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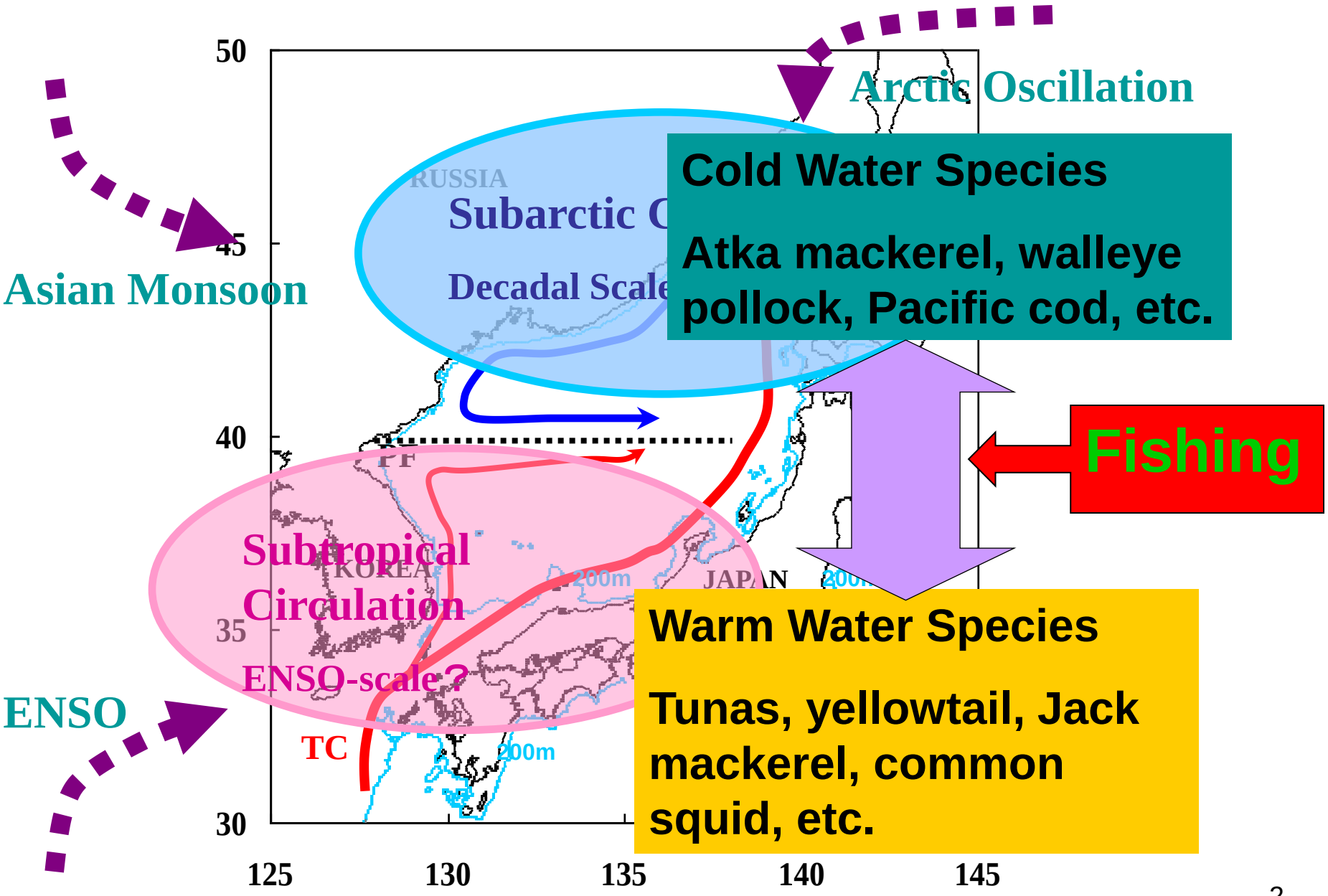
Interannual-decadal variability in the large predatory fish assemblage in the Tsushima Warm Current region of the Japan Sea with an emphasis on the impacts of climate regime shifts

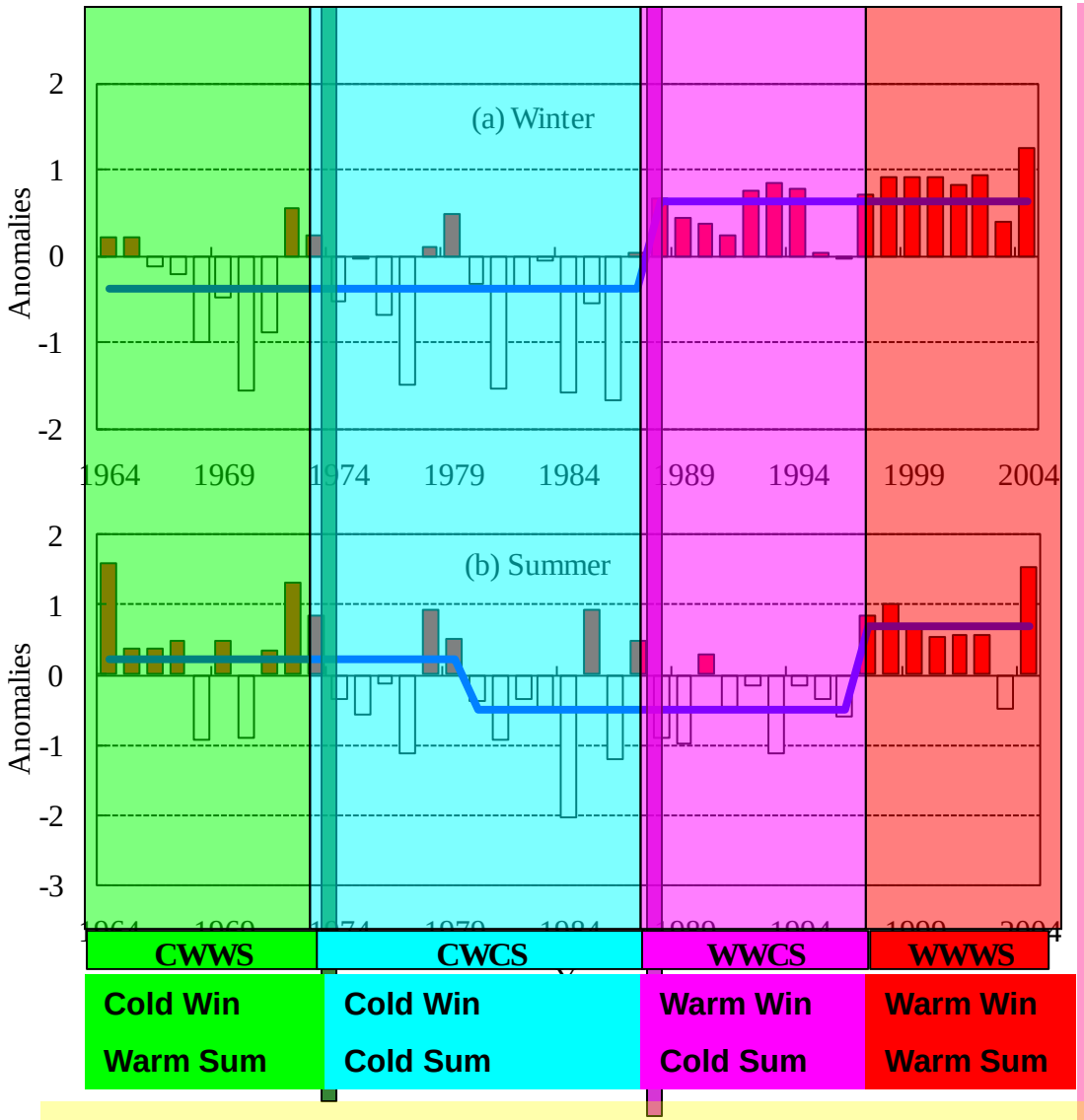
Yongjun Tian

Japan Sea National Fisheries Research Institute, Fisheries Research Agency (FRA), Niigata, JAPAN

独立行政法人 水産総合研究センター
日本海区水産研究所
JSNFRI:Japan Sea National Fisheries Research Institute,Fisheries Research Agency


Arctic Oscillation
Asian Monsoon
ENSO
RUSSIA
Subarctic C
Decadal Scale
PF
KOREA
JAPAN
200m
Subtropical
Circulation
ENSO-scale?
TC
Cold Water Species
Atka mackerel, walleye pollock, Pacific cod, etc.
Fishing
Warm Water Species
Tunas, yellowtail, Jack mackerel, common squid, etc.
50
45
40
35
30
125
130
135
140
145

50m WT: Indicator of Tsushima Warm Current



Winter WT:

regime shift around 1986/87

(linked with climate indices such as AO and MOI)

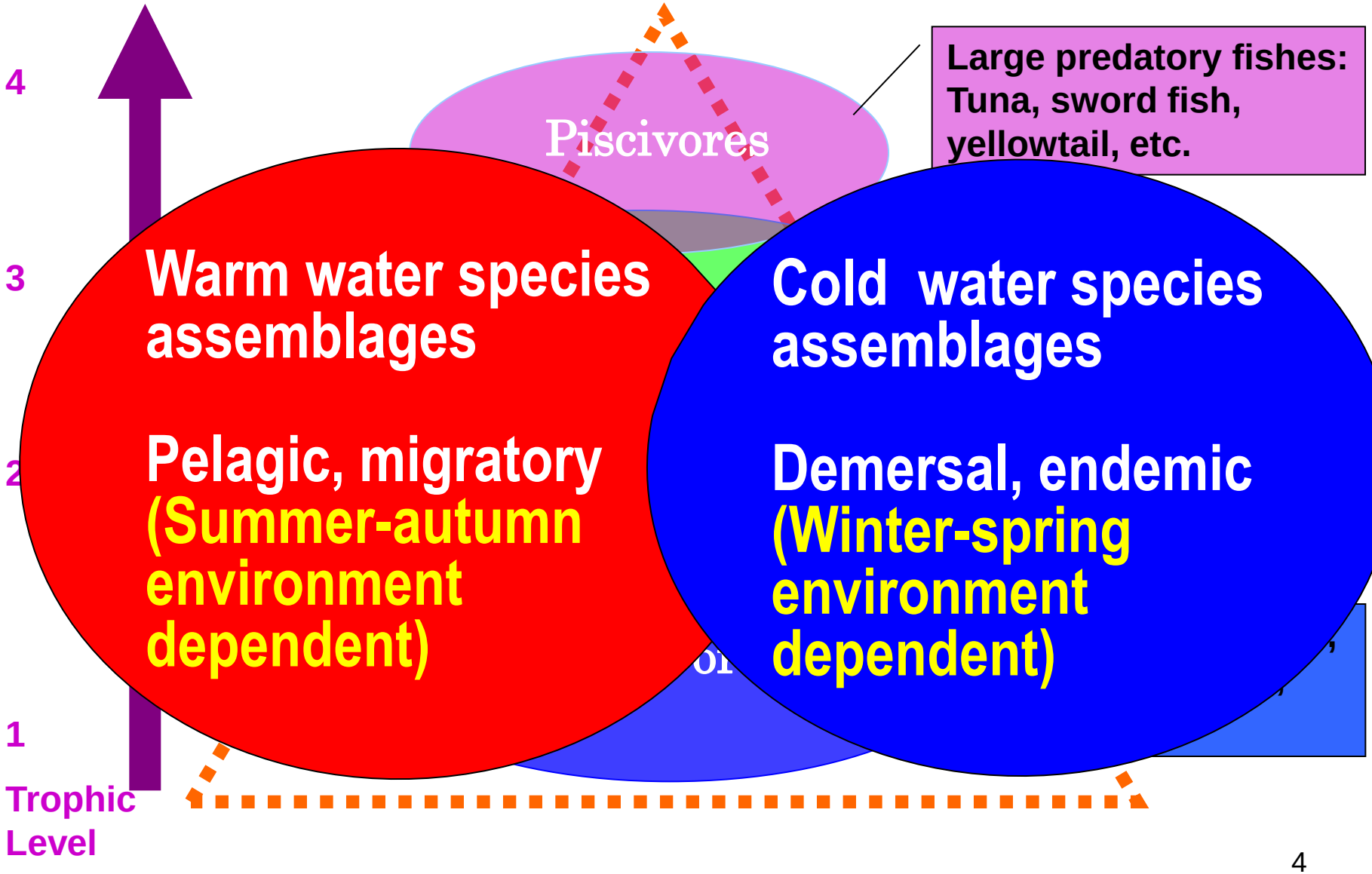
Summer WT:

WT: changes in early-1970s and late-1990s

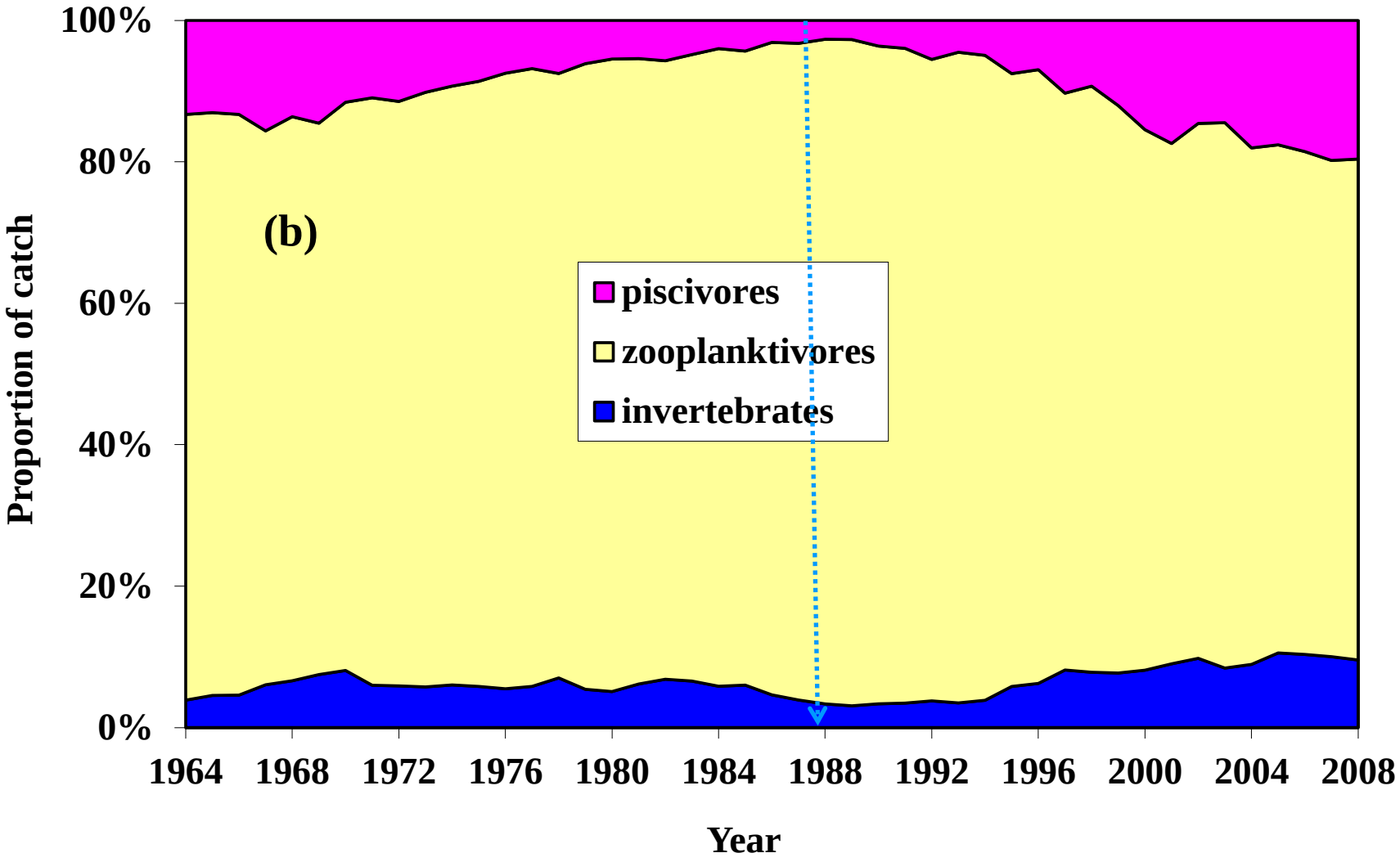
Variation patterns are different between winter and summer

Four periods: CWWS, CWCS, WWCS, WWWS.

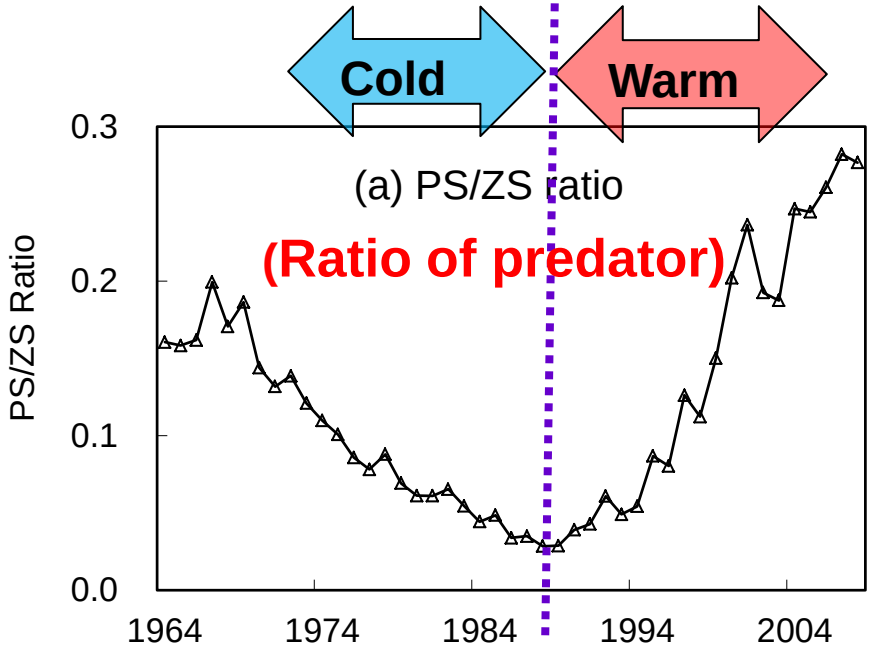
Fish Community Structure in the Japan Sea

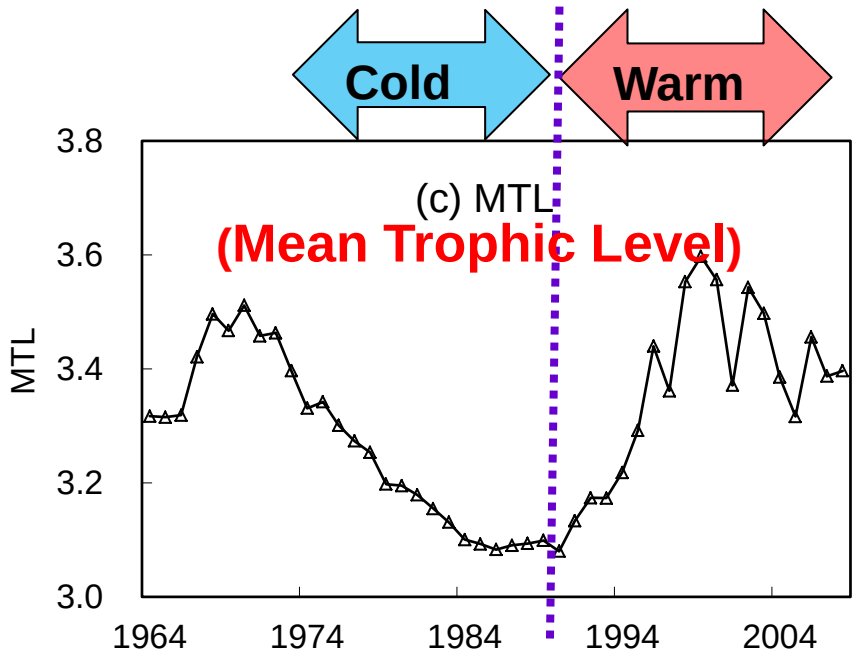


Catch Trend in the Japan Sea during 1964-2008 (54 species by trophic group)



Ecological Indicators for TWC





The two indicators decreased during cold-regime, but increased during warm-regime, indicating climate-forcing (regime shift) rather than fishing (Tian et al. 2013: ICESJMS)

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The late 1980s regime shift was the most evident change in TWC, seemed different with the mid-1970s regime shift in the North Pacific. Even within an ecosystem such as TWC, response to climate regime shift is species-specific, and the forcing is different.

Our question:

What is the response of large predatory fishes ?

cold 1980s regime shift warm 1990s

Tian et al. 2008:PO, 77

TWO OBJECTIVES

1. To identify the long-term variability in the large predatory fishes in TWC: **useful ecosystem indicators**?
2. To unravel their roles as top-predators in the fish community and their responses to climate changes

Data and Method

1. **Catch statistics:1964-2008:**

   54 species: 91% of the total catch in TWC

   18 piscivores species (large predatory fishes), 23 zooplantivores (most of small pelagic fishes), 13 invertevbates

2. **Demersal species: offshore bottom trawl data set: 1974-2008; Spatial-temporal variability in demersal fishes**
3. **PCA: applied to 18 catches to determine PCs**
4. **GAM: applied to PCs ~ environmental and biological (prey) factors**

List of large predatory fishes

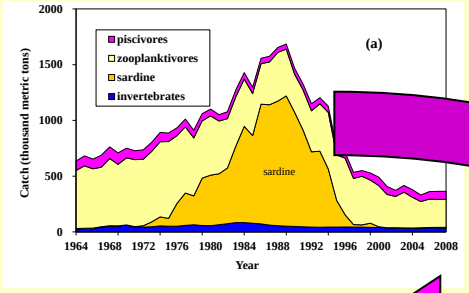
No.	English Name (main species)	Scientific Name	Depth (m)	Life Span (years)	Current System
1	Bluefin tuna	*Thunnus thynnus*	pelagic	>10	WW
2	Albacore	*Thunnus alalunga*	pelagic	>16	WW
3	Yellowfin tuna	*Thunnus albacares*	pelagic	7-10	WW
4	Swordfishes and billfishes	Xiphiidae and Istiophoridae	pelagic	10	WW
5	Common dolphinfish	*Coryphaena hippurus*	pelagic	?	WW
6	Frigate mackerel	*Auxis* spp. (*A. thazard*)	pelagic		WW
7	Yellowtail	*Seriola* spp. (*S. quinqueradiata*)	pelagic	>7	WW
8	Japanese Spanish mackerel	*Scomberomorus niphonius*	pelagic	6	WW
9	Salmons (Chum salmon)	(*Oncorhynchus keta*)	pelagic	2-7	CW
10	Trouts (Pink salmon)	(*Oncorhynchus gorbuscha*)	pelagic	2	CW
11	Japanese seabass	*Lateolabrax japonicus*	pelagic		WW
12	Bastard halibut	*Paralichthys olivaceus*	50-150	>10	WW
13	Sharks (Spiny dogfish and Starspotted dogfishe)	(*Squalus acanthias, Mustelus manazo)*	pelagic	>60	WW
14	Pacific cod	*Gadus macrocephalus*	200-300	>12	CW
15	Largehead hairtail	*Trichiurus japonicus*	20-140	8	WW
16	Lizardfish	Synodontidae	<200	<4	WW
17	Daggertooth pike conger	*Muraenesox cinereus*			WW
18	Skates and rays (Golden skate)	Rajiidae (*Bathyraja smirnovi*)		-	WW

Total 18 species taxa

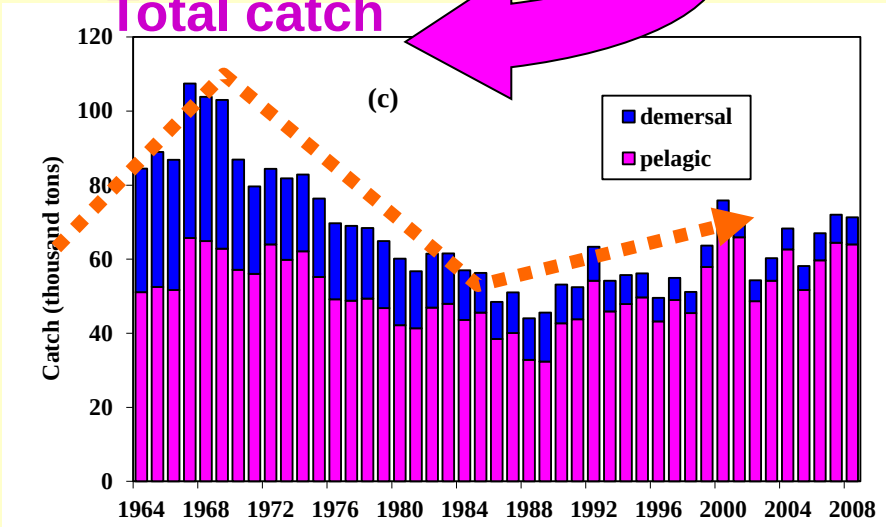
WW: Warm Water; CW: Cold Water

(Modified fromTian et al. 2006, PiO, 68)

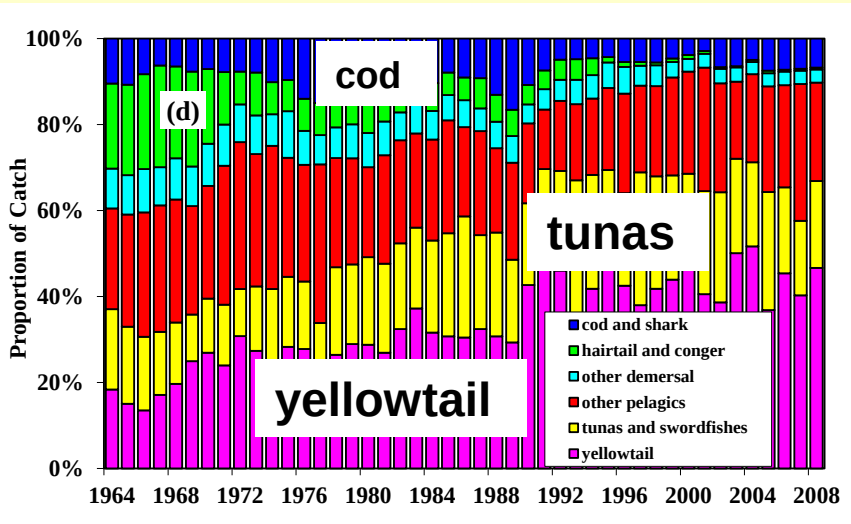
Total catch of 18 large predatory fishes



Total catch

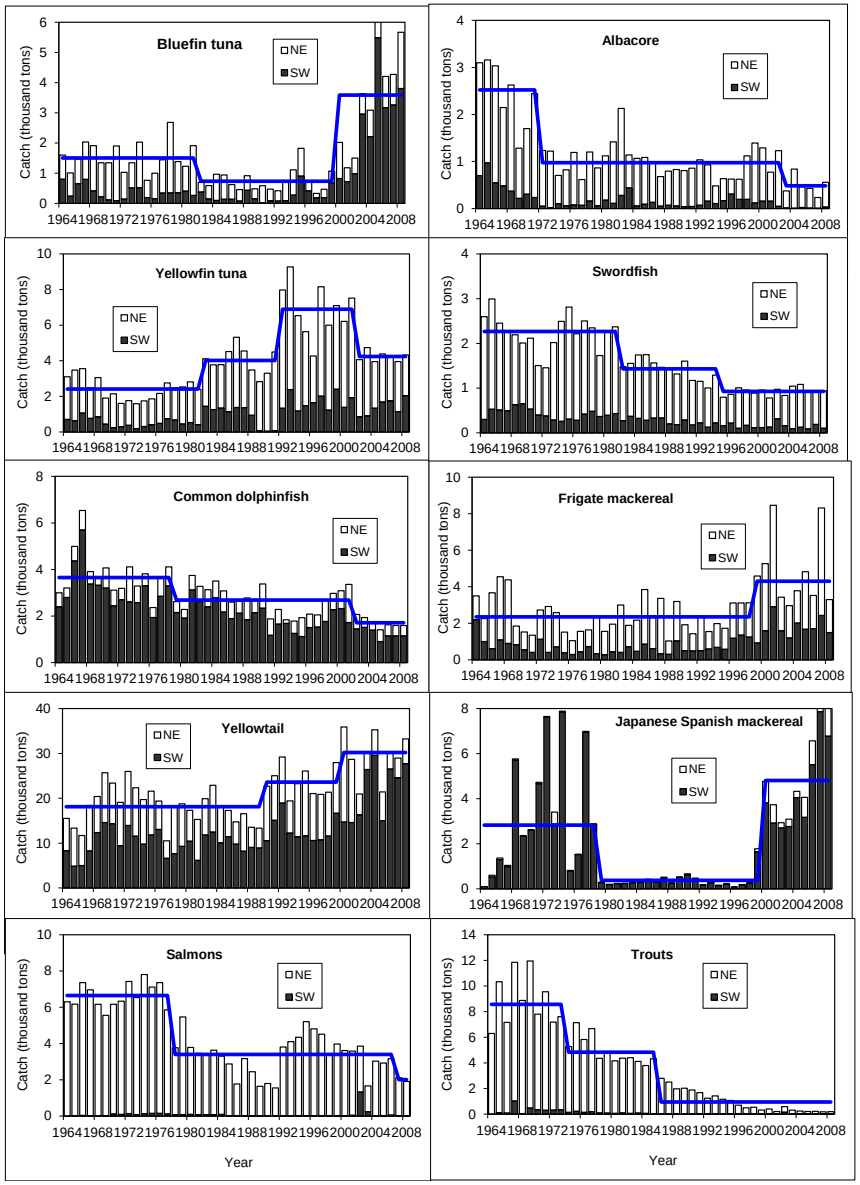


Proportion of catch by species or group



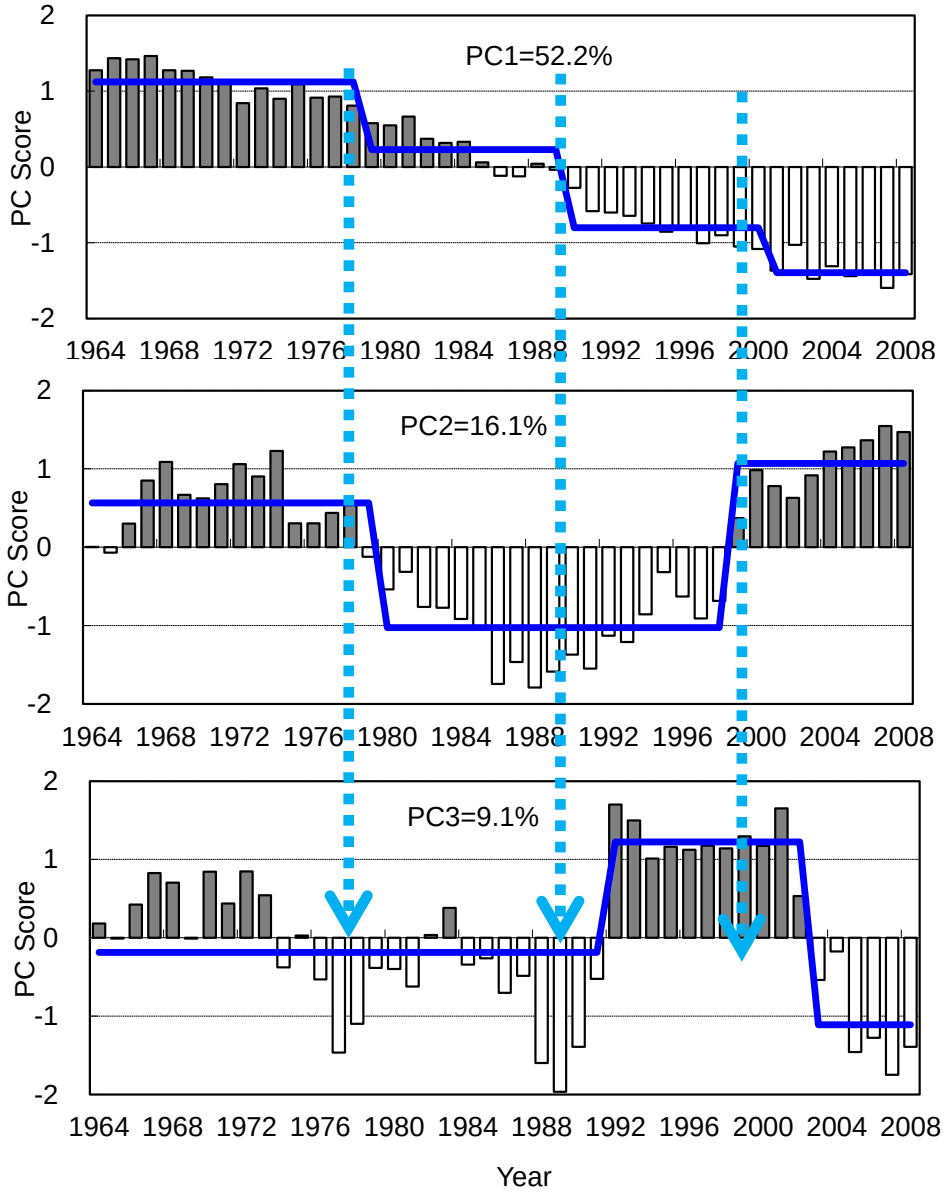
Total catch of large fishes decreased during 1970s and 1980s but increased since 1990s. Among the 18 species, proportion of pelagic fishes, particularly yellowtail increased distinctly; whereas the ratio of demersal fishes such as Pacific cod decreased markedly.

Catch trend for 18 species



Demersal, cold-water fishes showed declining trend; while most of pelagic, warm-water species showed opposite trend.

The first three PCs form PCA for 18 fishes



PC1-3 accounted for 74% of total variance showing decadal variation patterns.

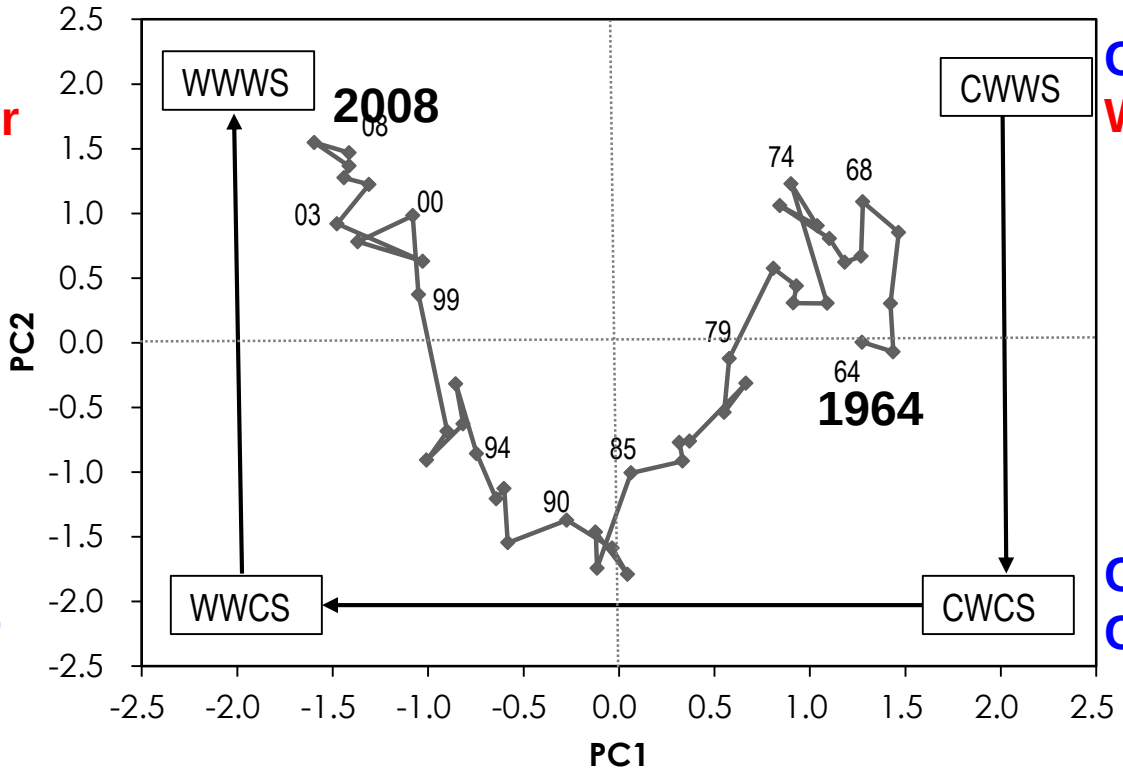
Step-changes detected in mid-1970s, late 1980s and late 1990s

PC1: corresponding well to winter WT;

PC2: corresponding well to summer WT

Phase trajectory between PC1 and PC2

Warm Winter
Warm Summer



Cold Winter
Warm Summer

Warm Winter
Cold Summer

Cold Winter
Cold Summer

The temporal variation forced largely on the pattern between the summer and winter water temperature: differences in winter and summer WTs make the complexity of the large fish assemblage?

This pattern was also identified in demersal fish assembalge (Tian et al., 2011)

Summary of GAMs for PC1-2

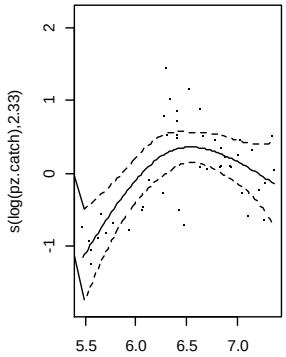
No.	Water temperature				Climate index				Biological index		Model fitness	
	WIN	SPR	SUM	AUT	AOI	MOI	PDO	SOI	ZS	DS	D.E.	AIC
	PC1											
1	+***	+	+***	+***	-	-	-	-	-	-	61.6	96.13
2	-	-	-	-	+*	+	+*	+	-	-	22.3	127.4
3	+***	+	+*	+*	+	+	+	+	-	-	65.9	98.8
4	+***	-	+*	-	+	-	+^	-	-	-	59.0	100.0
5	+***	-	+*	-	-	-	+*	-	-	-	59.0	98.0
6	+***	-	+**	-	-	-	-	-	-	-	55.4	100.2
7	-	-	-	-	-	-	-	-	+***	+***	72.5	83.2
8	+^	+	+	+^	+	+	+^	+	+**	+^	82.0	80.4
9	+^	-	+	-	-	-	+^	-	+**	+*	***79.9***	***77.7***
10	+^	-	-	-	-	-	-	-	+***	+**	77.4	79.6
11	+*	-	-	-	-	-	-	-	+***	-	68.2	89.6
	PC2											
1	+*	+	+	+	-	-	-	-	-	-	30.4	126.1
2	-	-	-	-	+	+	+*	+*	-	-	35.3	123.1
3	+	+	+	+**	+	+	+*	+	-	-	64.7	110.2
4	+*	-	+	-	+	-	+*	-	-	-	48.3	118.1
5	+**	-	+^	-	-	-	+*	-	-	-	37.7	119.2
6	+**	-	+*	-	-	-	-	-	-	-	29.6	122.7
7	-	-	-	-	-	-	-	-	+***	+^	77.2	74.8
8	+*	+	+	+^	+	+	+**	+*	+***	+	89.5	58.7
9	+*	-	-	+^	-	-	+**	+**	+***	+	***88.1***	***56.2***
10	+**	-	-	-	-	-	+**	+**	+***	-	84.7	60.4
11	+**	-	-	-	-	-	+*	-	+***	-	81.4	67.6

Final model for PC1

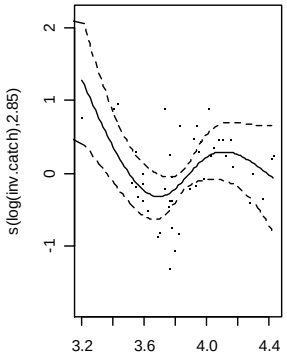
Final model for PC2

GAM: PCs ~ s(WT)+ s(Climate Index) + s(log(catch of prey)

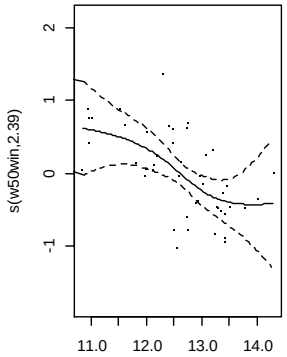
GAM: PC1



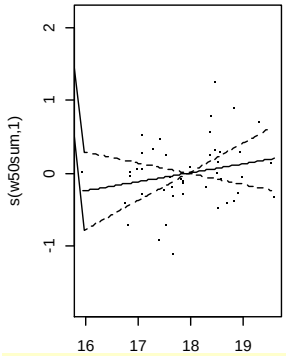
Catch_PZ



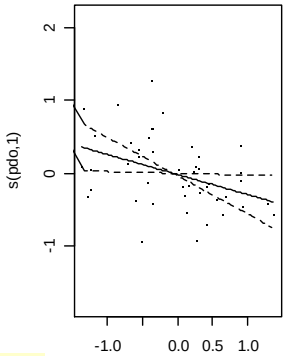
Catch_DS



Winter_WT



Summer_WT



PDO

It indicated the significant impacts of prey (Catch_PZ), oceanographic (winter WT) and climatic (PDO) factors.

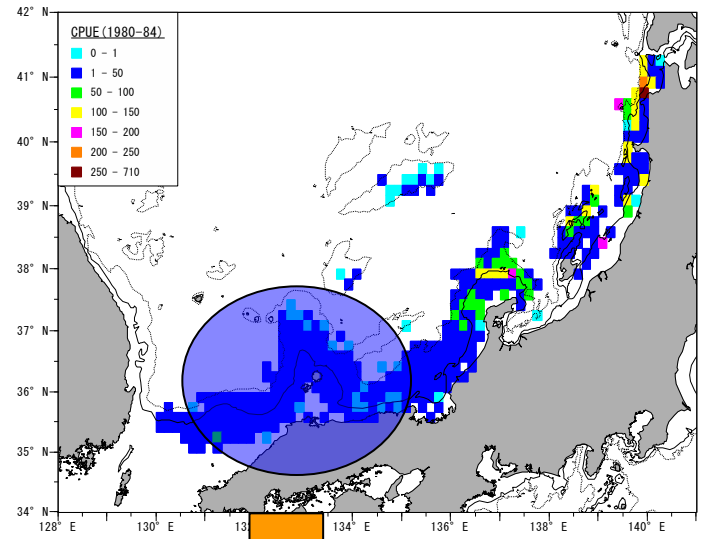
D.E. (Deviance explained)=80%

Changes in distribution: Pacific Cod

Example of Cold-water species

1980s

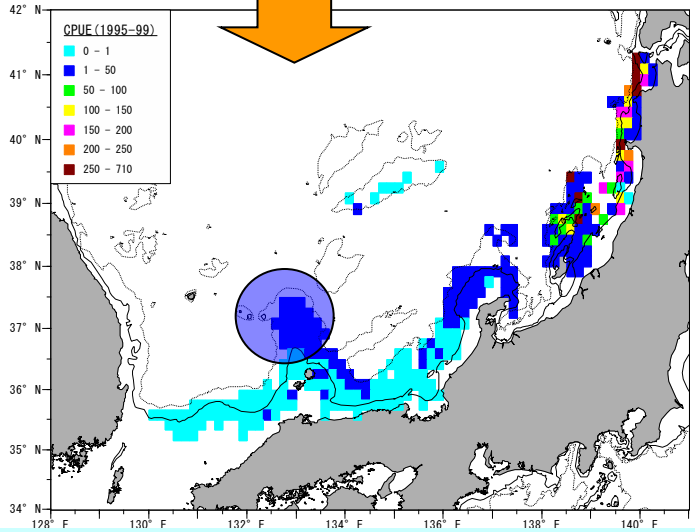
cold



Cold regime
Increase in abundance
(Expansion of distribution)

1990s

warm

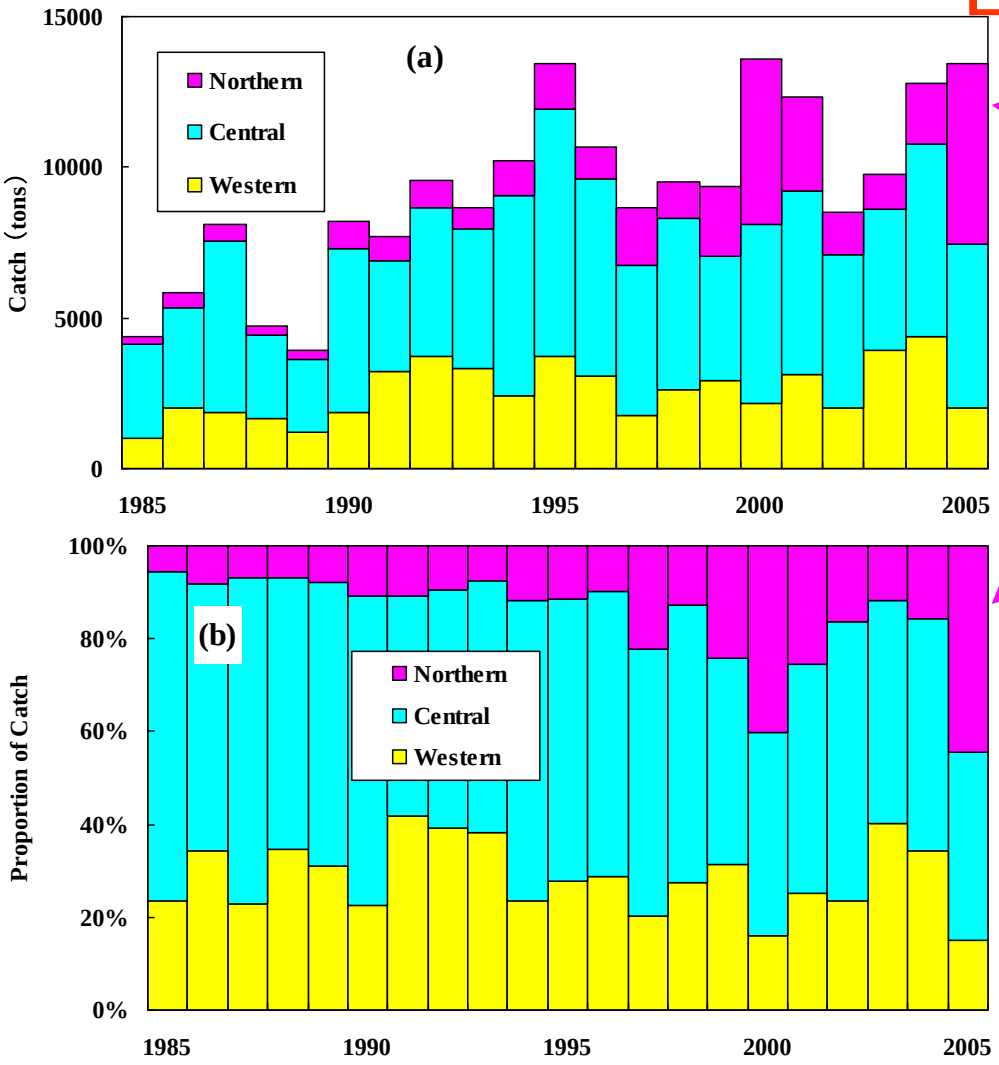


Warm regime
Decrease in abundance
(Reduction of distribution)

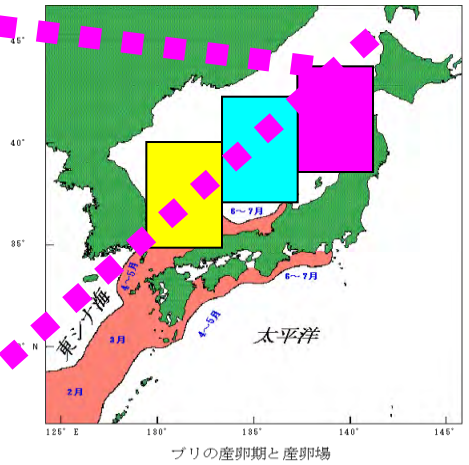
Bottom trawl fishery data

Changes in distribution: yellowtail

Example of warm-water species



Yellowtail catch from set-net fishery



During the warm regime (1990-), the catch of warm-water species such as yellowtail, Jap-Span. mackerel, tunas from northern region increased largely, indicating the northward movement and expansion of distribution

Summary

- The catch of large predatory fishes (PS) increased with the late 1980s regime shift. PCA showed decadal variation pattern with step changes in mid-1970s and, late 1980s and late 1990s.
- No “fishig-down food web” was identified in the TWC.
- GAMs showed PC1 and PC2 significantly affected by win-WT and sum-WT respectively; PC2 also depended on prey abundance. These results suggested that PS are forced primarily by oceanic conditions rather than their prey: environment depending variation pattern.
- Warm (cold) water species increased (decreased) their abundances and expanded (reduced) their distributions during the warm regime, and vice versa.