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Regime shifts in the fish assemblages around Japan over the last century and their early warning signals for ecosystem-based fisheries management

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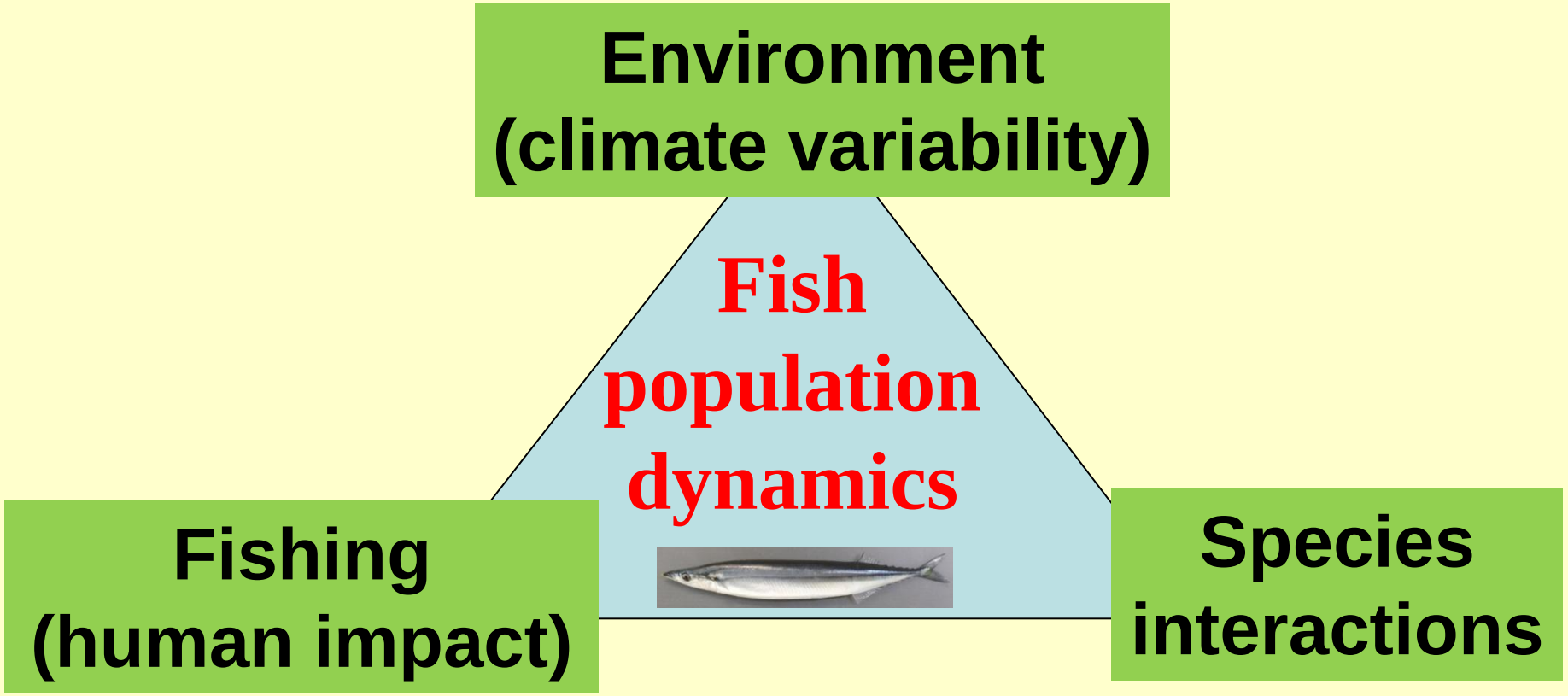
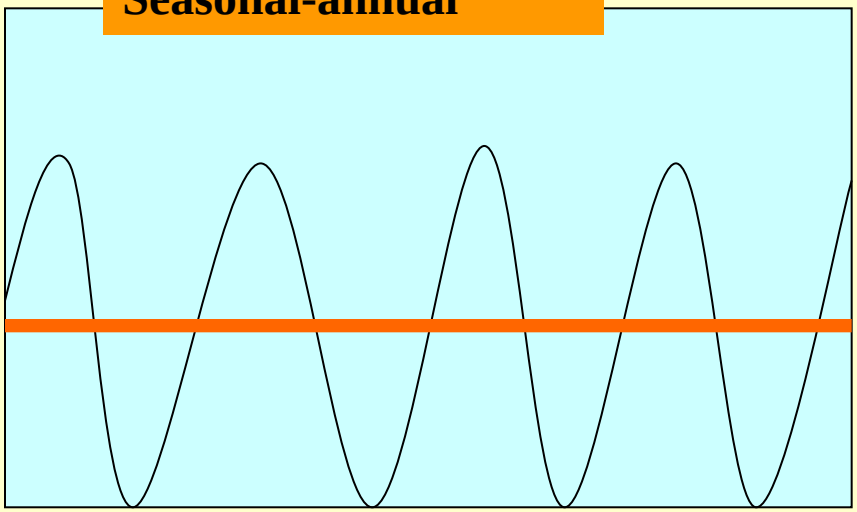
Fish population dynamics: human impact VS climate change



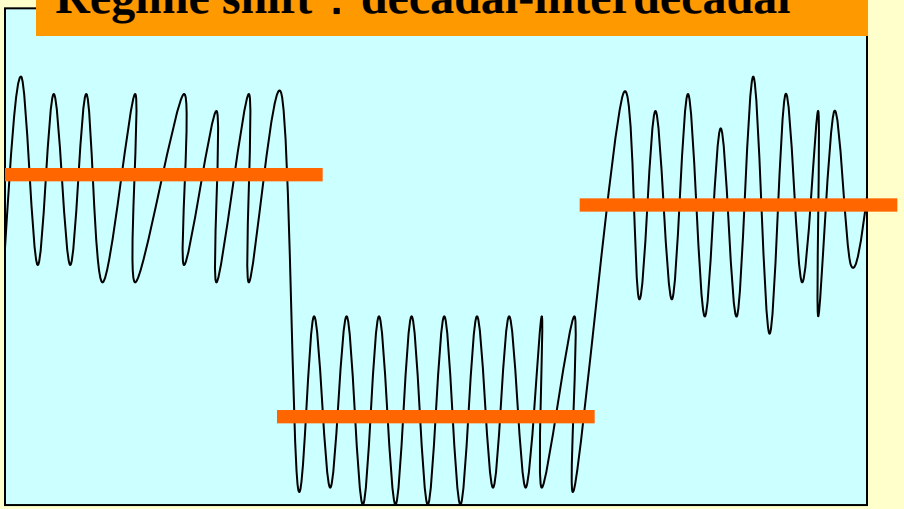
Understanding the climate impacts is essential for fish population dynamics and fisheries management

Time-scales in environmental variability

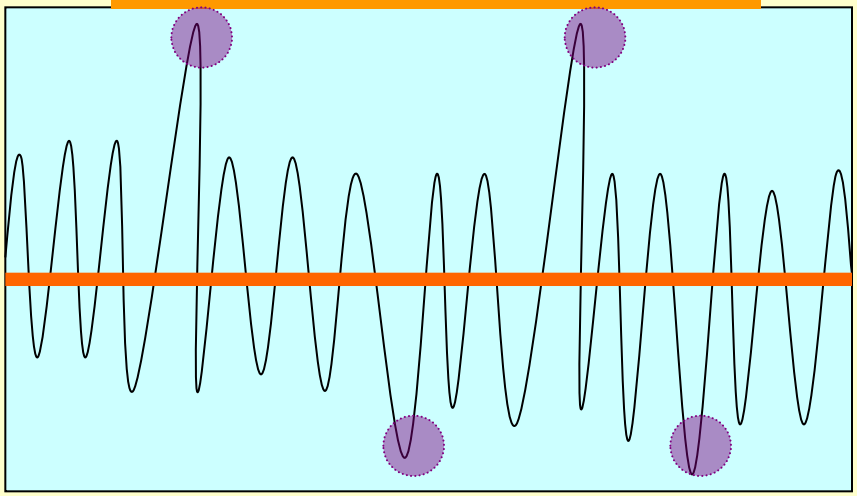
Seasonal-annual



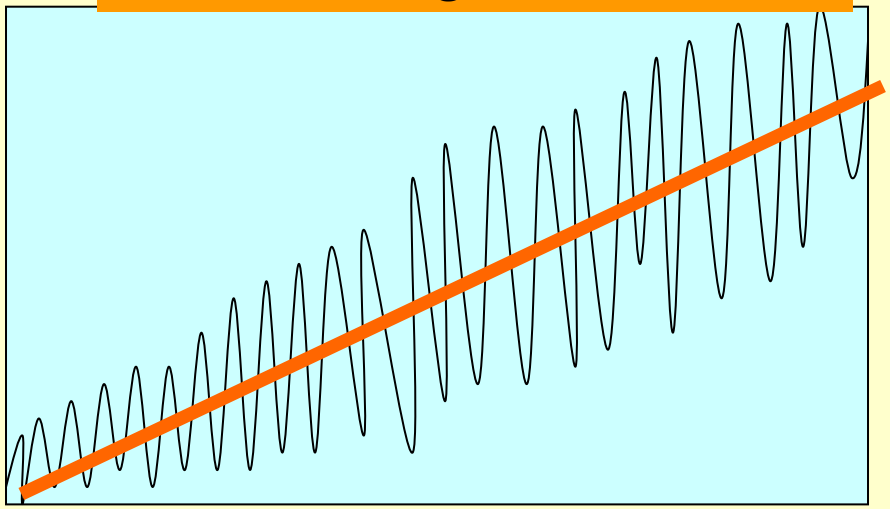
Regime shift：decadal-interdecadal



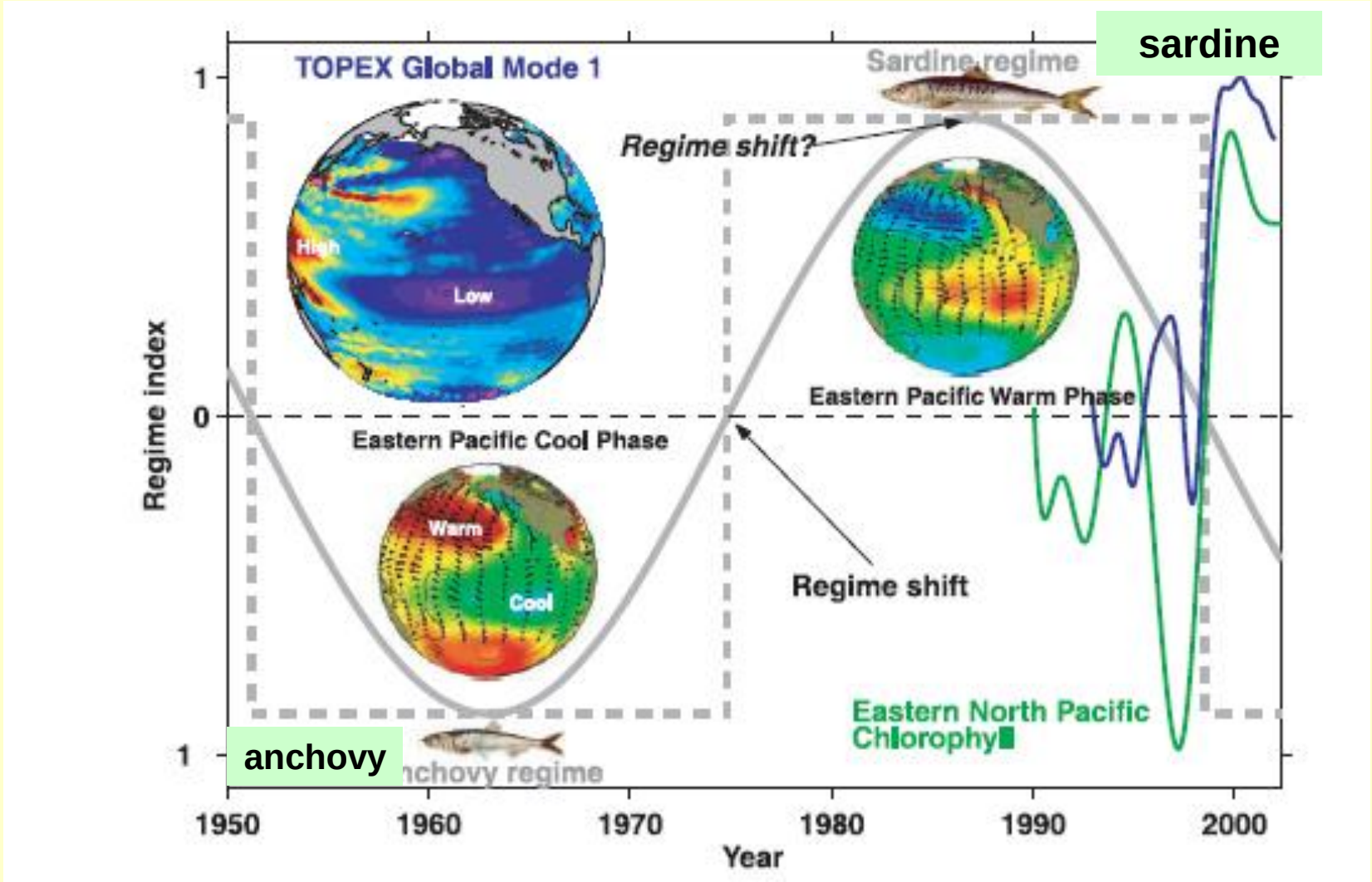
ENSO-scale：interannual



Global Warming ： centennial?



Regime shift: sardine VS anchovy



Chavez et al.(2003): Science 299, 217-221

Outline

- **What we had known**

  Features of the late 1980s regime shift around Japan from our previous studies

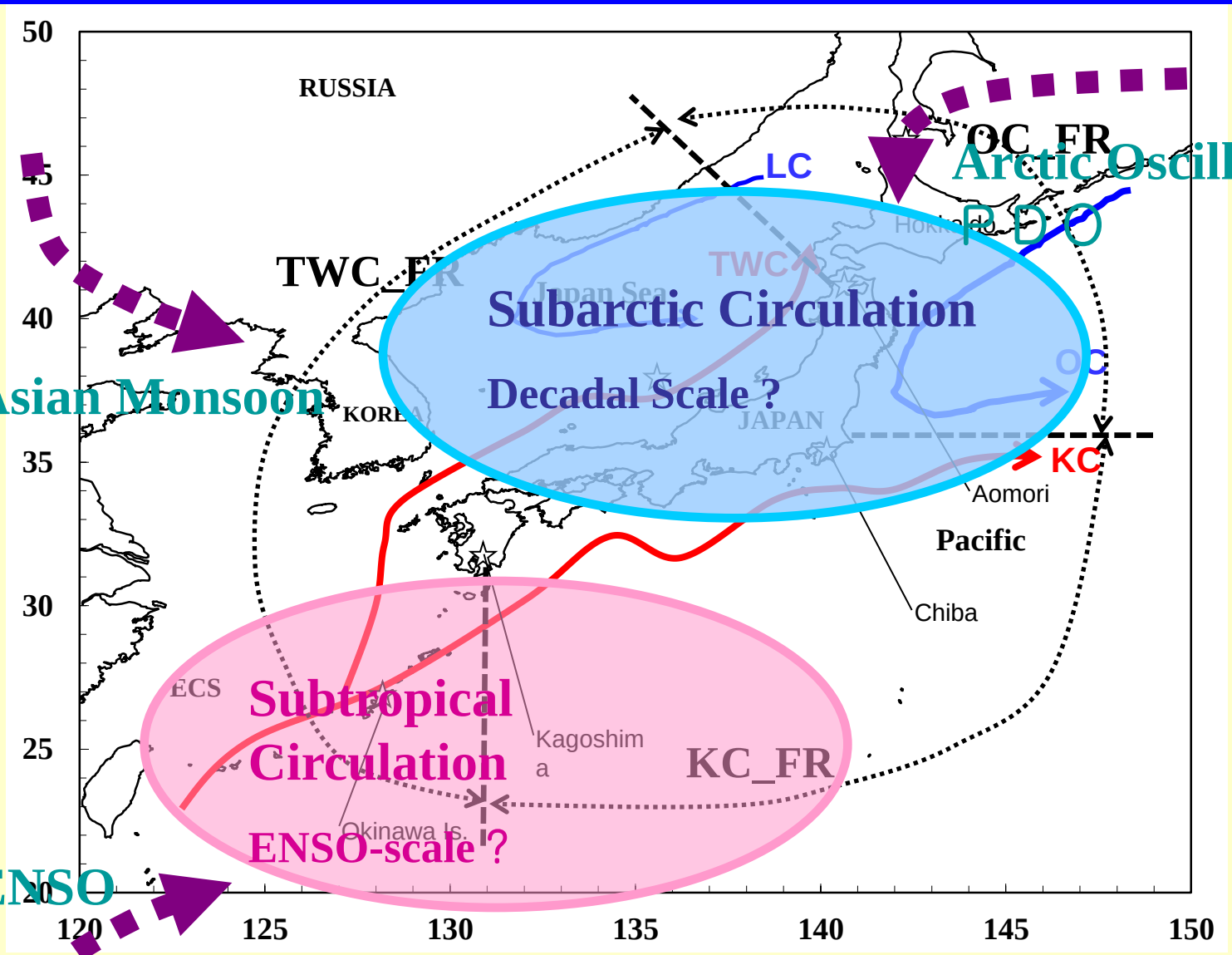
- **Regime shifts occurred before 1950**

  PCA results for 1900-2010, particularly focused on the regime shifts before 1950s.

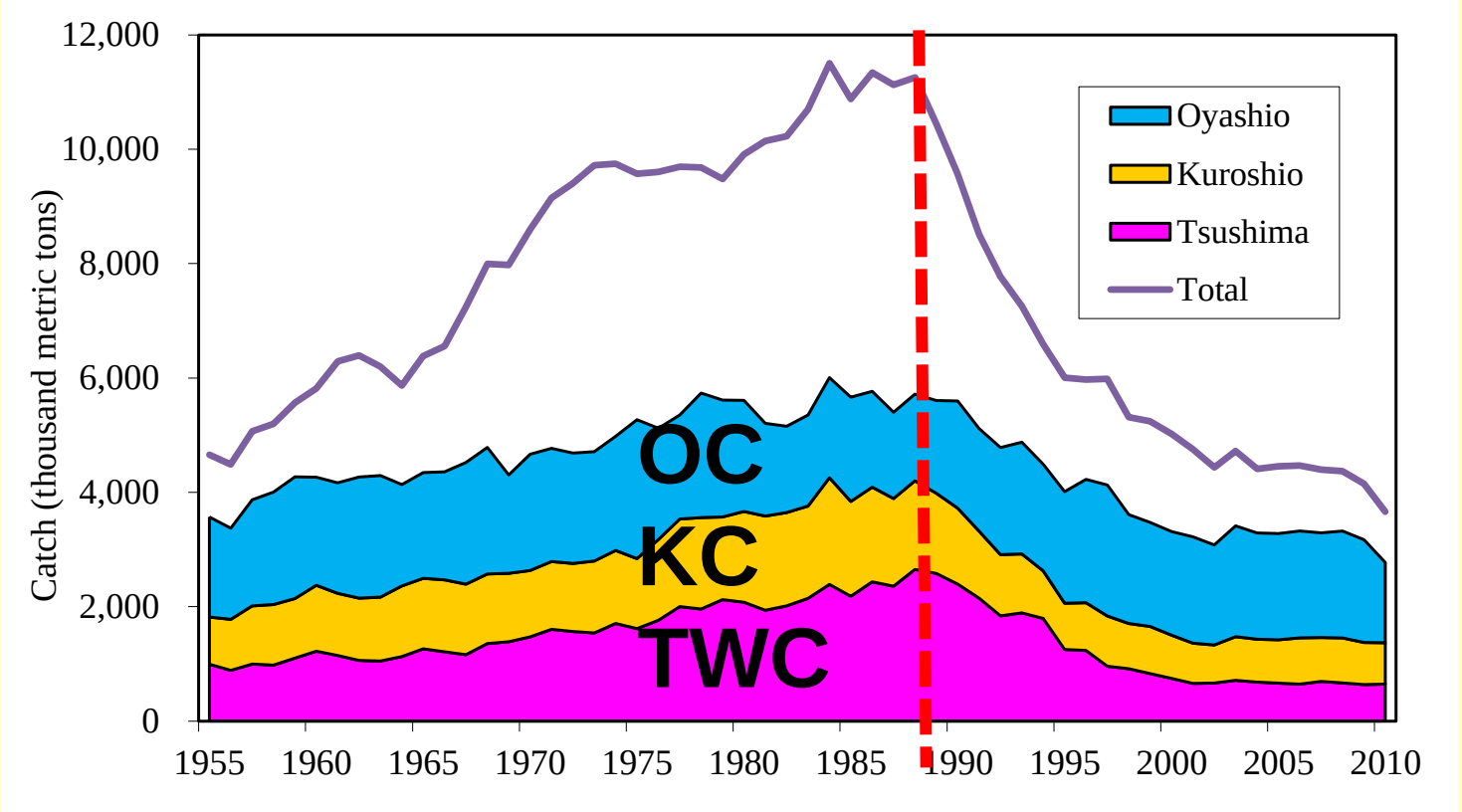
  Outlooks on early warning signals for future regime shift.

- **Summary (and discussion)**

Oceanographic structure and fisheries region



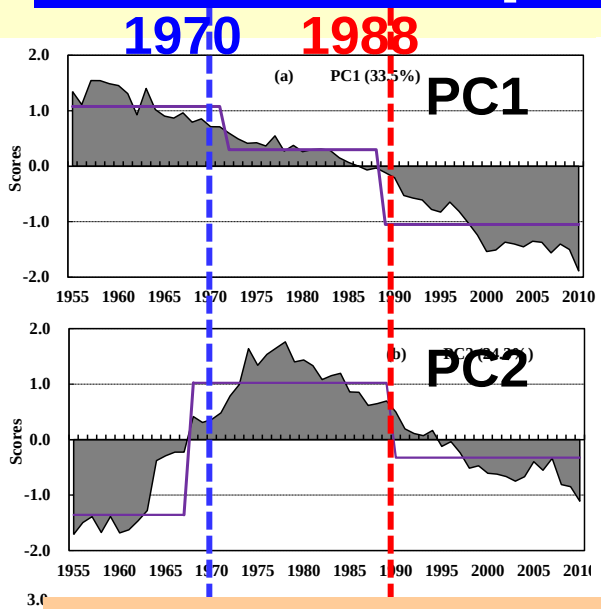
Catch trend by fisheries region: 1955-2010

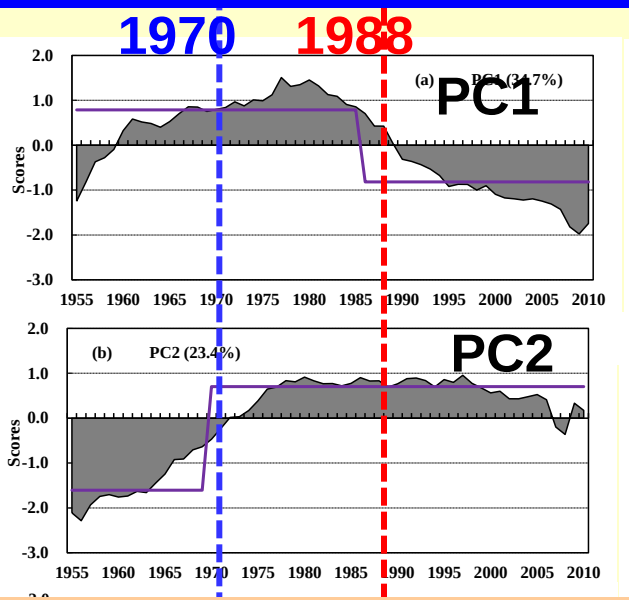


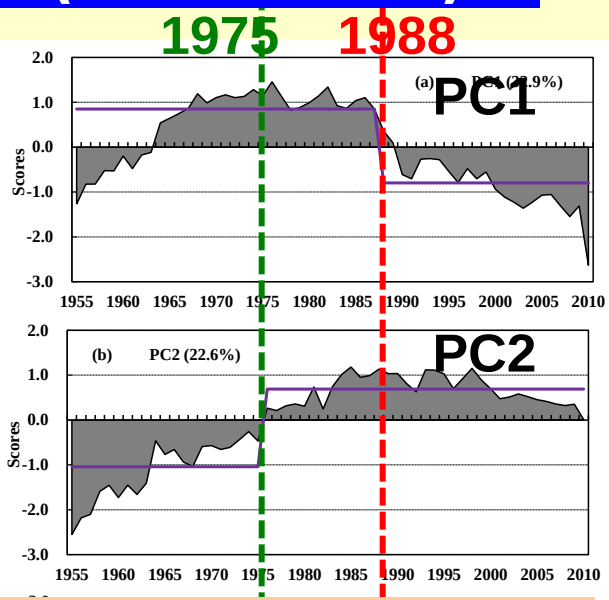
These 25 indicator species from the three regions accounted for about 75%(56-93%) of total Japanese catch, and the trends are generally same to total.

Tian et al. (2014) ICES JMS

Variation patterns from PCA (PC1-PC4)

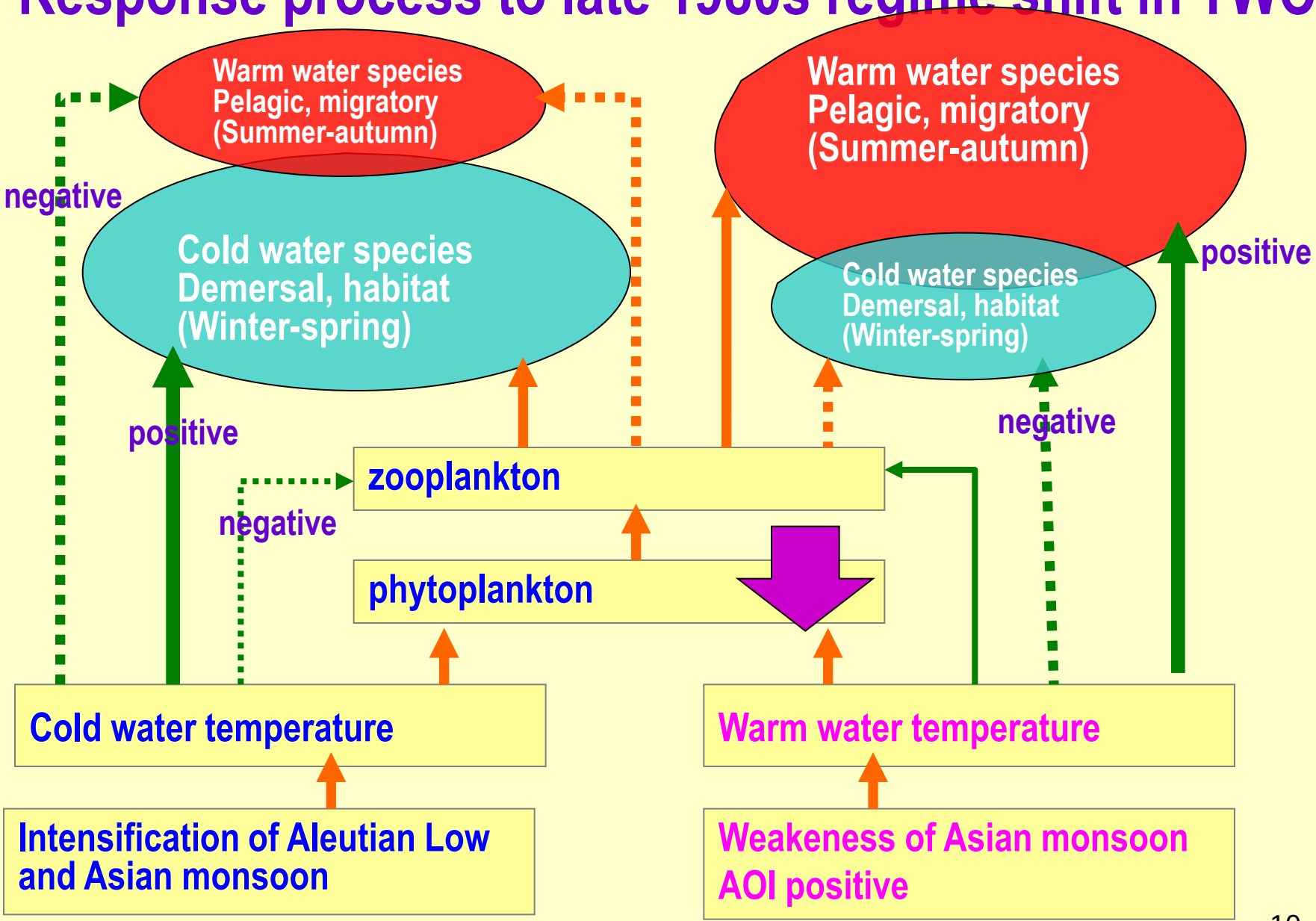






These results indicate that the most marked change across the three ecosystems around Japan occurred in the late 1980s, but only OC responded strongly to the mid-1970s regime shift in comparison with other two ecosystems

Response process to late 1980s regime shift in TWC



Tian et al. (2008)

Response process to late 1980s regime shift in TWC

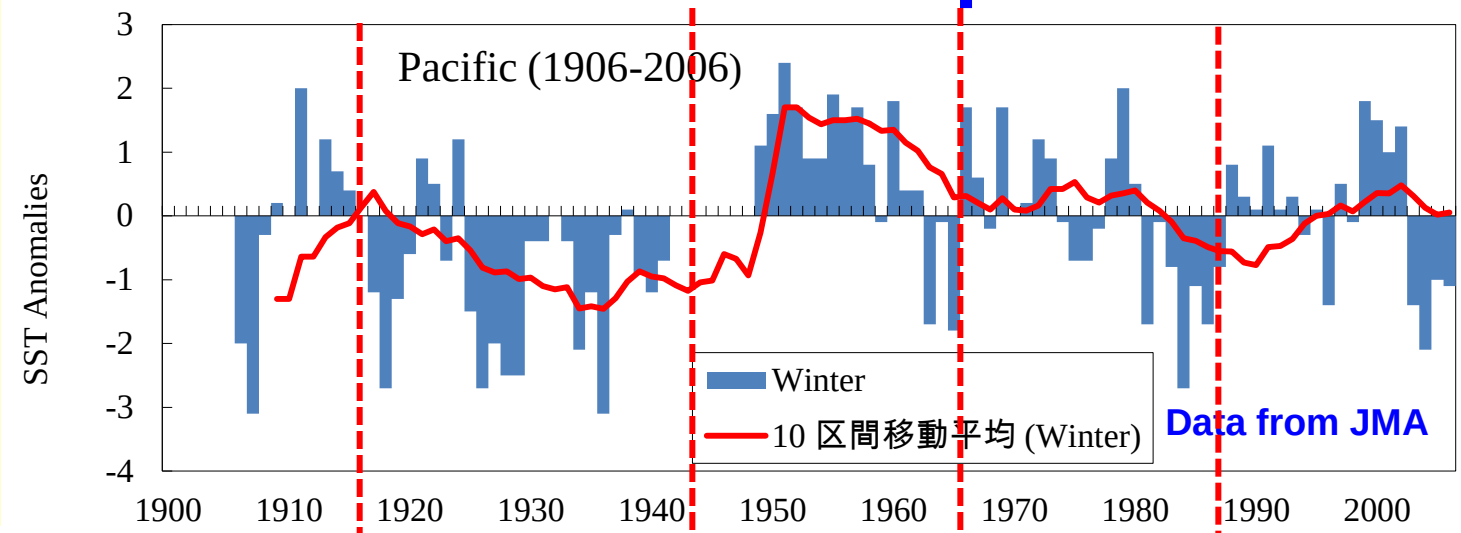
The late 1980s regime shift was the most evident change in Japanese water, seemed different with the mid-1970s regime shift in the NE North Pacific. The late 1980 regime shift was also identified in the East China Sea, and in North Atlantic.

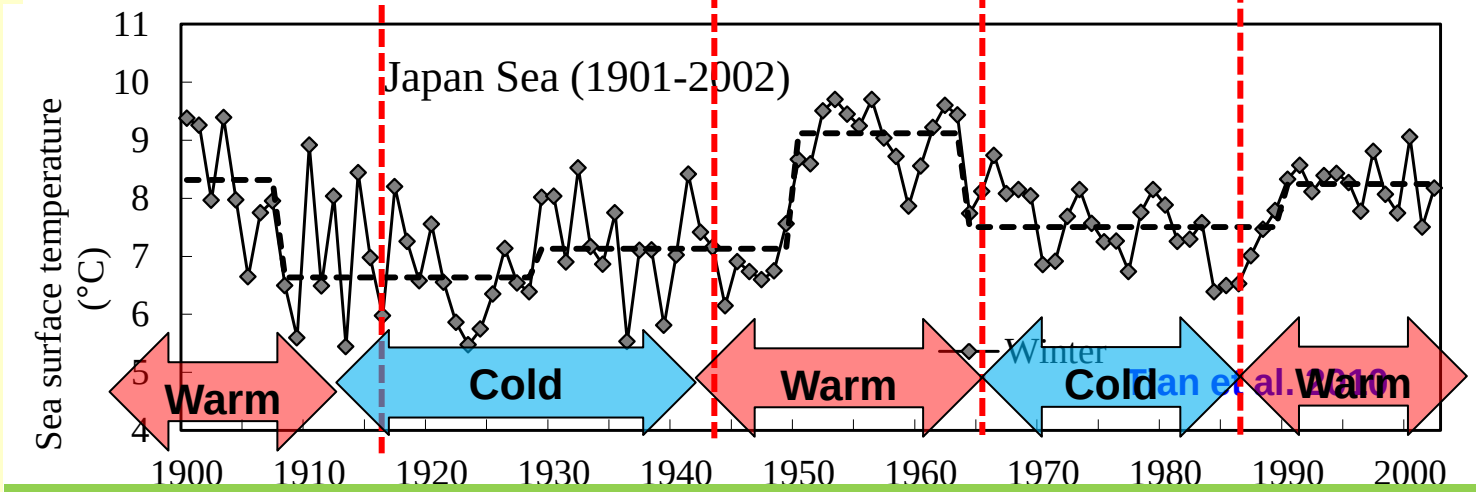
Question: What happened in the fish assemblages around Japan particularly before 1950?

Objective

- **To identify the long-term variability in the fish assemblages around Japan over last century, particularly focused on regime shifts occurred before 1950s.**
- **To discuss the possibility in using ecological indicators to detect the early warning signal of regime shift.**

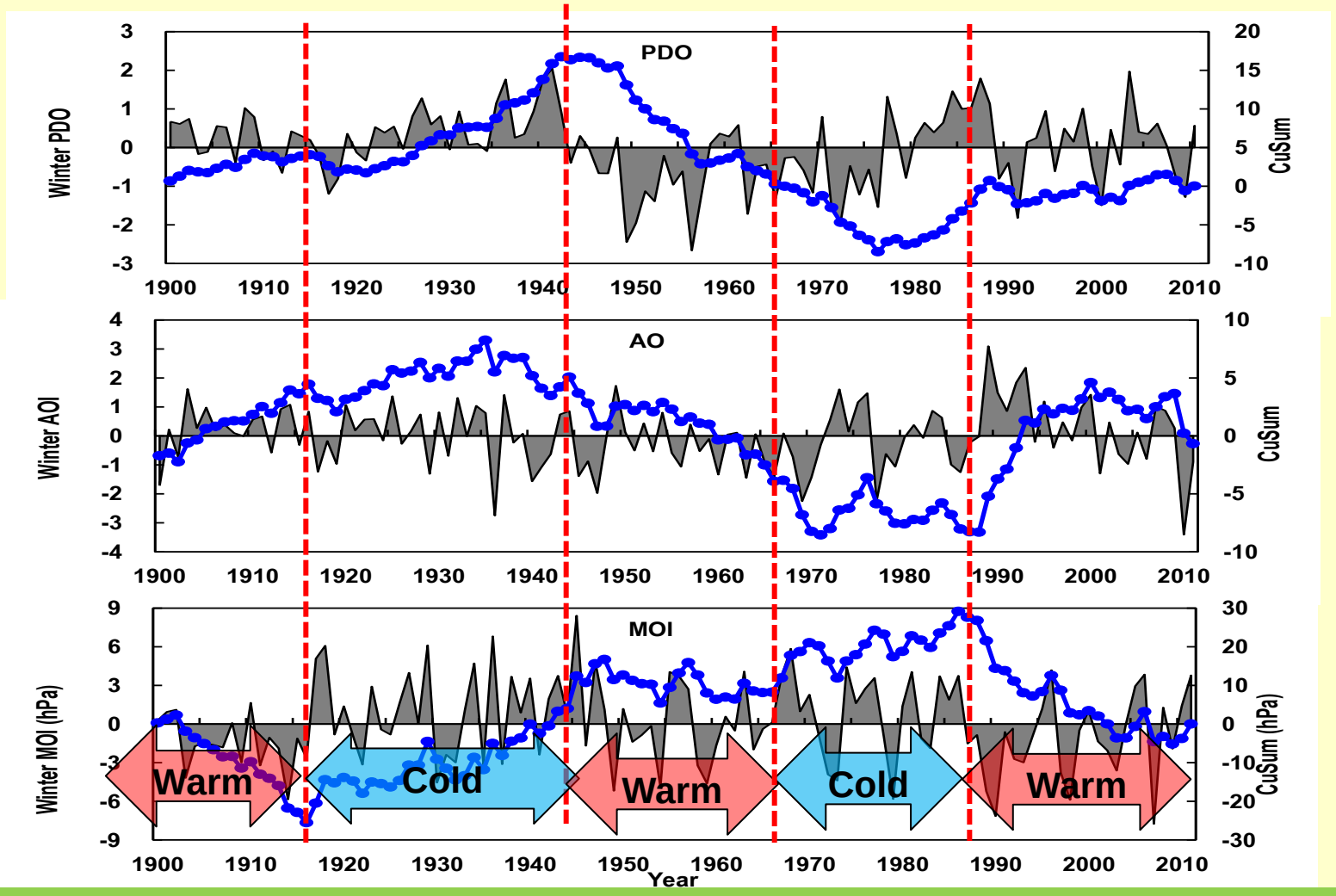
Trend in SST around Japan since 1900





SSTs showed cold period during 1920s to 1930s and warm period during 1950s to early-1960s.

Trend in Climate Index: 1900-2010



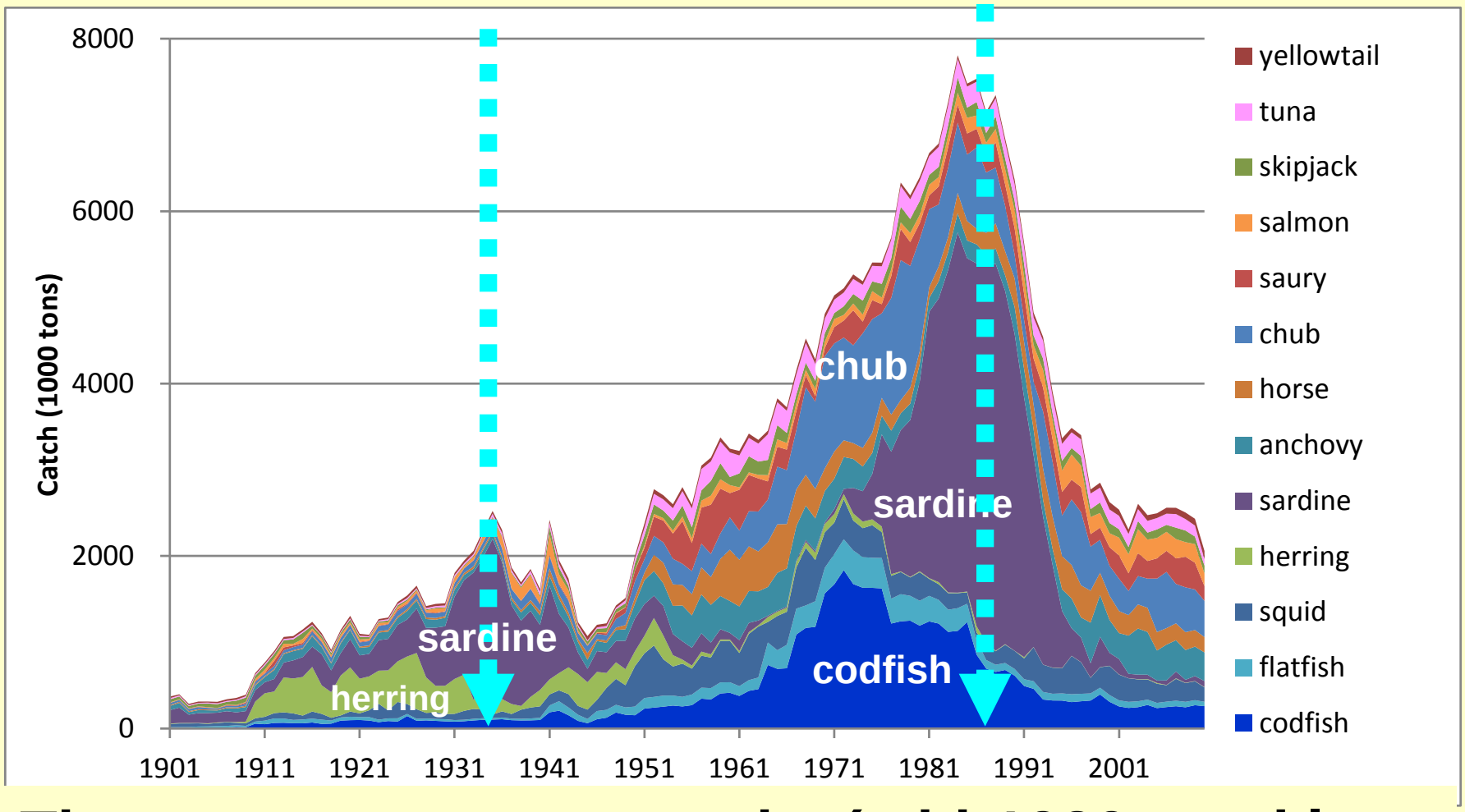
Cold (warm) periods corresponded well to the intensify (weakening) in AO and MOI.

Selection of Indicator Species

13 (not 25) commercially important specie from small pelagic to large predatory fishes with different trophic level and habitat are selected to representing the structure of fish assemblage.

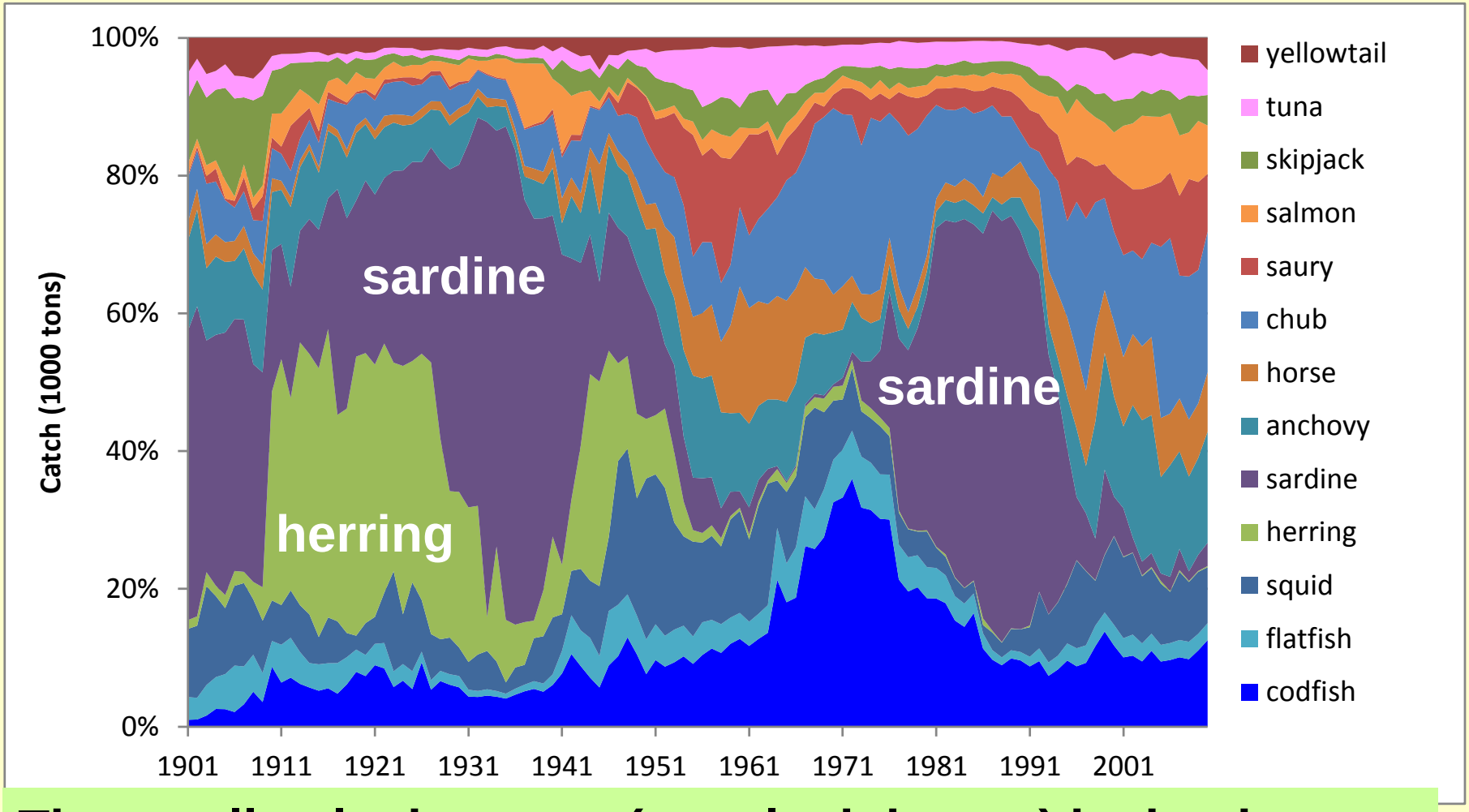
	Groups	Common Name	Scientific name	Age (age comp.) Spawning Season	Habitat (Current)	TL
4	**Large predatory Species (4 taxa)**	Yellowtail	*Seriola* spp.	*7 (0-3)* *L∞ (cm):98* *Feb.-June*	*Pelagic* *Migratory* *(Warm-water)*	4.1
		Skipjack tuna And Frigate mackerel	*Katsuwonus pelamis* *Auxis* spp.	*8(1-4?)* *L∞ (cm):140* *Nov-May*	*Pelagic* *Migratory* *(Warm-water)*	3.8
		Tunas (Bluefin tuna)	*Thunnus* spp.	*10(0-3?)* *300cm?* *June July*	*Pelagic* *Migratory* *(Warm-water)*	3.9
		Salmonidae (chum salmon)		*7(3-5)* *100cm?* *Dec-Mar*	*Pelagic* *(Cold-water)*	3.5
7	**Small Pelagic Species (7 taxa)**	Japanese sardine	*Sardinops melanostictus*	*7(0-3)* *25* *Dec-May?*	*Pelagic* *Migratory*	3.0
		Japanese anchovy	*Engraulis japonicus*	*2(0-1)* *15cm* *All seasons*	*Pelagic* *Costal* *(Warm-Water)*	2.8
		Pacific herring	*Clupea pallasii*	*18 (0-6)* *40cm* *Mar-May*	Pelagic *(Cold-water)*	3.6
		Horse mackerel	Carangidae (*Trachurus japonicus*)	*3(0-2)* *35cm* *Feb-May*	*Pelagic* *Migratory* *(Warm-water)*	3.2
		Chub mackerel	Scombrini (*Scomber japonicus*)	*4(0-3)* *43cm* *Apr-June*	*Pelagic* *Migratory* *(Warm-water)*	3.4
		Pacific saury	*Cololabis saira*	*2(0-1)* *30cm* *Nov.-June*	*Pelagic* *Migratory* *(Warm-water)*	3.3
		Flying squid	*Todarodes pacifcus*	*1(0-1)* *25cm(mantle len.)* *Oct.-Mar*	*Pelagic* *Migratory* *(Warm-water)*	3.0
2	**Demersal Species (2 taxa)**	Codfishes (Walleye Pollock abd Pacific cod)	*Theragra chalcogramma* *Gadus macrocephalus*	*12(3-5?)* *120cm* *Dec-Mar.*	*Demersal* *(Cold-water)*	3.5
		Flatfishes (Bastard halibut)	Pleuronectidae *(Paralichthys olivaceus)*		*Demersal and Costal* *(Warm-water)*	3.6

Catch Trend from Japanese Water: 1901-2010



There were two great peaks (mid-1930s and late 1980s) characterized with abundant sardine.

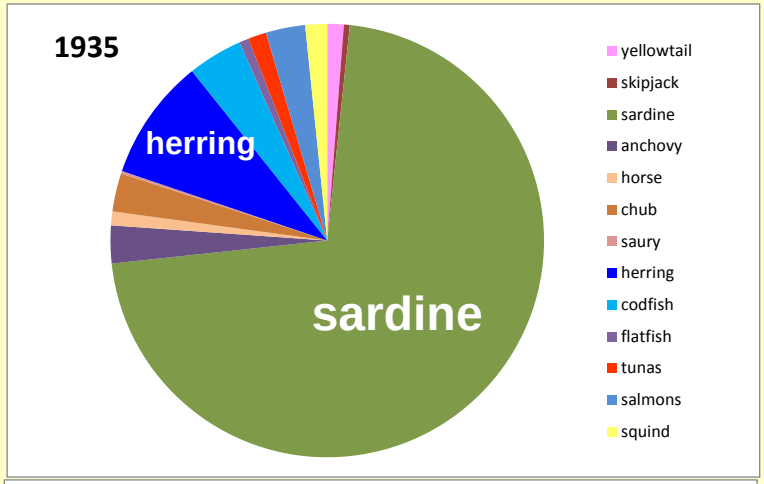
Catch Trend from Japanese Water: 1901-2010

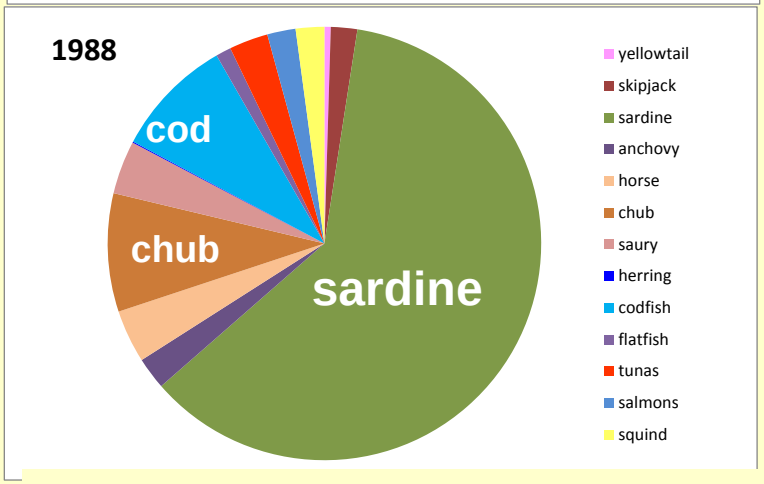


The small pelagic group (zooplanktivores) is dominant (wasp-waist) with large inter-annual variations.

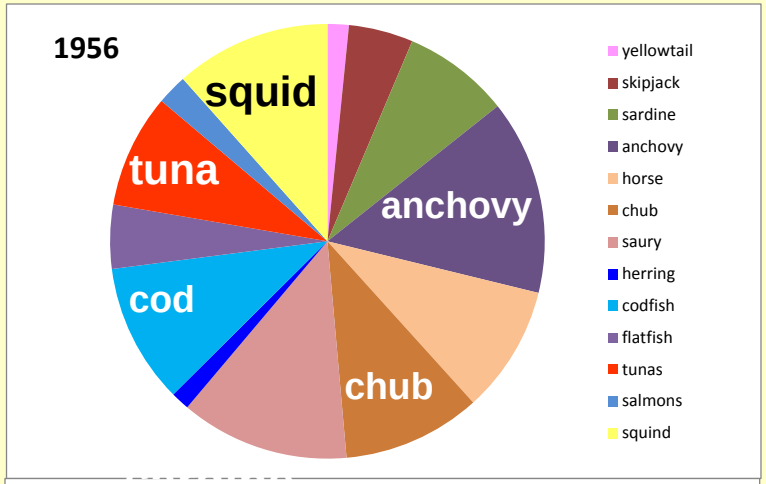
Catch compositions in different regimes

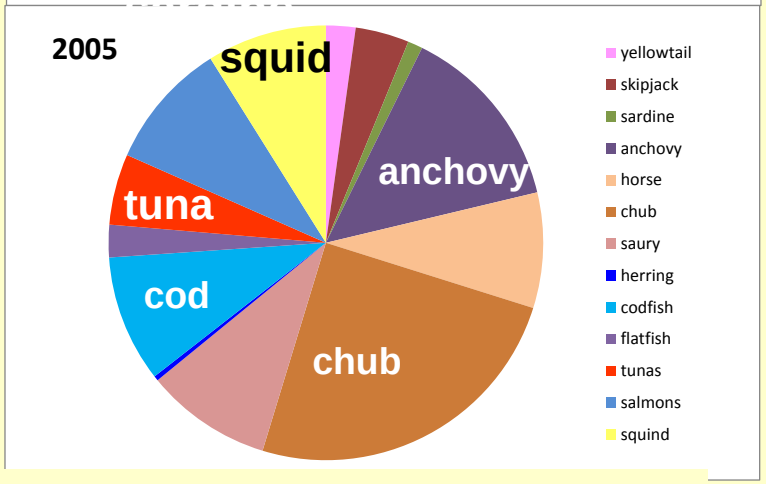
Cold regime (1930s and 1980s)





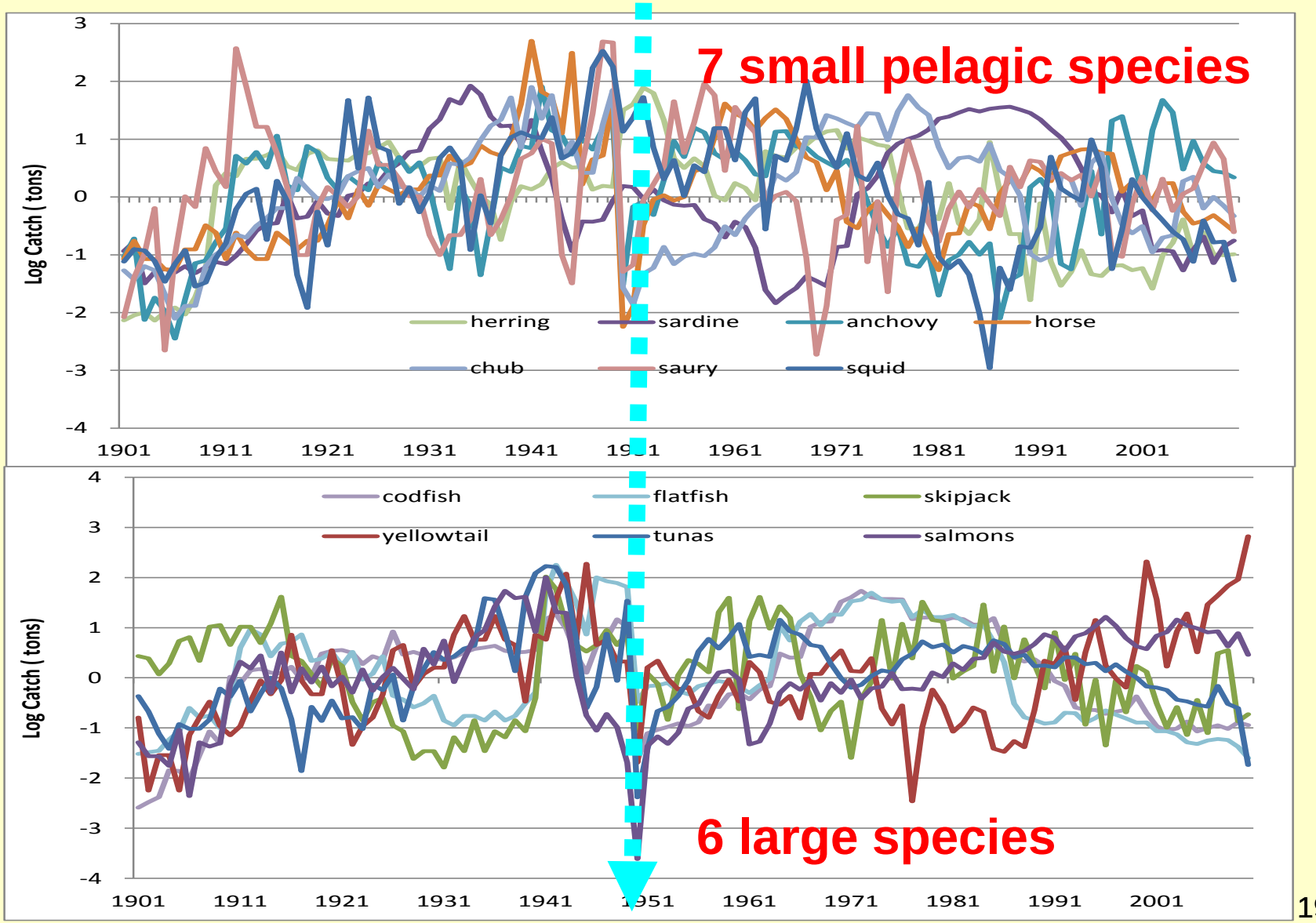
Warm regime (1950s and 2000s)



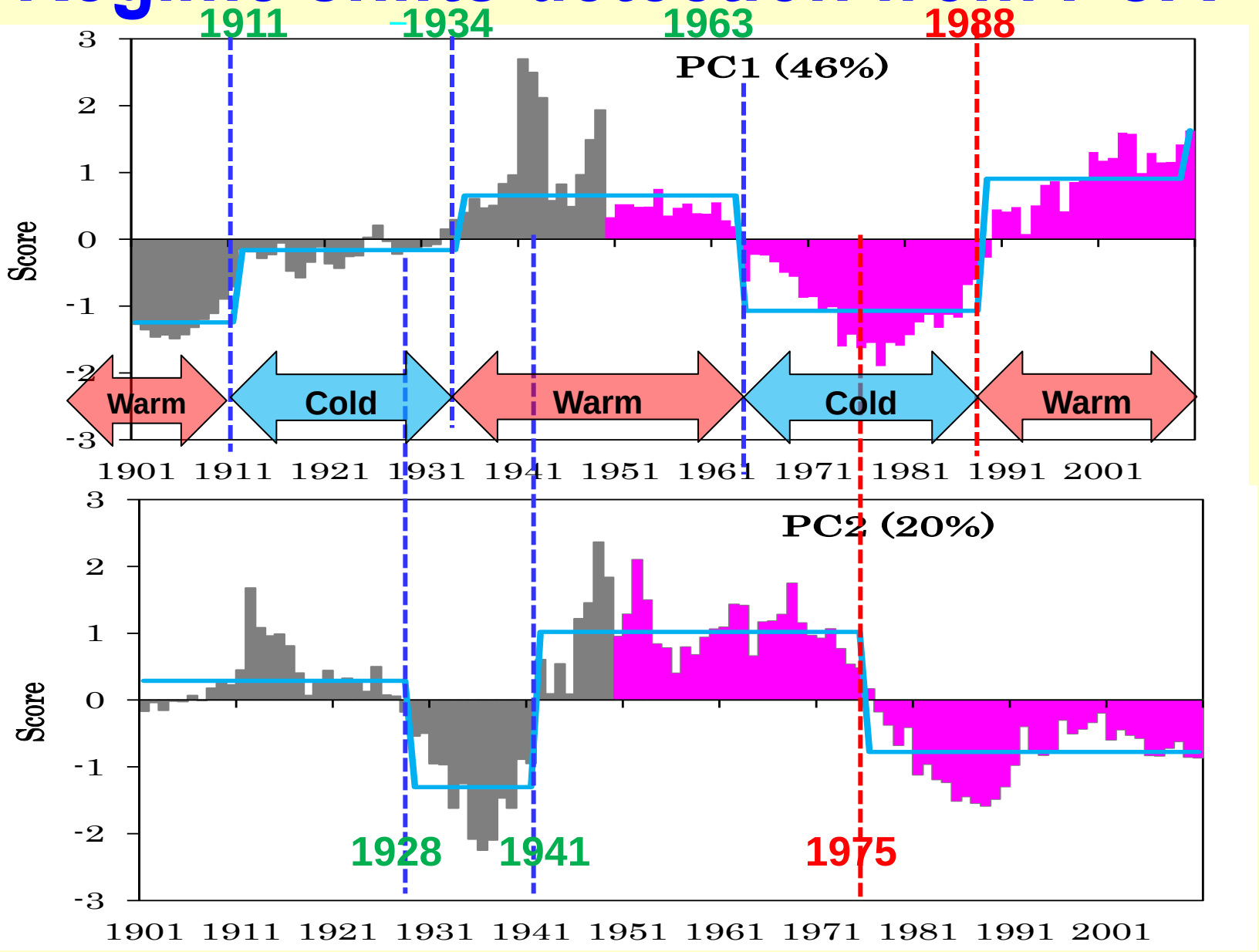


1930s was characterized with extremely abundant sardine and herring.

Standardization of catch data for PCA

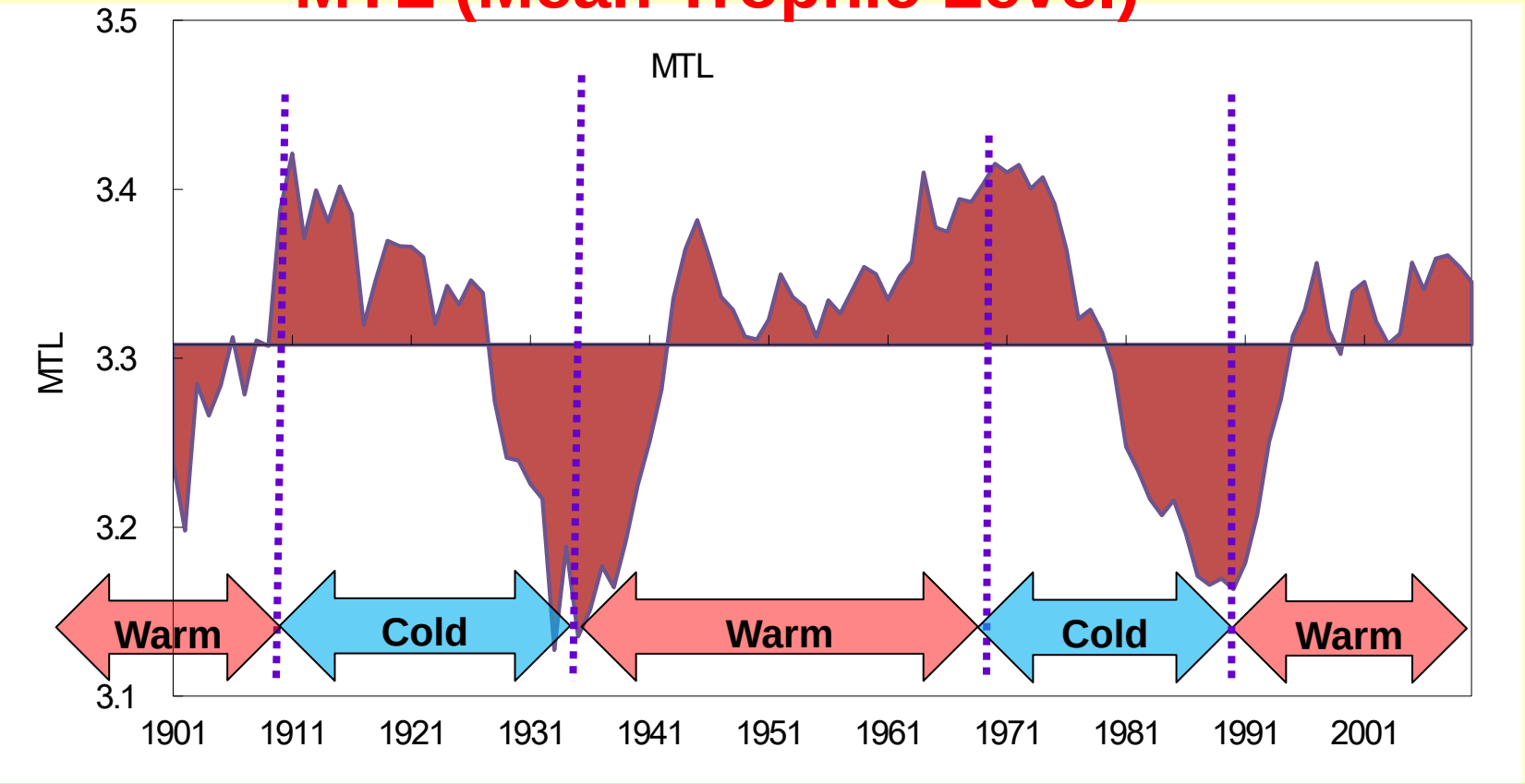


Regime shifts detection from PCA



Ecological Indicators

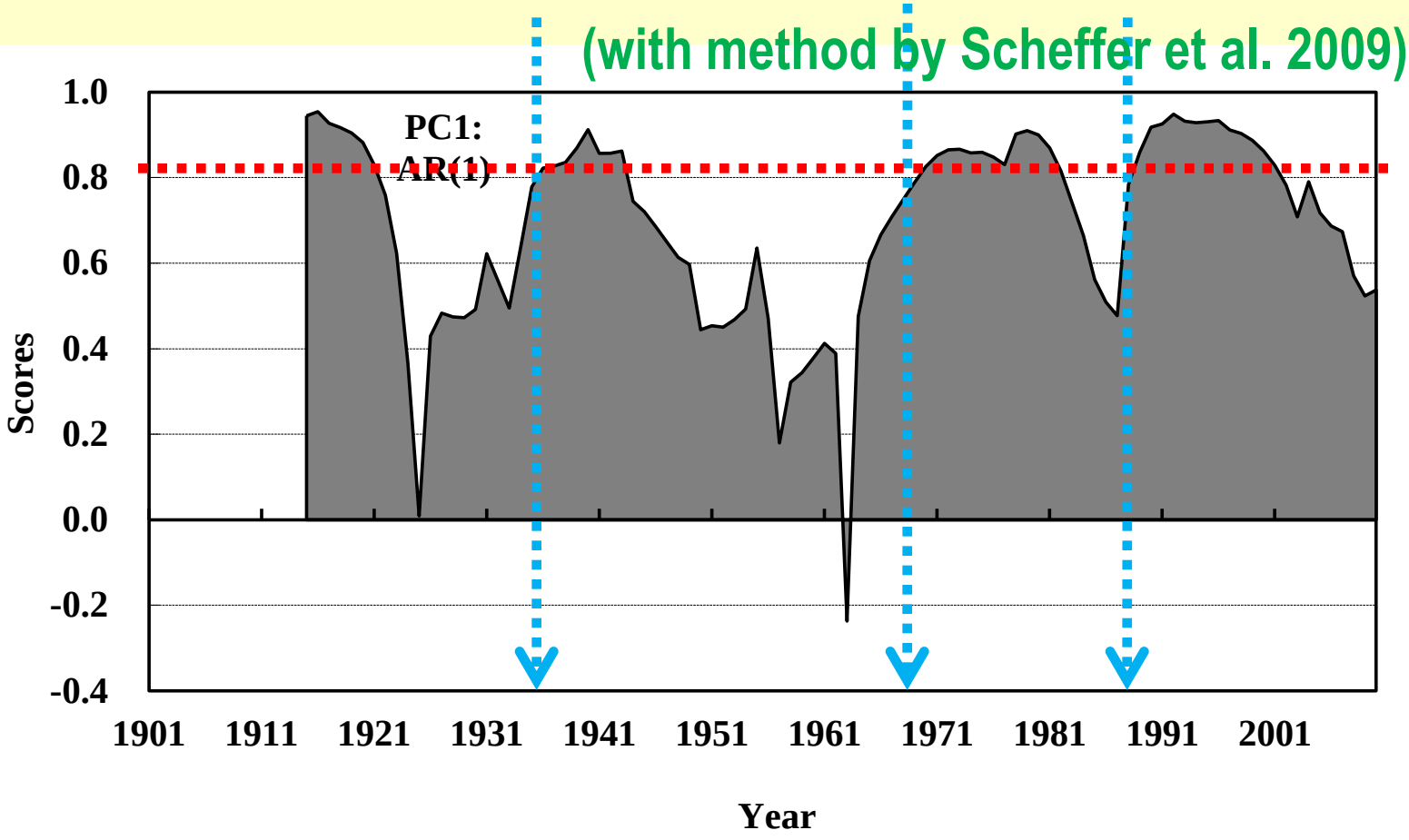
MTL (Mean Trophic Level)



The MTL decreased (increased) during cold- (warm-) regime, reflecting the changes in small pelagic species, indicating climate-forcing (regime shift) rather than fishing

Early Waning Signal from PCA (PC1)

(with method by Scheffer et al. 2009)



Coefficient of AR(lag1) abruptly increased around early 1930s, early 1960s and late 1980s, demonstrating the usefulness as indicator of regime shift prediction.

Conclusions

- **Five regime shifts in the fish assemblage around Japan were detected over last century: 1911, 1934, 1963, 1975 and 1988.**
- **The regime shifts were well coincided with SST and climate index. Regime in 1920s-1930s was cold-period with abundant sardine.**
- **MTL decreased during cold regime reflecting the increase in small pelagic species, not from fishing down food web effect.**
- **Ecological indicators such as PC1 is useful as early warning signal for forecasting the future (current) regime shift.**

Discussion

- **The late 1980s regime shift was similar in the Japanese water (NW North Pacific) and North Atlantic. But, the 1920s-1930s regime shift was resulted cooling in Japan but warming in the North Atlantic (Drinkwater (2006) : regime shift of 1920s and 1930s in fishes caused by the warming)**

- **What happens in central-eastern North Pacific? Johnstone and Muntua (S5-01): NE North Pacific SST 1920-1940 warming trend.**