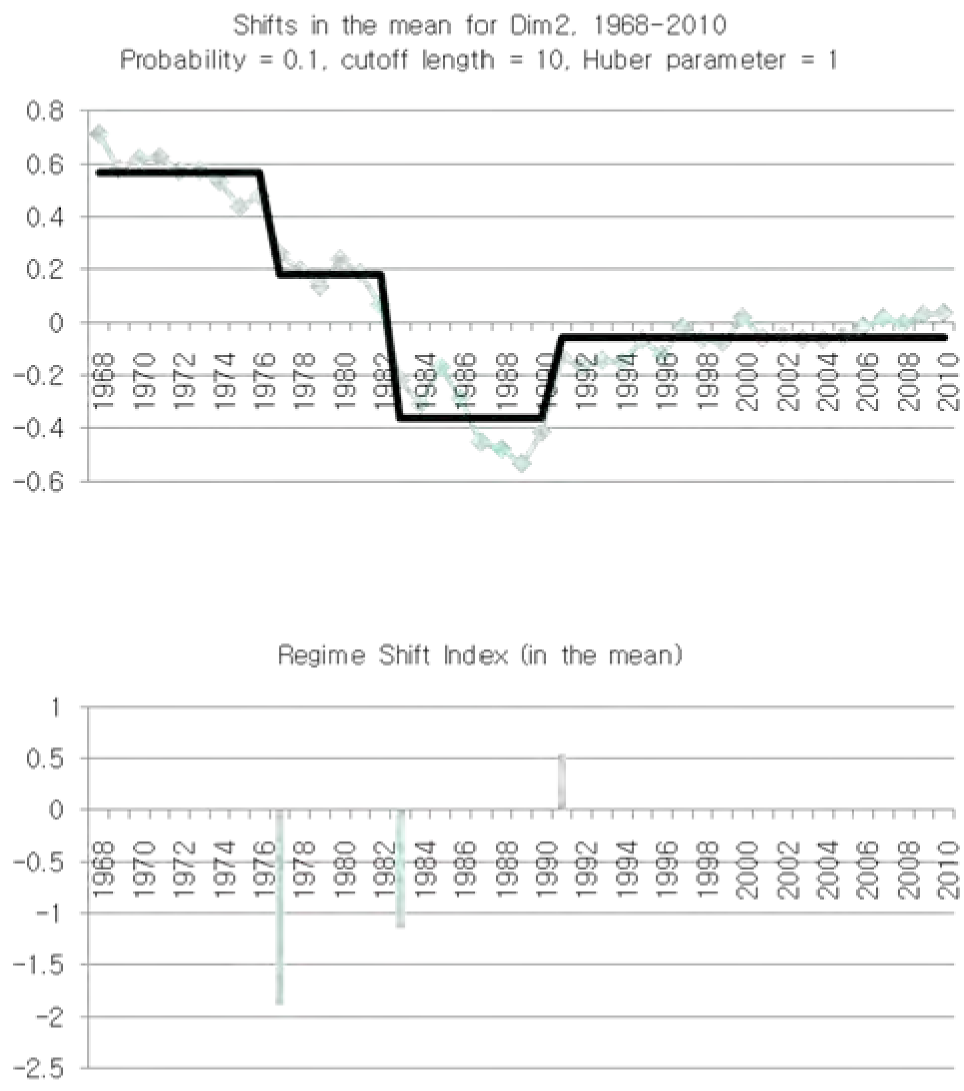
1995





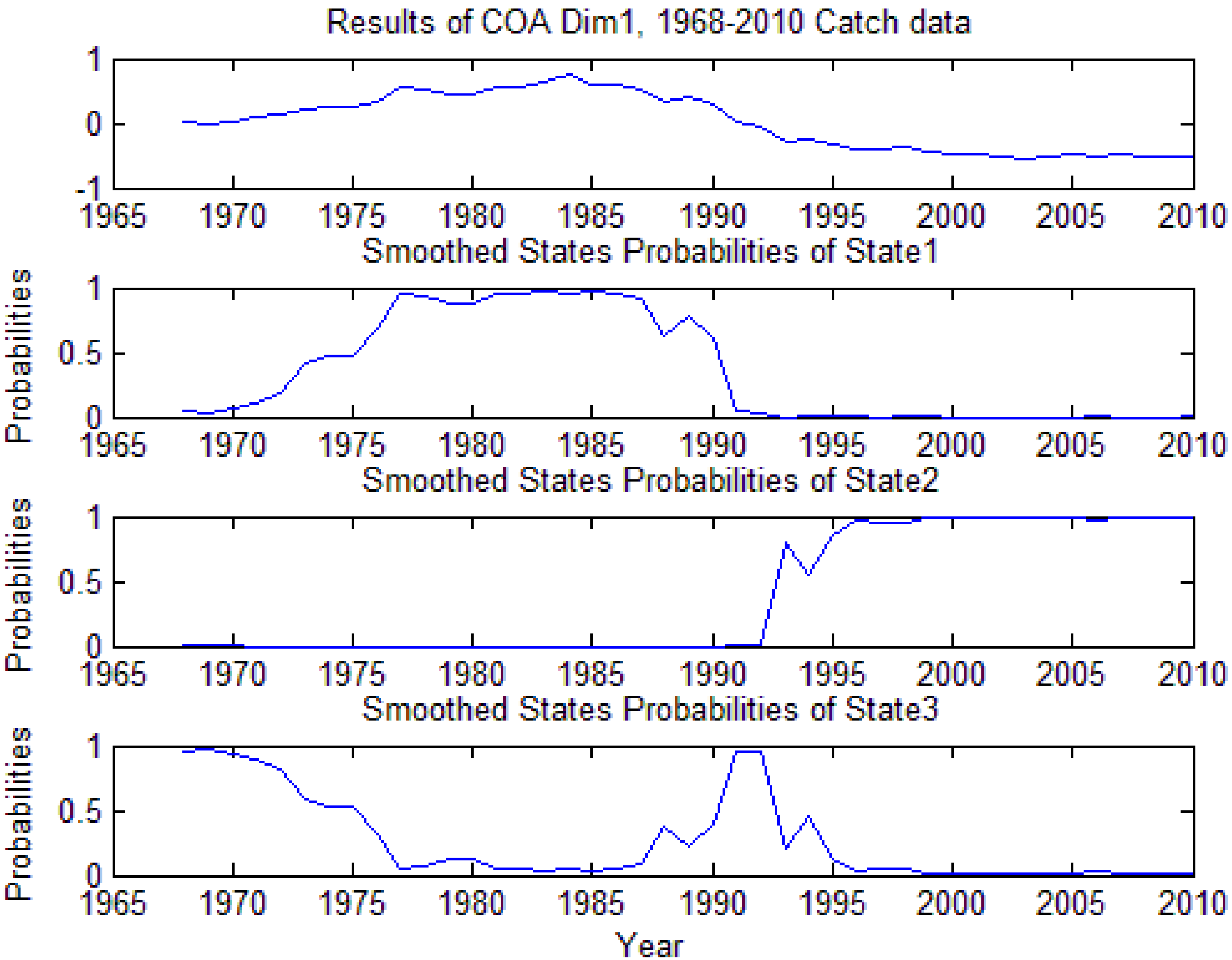
Dim 2
Stars2

1977
1983
1991



Dim 1
Bayesian Markov switching models

1976
1991

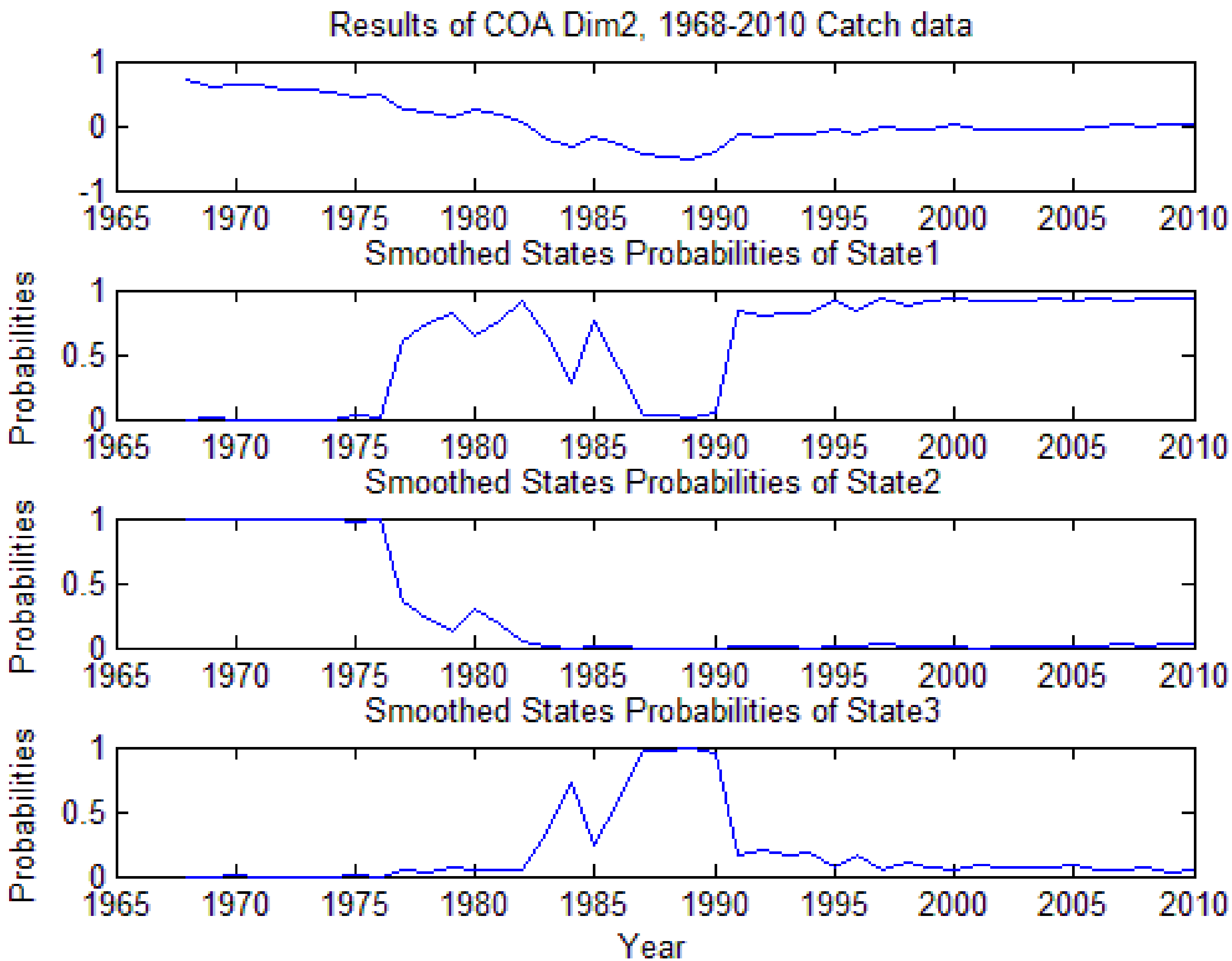


Dim 2
Bayesian Markov switching models

1976

1983

1991

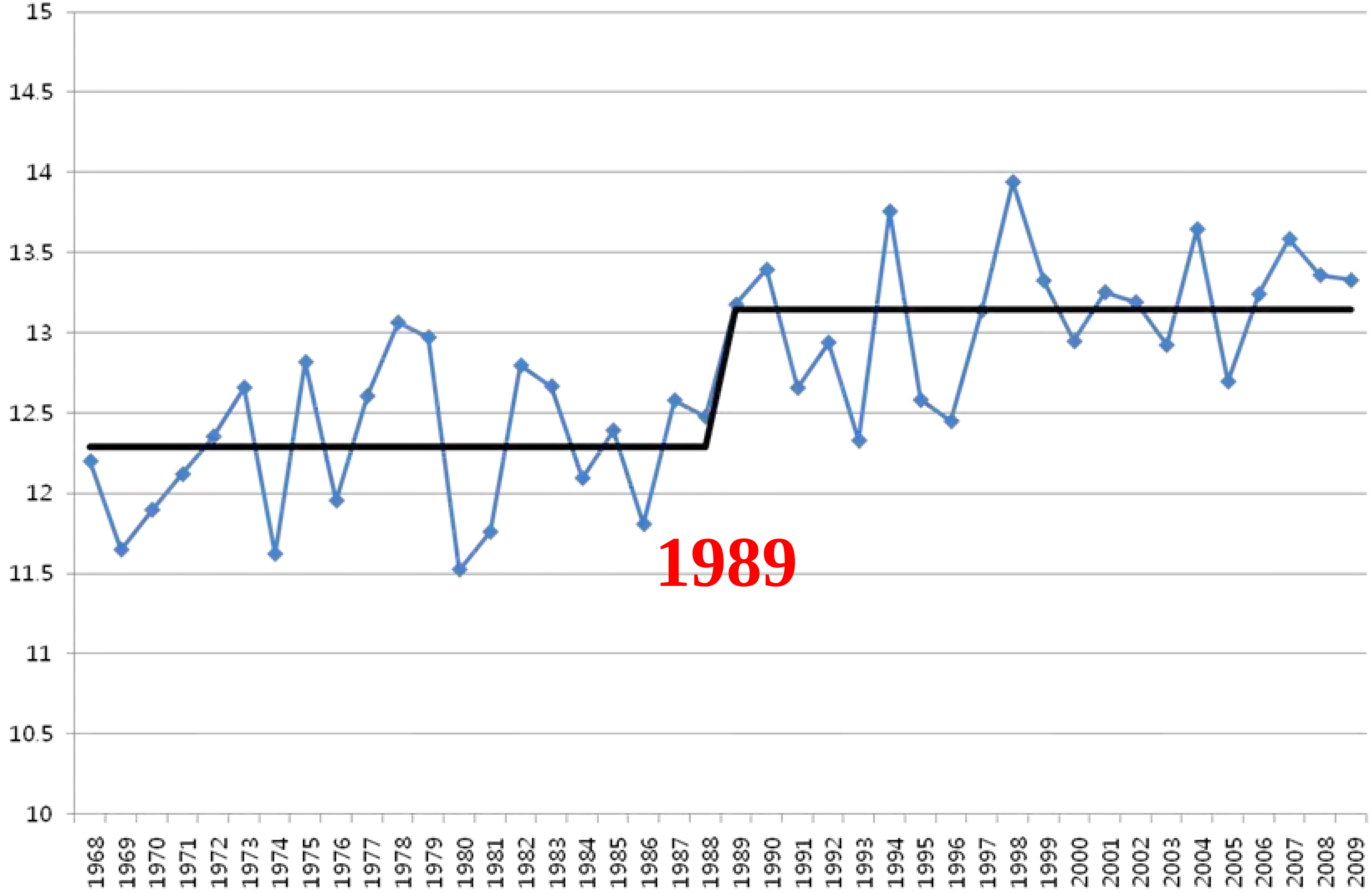


Detected Shifts

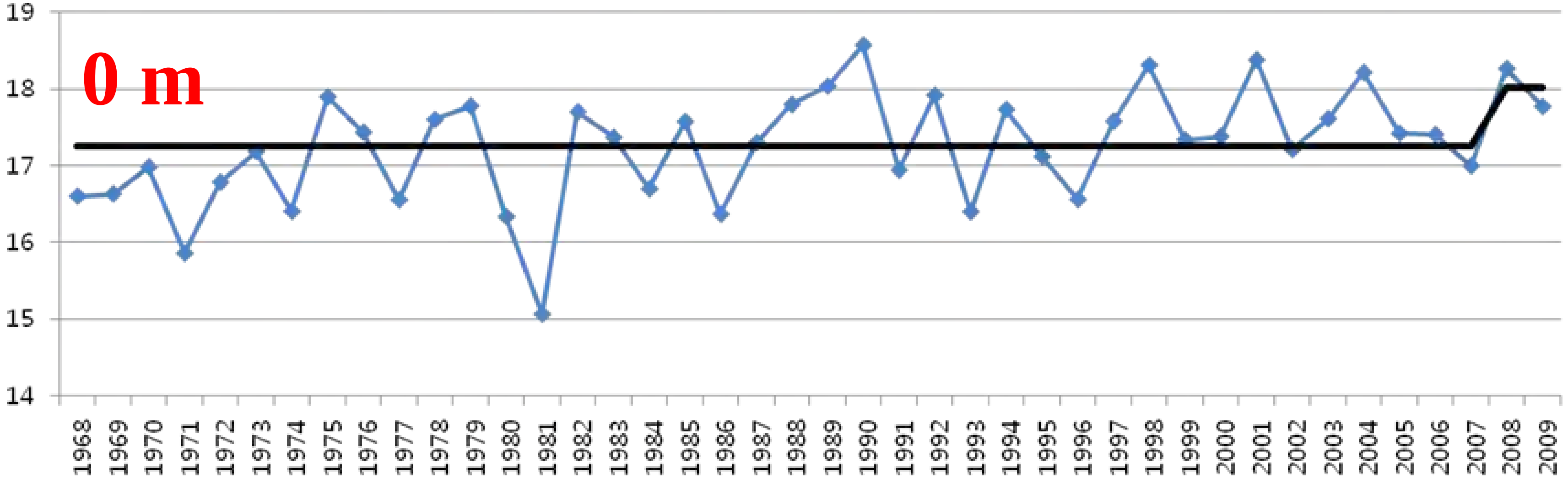
STARS 2	Bayesian Markov
1976-1977 1983 1988 1991 1995	1976 1983 1991

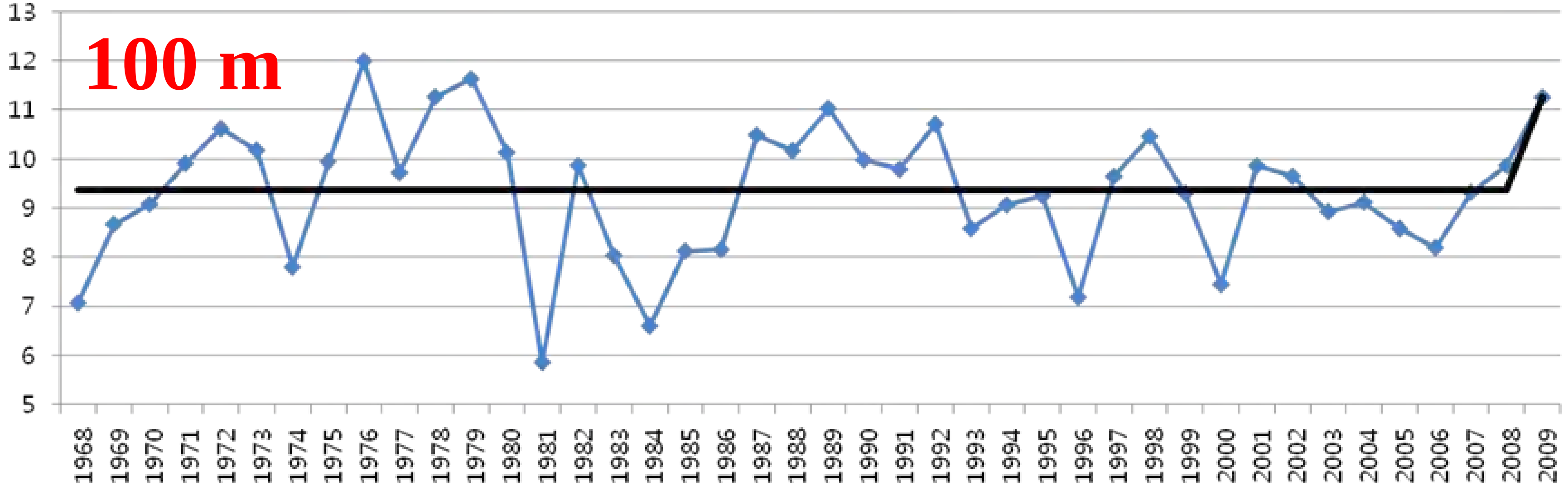
- **The 1983 shift seems to be related with the strong 1983 ENSO.**
- **The 1991 shift seems to be related with the 1989 shift, considering a time lag of 2 yr for recruitment and fishermen’s preparation for catching new target species.**

A shift in the time-series of air surface temperature in the Korean peninsula

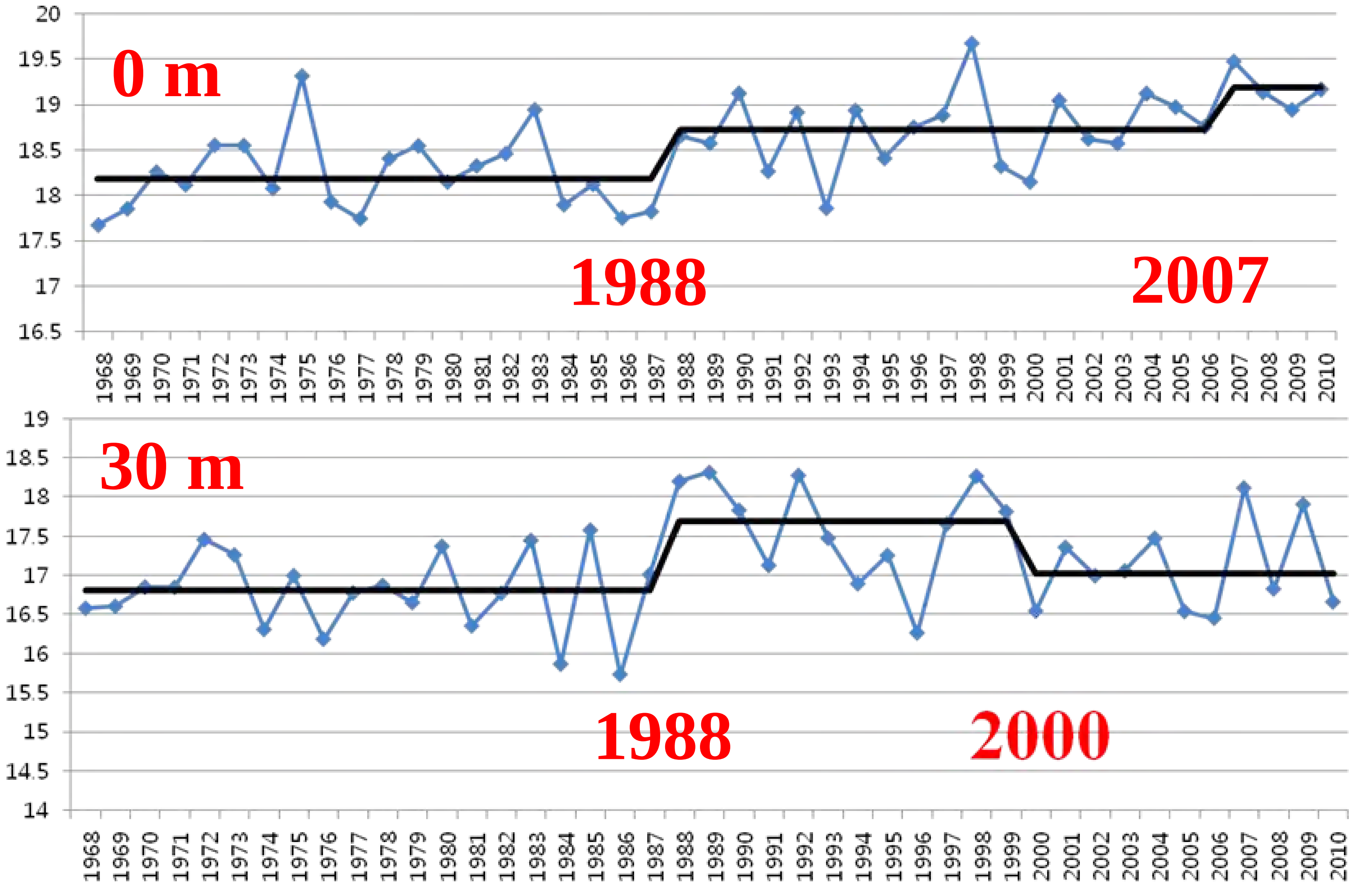


No detectable shift in depth-specific water temperatures in the JES

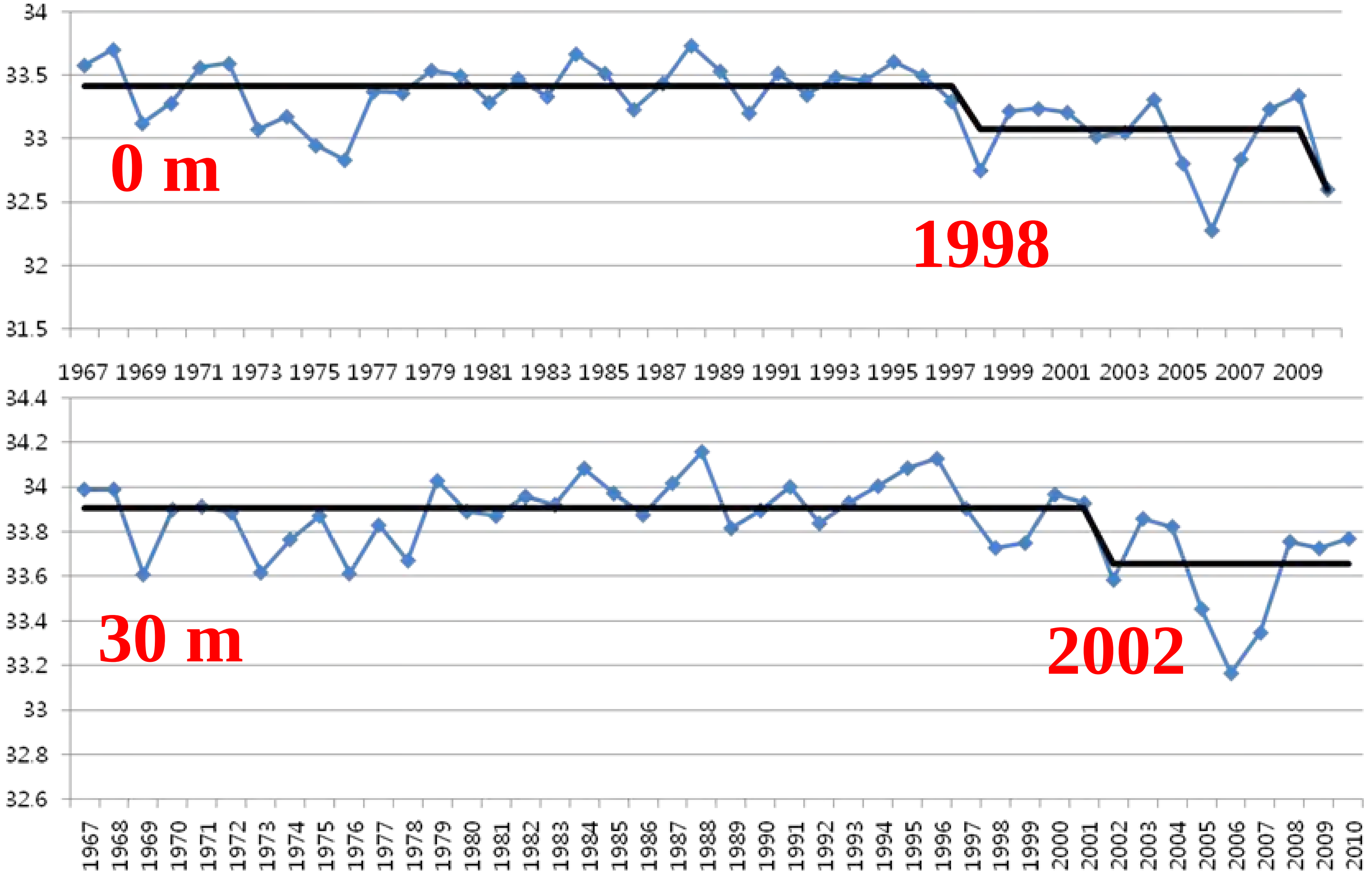




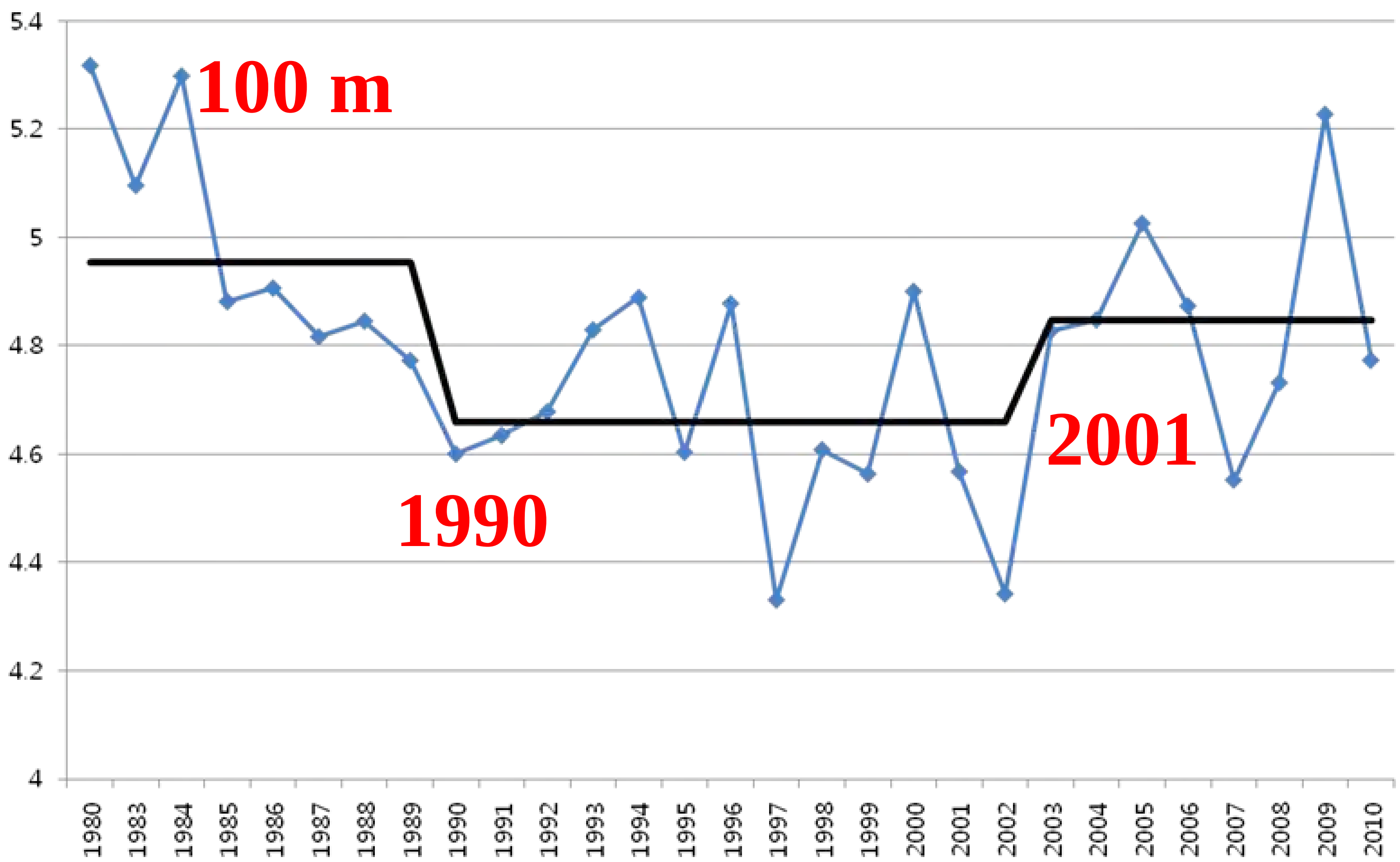
Shifts in depth-specific water temperatures in the Korea Strait



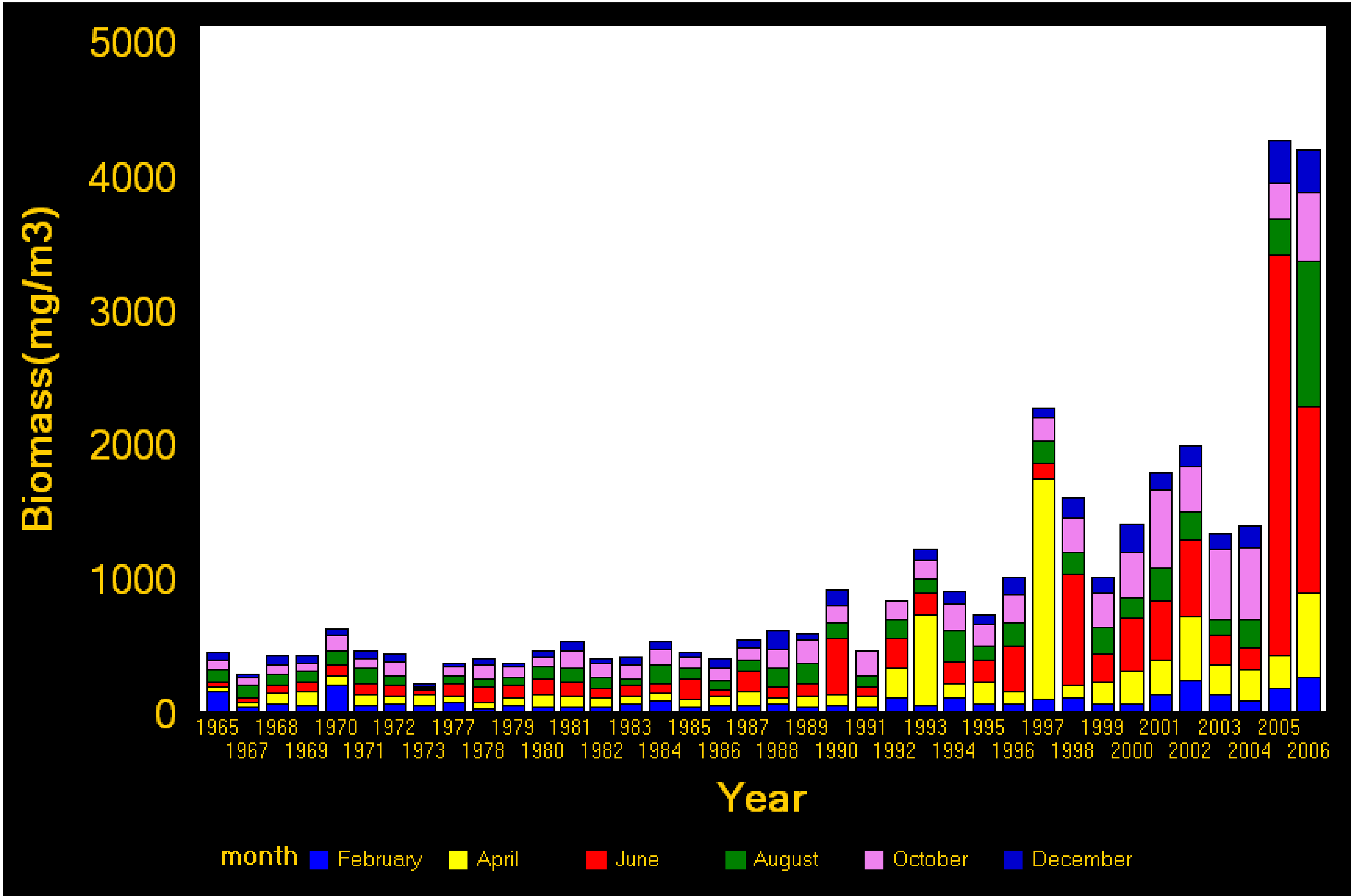
Shifts in depth-specific salinity in the Korea Strait



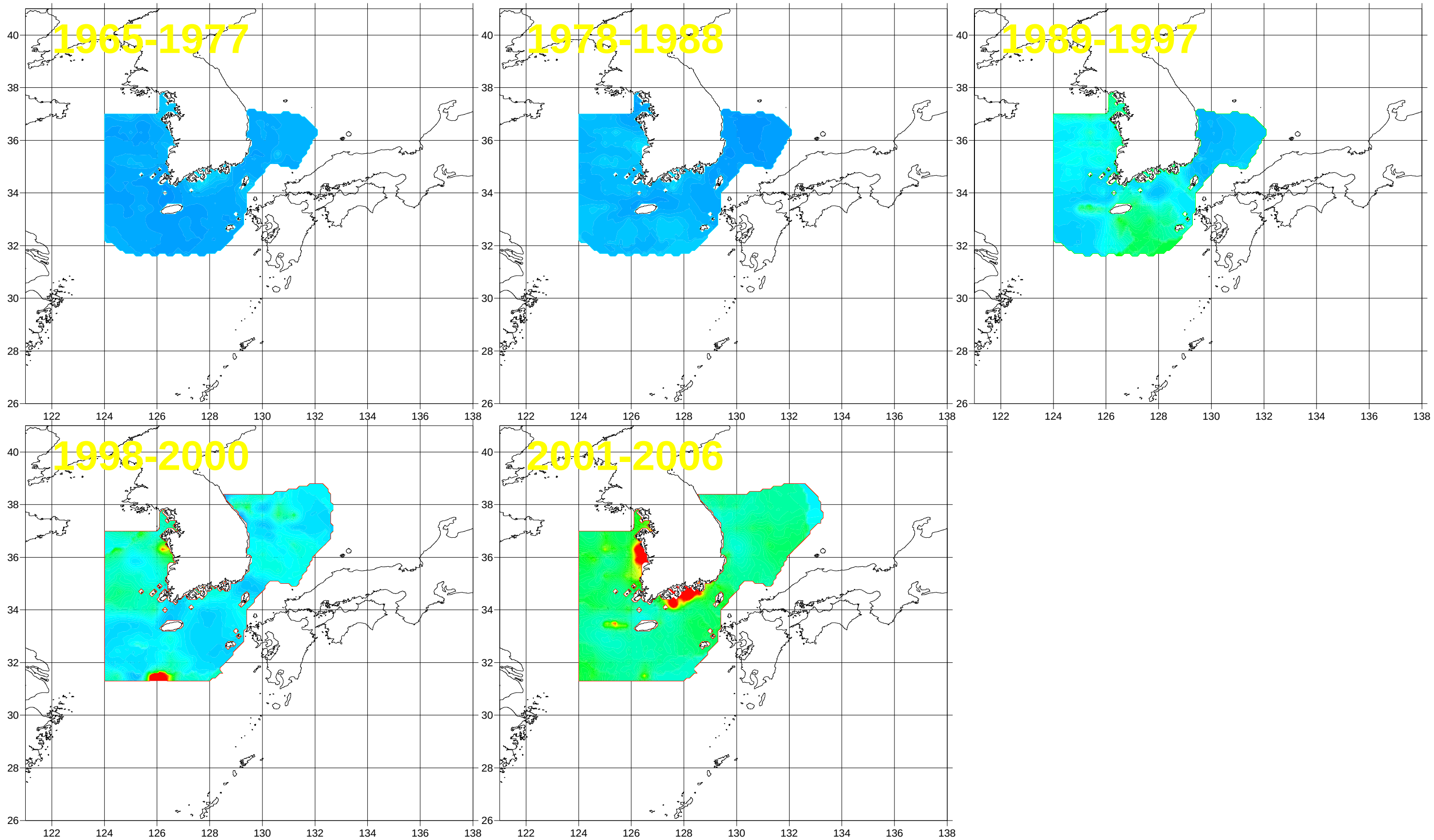
Shifts in Dissolved Oxygen in the Korea Strait

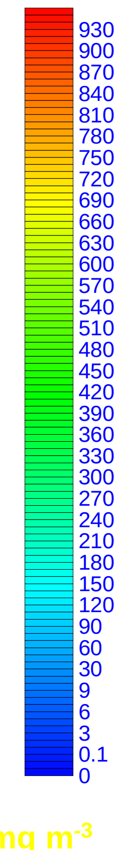


Meso- and macro-zooplankton biomass 1965-2006, from KODC



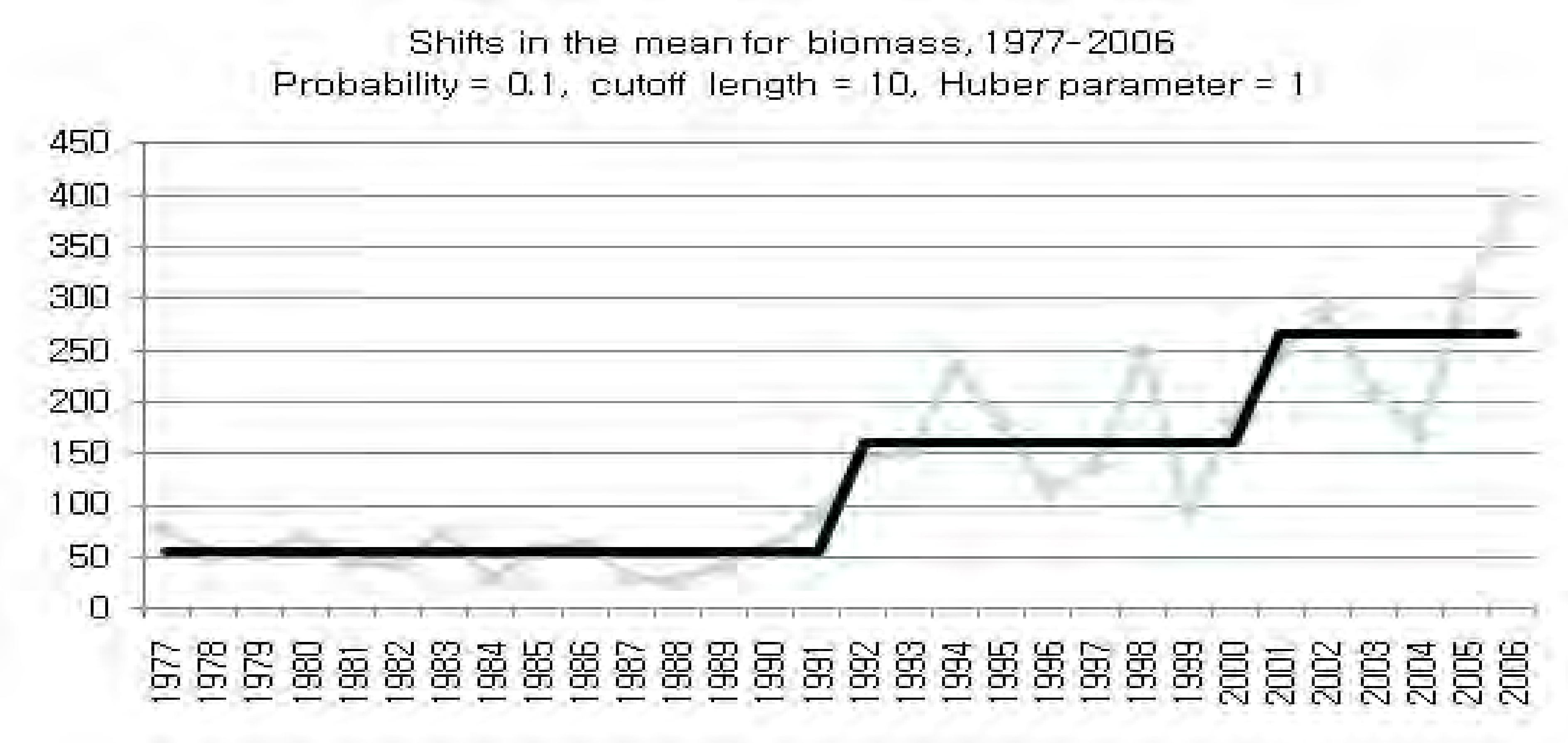
Meso-zooplankton Averaged biomass (1965-2006)





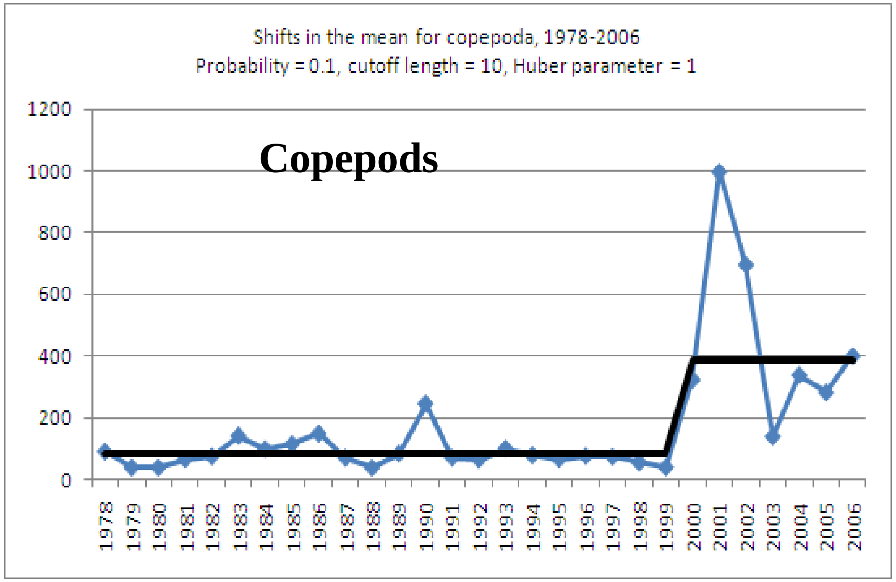
◆ **Mesh size = 330 micron**

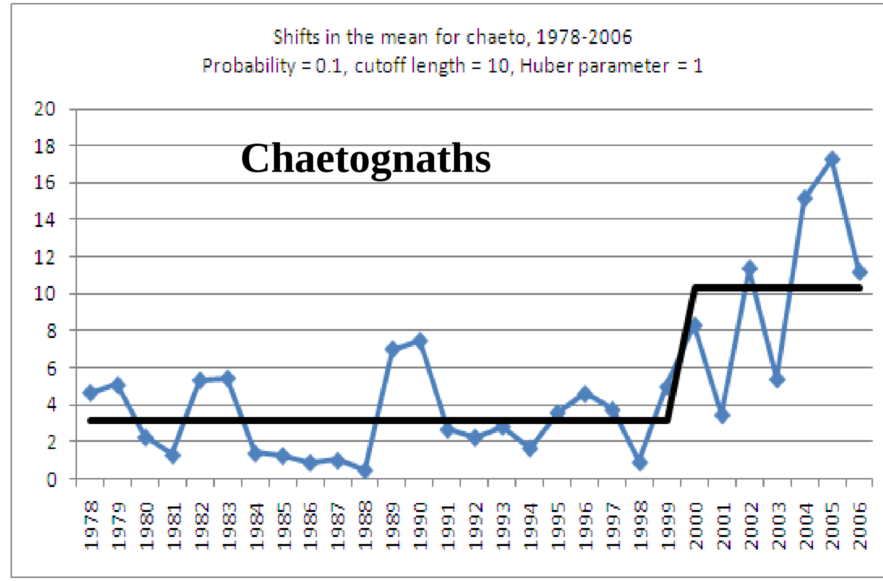
Zooplankton mean biomass in the Japan/East Sea

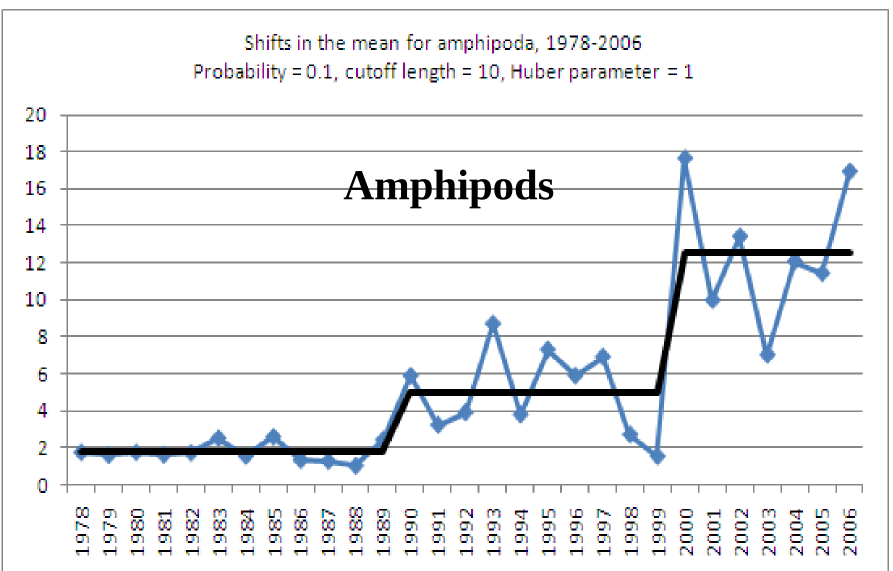


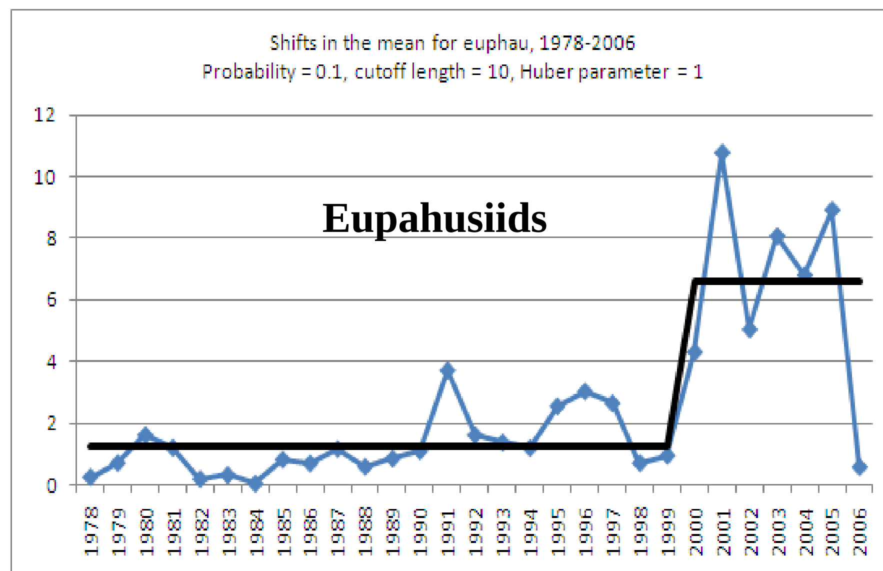
1992, 2001

Mean numerical density of major zooplankton groups in the JES: 1999 shift









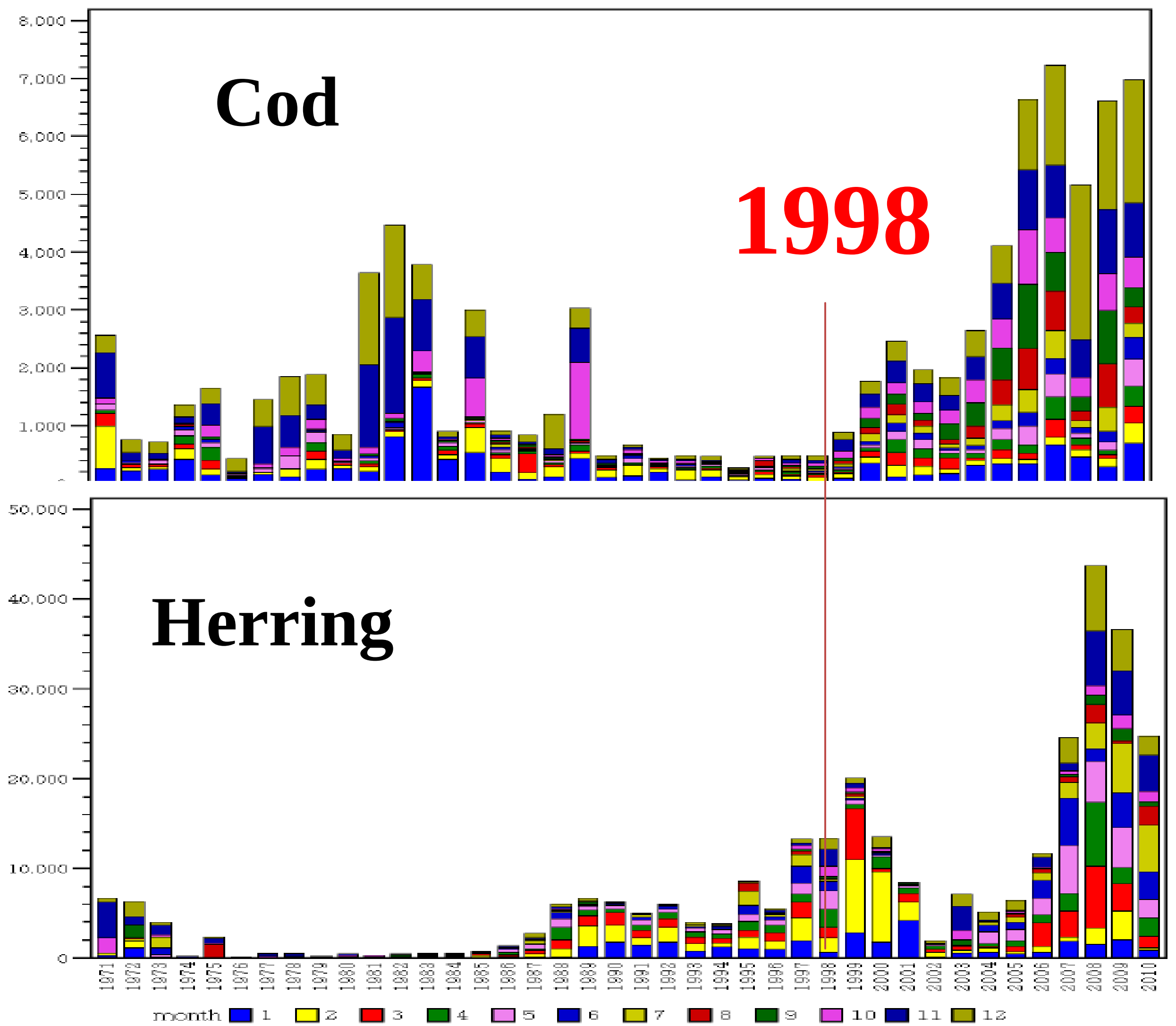
Summary of responses of Korean marine ecosystems to the past regime shifts and El Niño events

(Kang et al. Submitted to Progress in Oceanography)

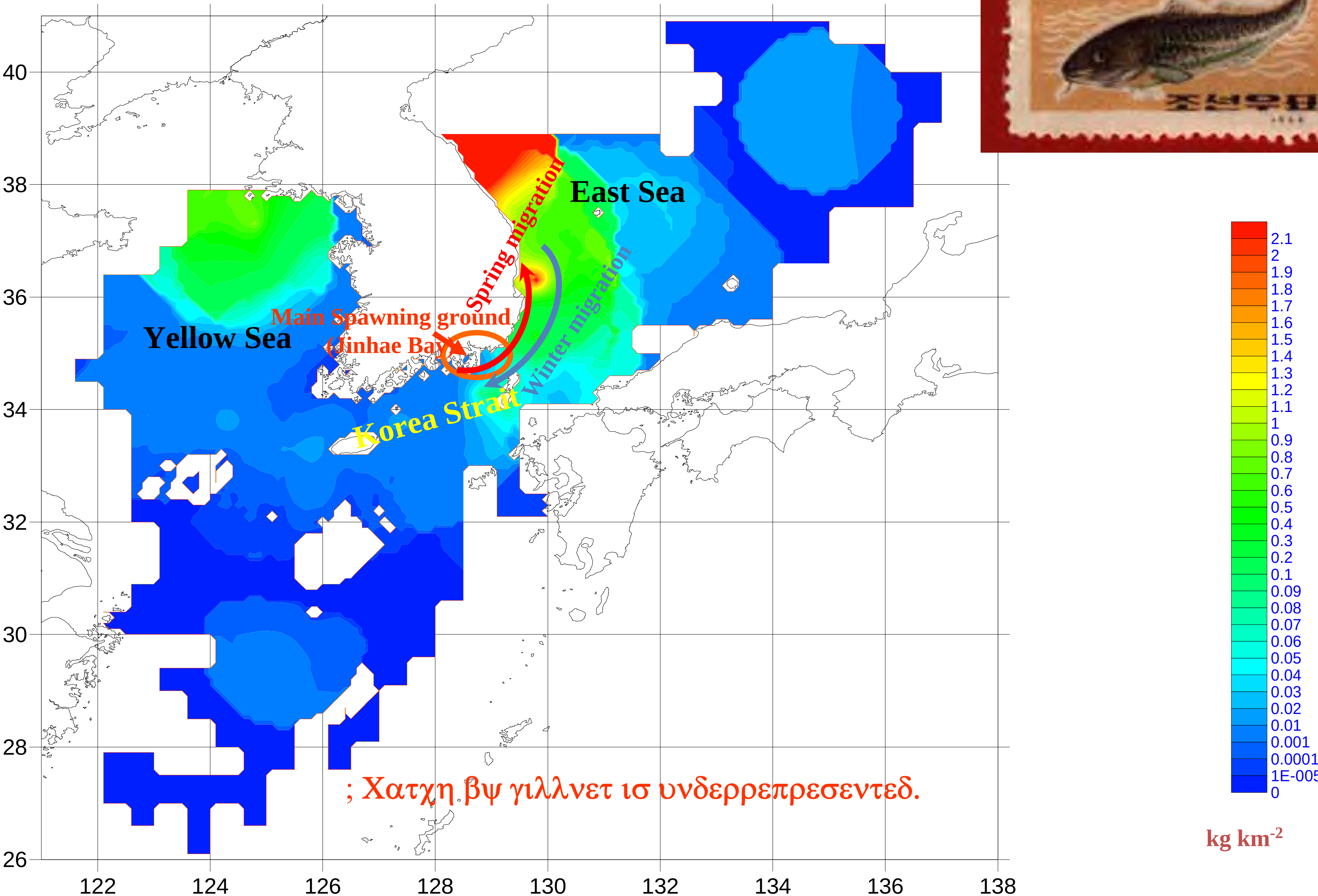
	Region	1977 regime shift	1982 El Niño	1989 regime shift	1998 El Niño
Air Temp.	Korea	X	X	O	X
Rainfall	Korea	X	X	X	O
Temperature	EYS	X	X	O	O
	KS	X	X	O	X
	SJES	X	X	X	O
Salinity	EYS	O	X	X	O
	KS	X	O	X	O
	SJES	X	O	X	O
Zooplankton biomass	EYS	X	X	O	O
	KS	X	X	X	O
	SJES	X	X	O	X
	NJES	–	–	X	O
Zooplankton community structure	EYS	–	O	O	O
	KS	–	X	O	O
	SJES	–	X	O	O
	NJES	–	–	X	O
Fish	**Korean waters**	**O**	**O**	**O**	**X**
Total		2	4	9	13

Symbols: X = Not detected, O = Detected, – = Data unavailable

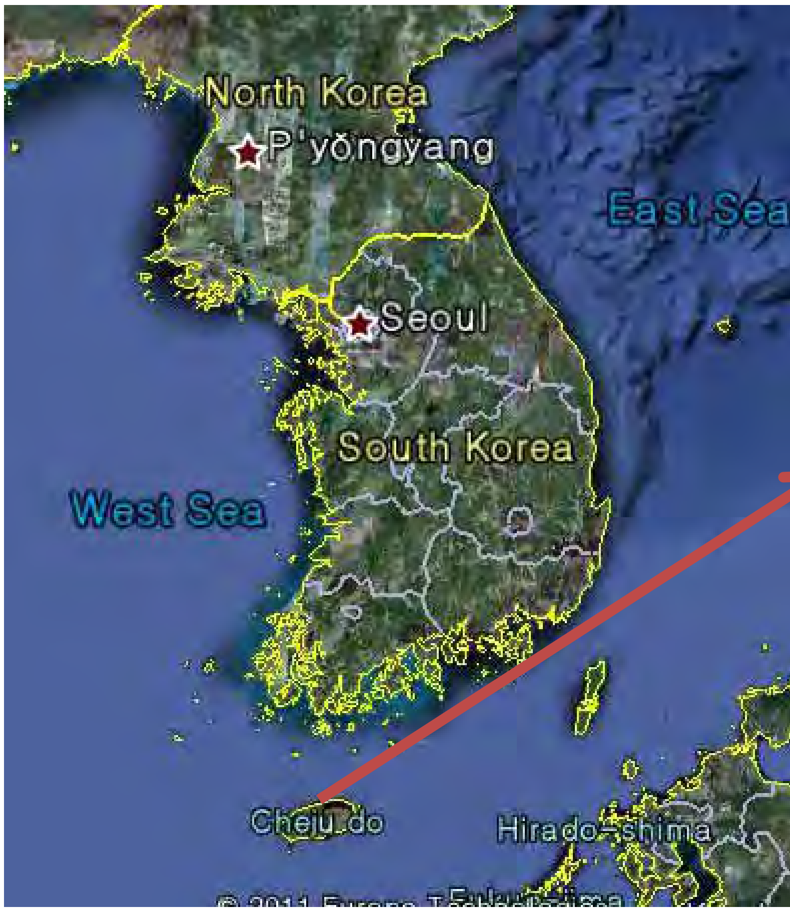
Landings of Pacific cod and Herring in Korea 1971-2000



Cod, Mean catch level (1994-2008) based on location reports from fishing boats

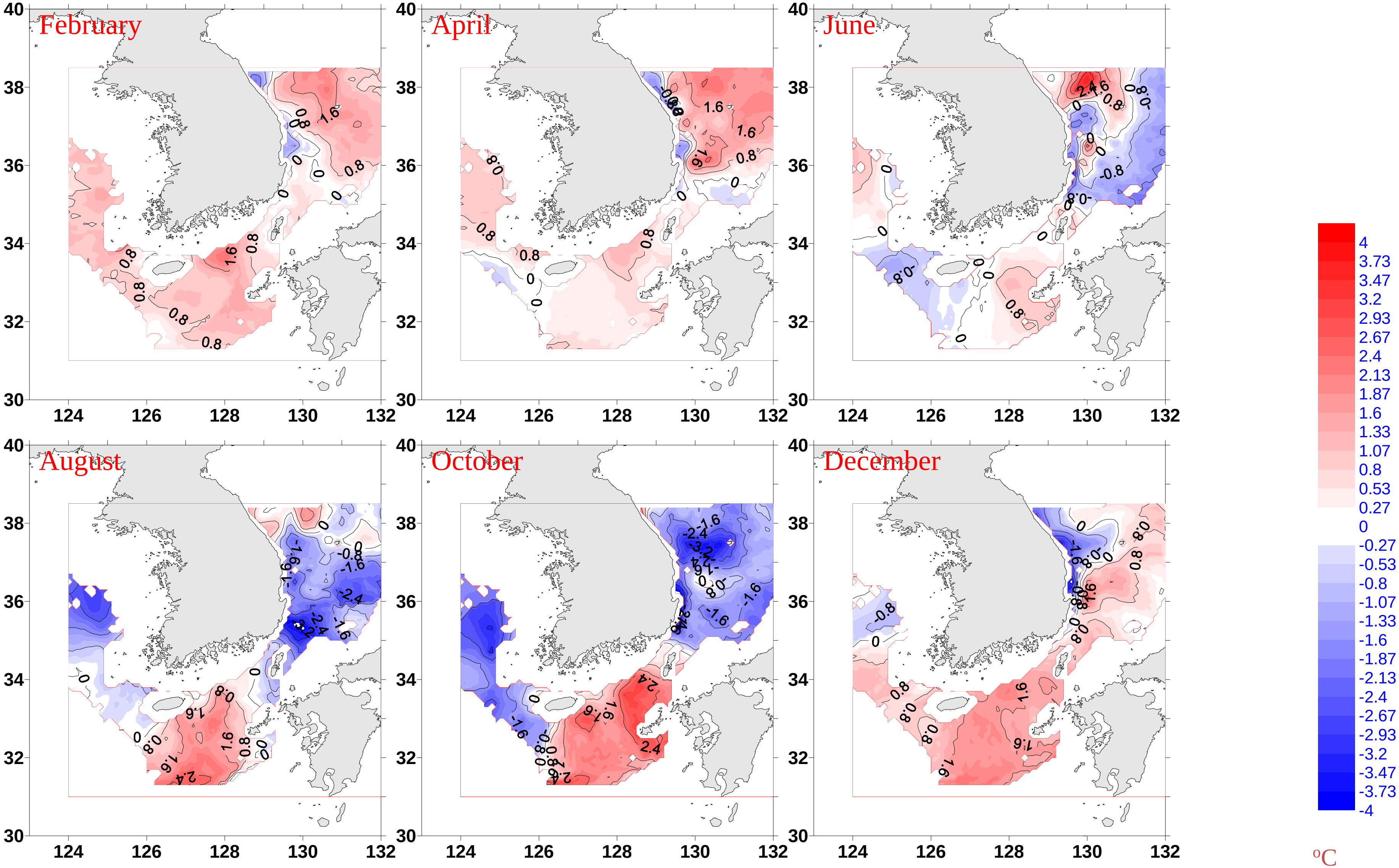


Southward Expansion of Pacific cod to Jeju Island

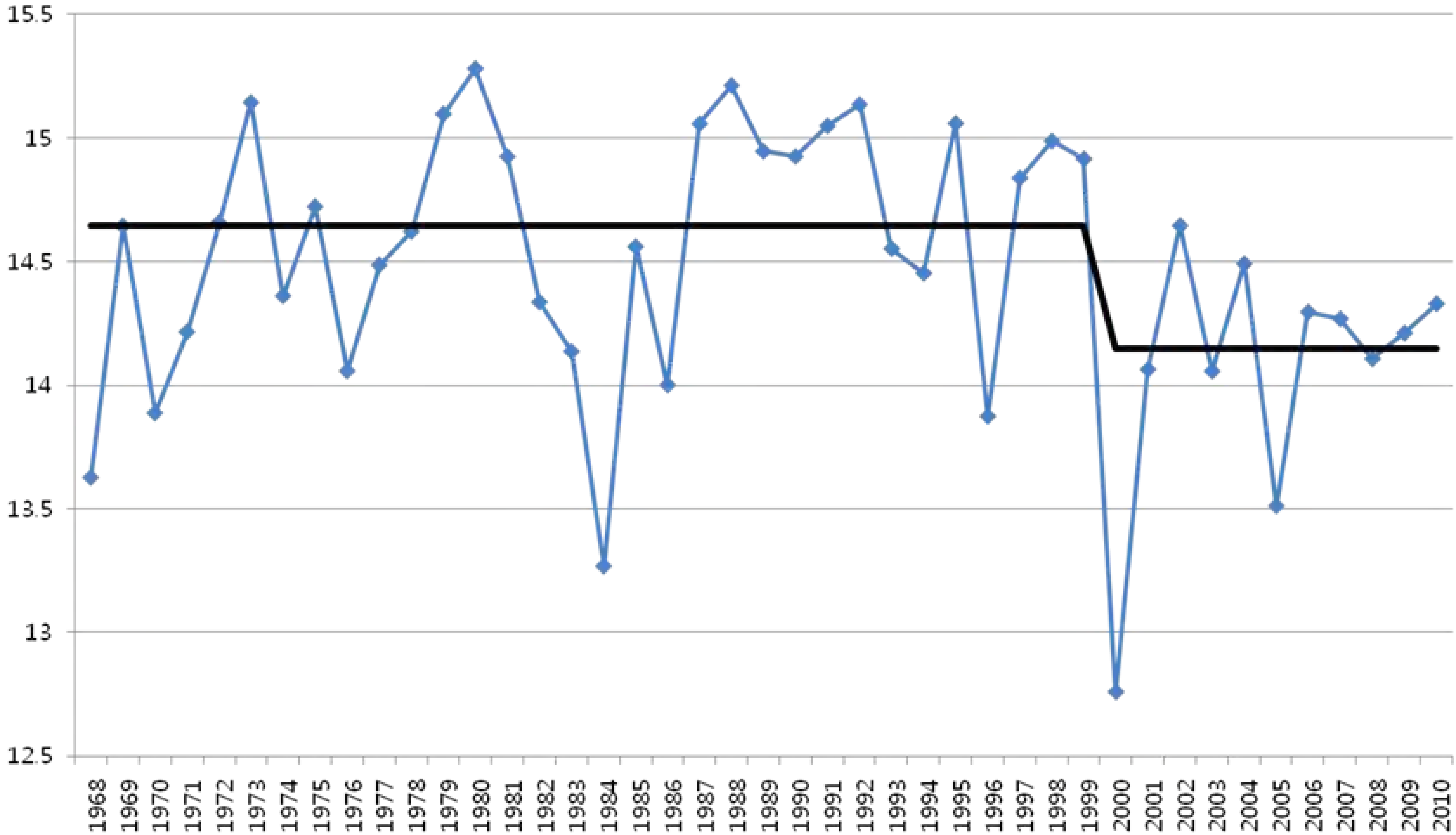


Caught on September 9, 2011
Length = 32~35 cm (2 yrs old)

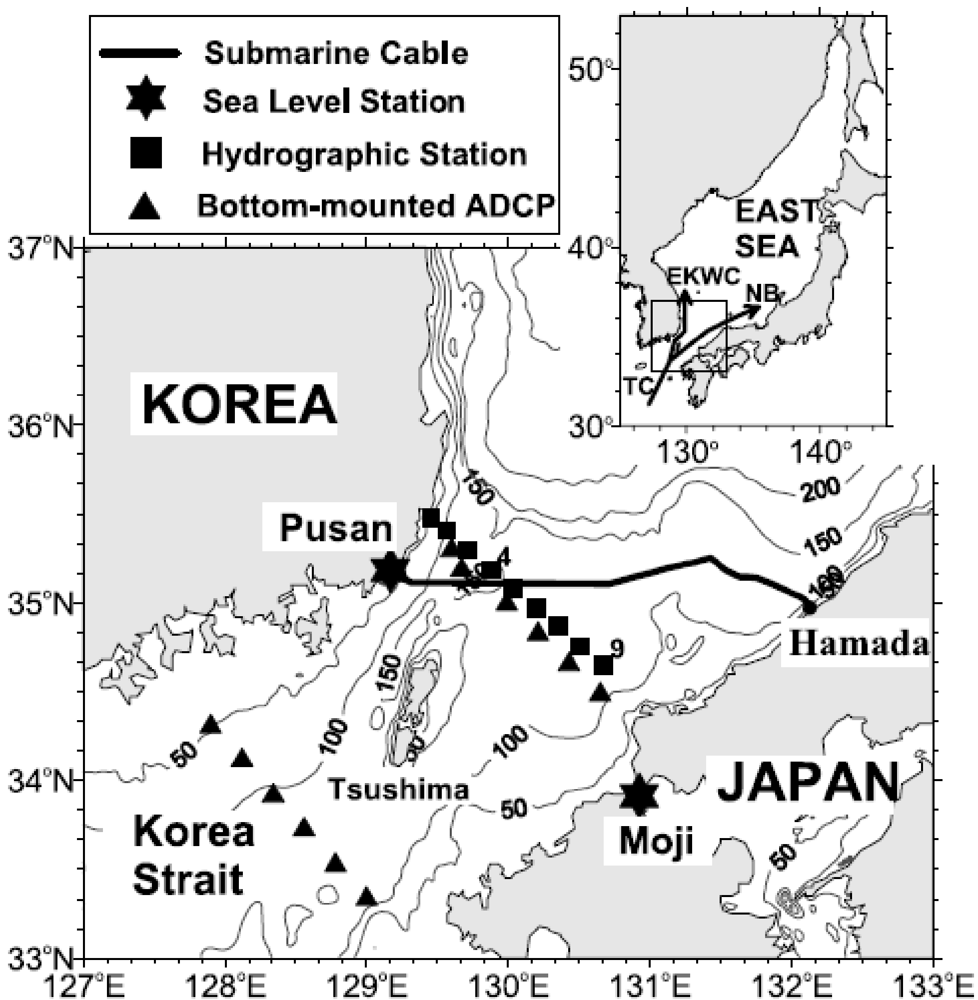
Linear Trend of Change in Water Temperature at 75 m (1968-2006)



Water temperatures at100-m depth in the Korea Strait



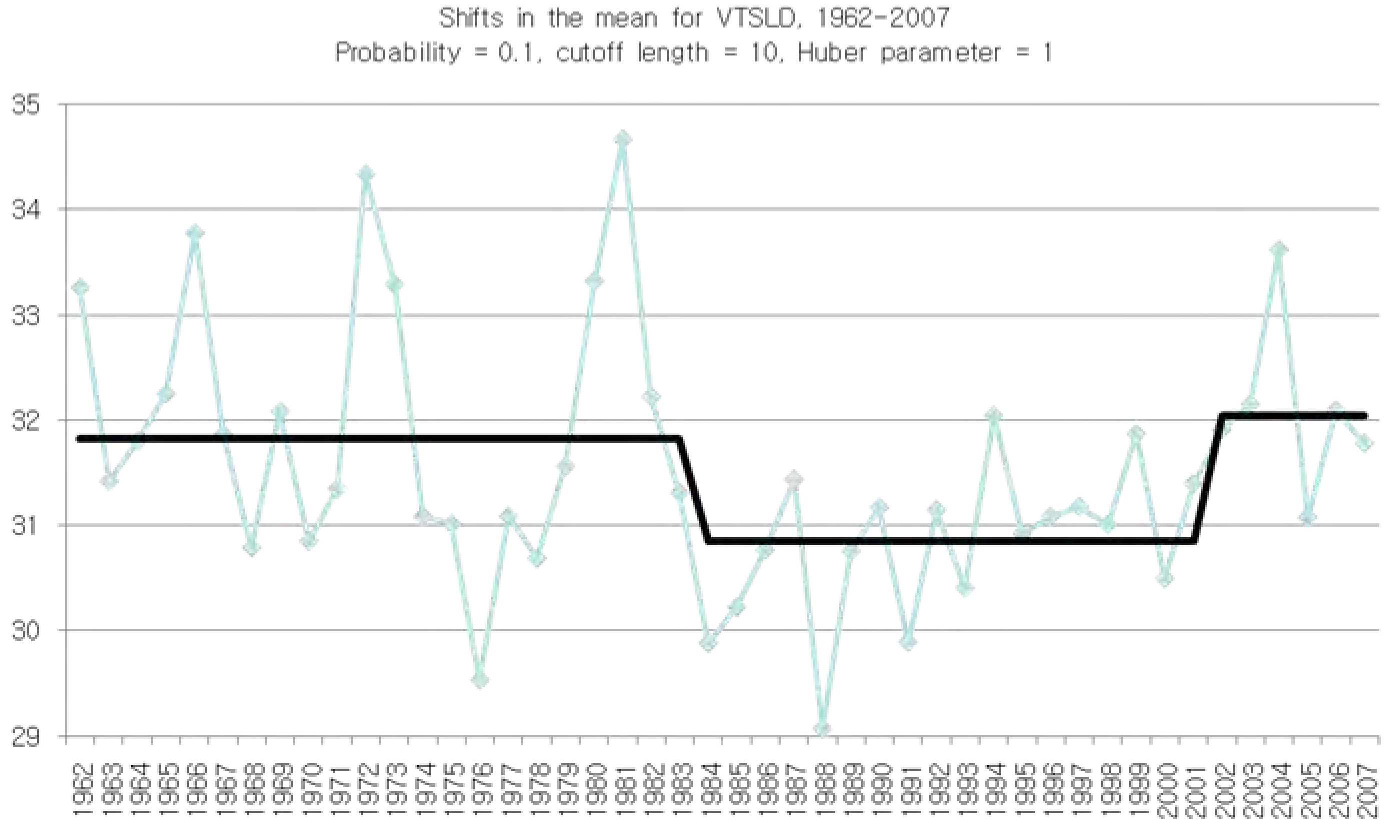
Volume Transport by the Tsushima Warm Current (1962-2008)



From Lyu & Kim. 2003. Absolute transport from the sea level difference across the Korea Strait. Geophysical Research Letters 30(6): 18-1 - 18-4.

TWC volume transport

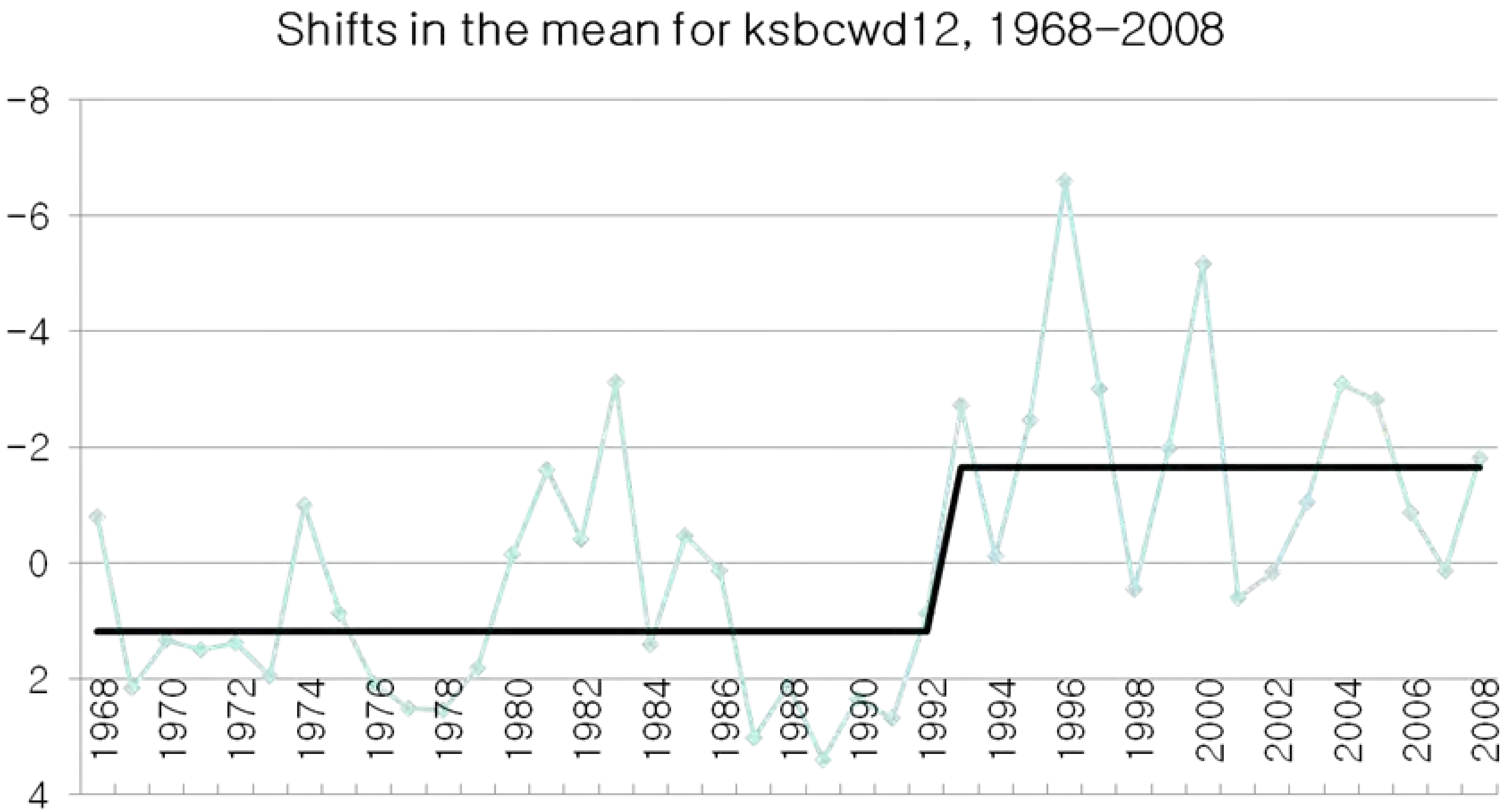
Courtesy of Hanna Na, Seoul National University



1984, 2002

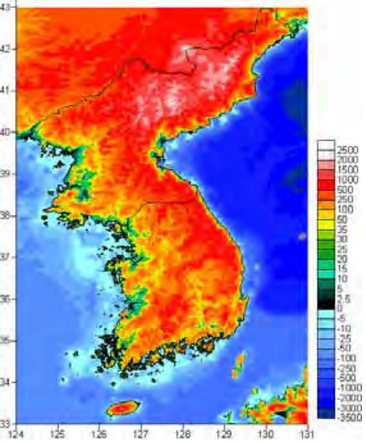
KSBC (Estimated relative volume transport of bottom cold water from the Japan/East Sea

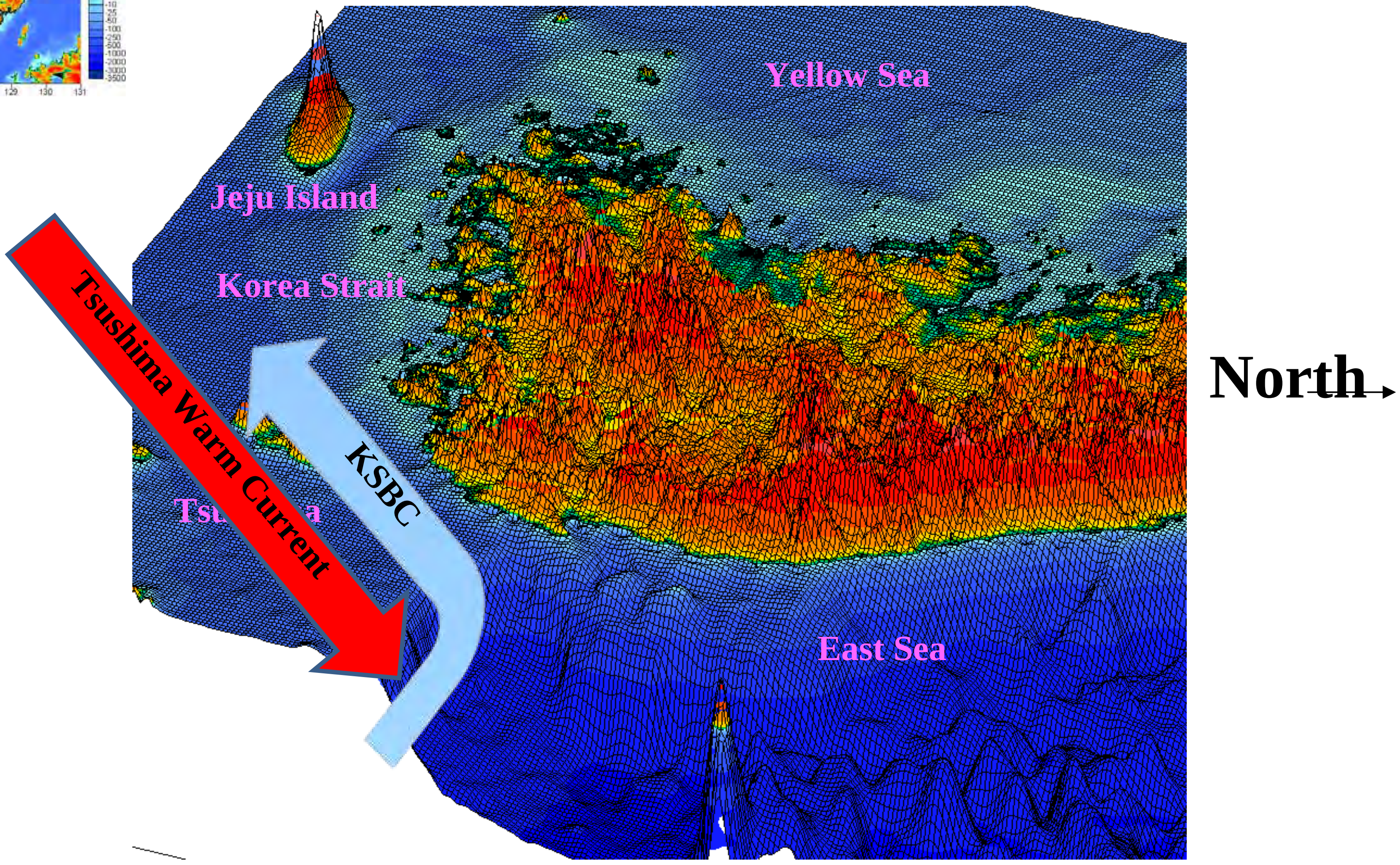
Courtesy of Hanna Na, Seoul National University



1993

Topography





Yellow Sea
Jeju Island
Korea Strait
Tsushima Warm Current
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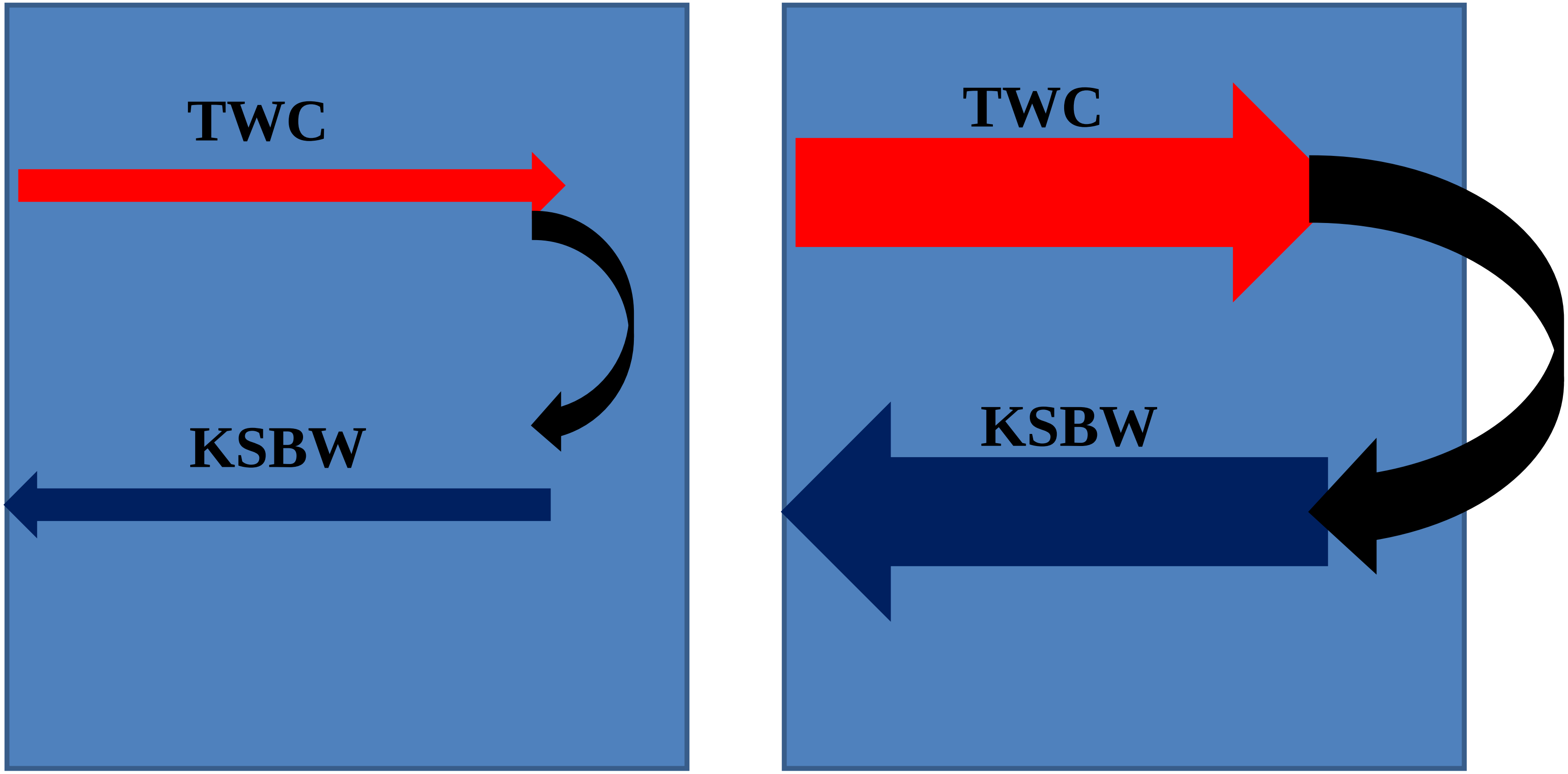
Tsushima Warm Current (TWC) vs. Korea Strait Bottom Cold Water (KSBW)



Conclusions

- Responses to the reported regime shifts can vary depending on region and depth, and which variables you choose.
- In Korean waters, the shift in 1998 was the most evident, followed by 1989.
- Although the CCA did not detect the 1998 shift in fish community structure, the recent increase of cod and herring catch supports the idea of the 1998 shift, related with strengthened TWC.

Future Works

- Develop a robust shift detection method that can incorporate and reflect spatial variability in hydrographic conditions
- Improve reliability in estimation of volume transports of the TWC and KSBCW by applying general circulation models