Synchronicity of climate driven regime shifts among the East Asian Marginal Sea waters and major fish species

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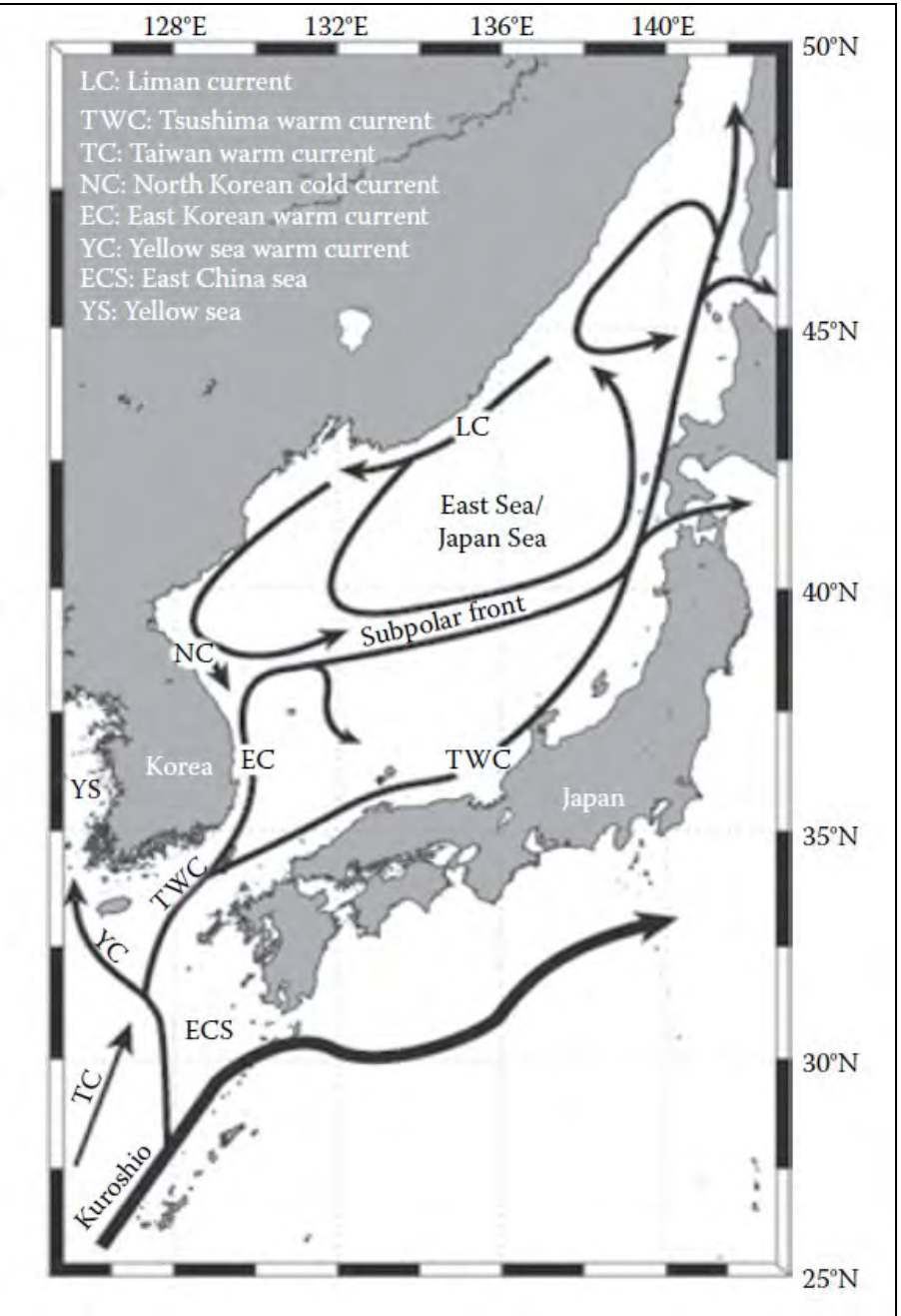
East Asian Marginal Sea (EAMS) - South Korean marginal sea



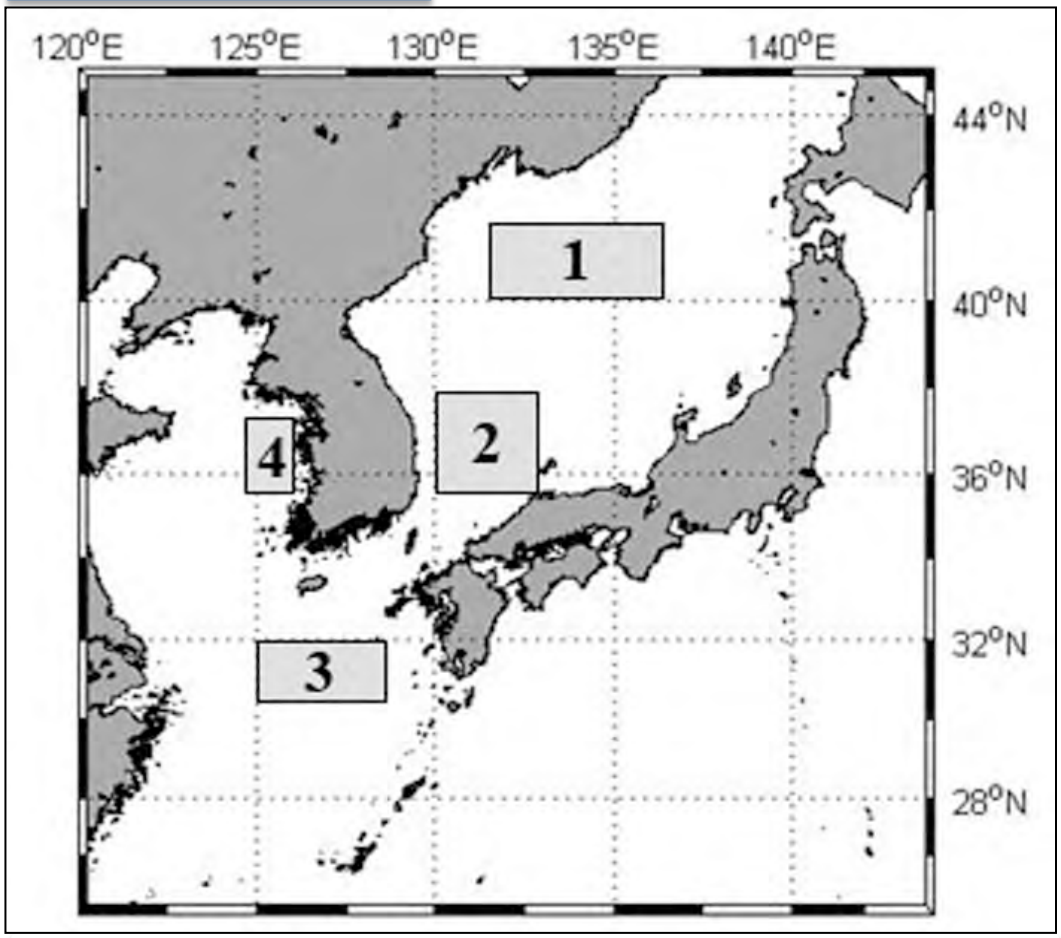
❑East/Japan Sea, East China Sea and Yellow Sea are three contiguous seas comprise the **East Asian Marginal Sea (EAMS)**

❑They are subject to climate forcing just as much as open seas are, but they take **more time to recover**.

❑The East Sea/Japan Sea is situated between **subtropical and subpolar zones.** It represents a miniature version of a large ocean.

❑The Tsushima Warm Current in the southern region and the Liman Cold Current in the northern region are two major currents and they are divided into warm (southern) and cold (northern) regions, with the **boundary (polar front) around 40°N.**

Study area



❑**The Yellow Sea** is characterized as a shallow water body (average depth of about 44 m) with mud flats and a low-saline, high-nutrient, semi-enclosed shelf sea.

❑The average depth of the **East China Sea** is about 272m and is mostly controlled by the TWC, the Kuroshio Branch Current, and the Changjiang River discharge.

1) North East/Japan Sea (NES): 40⁰- 42⁰N, 133⁰-137⁰E

2) South East/Japan Sea (SES): 35⁰- 38⁰N, 130⁰- 133⁰E

3) East China Sea (ECS): 30⁰- 32⁰N, 124⁰- 129⁰E

4) Yellow Sea (YS): 35⁰- 37⁰N, 123⁰- 126⁰E

Data and Methodology

❖ Major climate variability in the North Pacific region:

1) Pacific Decadal Oscillation (PDO) (Mantua et al., 1997)
2) North Pacific Index (NPI) (Trenberth and Hurrel, 1994)
3) Arctic Oscillation (AO) (Thomson and Wallace, 1998)
4) Siberian High Pressure (SHP) (Gong and Ho, 2002)
5) East Asian Winter Monsoon (EAWM) (Jhun and Lee, 2004)
6) ELNino Southern Oscillation (ENSO) (Wolter and Timlin, 1993)

❖ Sea water temperatures (winter: Jan-Feb-Mar):

1) North East/Japan Sea : 10m, 50m and 100m
2) South East/Japan Sea: 10m, 50m and 100m
3) East China Sea: 10m, 50m and 100m
4) Yellow Sea: 20m

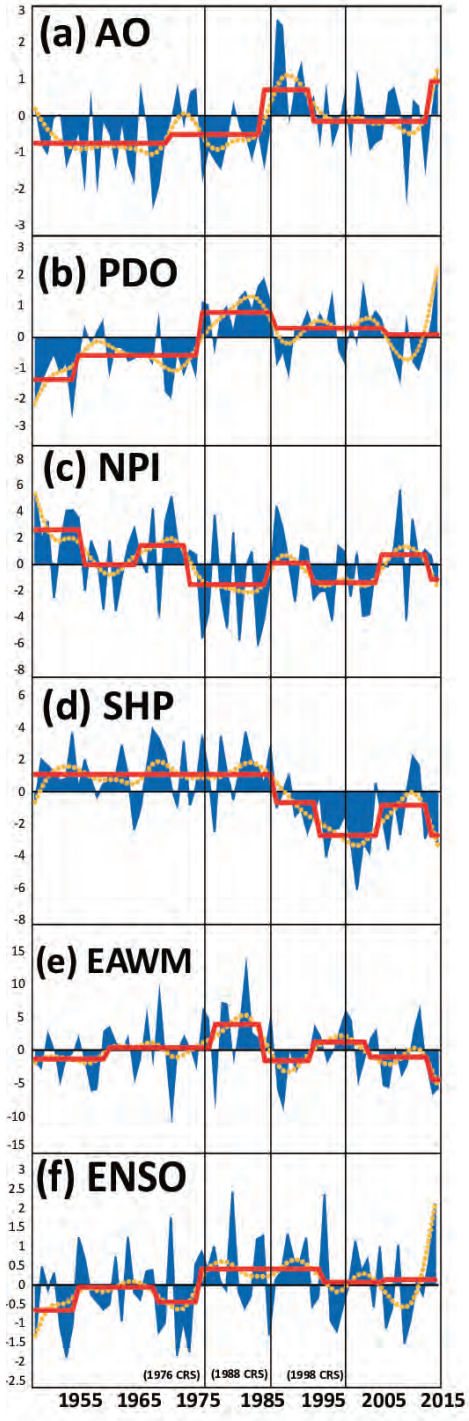
[World Ocean Database (WOD13), National Oceanographic data Center (NODC), NOAA, 2013]

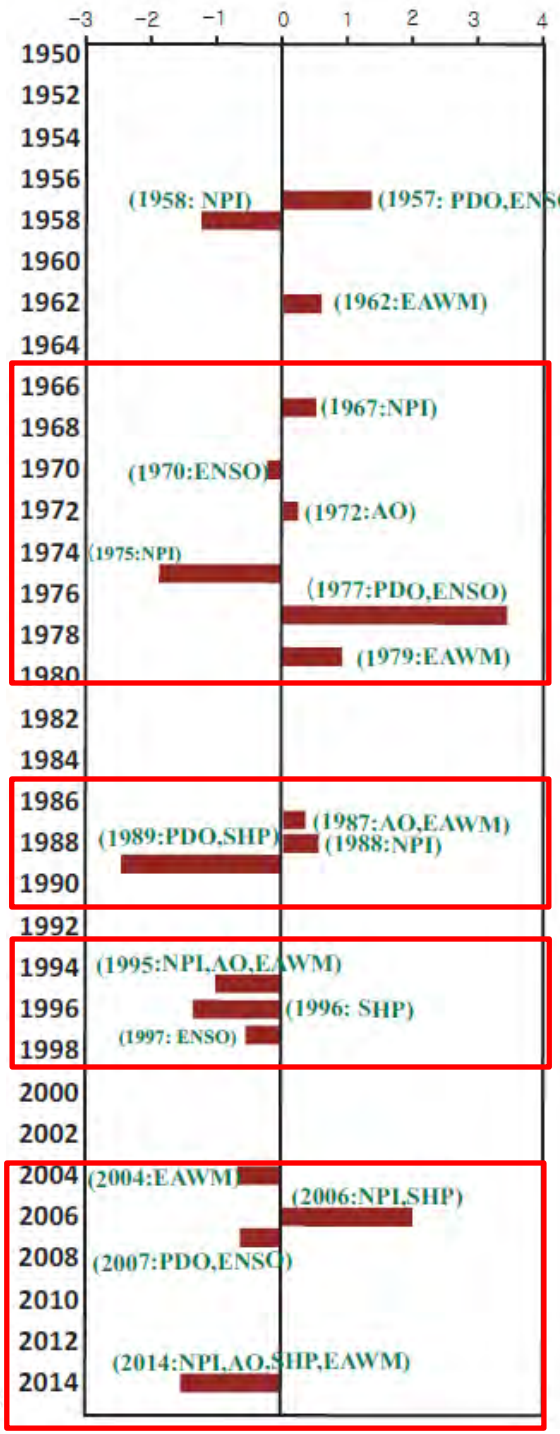
❖ Fisheries commercial catch of Korean marine waters:

[Korea Fisheries Association, KFA, 2014]: 10 Species catch anomaly

❖ Regime shift detection and analysis

1) Sequential t-test analysis of regime shift (STARS) (Rodionov, 2004)





Climate variability & Regime shifts

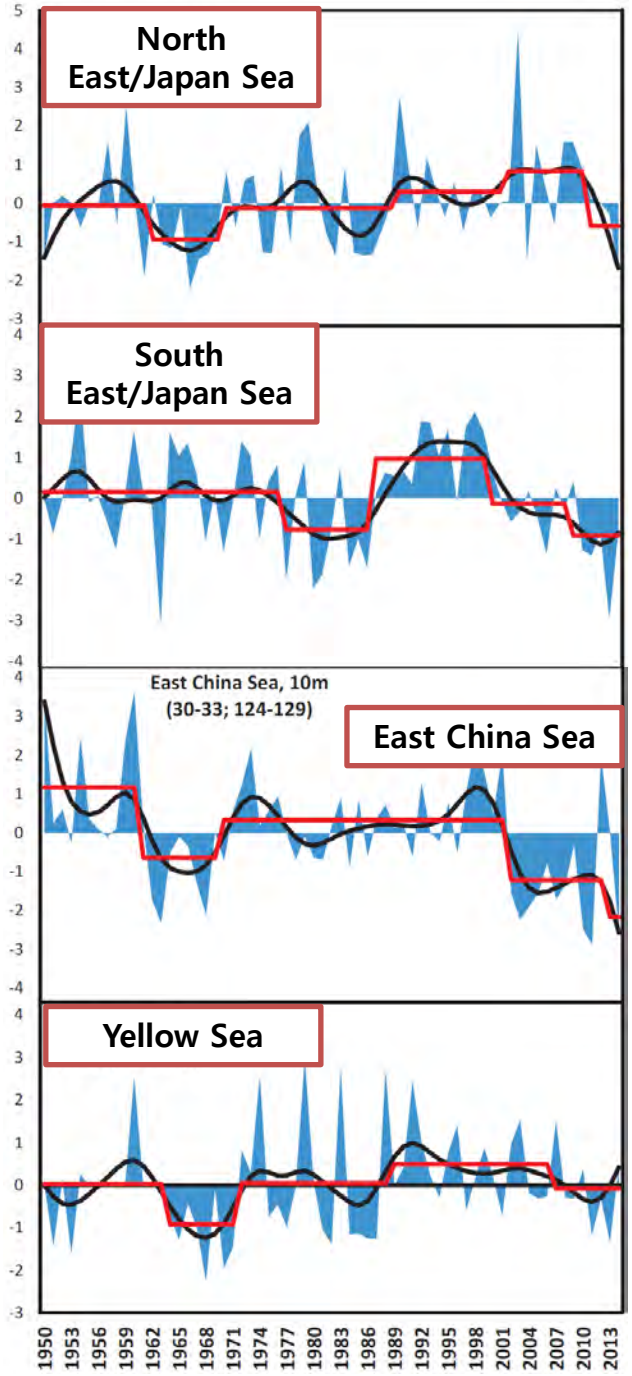
1976/77 Climate regime shift:
1967:NPI (+)
1970:ENSO (-)
1972:AO (+)
1975:NPI (-), ALP (+)
1977:PDO, ENSO (+)
1979: EAWM (+)

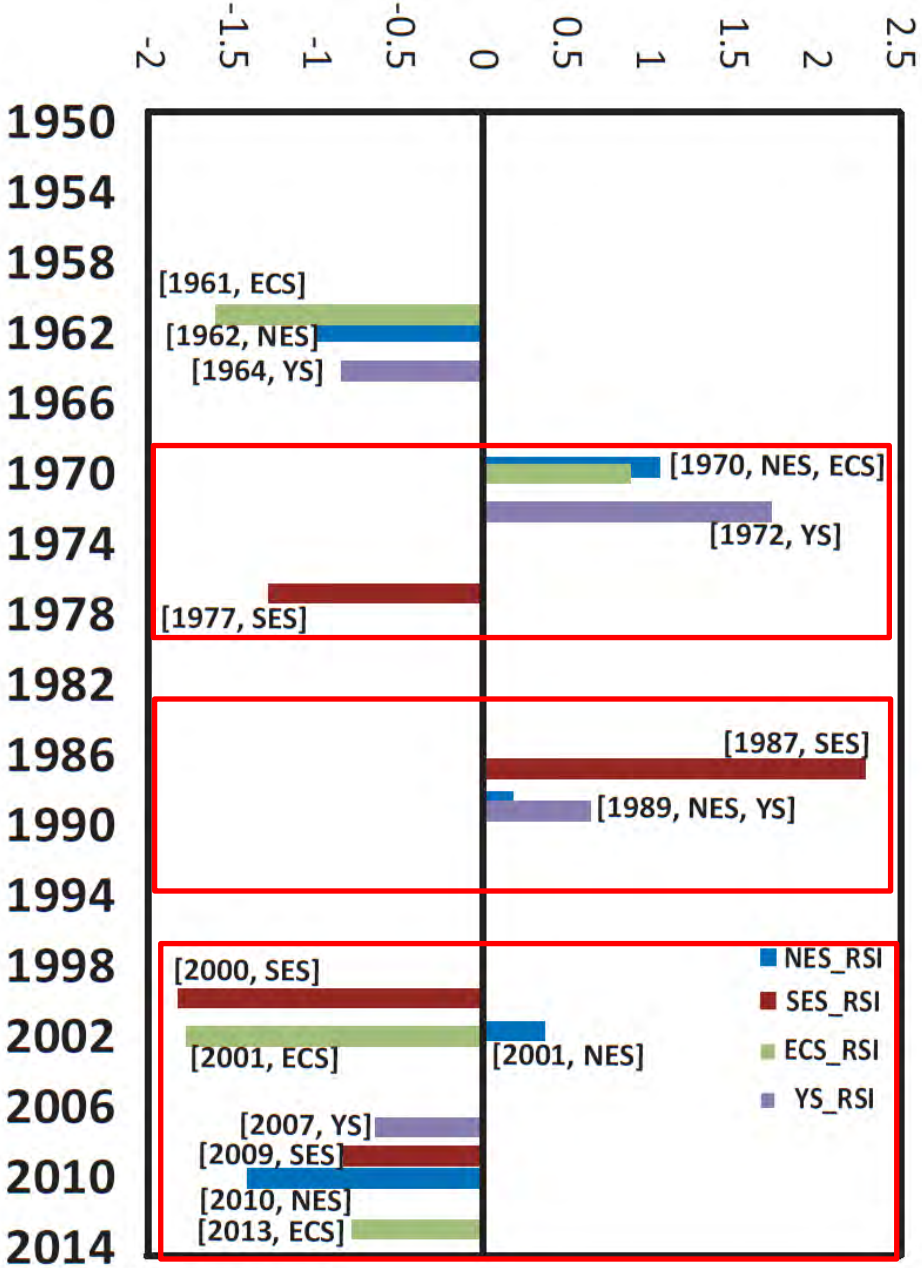
1988/89 Climate regime shift:
1987:AO (+), EAWM (-)
1988: NPI (+), ALP (-)
1989: PDO (-), SHP (-)

1998 Climate regime shift:
1995: NPI (-), ALP (+), AO (-), EAWM (+)
1996: SHP (-)
1997: ENSO (-)

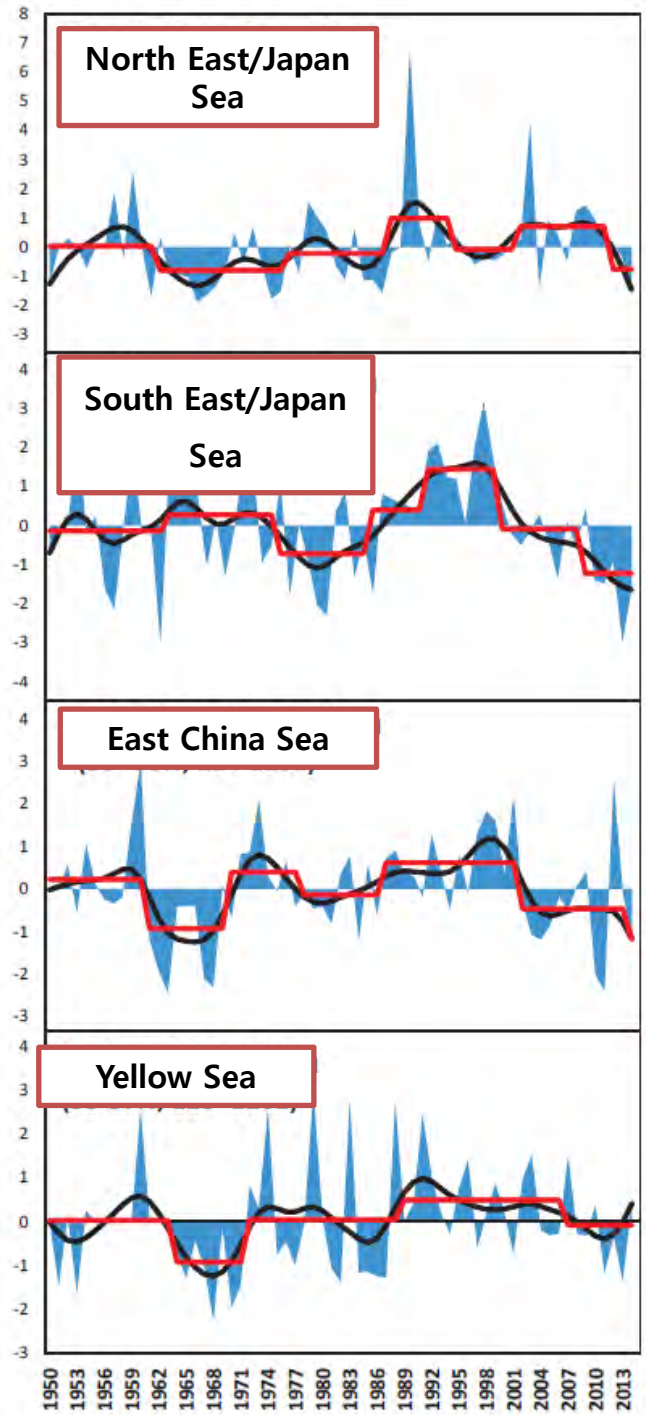
Recent Climate regime shift:
2004: EAWM (-)
2006: NPI (+), ALP (-), SHP (+)
2007: PDO (-), ENSO (-)
2014: NPI (-), ALP (+), AO (+), SHP (-)
EAWM (-)

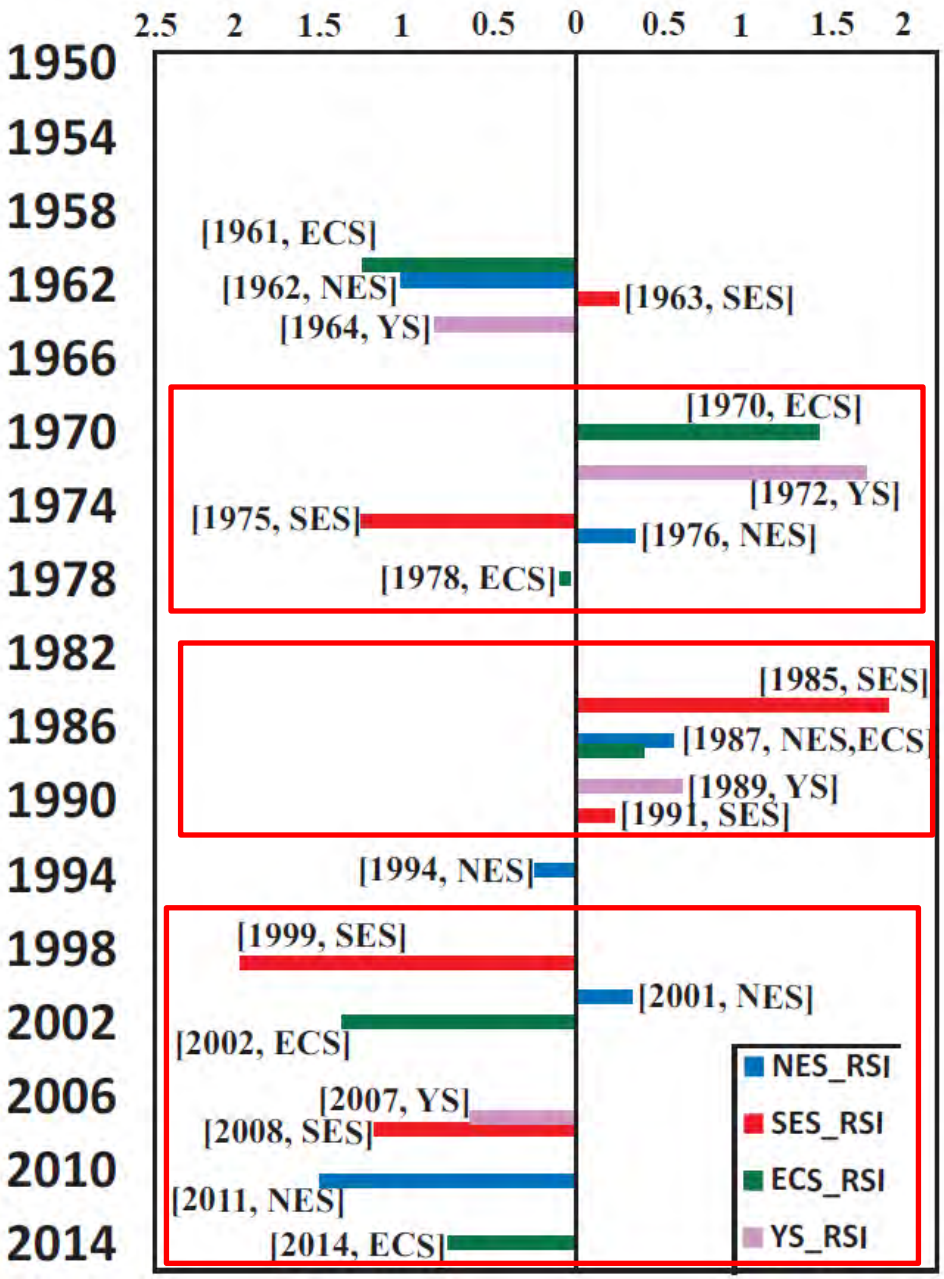
10m sea water temperature & Regime shifts



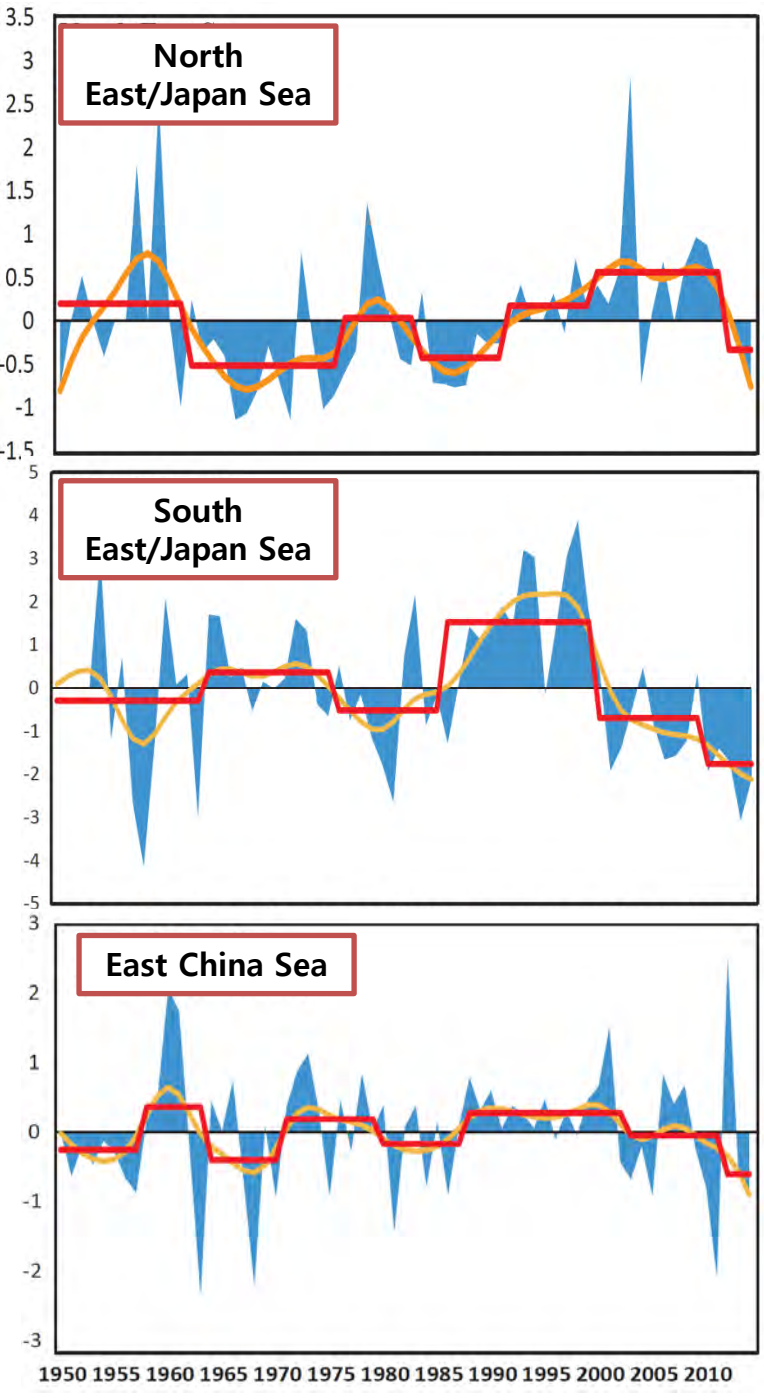


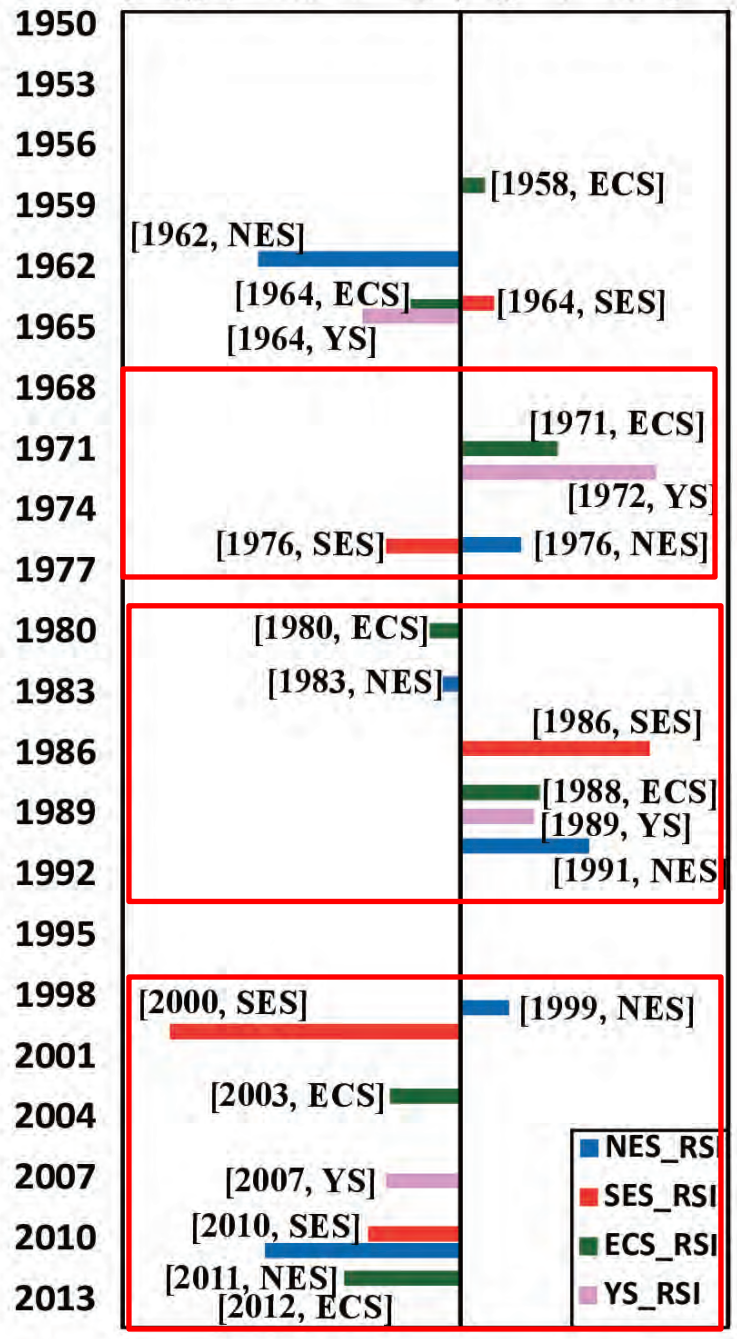
50m sea water temperature & Regime shifts





100m sea water temperature & Regime shifts

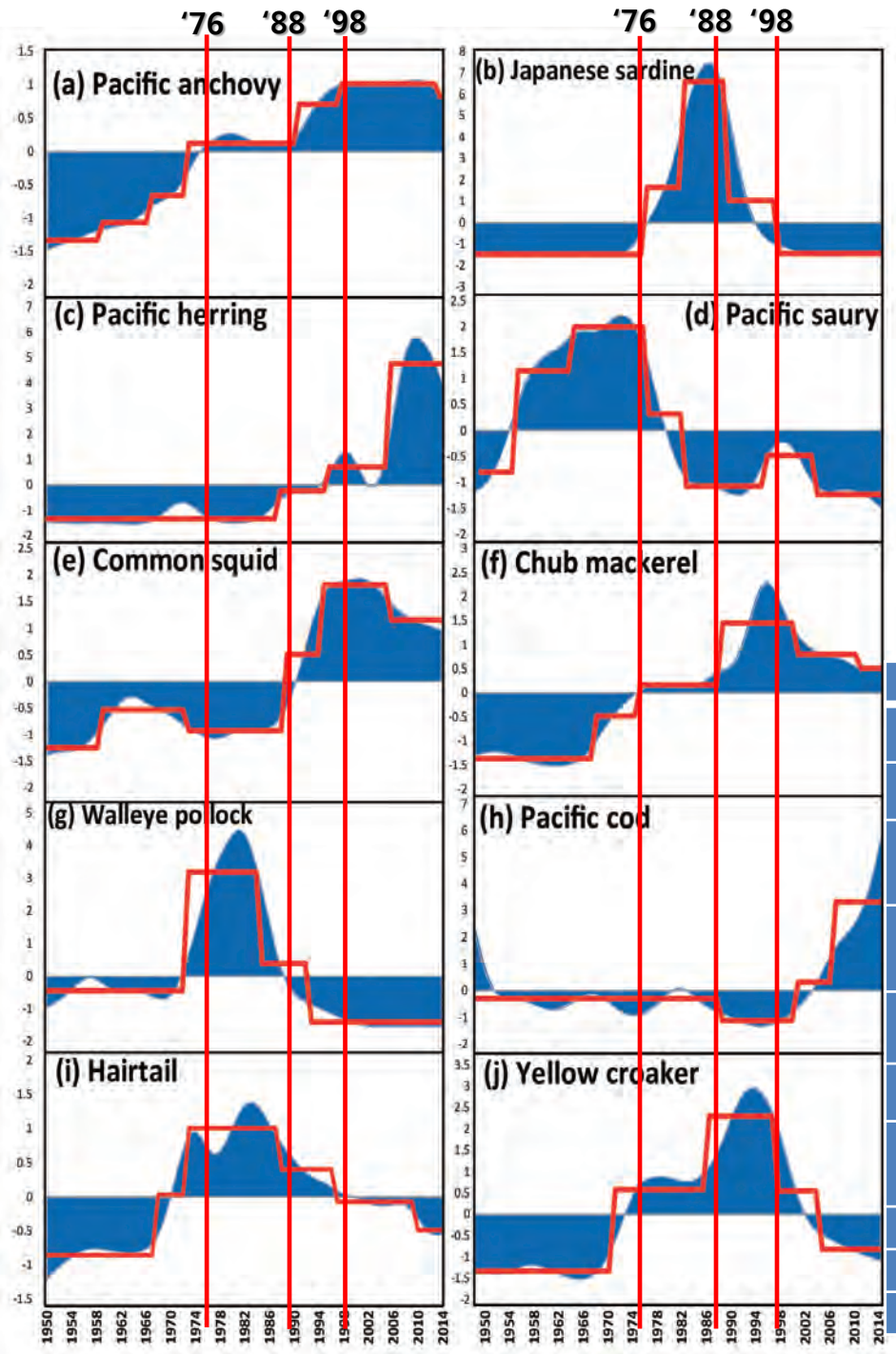


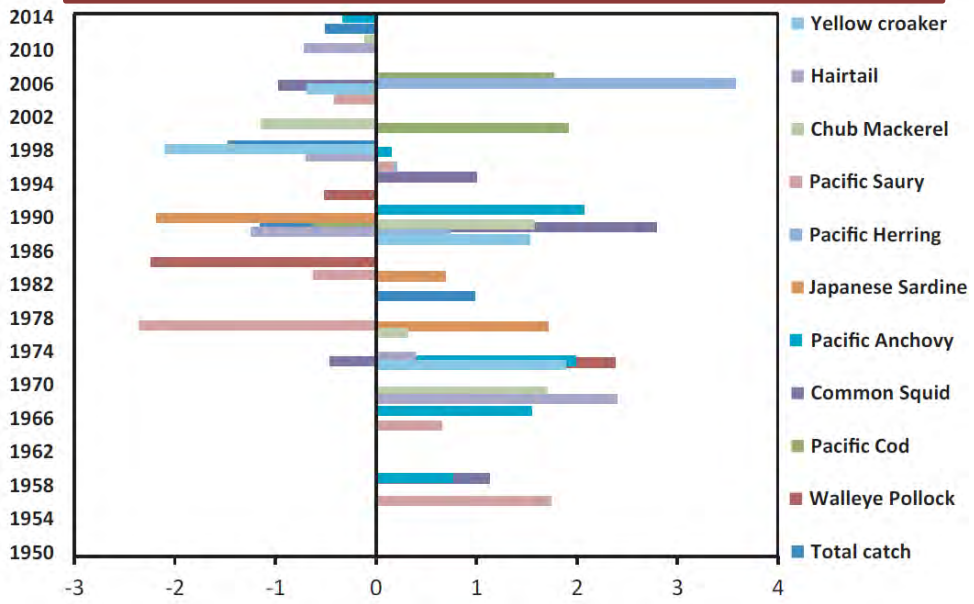


Summary of Regime shifts in SWT

- **1976/77 CRS:** Only negative shifts in the SES region and other regions were in positive mode. All SWT were shifted before the 1976 CRS.
- **1988/89 CRS:** All SWT were shifted within very short time between 1985-1991.
- **1998 CRS:** All SWT were shifted negatively since 2000, however, the NES was only in positive shift in the 2001.

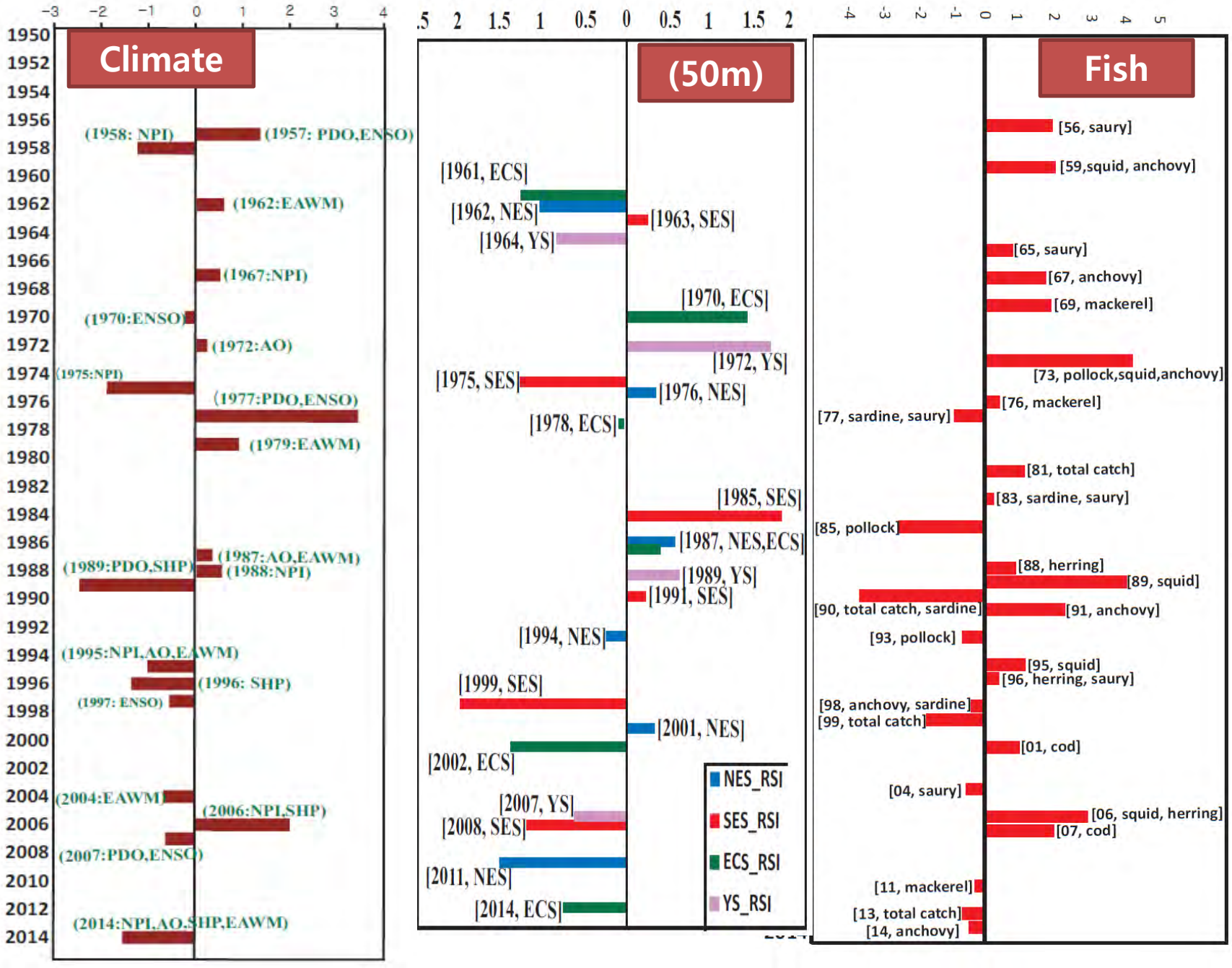
Major fish species & Regime shifts





Major species	Regime shifts
Walleye Pollock	**1973, 1985**, 1993
Pacific Cod	**1989**, 2001, 2007
Common Squid	1959, 1973, **1989**, 1995, 2006
Pacific Anchovy	1959, 1967, 1973, **1991**, 1998, 2014
Japanese Sardine	**1977**, 1983, **1990,** 1998
Pacific Herring	**1988**, 1996, 2006
Pacific Saury	1956, 1965, **1977**, 1983, 1996, 2004
Chub Mackerel	1969, 1976, **1989**, 2001, 2011
Hairtail	1968, 1973, **1988**, 1997, 2010
Yellow croaker	1972, **1987, 1998**, 2005

Climate vs Sea water temperature vs fish abundance



1983:Sardine (+)

1987:NES (+), ECS (+)

1985: SES (+)

1987: AO (+)

1988: Herring (+)

1989: Squid (+)

1991: Anchovy (+)

1989: YS (+)

1988: NPI (+)

1983

1988

1990

1987: EAWM (-)

1988: ALP (-)

1989:PDO(-), SHP (-)

1990:Sardine (-)

1983: Saury (-)

1985: Pollock (-)

1988/89 regime shifts: Climate – SWT - fish abundance

2001:Cod (+)

2001: NES (+)

2006: Herring (+)

2006: NPI (+), SHP (+)

2007:Cod (+)

2006: AO (+)

2000 | 2005 | 2010 | 2015

1999: SES (-)

2002: ECS (-)

2004: EAWM (-)

2004: Saury (-)

2006: ALP (-)

2006: Squid (-)

2007: YS (-)

2007:PDO(-), ENSO (-)

2008: SES (-)

2011: NES (-)

2011: Mackerel (-)

2014:NPI(-), SHP (-) EAWM (-)

2014: ECS (-)

2014: Anchovy (-)

Recent regime shifts: Climate - SWT- fish abundance

Climate vs Sea water temperature vs fish abundance

- **Walleye Pollock:** Pollock had **positive shift in 1973** might be related with the lower temperature in the **southern East Sea region (1962-1975)**. Also 1975 negative shifts of the SWT of SES had an positive impact on the higher abundance of pollock. However, **negative shift in the 1985** was related with **the positive shifts of SES in the 1985**.
- **Squid: positive shifts in the 1989 related** with the **positive shifts of SWT from SES (1985), NES-ECS (1987).** Negative shifts in 2006 related with the negative shift of SES since 1999 and ECS 2002.
- **Anchovy:** closely relate with the 1988/89 CRS of positive shift of ECS, SES.
- **Sardine:** Prefer the cold regime, very closely follow the 1976/77 and 1988/89 CRS
- **Saury:** 1977-low, 1988-high, 1998-low

Summary

- **1976/77 CRS** was occurred for a long duration period (1970-1979).
- Most abrupt shifts were observed in NPI (1975) and PDO (1977) and ENSO (1977).
- Early abrupt shifts were detected in SWT of ECS (1970), YS (1972) and NES (1976).
- Early positive shifts were detected in walleye pollock, Japanese anchovy and hairtail; a sudden enhancement of Japanese sardine and a collapse of Pacific saury occurred in 1977.

- **In 1988/89 CRS**, most climate patterns were shifted within very short time (1987-1989).
- Abrupt shifts were observed in AO (1987), EAWM (1987) and SHP (1989).
- Positive shift of SWT in all of the EAMS were detected within very short time (1985-1989).
- Collapse of Japanese sardine (1983) and walleye pollock (1985) occurred early; a positive shift was detected in squid (1989).

- All climate patterns were shifted **earlier in 1998 CRS period**;
- Abrupt negative shift was detected in SWT of SES (1999) and ECS (2002).
- Negative shift was detected in yellow croaker (1998), chub mackerel (2001) and a positive shift in the Pacific cod (2001).

Thank you