What will happen on the stock of chum salmon, walleye pollack, and common squid in the Northern Pacific by global warming?

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Grants-in-Aid for Scientific Research(Kiban Kenkyu S)

Historical transition and prediction of Northern Pacific ecosystem associated with human impact and climate change

Michio Kishi(Hokkaido Univ.) (2004-2008)

【Objectives】

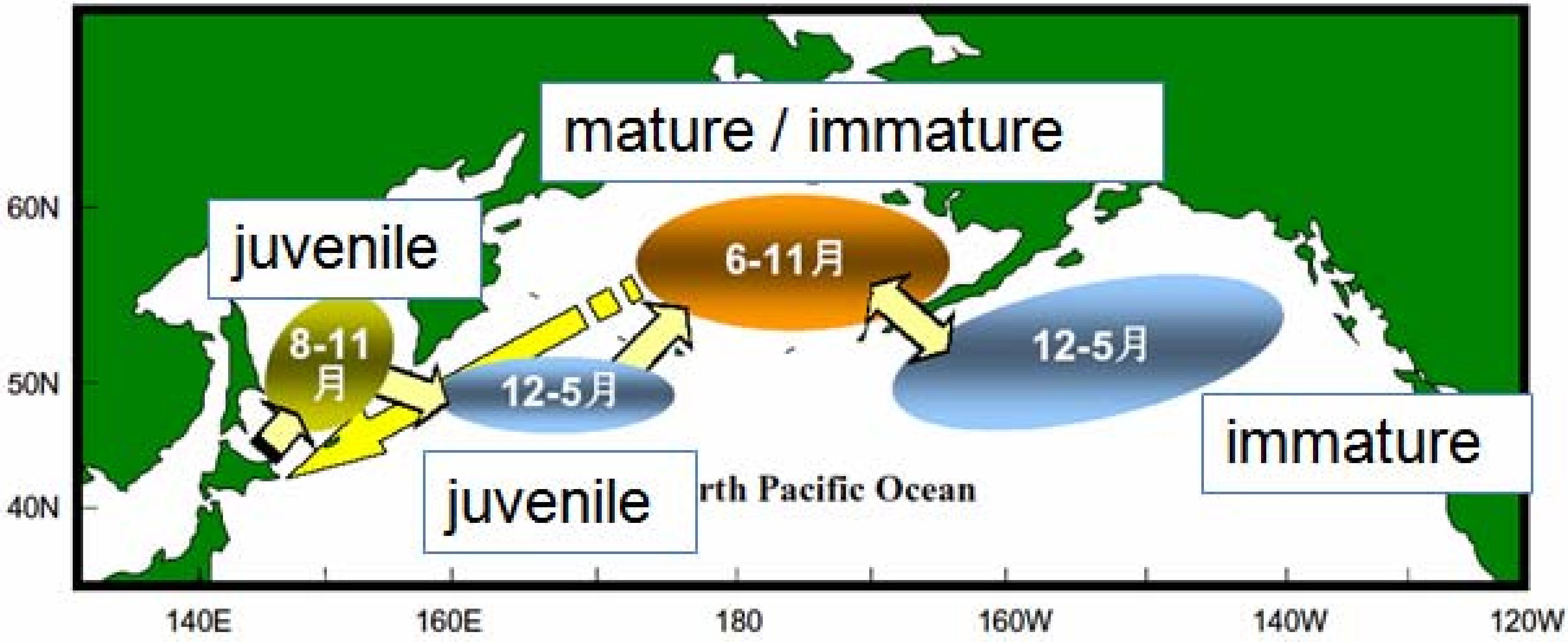
To analyze historical fish catch data and the other historical information on fish

To investigate the role of human impact (mainly fishing)and climate change on fish abundance

To make models (physical- ecological coupled models and population models that will be embedded in physical-ecological model)

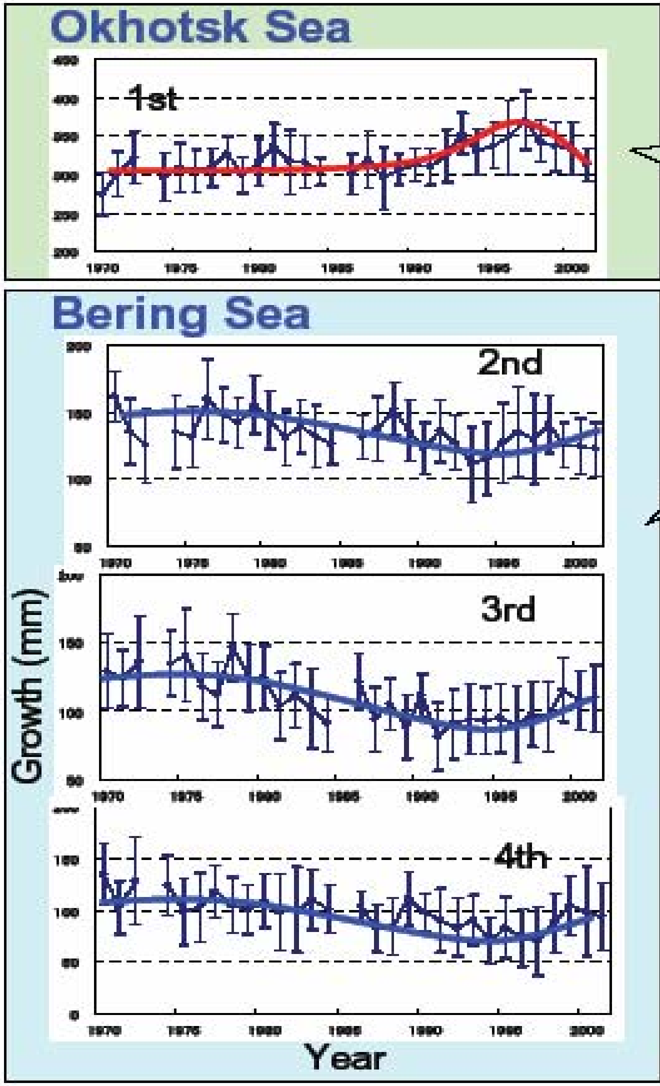
To predict the future status of marine ecosystems and marine living resources abundance of the Oyashio/ Kuroshio regions related to the 21st global warming scenario.

§1. Chum salmon



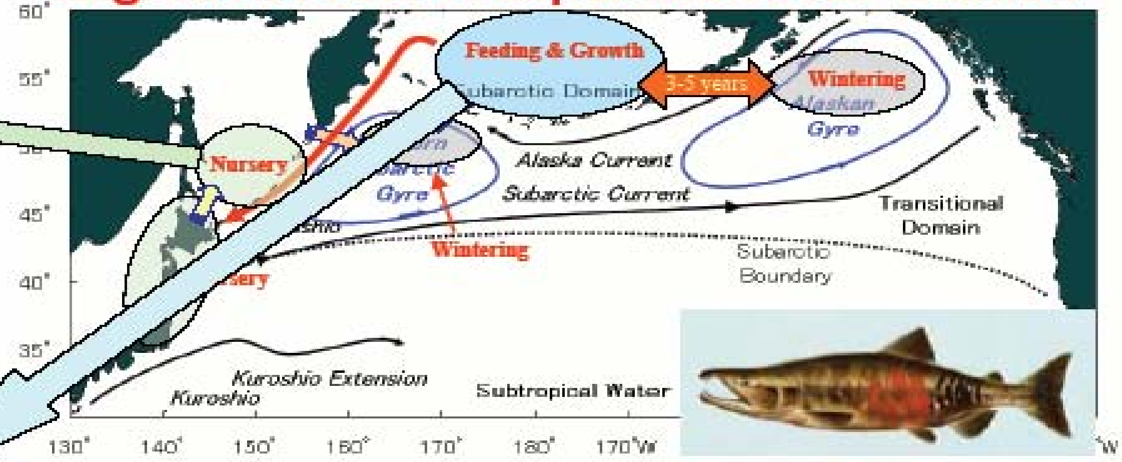
Urawa （2000）Migration route of Japanese salmon. National Salmon Resources Center (NASREC) Newsletter No.5pp.3-9, in Japanese

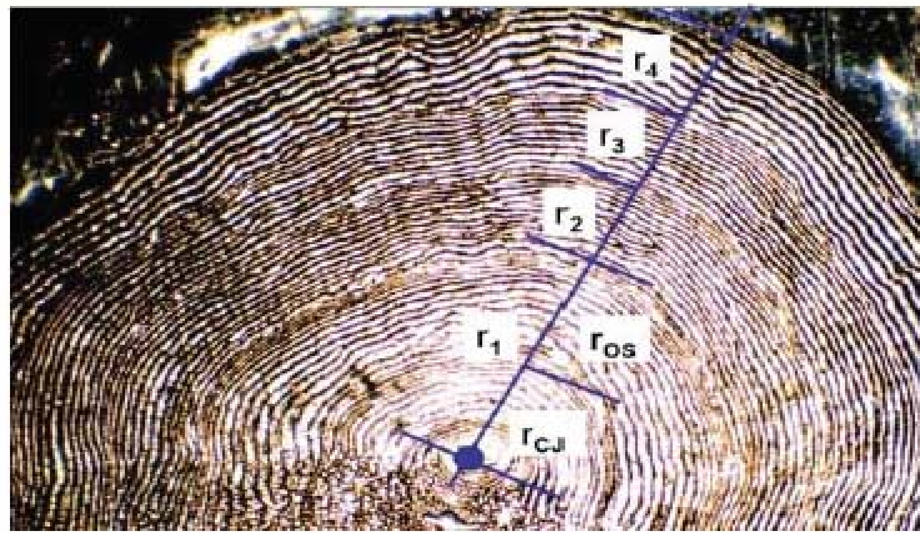
Temporal change in growth pattern of Hokkaido chum salmon



Temporal changes in growth of chum salmon returning to the Ishikari River by age

Migration route of Japanese chum salmon

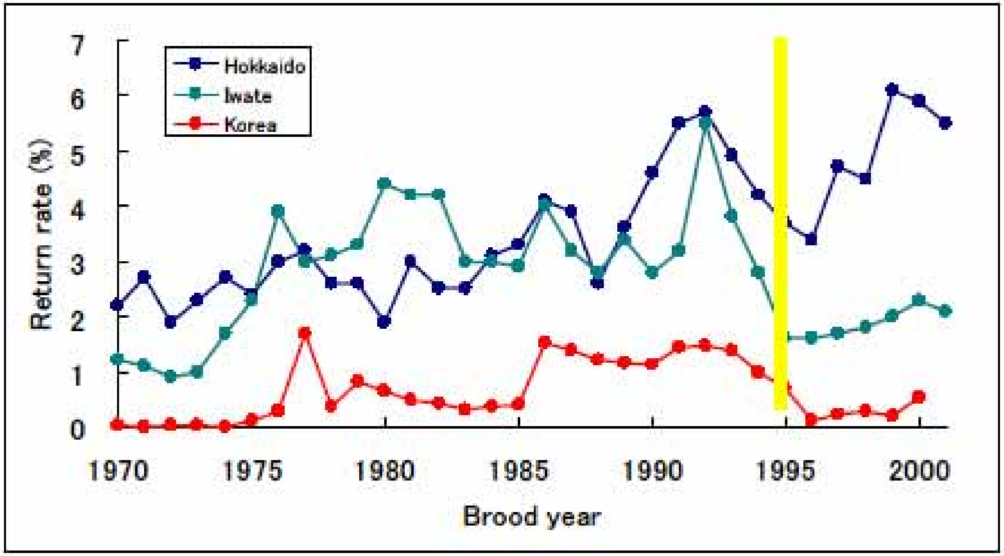




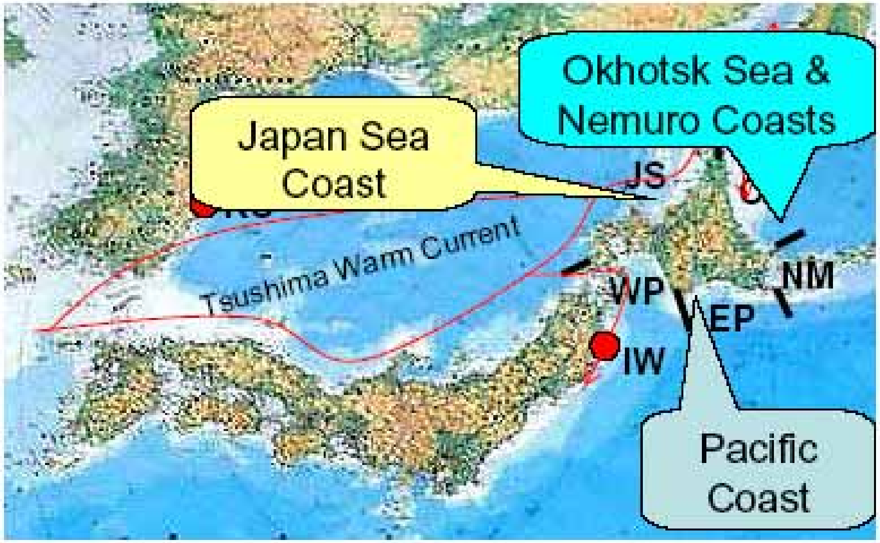
Scales of age-4 adult chum salmon returning to the Ishikari River, Hokkaido.

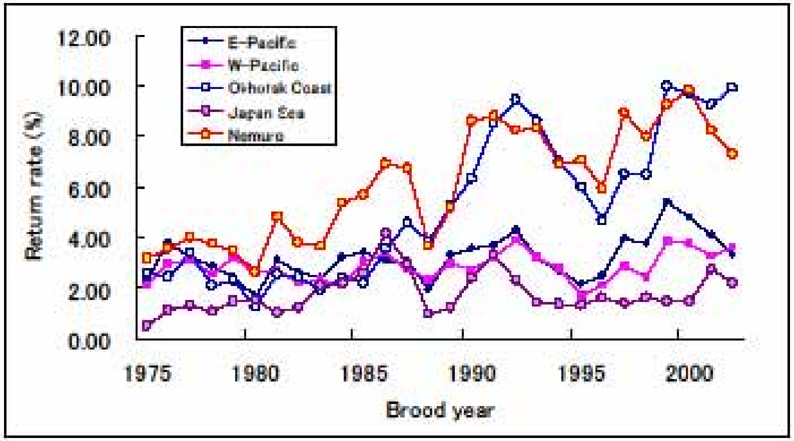
Yatsu, and Kaeriyama. (2005). Deep-Sea Research II 52: 727-737

Kaeriyama et al.(2007) North Pacifi c Anadromous Fish Commission Technical Report No. 7: 52–55,



Change in return rates of chum salmon released from Japan and Korea

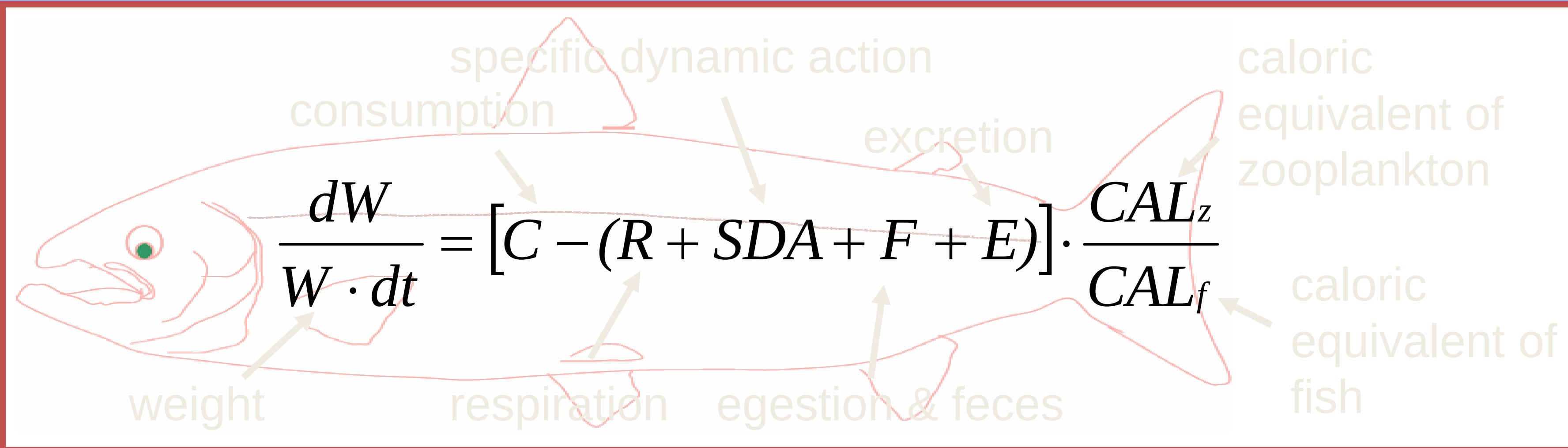




OS: Okhotsk Sea Coast, NM: Nemuro Coast, EP: Eastern Pacific, WP: Western Pacific, JS: Japan Sea, IW: Iwate Pref., KO: Korean H.

1) Salmon Bio-energetic model
+ lower-trophic model (NEMURO)

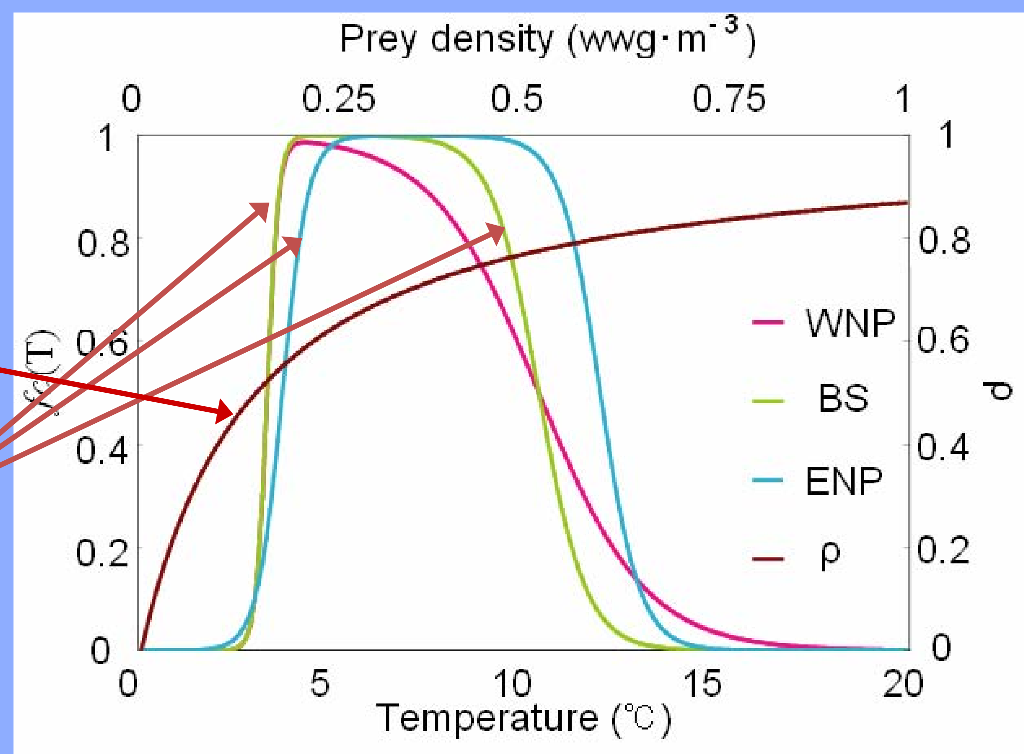
Rudstum(1988)



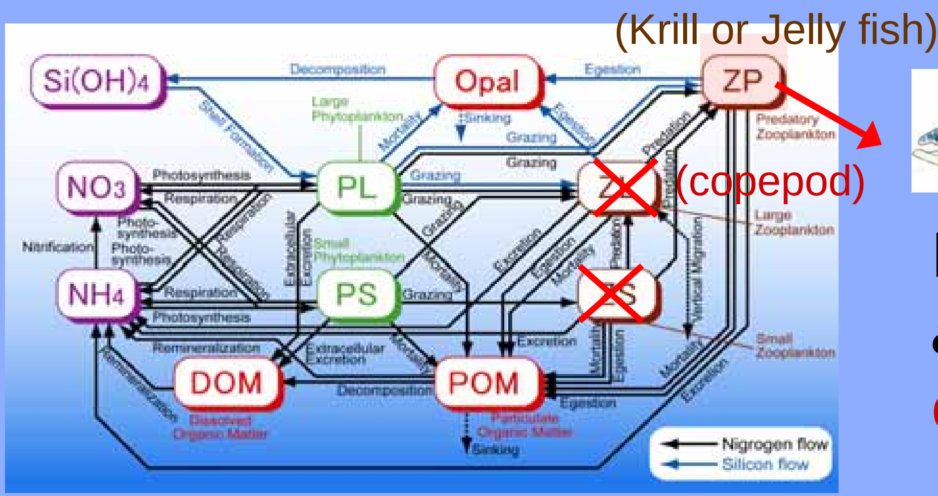
$$\frac{dW}{W \cdot dt} = [C - (R + SDA + F + E)] \cdot \frac{CAL_z}{CAL_f}$$

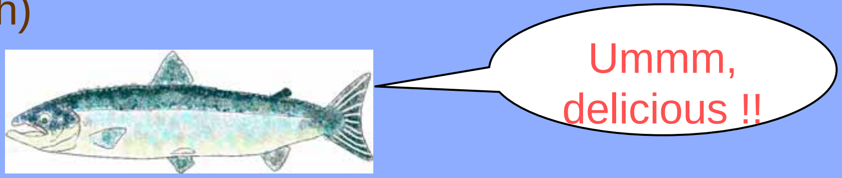
$$\mathbf{C = C_{MAX} \cdot \rho \cdot f_c(T)}$$

- C_{MAX}: maximum consumption rate ($C_{MAX} = ac \cdot W^{bc}$).
- **ρ:** prey density dependence function **(0<ρ< 1).**
- $f_c(T)$: temperature dependence function **(0<** $f_c(T)$ **< 1).**



-Forcing data set -





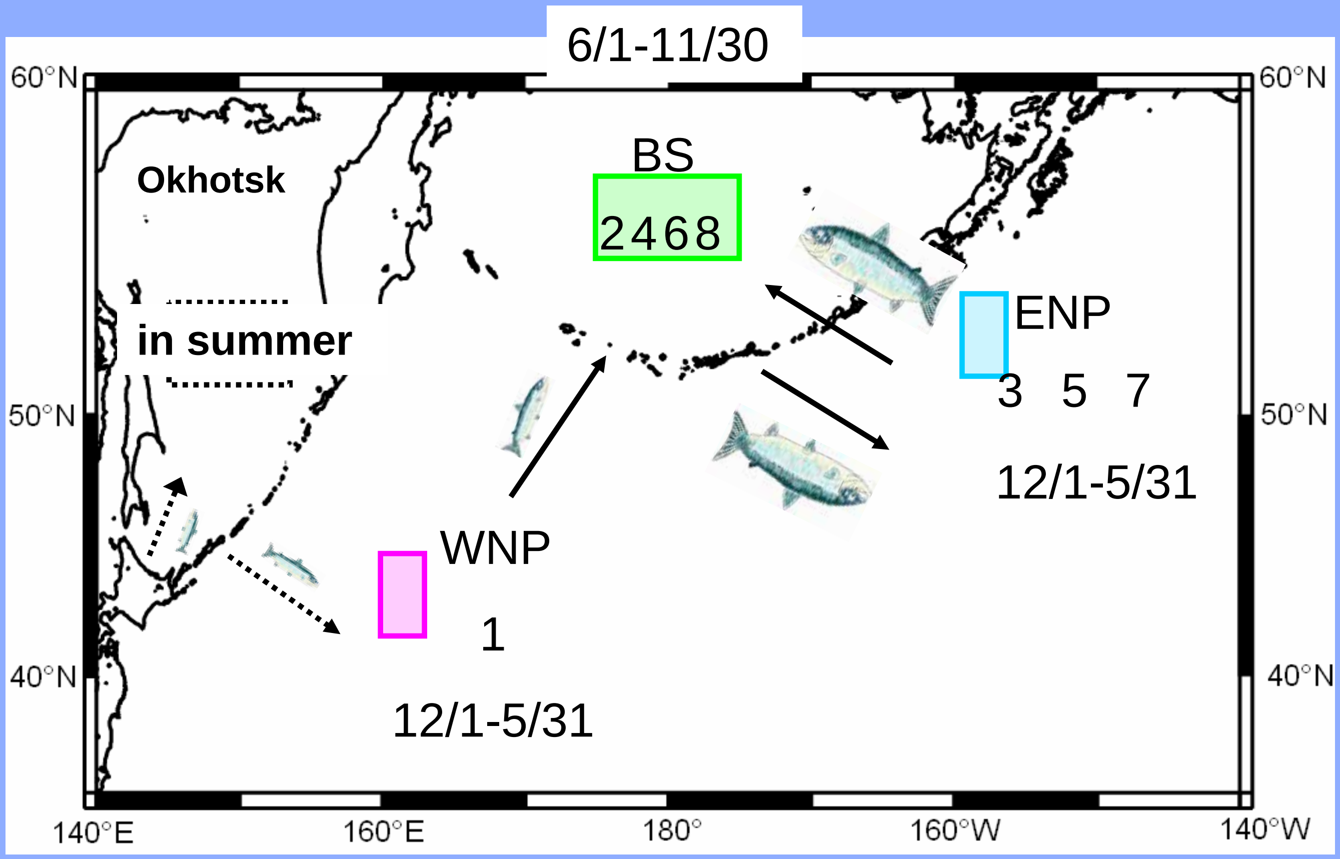
Referring to Kaeriyama *et al*.(2004), we decided to use only ZP as prey zooplankton.

<u>NEMURO developed by PICES Model Task Team</u>

(North pacific Ecosystem Model Used for Regional Oceanography)

- The forcing data set (SST,Salinity and prey zooplankton density) are obtained from the result of NEMURO embedded in 3-D physical model (Aita *et al*.,2006), along the migration route of chum salmon.

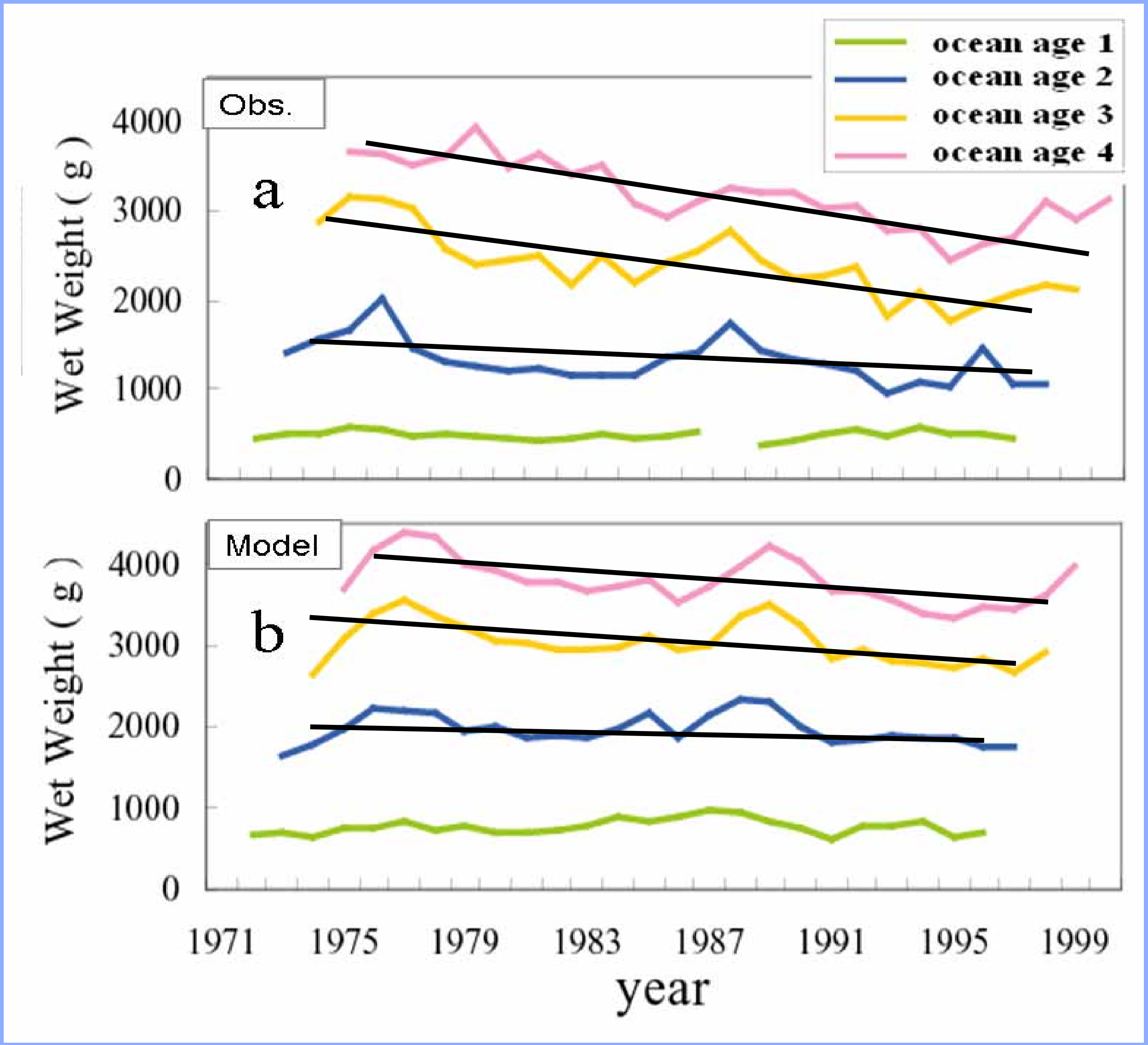
Kamezawa,Y., T,Azumaya, T.Nagasawa and M. J. Kishi(2007): Bull. Japan. Soc.Fish.Oceanogr., 71,87-96. *North Pacific Anadromous Fish Commission Technical Report No. 7: 95–98*



(drawn from Urawa,2000)

In summer : Feeding & Growth , In winter : Wintering.

Result 2/2



(Time-dependent features of body size in the Bering Sea in summer from 1971 to 1999.)

Summary of the model

- Reproduced body size of the 1972 year class is larger than that of 1991 year class. This result shows a good agreement with the observational in the Bering Sea.

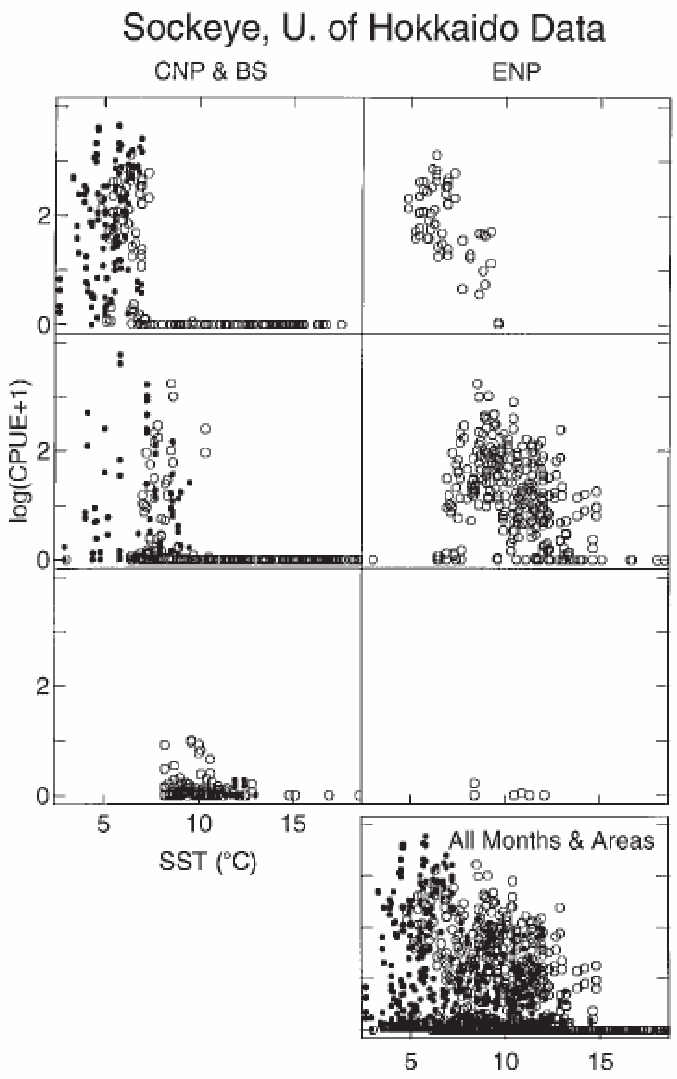
- The prey density, especially in the eastern North Pacific, gives larger influence to the change of wet weight rather than the SST does. Moreover, our model reproduces the trend of observations in l971-1999 well.

- This suggests that body size reduction of Japanese chum salmon in 1990s was partly affected by the prey density.

What will happen by global warming on salmon migration?

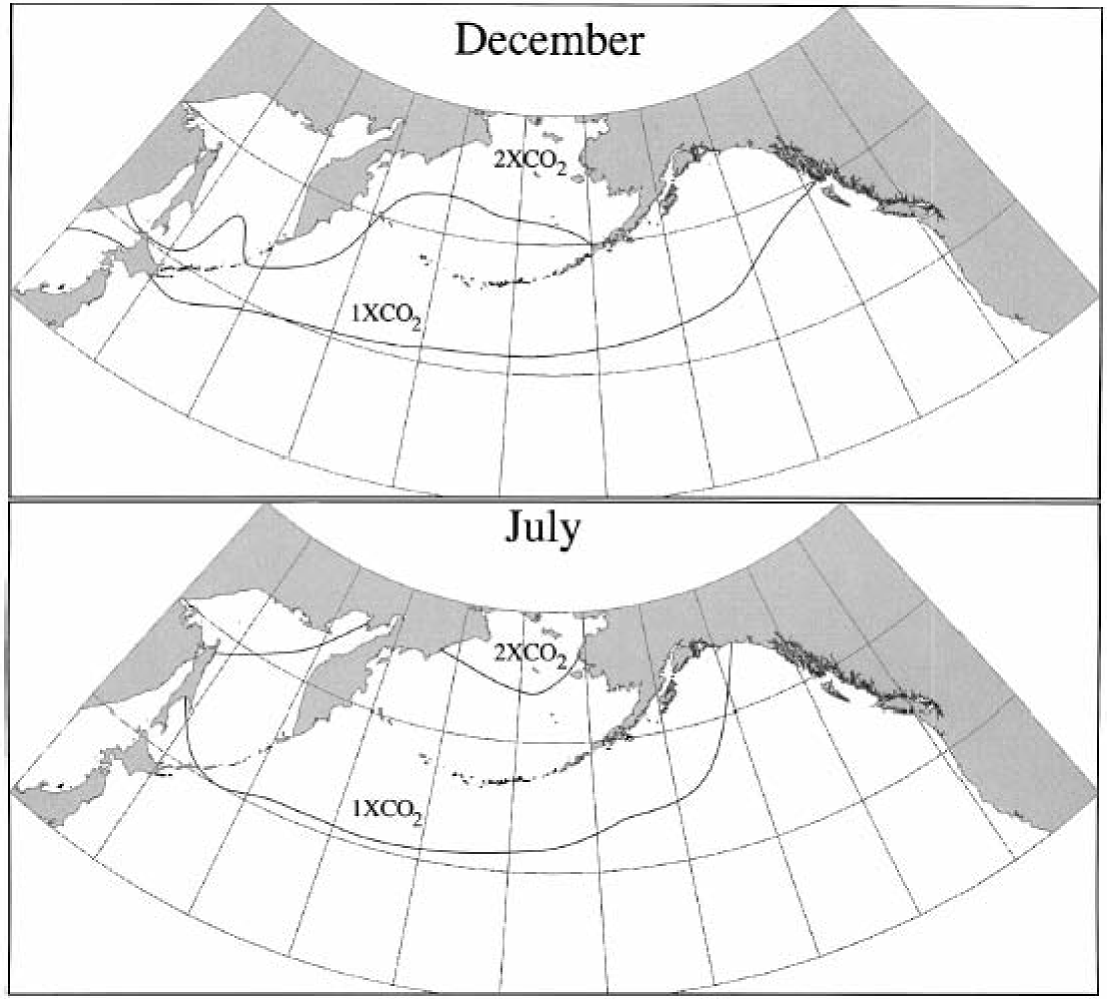
“Poikilotherm” No adaptation / dissilency

Fig. 12. Comparison of the sockeye response to SST for the University of Hokkaido data (1972–1993) divided by areas (columns) and months (rows) (the 1978–1993 subset is shown using open circles and earlier years using solid circles). The same sharp thermal limits shown in Figs. 3–5 are evident for this subset. Note that, as for the full data set, the aggregation of the data for all months and areas results in a more ambiguous relationship because combining data with differing thermal boundaries blurs the overall response.



D.W. Welch, Y. Ishida, and K. Nagasawa(1988) Can. J. Fish. Aquat. Sci. 55, 937-948

Fig. 11. Comparison of the predicted winter (7°C) and summer (12°C) positions of the sockeye salmon distribution under current and fu climates (Albers equal area projection). Under a doubling of atmospheric CO_2 the area of acceptable thermal habitat in the North Pacific predicted to decrease to zero in summer and decline sharply in winter. The predictions are based on the Canadian Climate Centre's coup ocean–atmosphere general climate model (Boer et al. 1992; McFarlane et al. 1992).



Fukuwaka, M., S. Sato, S. Takahashi, T. Onuma, O. Sakai, N. Tanimata, K. Makino, N.D. Davis, A.F. Volkov, K.B. Seong and J.H. Moss (2007): Winter Distribution of Chum Salmon Related to Environmental Variablesin the North Pacific. North Pacific Anadromous Fish Commission, Technical Report No. 7: 29–30

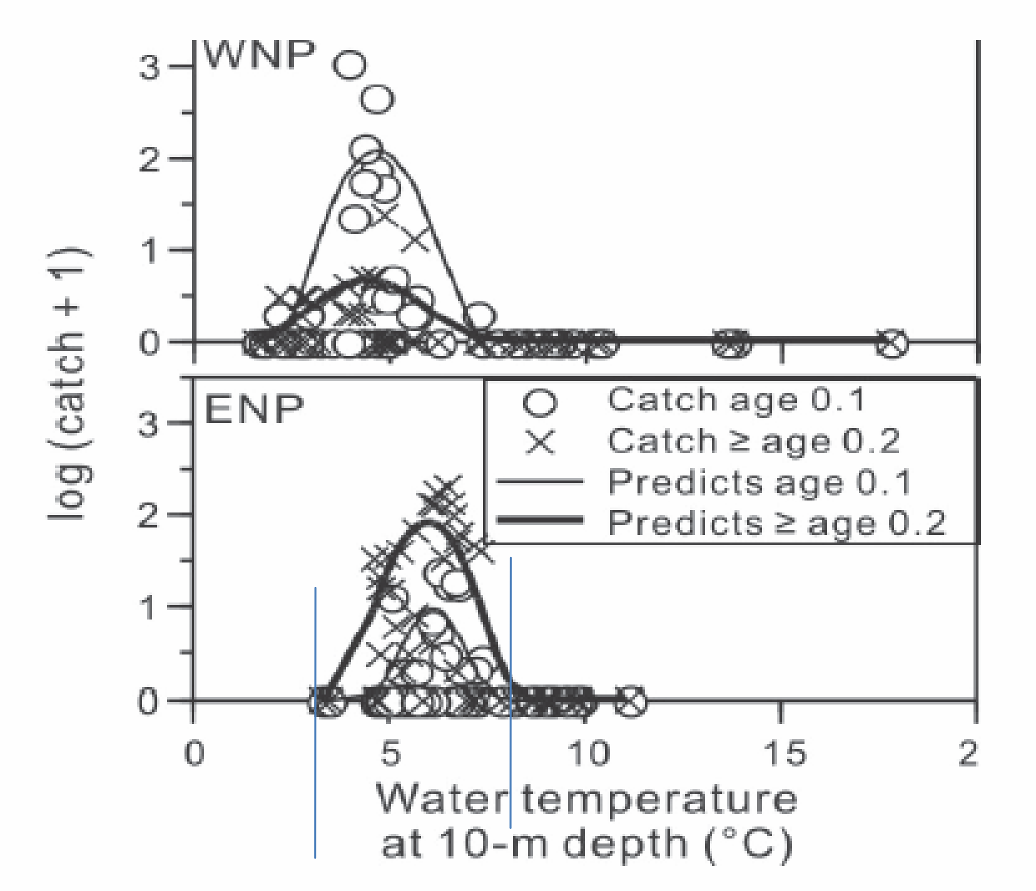
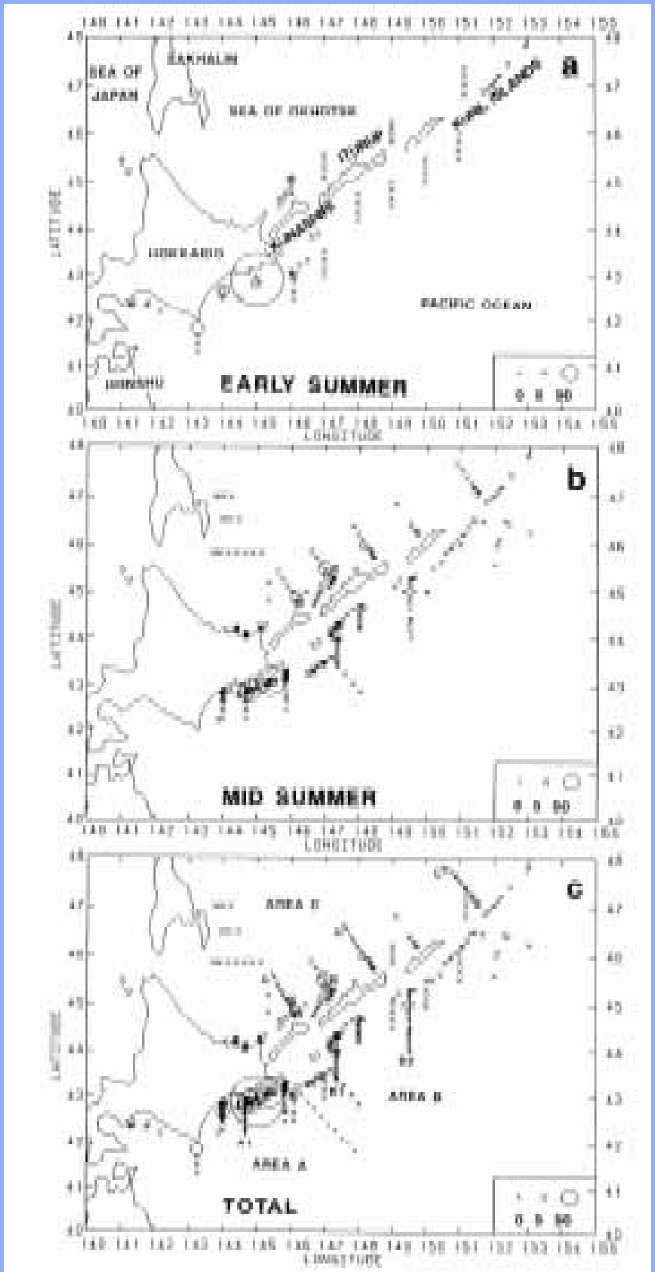
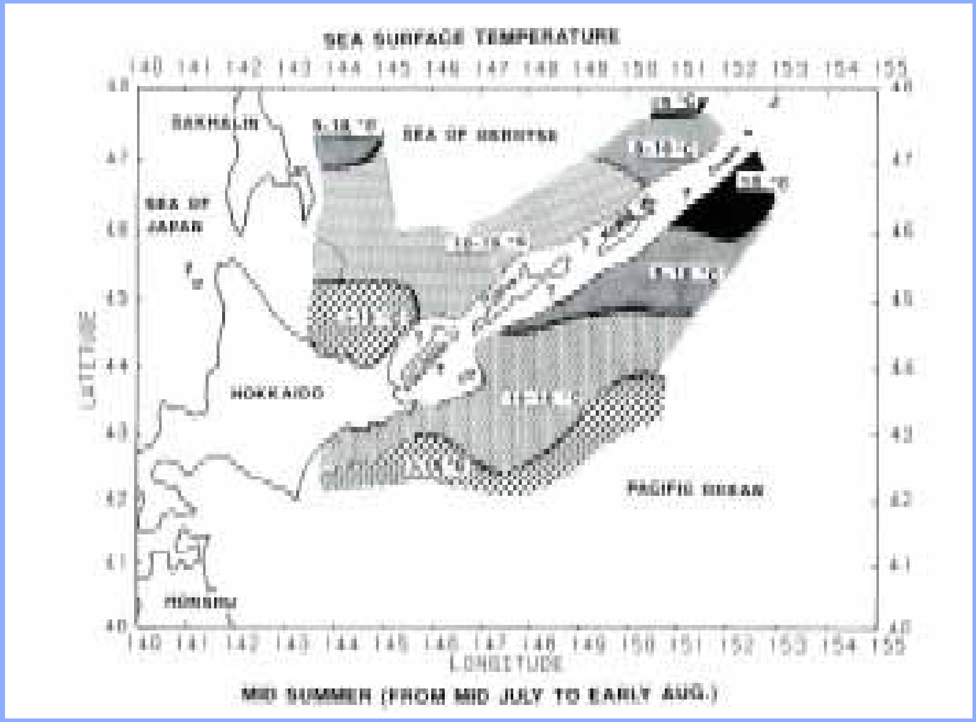


Fig. 1. Relationship between log-transformed catch of chum salmon caught in one-hour trawls and water temperature at 10-m depth. Fishing operations were conducted during winter in the western North Pacific (WNP; upper) and the eastern North Pacific (ENP; lower). Lines indicate the mean catch of young and older age chum salmon at temperatures predicted by a distribution model.

Ueno,Y. and Y.Ishida (1996) Summer distribution and migration routes of juvenile chum s
(Oncorhynchus keta) originating from rivers in Japan. Bull. Nat. Res. Far Fish., 33, 139-1





Growth, Feeding : 8 ~ 12℃

1st year in the Okhotsk Sea (July ~ October)

Wintering: 4 ~ 6 ℃

1st year in Northwestern Pacific (November ~ June)

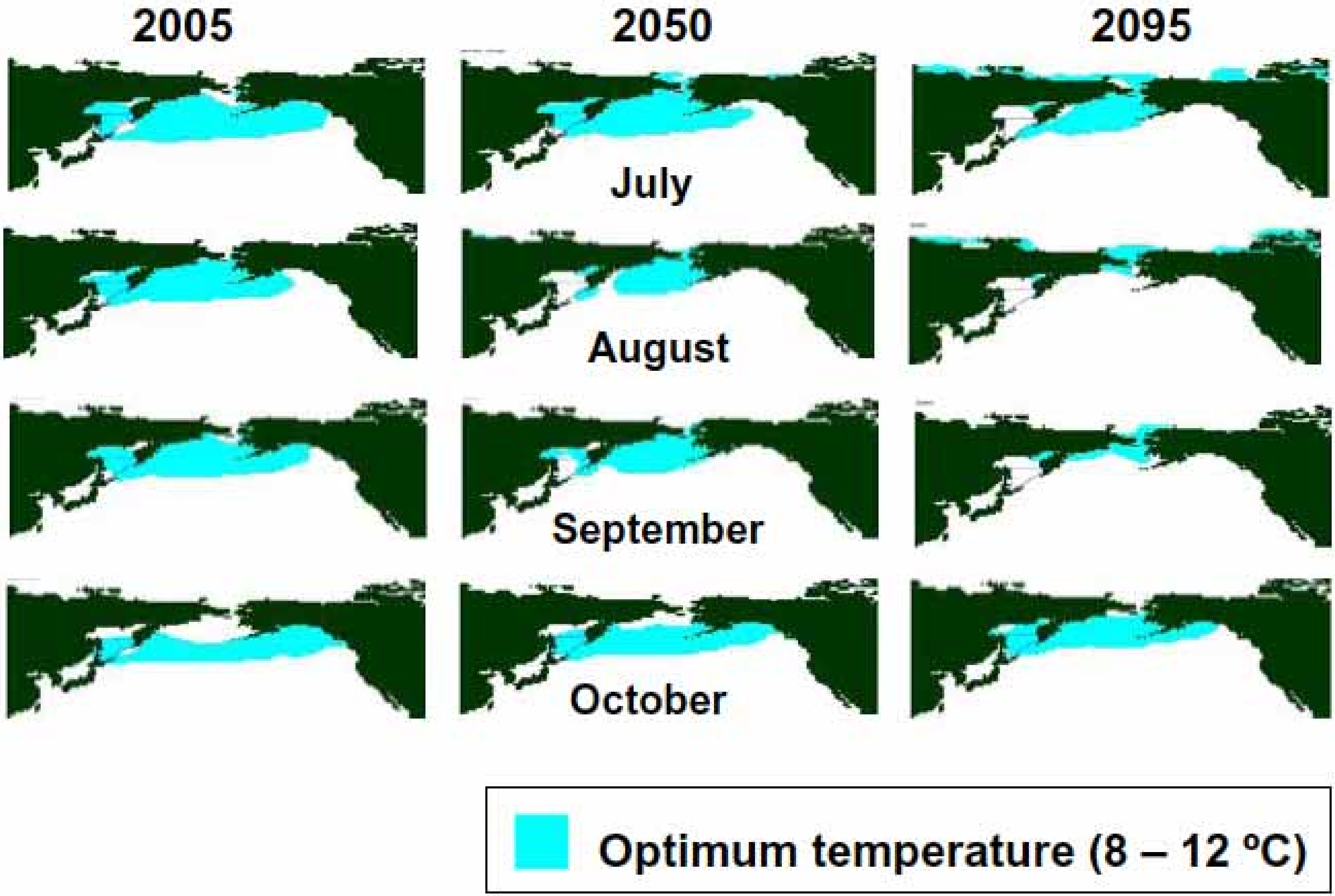
Growth, Feeding : 8 ~ 12℃

2nd year in the Bering Sea (July ~ October)

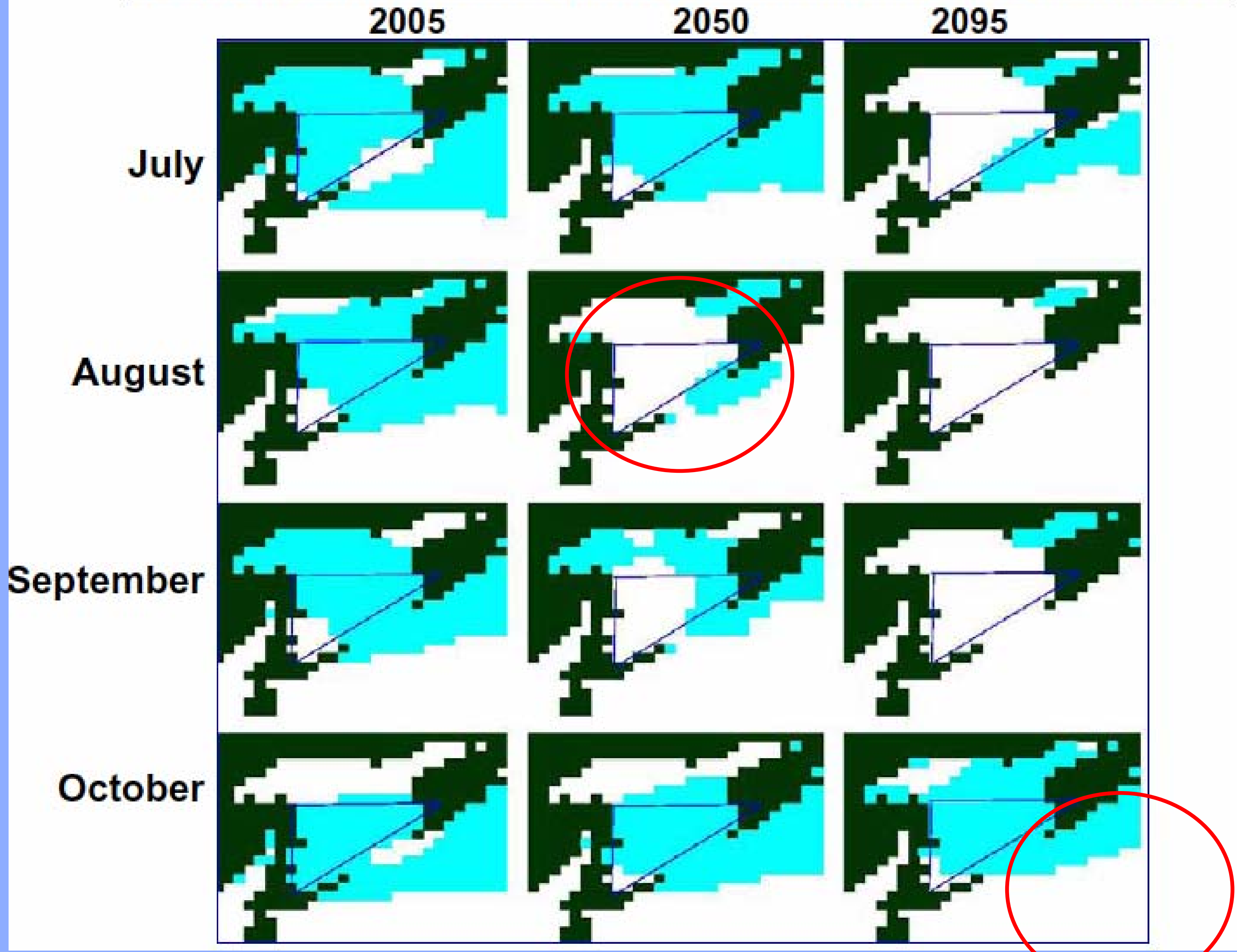
Wintering: 4 ~ 6 ℃

2nd year in the Gulf of Alaska (November ~ June)

Prediction about the Global Warming effect on chum salmon in the North Pacific Ocean based on the SRES-A1B scenario



Hokkaido chum salmon in the Okhotsk Sea



Global Warming Effect for Chum salmon

- **At present,** the global warming is affecting:
  - Positively for increases in growth and survival of Hokkaido chum salmon in the Okhotsk Sea since the 1990s
  - Negatively for reduction in growth and survival of the southern chum salmon (e.g., Korean and Iwate populations) since the late 1990s
- **In the Future,** the global warming will affect:
  - Decrease in their carrying capacity for reducing distribution area in the Gulf of Alaska and the Bering Sea
  - Strongly the density-dependent effect
  - Hokkaido chum salmon population which will lose migration route to the Okhotsk Sea by 2050 and will be crushed by 2100

サケの回遊　姿消す？

知に挑む

海

① 温暖化シナリオの警鐘

地図上に、緯度と経度で1度ごとに区切った黄色の小さなマス目が、日本の近海を北上していく。

黄色はサケが生息できる水温の海域。サケの生態研究に取り組む北海道大学水産科学研究院の帰山雅秀教授が、国連の「気候変動に関する政府間パネル（IPCC）」による地球温暖化のシナリオの一つを当てはめて解析した。

2050年。海水温が平均2度上がるシナリオでは、黄色のマス目は北海道のオホーツク海沿岸を離れ、はるか沖に遠ざかってしまう。

温度に敏感な魚にとって、1度の上昇は大きな事件だ。人間にとっては5～10度の上昇に相当するという。「川を下ったサケの稚魚は水温が高すぎると海に出られなくなる。サケが海に戻る回遊ルートが失われ、次第に川に帰るサケもいなくなるかもしれない」。帰山教授の温暖化の予測だ。

実際、サケが回遊し、豊かな生態系をもつオホーツク海で温暖化が進んでいる確かなデータも蓄積されつつある。北大低温科学研究所の研究者たちは、オホーツク海を含む北太平洋の過去50年間の海水温などを分析した。その結果が最近、米国の専門誌に発表された。

遊楽部川にサケの稚魚の調査に訪れた帰山さん。「サクラマスの方が多いなあ」＝26日午後、八雲町栄町で、川津陽一撮影

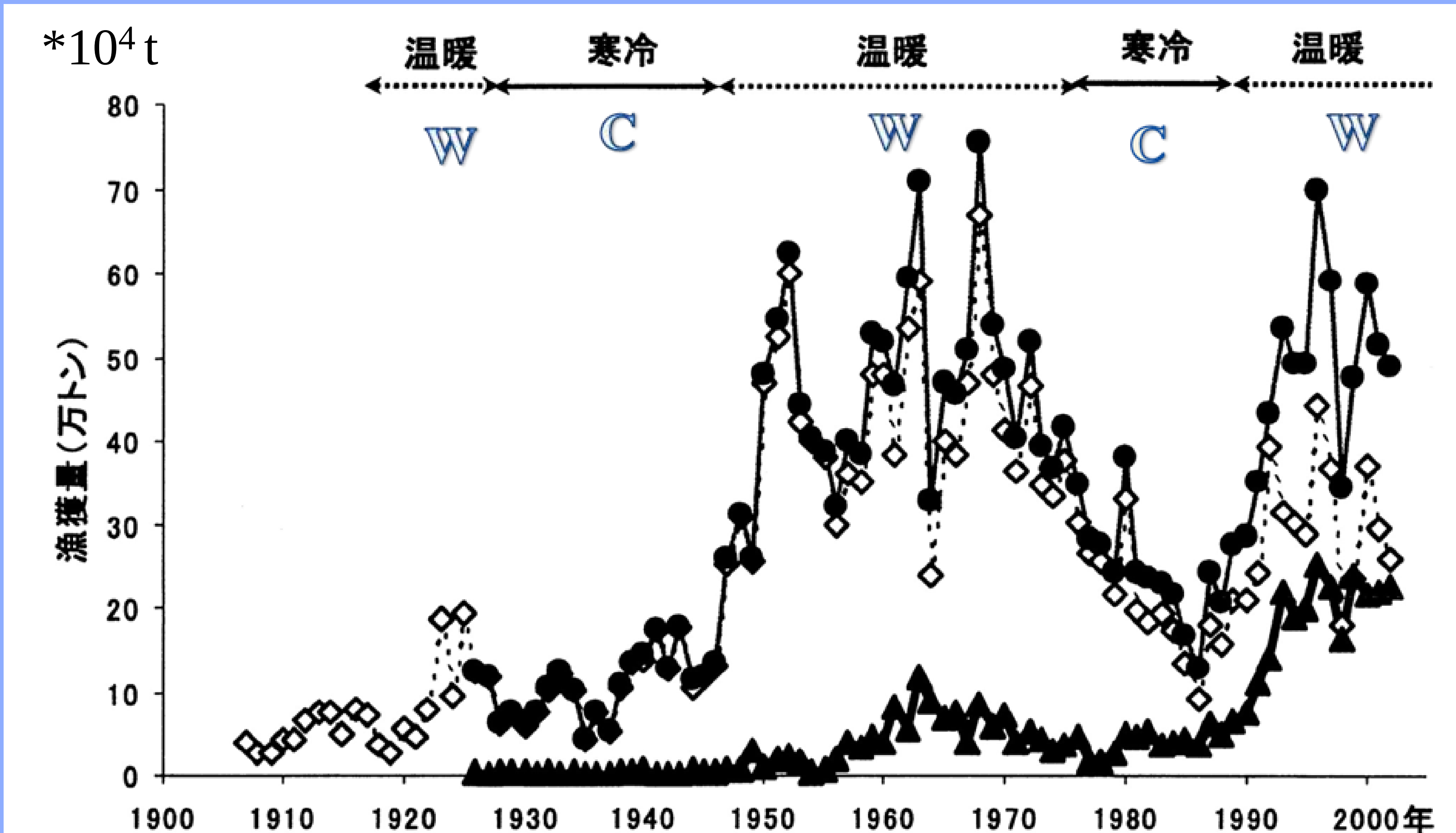
魚など海の生物が生きていくのに不可欠な栄養分の源になっている水深300～500㍍ほどの中層部で、オホーツク海の水温が50年間に平均約0・6度上昇していることがわかったという。

この「サケの温暖化シナリオ」を先取りするように、対馬暖流が沖合に回り込む韓国と岩手県で、温暖化の影響とみられる兆候が現れていると帰山教授は指摘する。

韓国へのサケの回帰率は90年代後半から下落傾向。岩手県のサケも放流

水ぬ

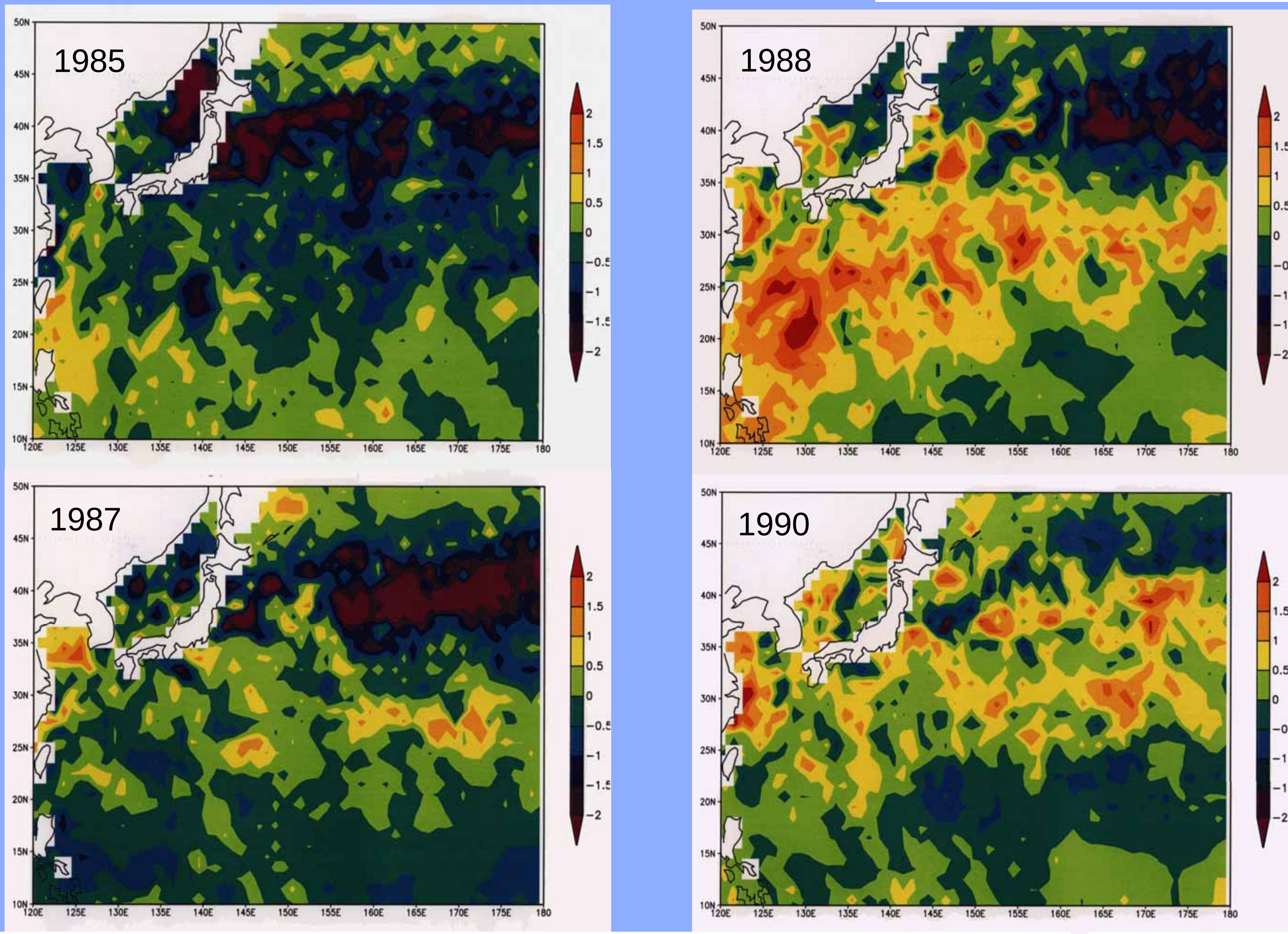
§2. Common squid



Fisheries of common squid:◇：Japan，●：Japan+Korea▲：Korea上の矢印線は、
（Sakurai et al，2000）

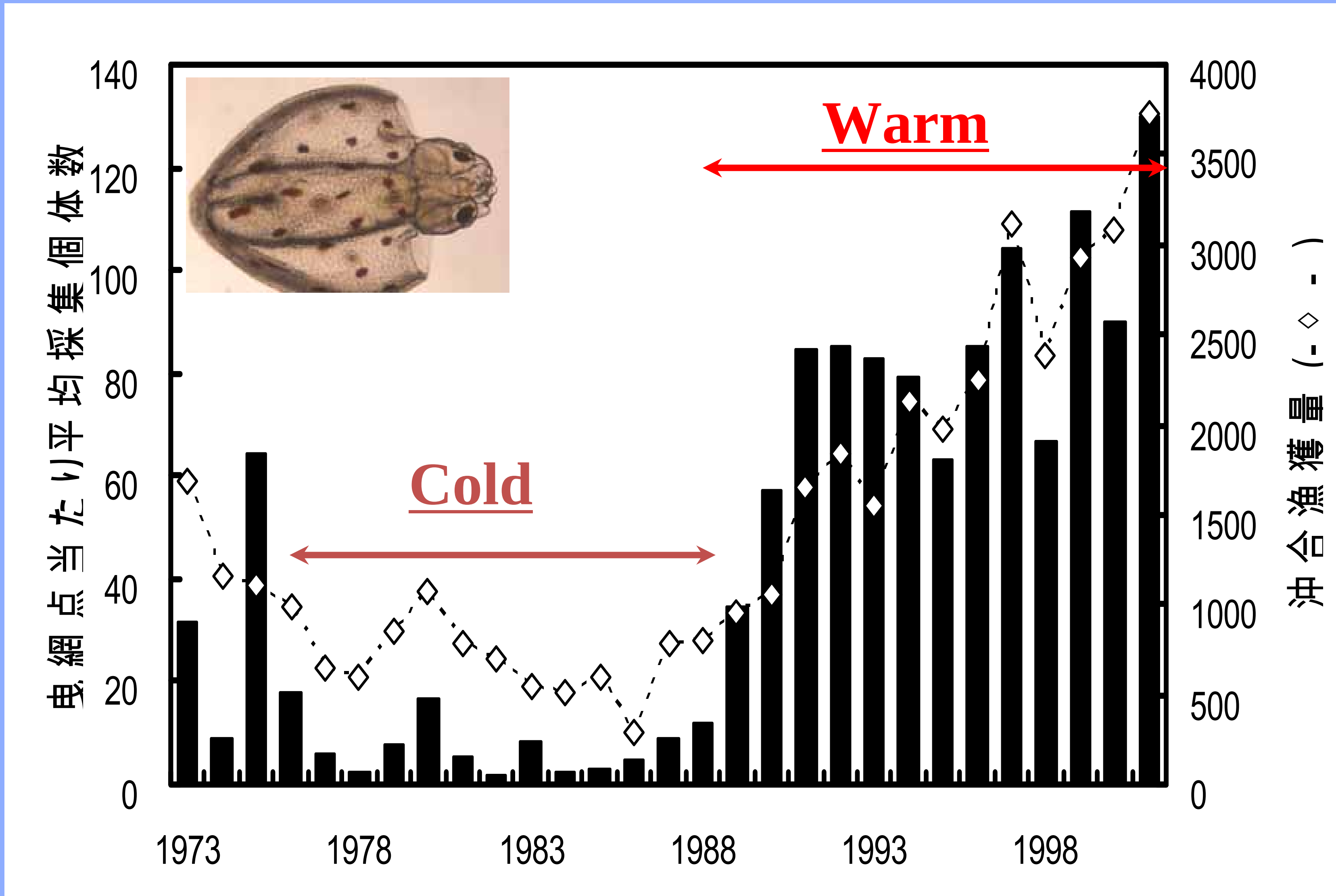
SST anomaly in February

Regimshift



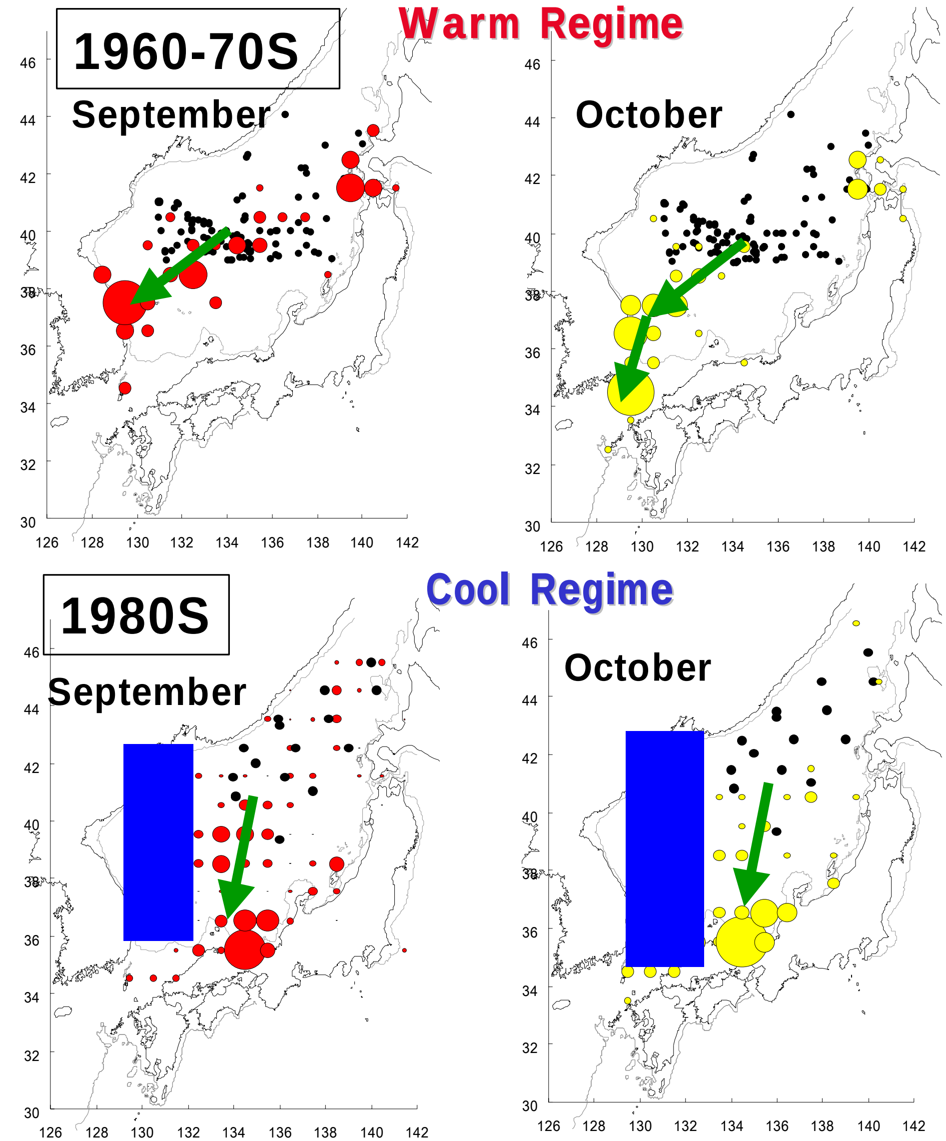
２月の海面水温のアノマリー（過去３０年間平均からの高温，低温差）

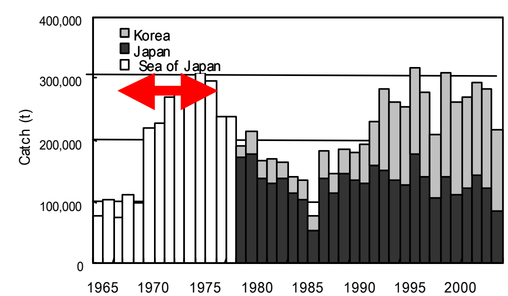
(Noto & Yasuda, 1999)

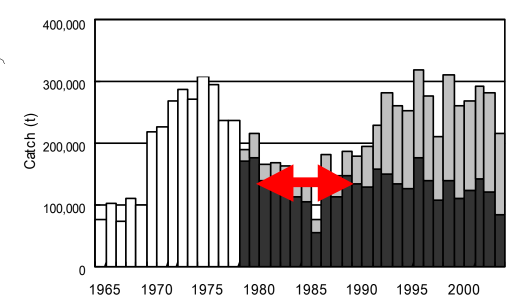


Juvenile CPUE (1/1000m^3) and catch (kg/day : May-Dec)-
Hyogo Pref.

Routes of spawning migration based on the release & catch data of tagged squids



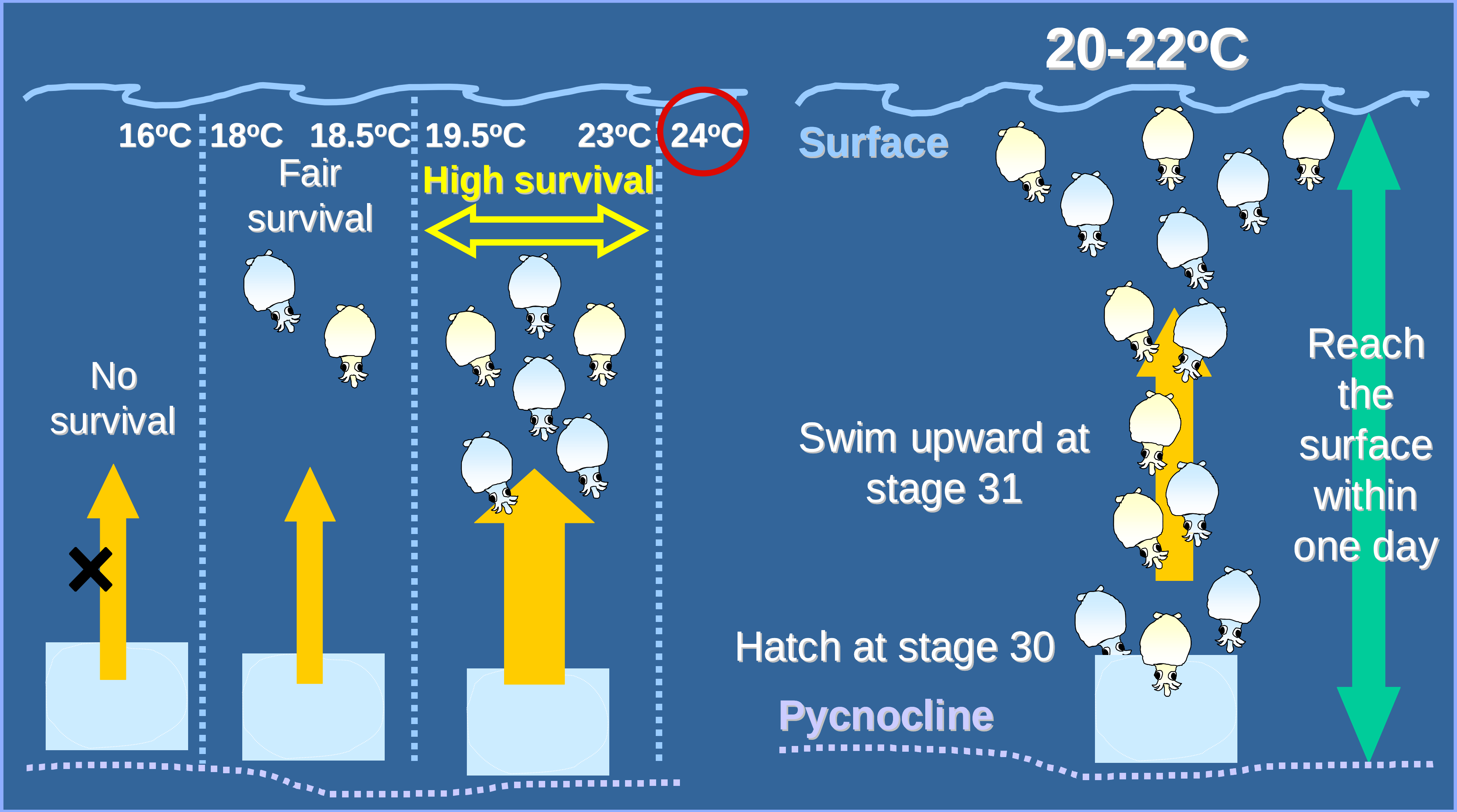


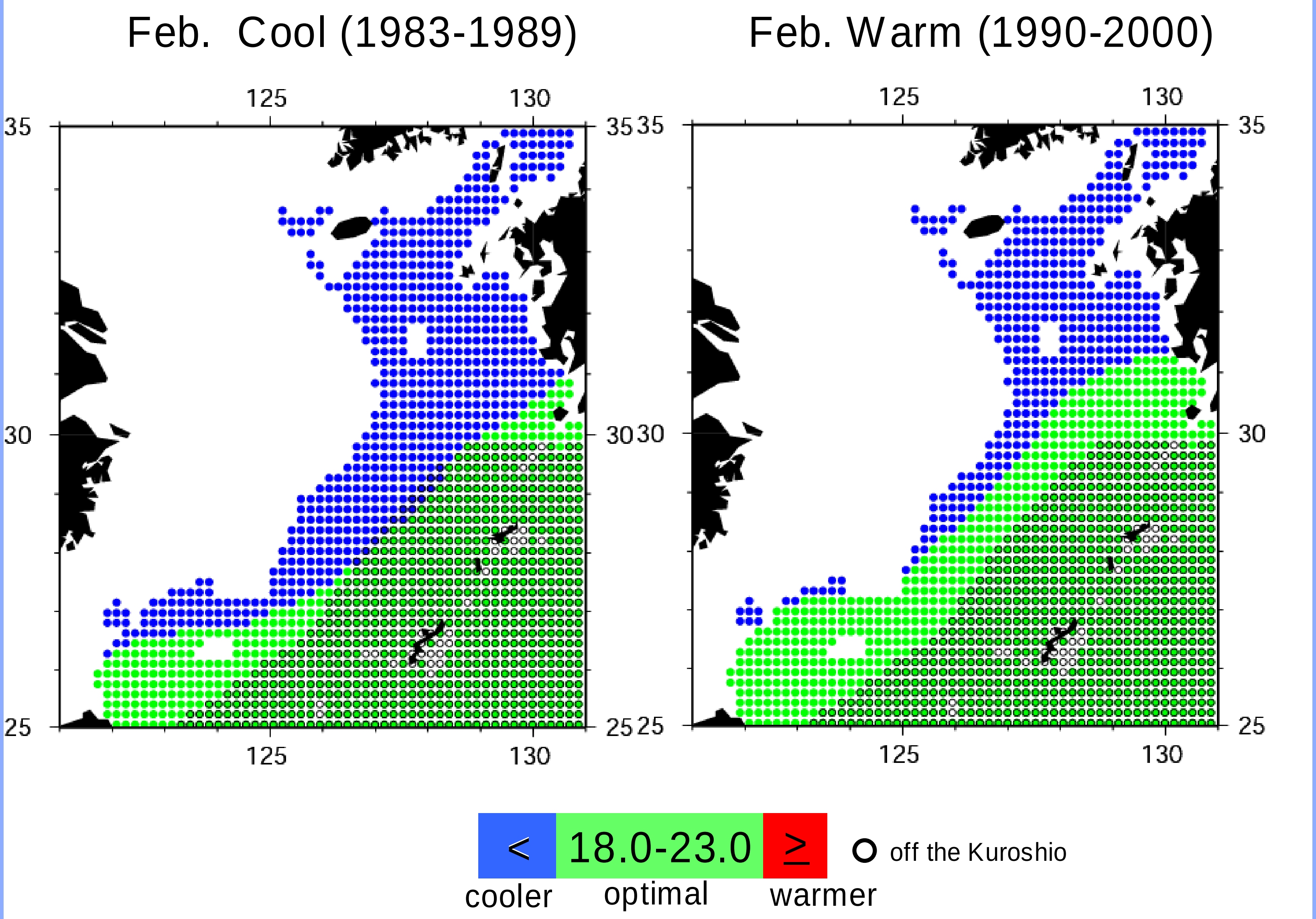


Kidokoro (Pers. Com.)

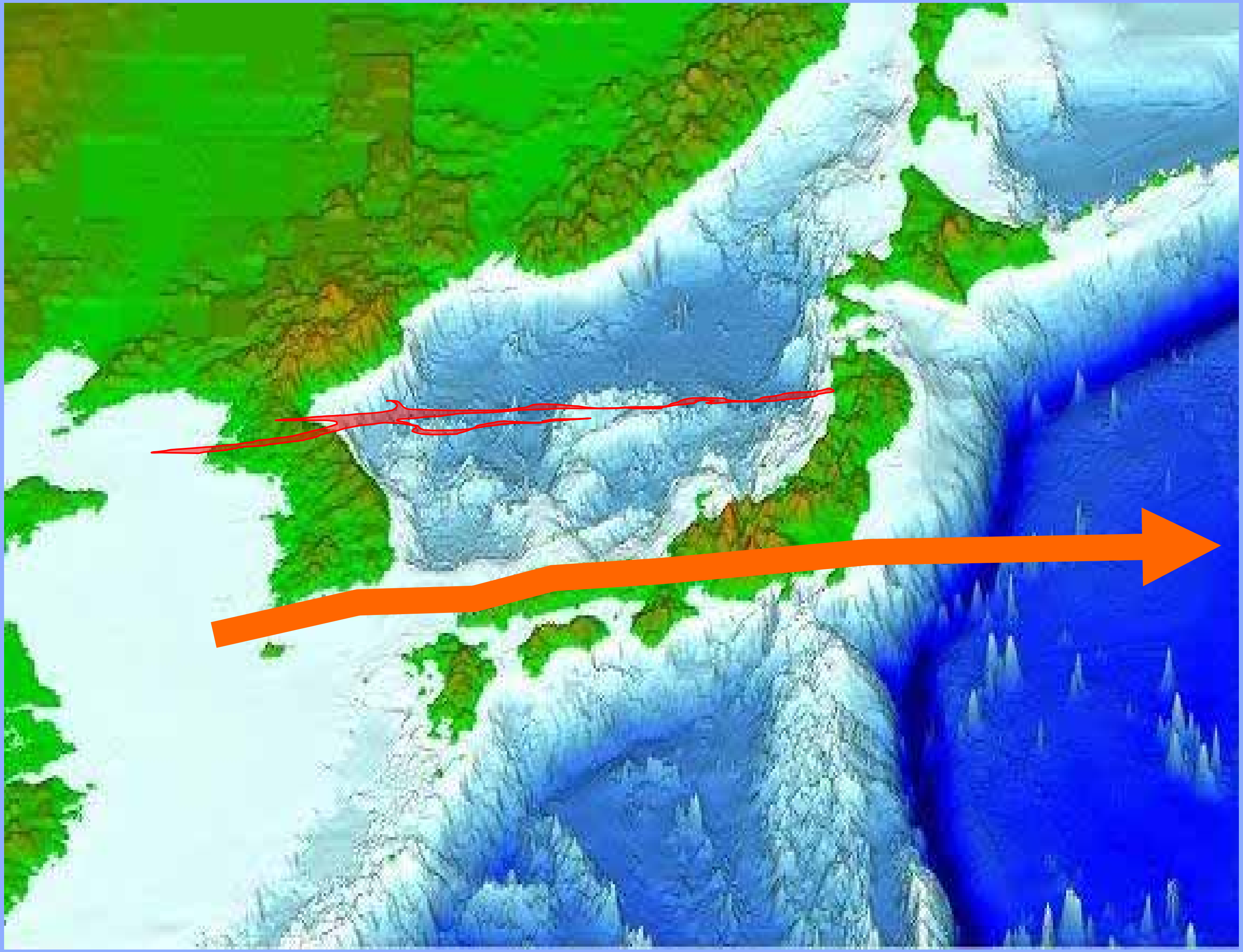
Black circle: release point, colored circle: caught （Kidokoro et al., 2004）

Egg is hatched out above thermocline , and juvenile can be survived 18-23℃ (especially 19.5-23℃) swims up to the surface water within a day

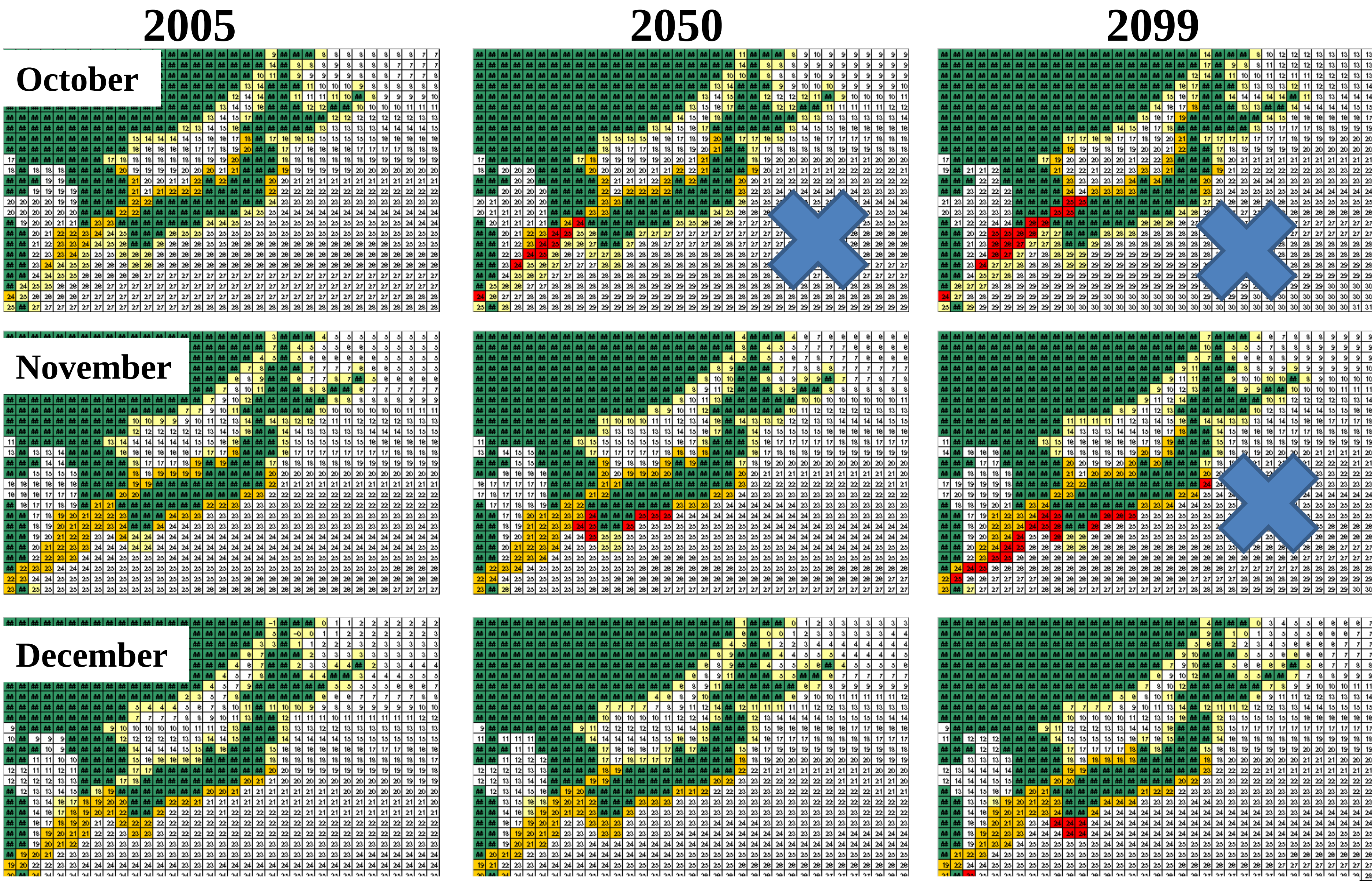



Feb. Cool (1983-1989)
Feb. Warm (1990-2000)
125
130
35
30
25
< 18.0-23.0 ≥
cooler
optimal
warmer
off the Kuroshio

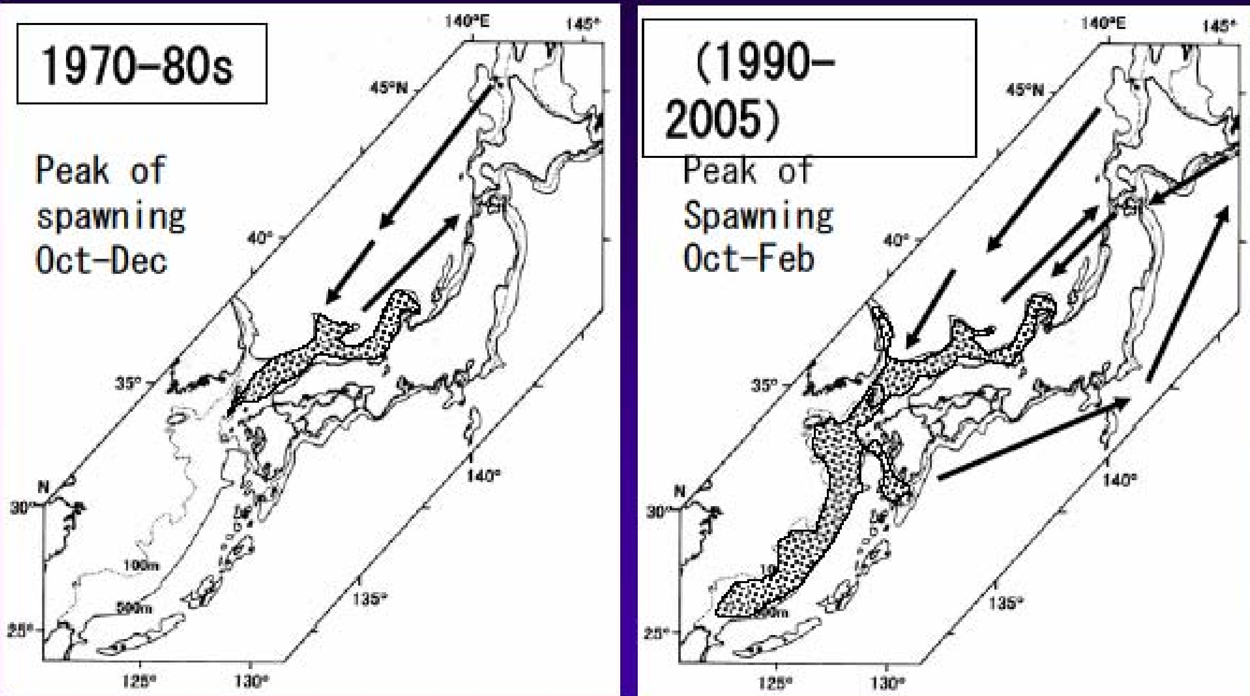
スルメイカの産卵可能海域は，100-500mの陸棚・陸棚斜面という制限要因がある



Changes of inferred spawning areas of *Todarodes pacificus* based on the Global Warming Scenario by the Earth Simulation System (FRCGC, Japan)



Green cell: land area, orange cell: inferred spawning area, red cell: disappeared spawning area with global warming



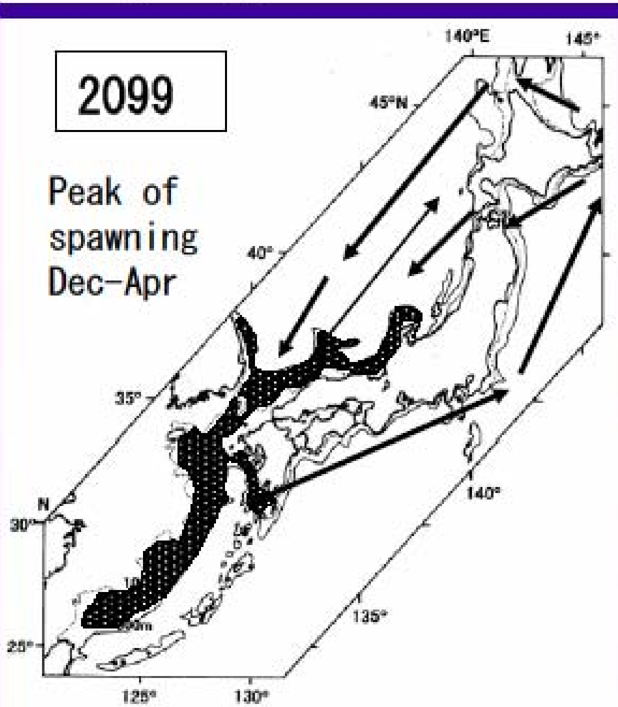
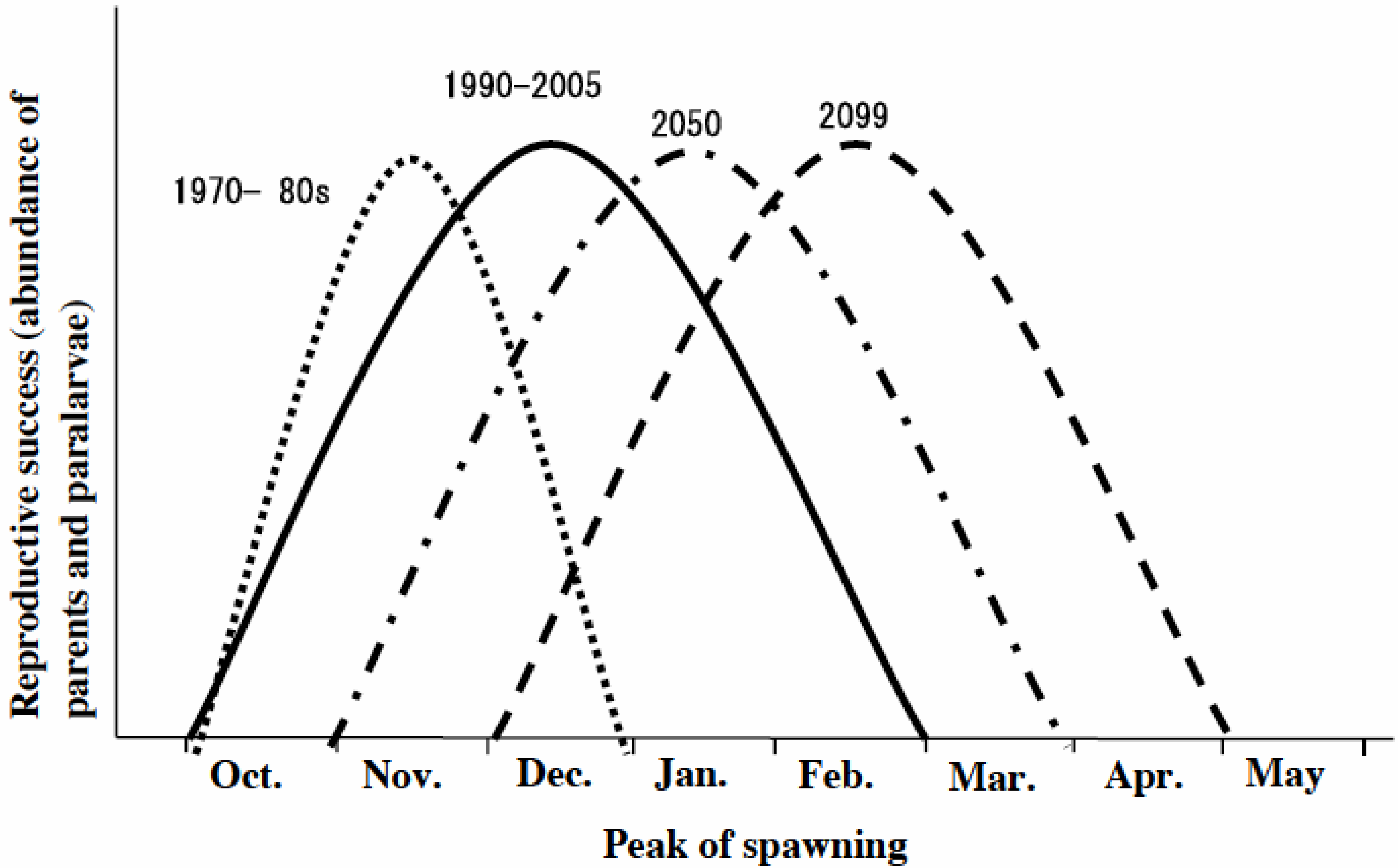
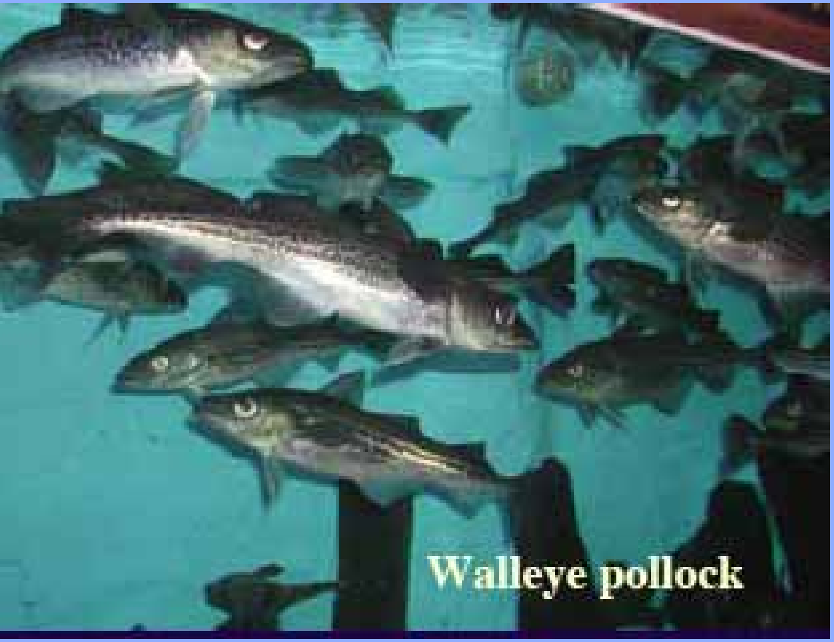


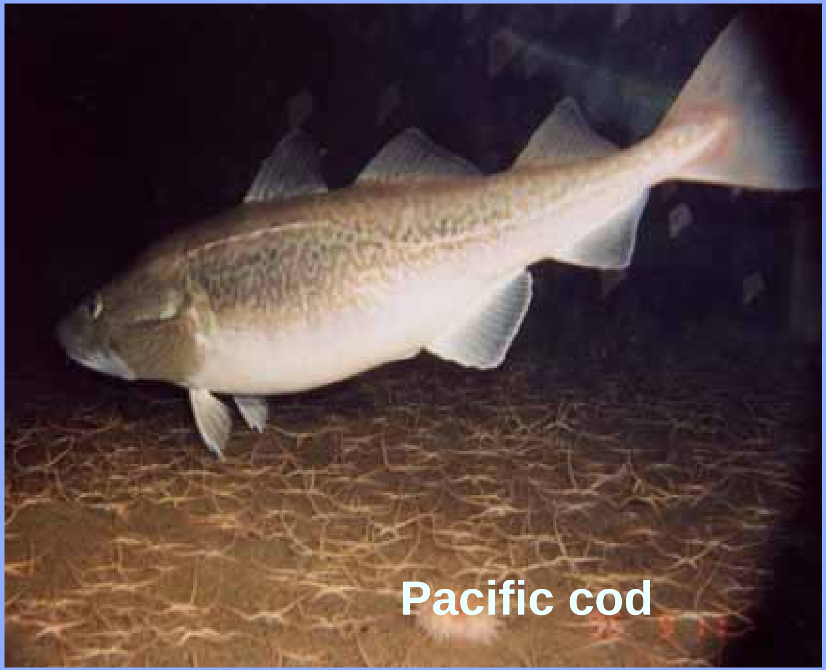
Fig. Predicted spawning periods,areas, and migration routes of *T. pacificus* during 1970-80s(cool regime),1990-2005(warm regime),2050(SST: 2℃ increase), 2099(SST: 4℃ increase). Estimated environmental changes in waters around Japan based on the IPCC global warming scenario (Kawamiya et al., 2007)



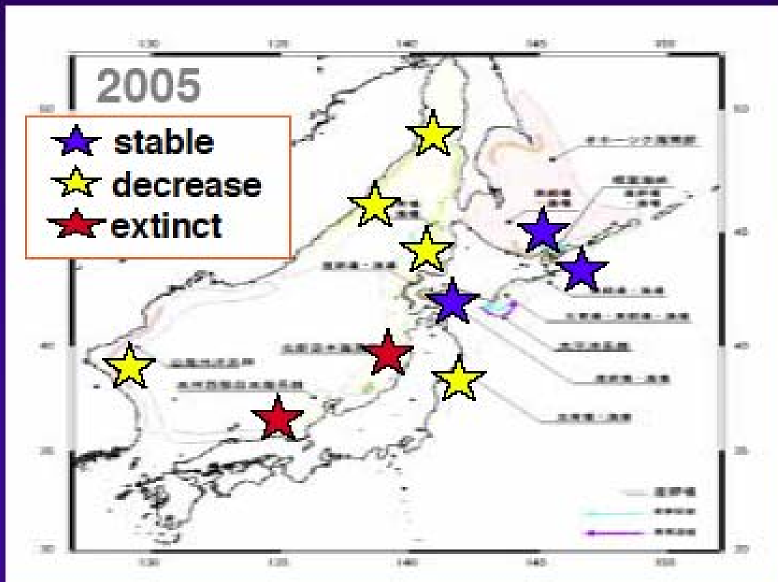
1990–2005
2050
2099
1970– 80s
Reproductive success (abundance of parents and paralarvae)
Oct.
Nov.
Dec.
Jan.
Feb.
Mar.
Apr.
May
Peak of spawning

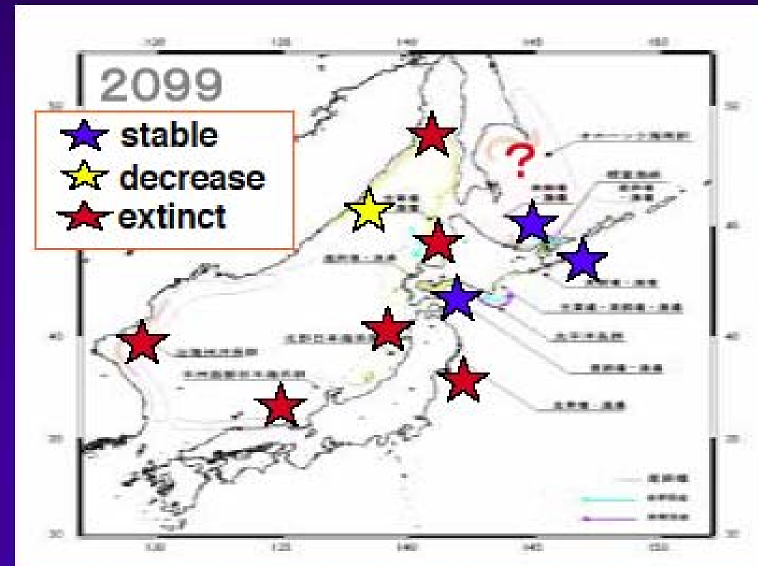
§3. Walleye pollock and Pacific co

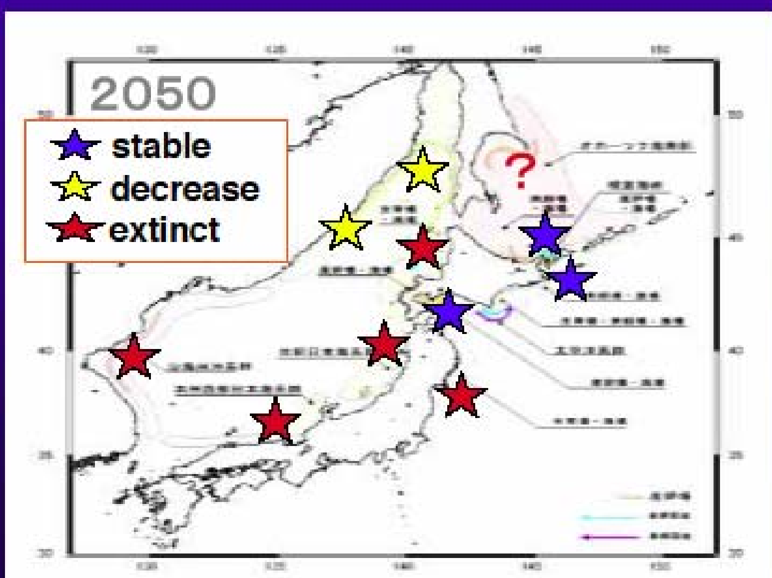


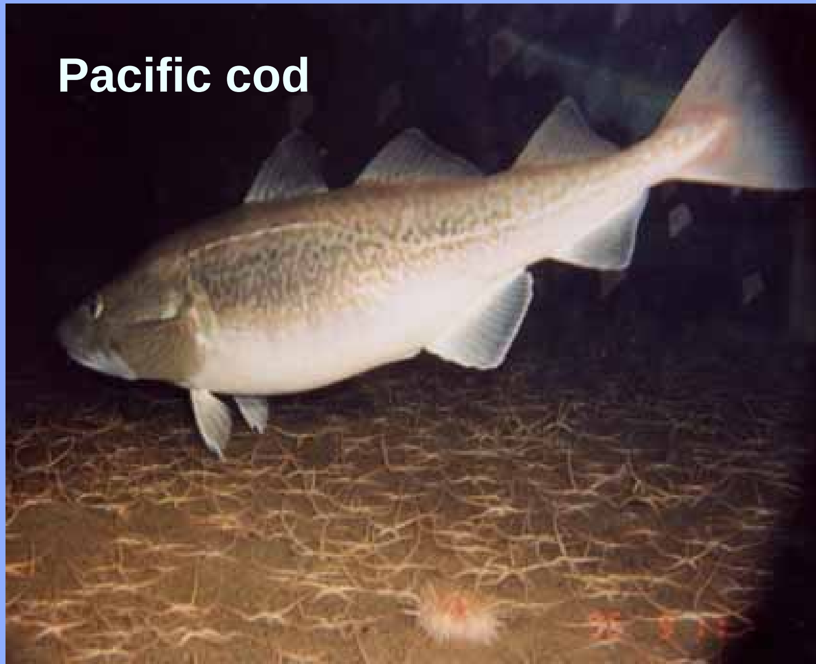


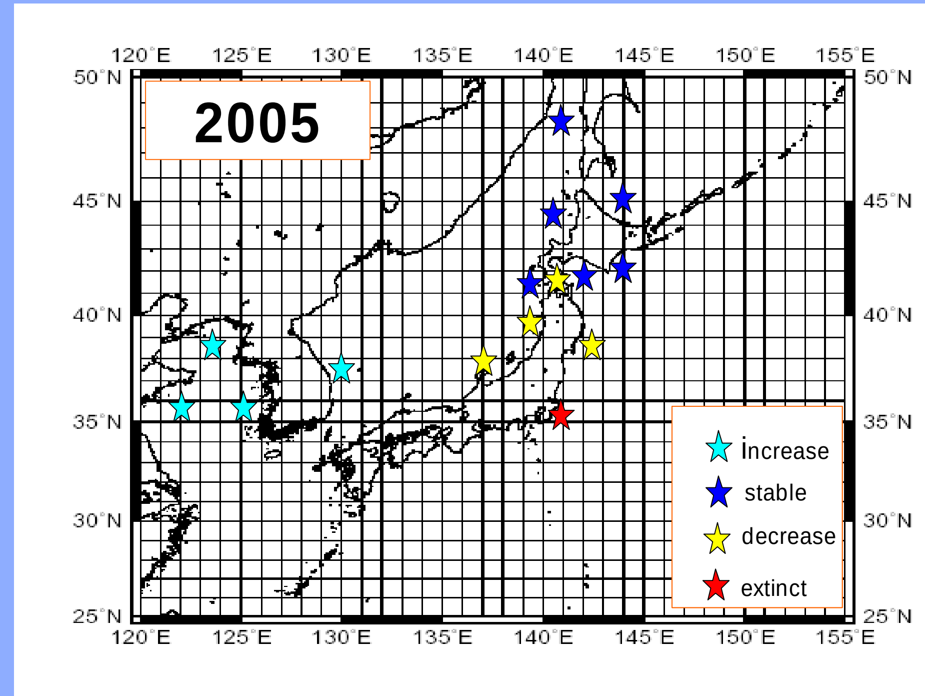
Changes of inferred spawning areas of Walleye pollock *Theragra chalcogramma* based on the Global Warming Scenario by the Earth Simulation System (FRCGC, Japan)

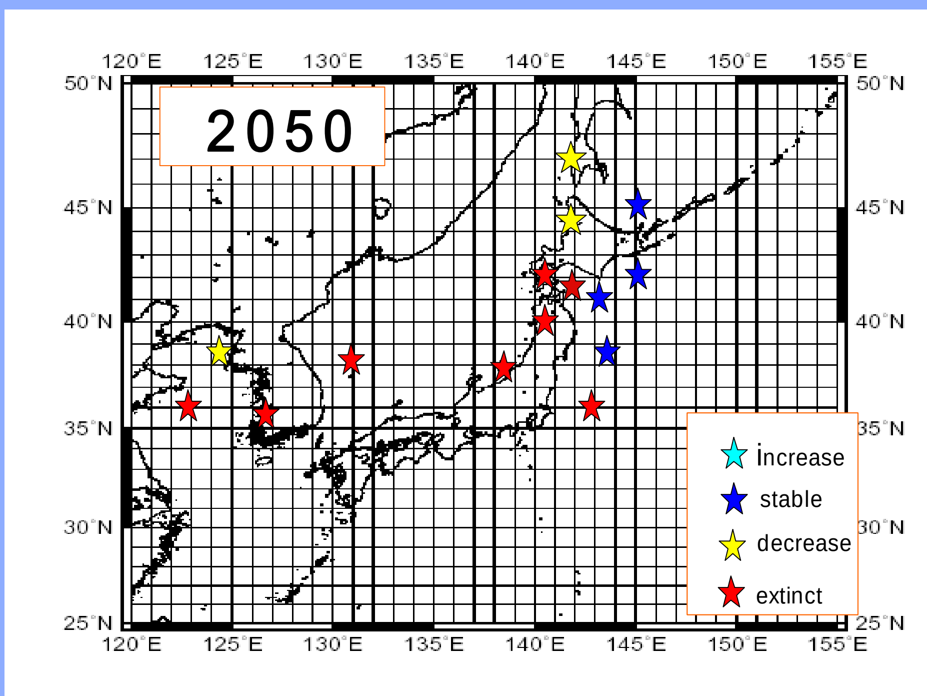


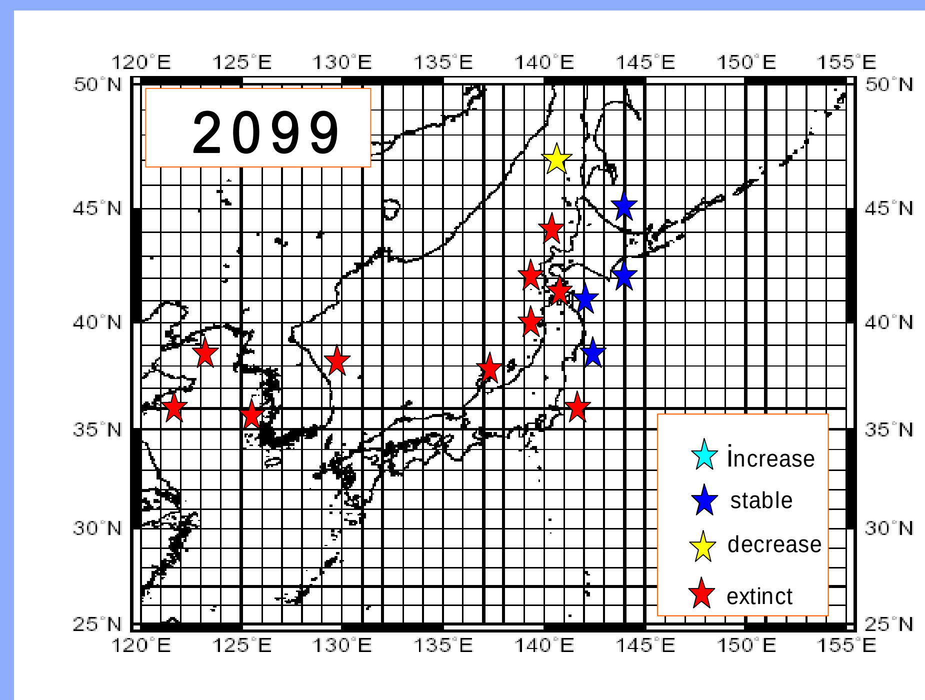





Pacific cod


2005
120°E 125°E 130°E 135°E 140°E 145°E 150°E 155°E
50°N 45°N 40°N 35°N 30°N 25°N
increase
stable
decrease
extinct


2050
120°E 125°E 130°E 135°E 140°E 145°E 150°E 155°E
50°N 45°N 40°N 35°N 30°N 25°N
increase
stable
decrease
extinct


2099
120°E 125°E 130°E 135°E 140°E 145°E 150°E 155°E
50°N 45°N 40°N 35°N 30°N 25°N
increase
stable
decrease
extinct

General conclusion

Traditional Fisheries Science

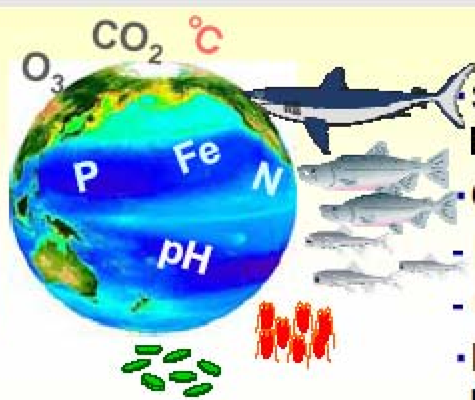
For only Fisheries

- **Change in Marine Ecosystem**
  "Fishing down marine food webs" (Pauly et al. 2003)
- **Sea Food Gourmet**→Tuna Laundering / Overfishing
- **"Tragedy of Commons"**
  First come→Overfishing
- **Ecosystem Crash & Food Polution**
  Vanishing Mangrove forest ecosystem, Cutoff food chain, Food security
- **Food Import**
  →"Eco Backpack", "Food Mileage"
- **Seafood: "Inexpensive is best?"**
  →Overfishing

Paradigm Shift

New Fisheries Science & Oceanography

For Marine Ecosystem & Human Food Sciences



- **Sustainable Fisheries Management based on the Ocean Ecosystem**
- **Carrying Capacity**
- **Marine Reserves (MRs)**
- **Greenhouse Gas Emission**
- **Food Traceability** – HACCP, ISO9000
- **Seafood Card (Eco-card)**
- **Marine Stewardship Council (MSC)**

My (not “our”)conclusion

Do you really believe that you can predict the future status of higher trophic ecosystem?

Who could predict noctiluca bloom in Arabian Sea?

Who could predict coccolith bloom in Bering Sea?
Even lower trophic!

Who could predict multiplication of giant jelly in the Sea of Japan?


Thank you
ありがとう