Effects of climate change on marine ecosystems around Japan: Implications for fisheries management

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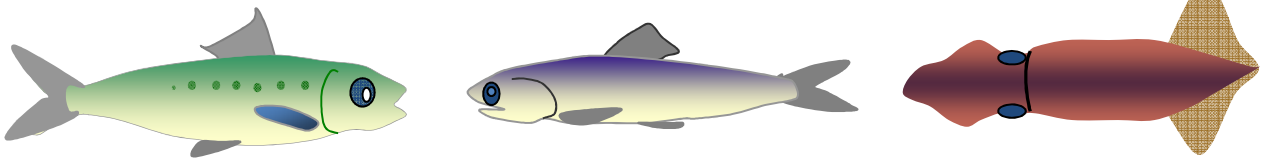
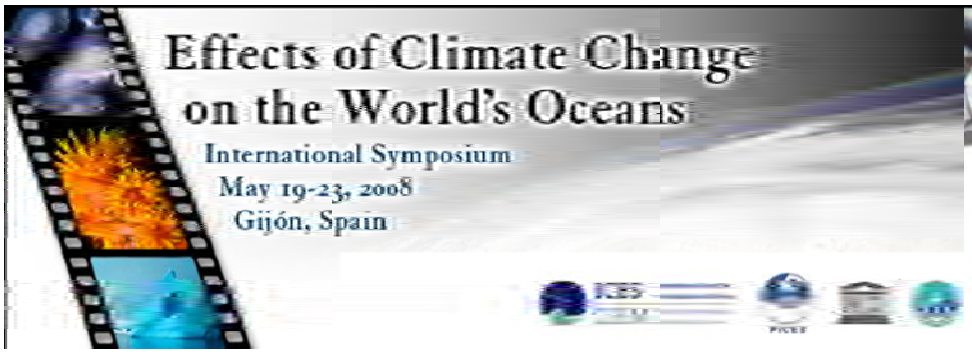
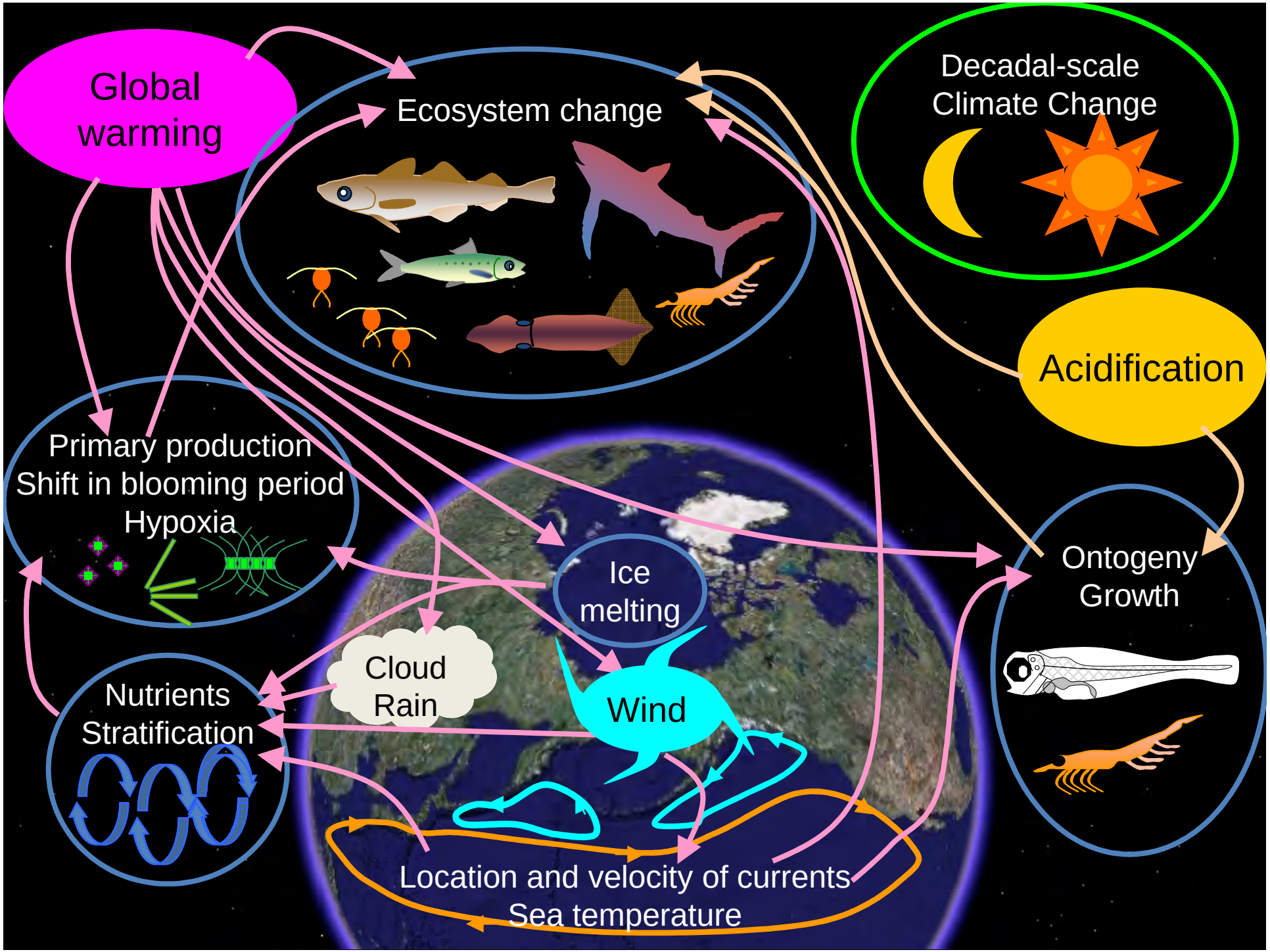
26 April 2010, Sendai

Outline

1. Effects of climate change on fishes: Gijon Symposium (2008) and after
2. Effects of sea temperature rise around Japan
3. Outlook of Japanese sardine, anchovy and common squid: the decadal change issue
4. Adaptation





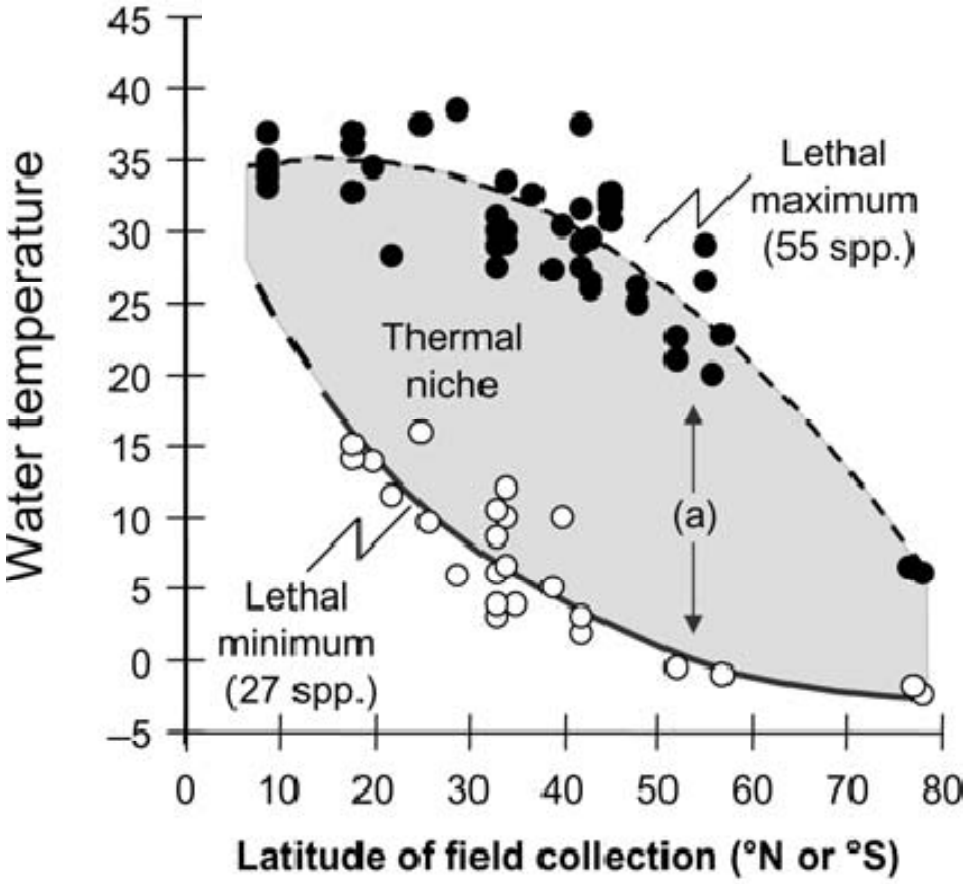

Global warming
Ecosystem change
Decadal-scale Climate Change
Acidification
Primary production
Shift in blooming period
Hypoxia
Ice melting
Cloud
Rain
Wind
Nutrients
Stratification
Ontogeny
Growth
Location and velocity of currents
Sea temperature

1. Effects of climate change on fishes

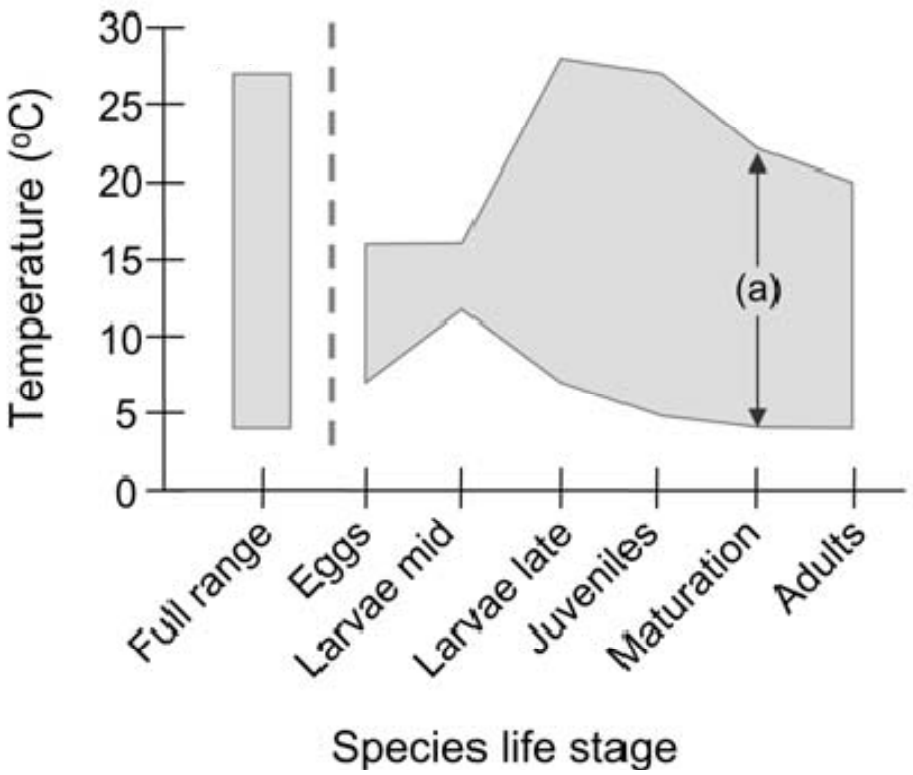
- Distribution and migration: shifts, shrinkage, expansion
- Productivity: recruitment, growth, maturation, etc.
- Connectivity: ecological interactions such as prey-predator relations, competitions (direct and indirect)
- Biodiversity
- Phenology (seasonality)
- Economy and human society: sustainability of ecosystem services including fishery products

Sensitivity for temperature: where and when?

(Rijnsdorp et al. 2009 ICESJMS)

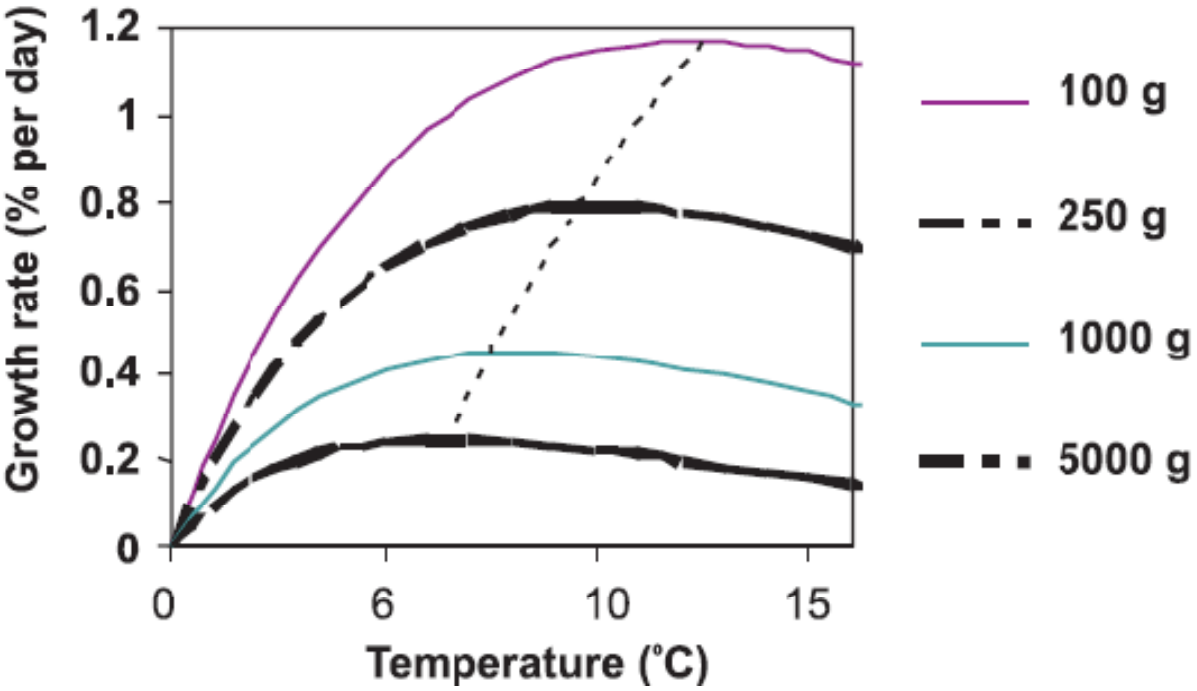


Range of tolerable temperature (a) is narrower in higher and lower latitudes

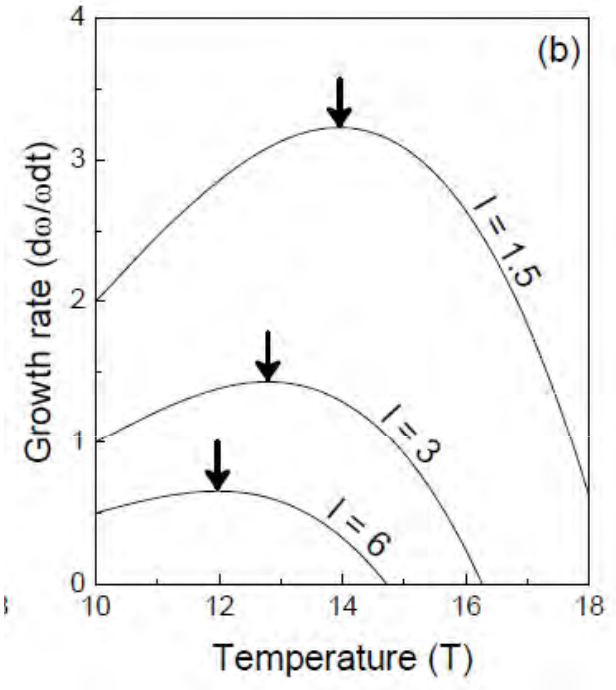


Range of tolerable temperature (a) is narrower at egg and mid larvae stages

Sensitivity for temperature: growth rate by different body size



Growth rate of four sizes of Atlantic cod in rearing experiments at different temperatures (Brander 2009 JMBAI)



Theoretical relationship between temperature and growth rate for three different lengths (l) (Morita et al. 2010 Oikos)

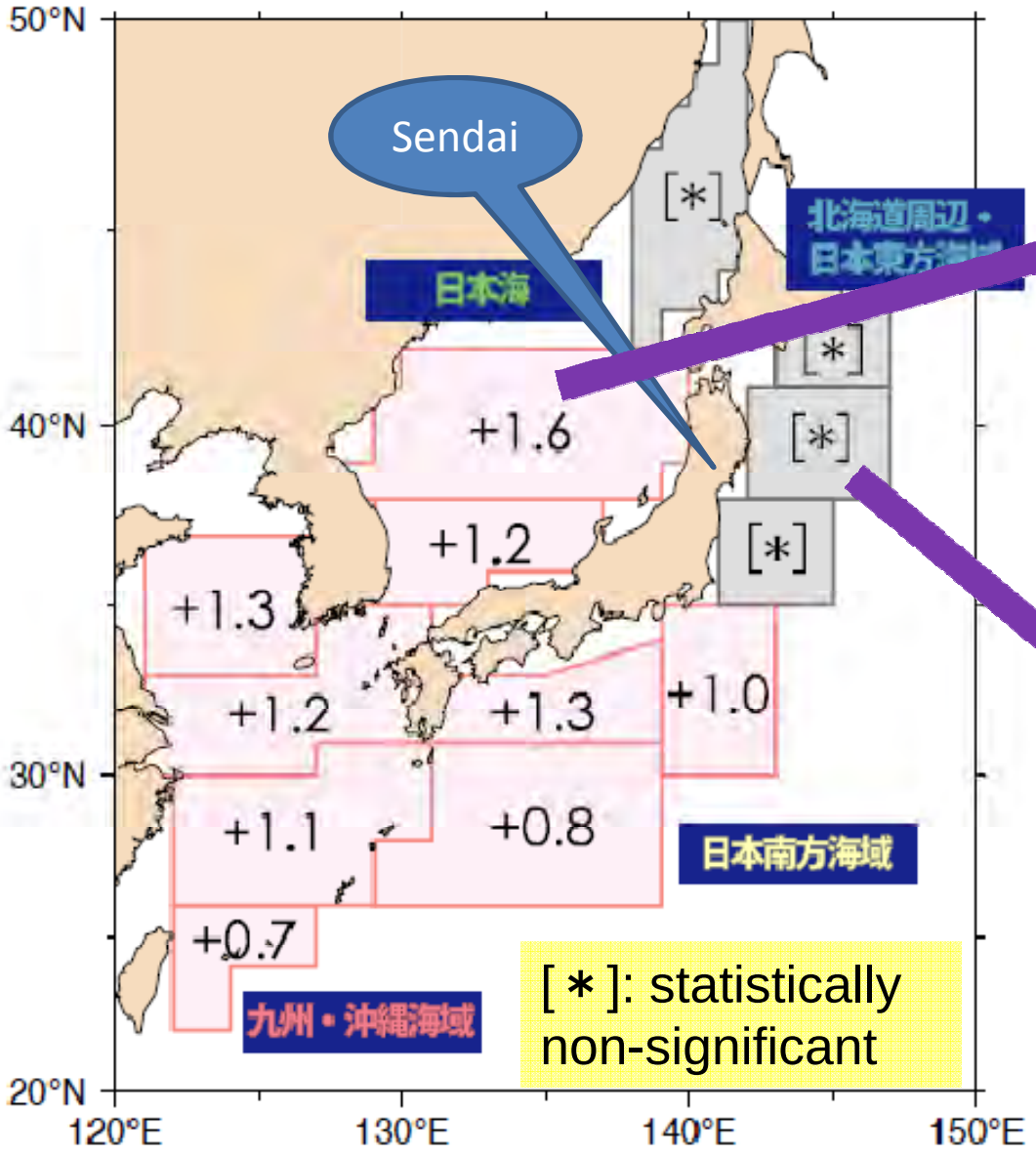
Effects of temperature rise will be more prominent in larger fish

Issues in forecasting high trophic ecosystems

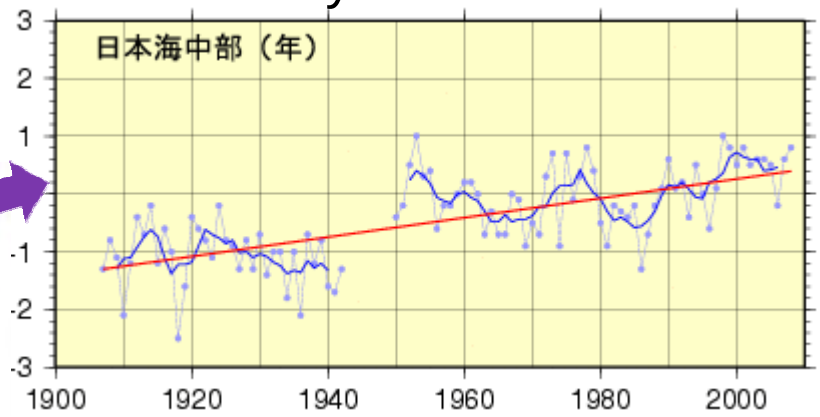
- Understand mechanisms: downscaling physical forcing from global/basin scale to regional scale
- Consideration of life-history and physiological traits: taxonomic groups
- Thresholds and rate of change (beyond the observed range): more biological studies (e.g., tank experiments)
- Mixed ecosystems: changes in ecosystem components
- Development of ecosystem indicators: for comparative studies, monitoring and evaluating vulnerability to climate change

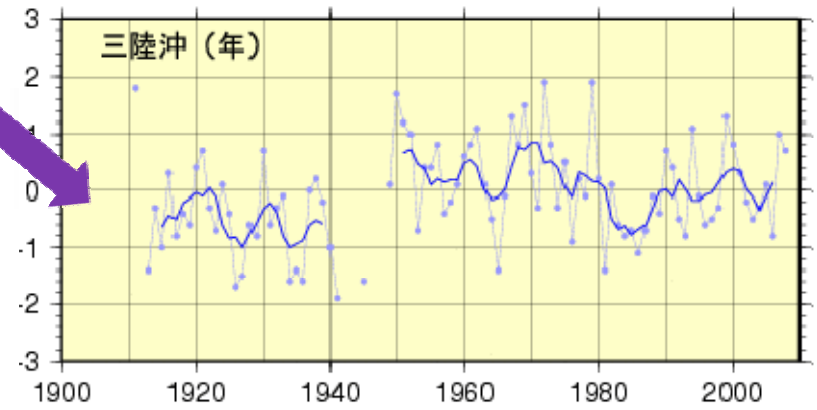
2. Effects of SST rise (℃) since 1900 around Japan

(SST data: Meteorological Agency of Japan)



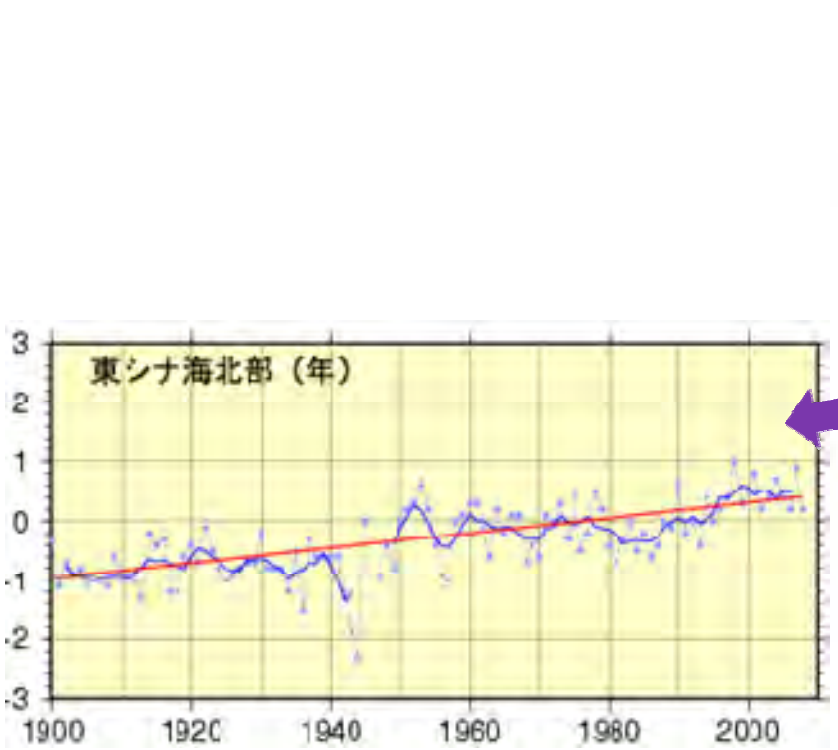
SST anomaly

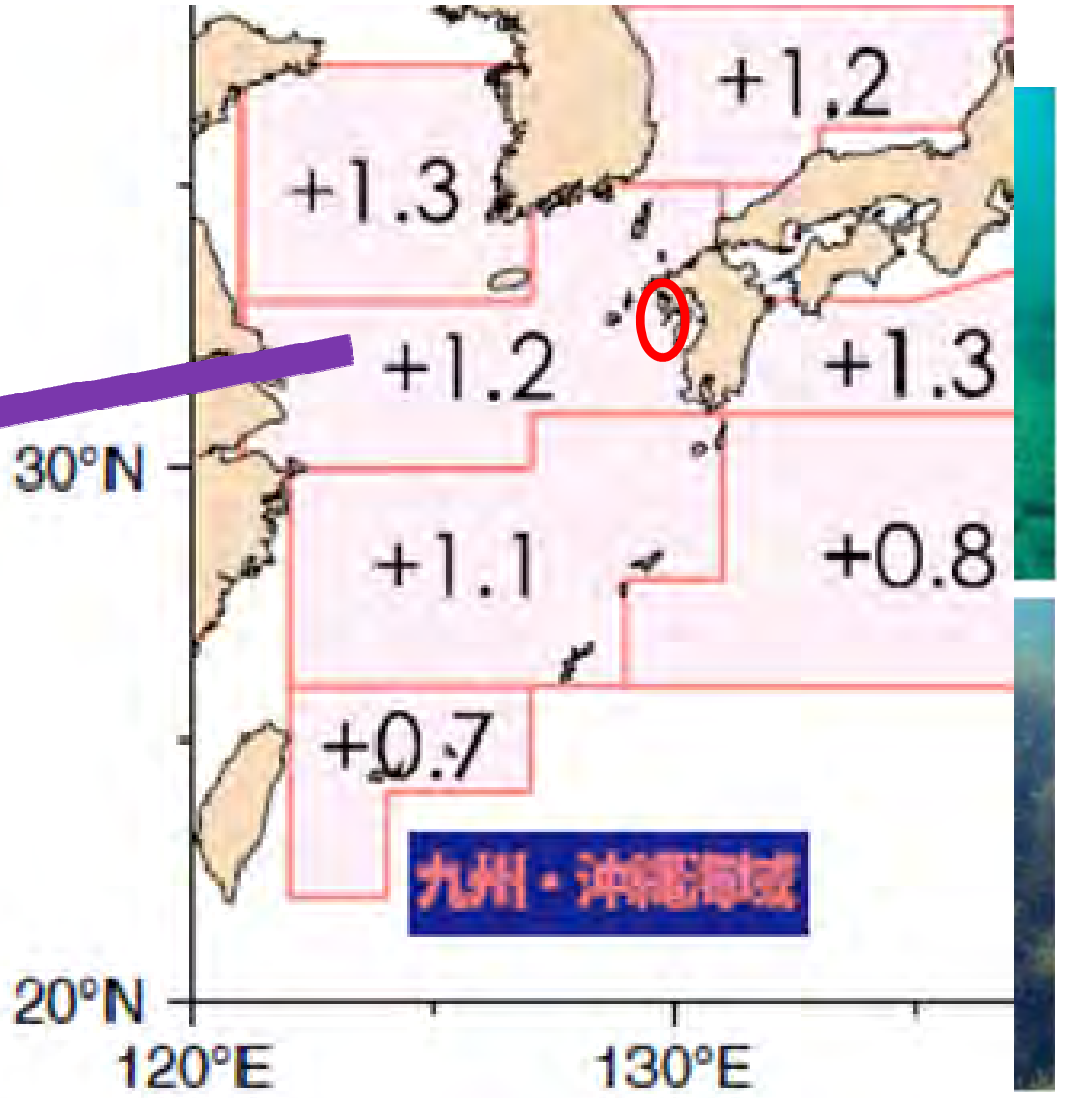




SST anomaly: decadal-scale var. + warming trend

Invasions of tropical species: loss of macroalgal bed during summer-winter in western Kyusyu





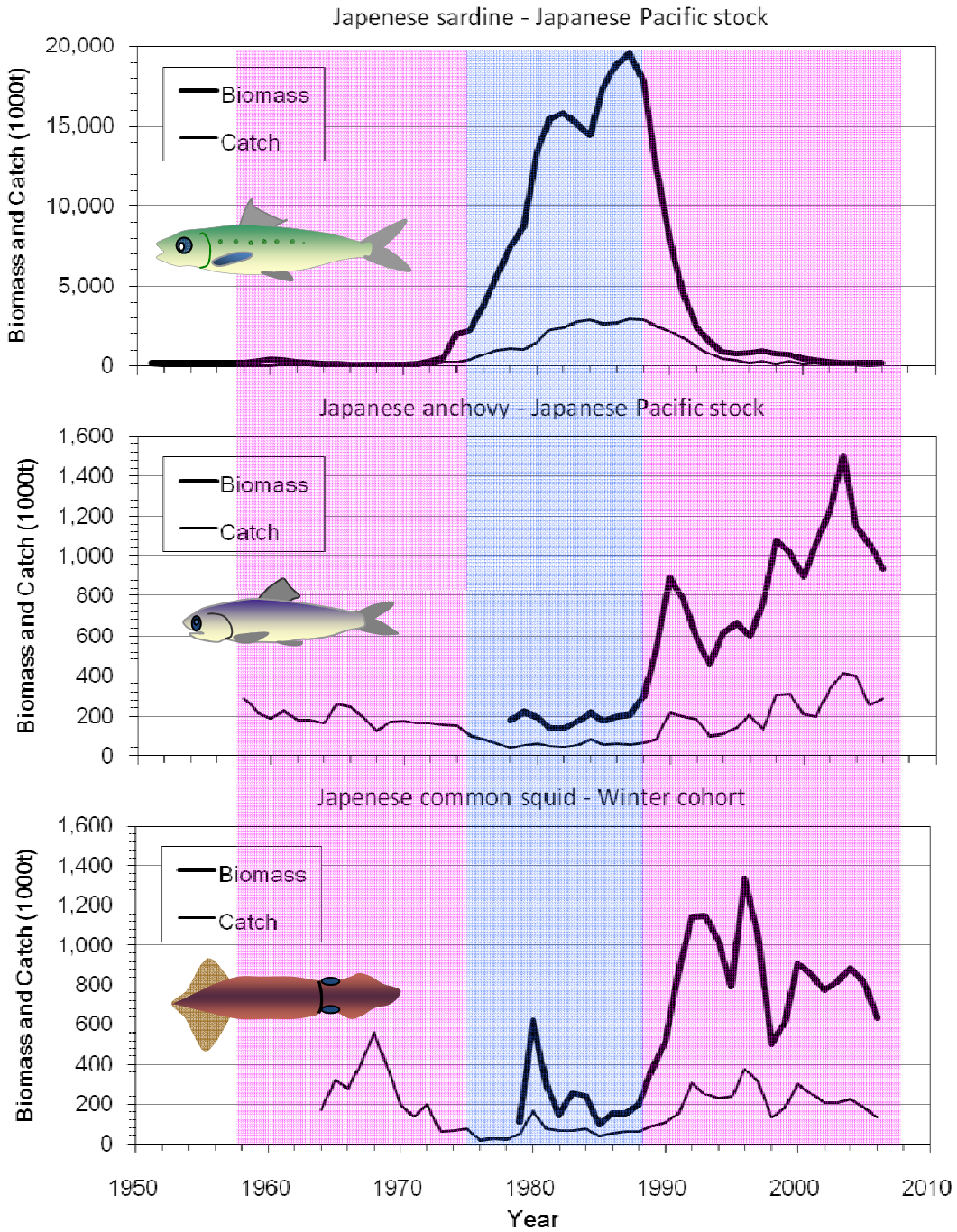
Loss of macroalgal bed from summer to winter due to changes in species composition of macroalgae and mass predation by tropical herbivorous fishes (Yoshimura et al. 2009)

Siganus fuscescens and *Kyphosus bigibbus*

Sargassum macrocarpum: results of a cage experiment protecting from predation by fishes

Loss of macroalgal bed deteriorated nursery of many fishes and invertebrates including commercial species such as spiny lobster

3. Outlook of Japanese sardine, anchovy and common squid: the decadal change issue



Japanese sardine prevailed in cool period (positive PDO* regime)

Japanese anchovy and common squid flourished in warm period (negative PDO* regime)

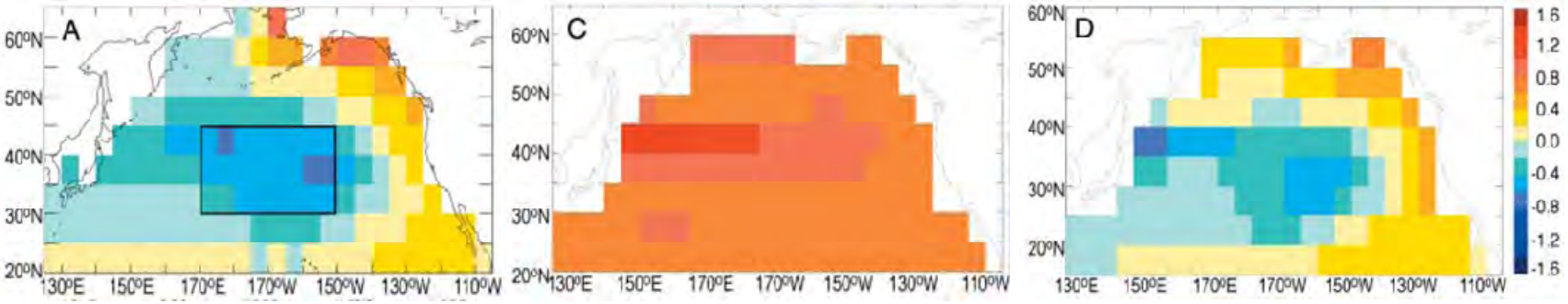
***Pacific Decadal Oscillation**

PDO pattern will remain: downscaling IPCC-AR4 descriptions for Kuroshio and Oyashio

(PICES CFAME Task Team Final Report)

- PDO is likely to continue to exist during 21st century. However, the change in the mean background SST field under anthropogenic influences will surpass the magnitude of natural PDO variability.
- Kuroshio and Oyashio are likely intensified (spin-up) according to *MIROC* (Model for Interdisciplinary Research on Climate, K-1 Model Developers 2004).

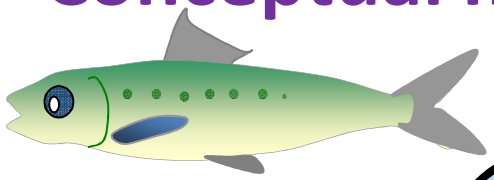
PC1 for 1901-1999 (PDO) **PC1 for 2001-2099** **PC2 for 2001-2099**



Spatial winter SST patterns in 20th and 21st Century North Pacific based on 10 GCM models (Overland and Wang 2007 Eos)

Conceptual model diagram for Japanese sardine

(Japanese Pacific Stock, Yatsu 2004)



Positive SOI, etc.

Positive PDO: Strong Aleutian Low

Winter MLD Deepening in Kuroshio, Expansion of Oyashio area

Lower SST of Kuroshio and Oyashio

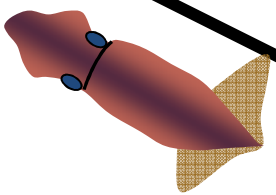
Less Arrival of Subtropical Predators (Common Squid, etc.)

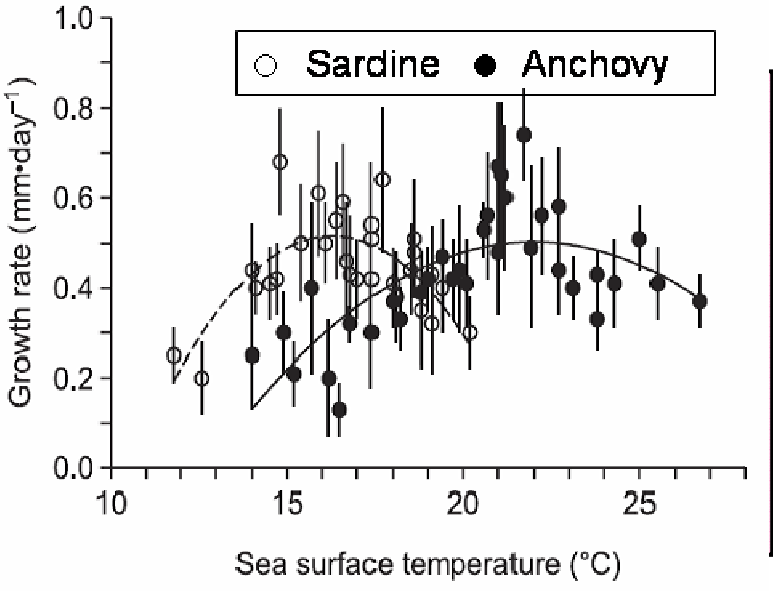
Improved Early Growth

Improved Early Surv

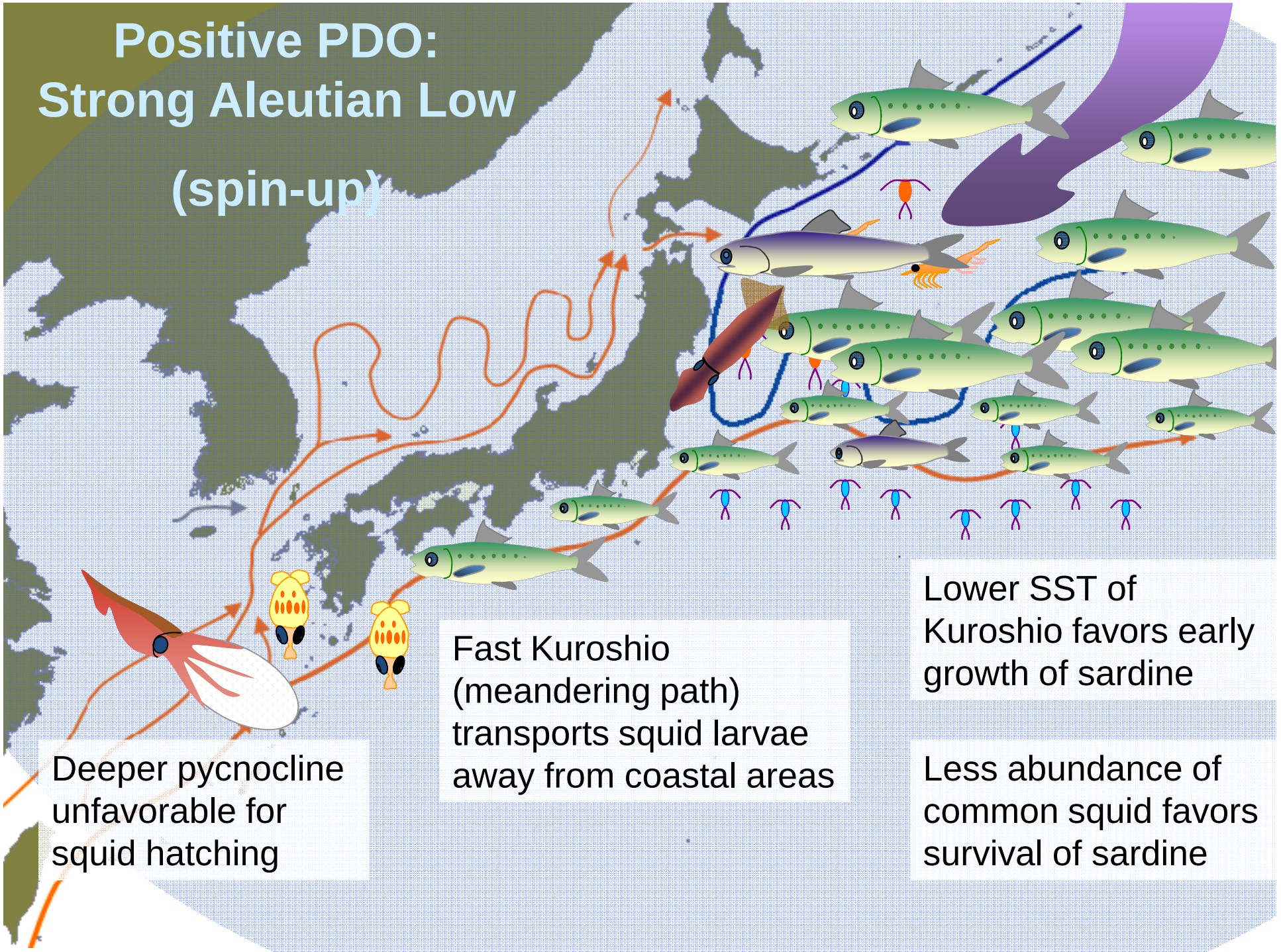
Accumulation of Bio

Alternate to Ancho



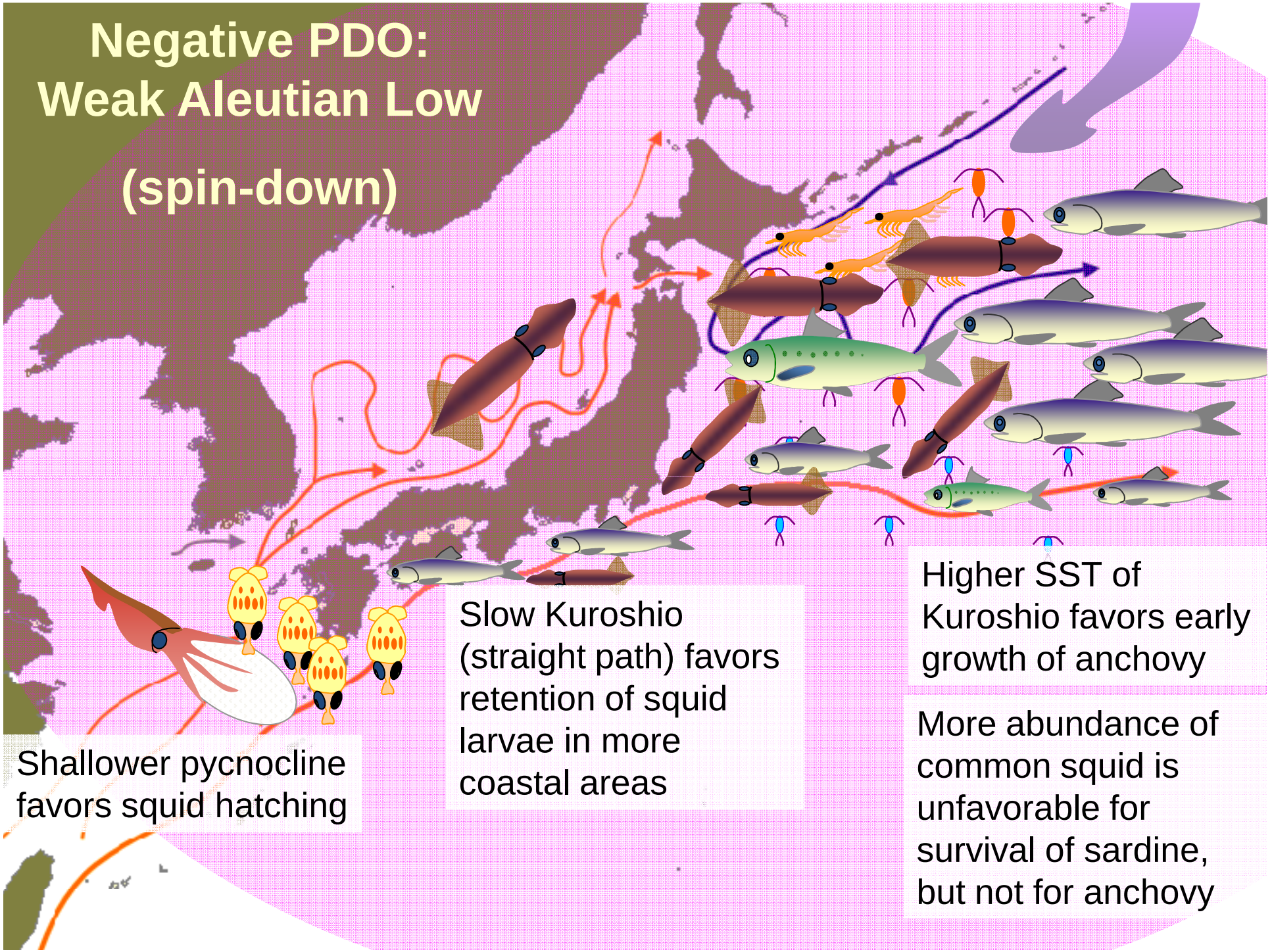


Optimum temperature for early growth of sardine and anchovy (Takasuka et al. 2007)


Positive PDO:
Strong Aleutian Low
(spin-up)
Deeper pycnocline unfavorable for squid hatching
Fast Kuroshio (meandering path) transports squid larvae away from coastal areas
Lower SST of Kuroshio favors early growth of sardine
Less abundance of common squid favors survival of sardine

Negative PDO:
Weak Aleutian Low

(spin-down)



Shallower pycnocline favors squid hatching

Slow Kuroshio (straight path) favors retention of squid larvae in more coastal areas

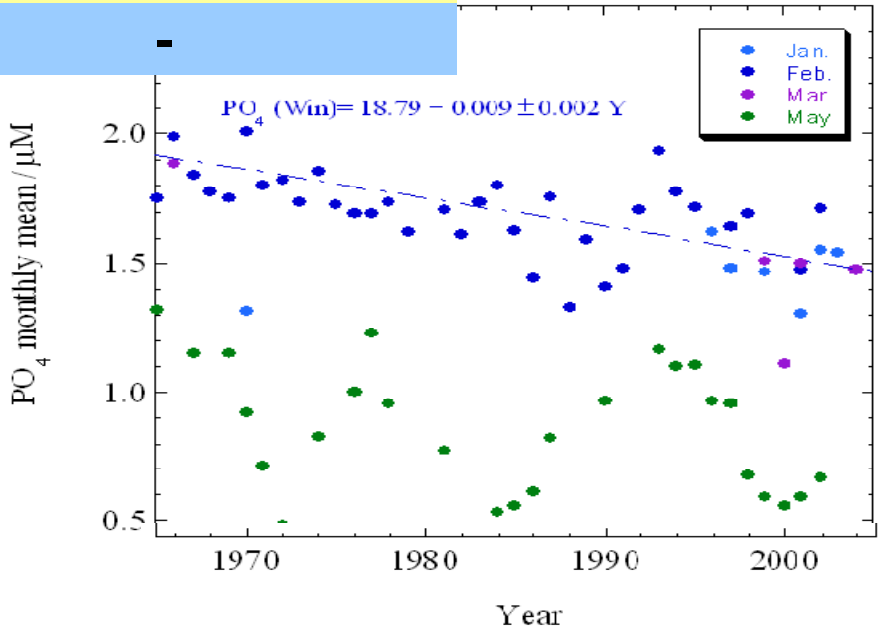
Higher SST of Kuroshio favors early growth of anchovy

More abundance of common squid is unfavorable for survival of sardine, but not for anchovy

Possible effects of global warming on productivity in Kuroshio (Kr) and Oyashio (Oy)

Producutivity of area/species	Temperature rise	Spin-up of currents
Oyahsio	+	+ (Areal expansion)
Kuroshio	-	?
Sardine	+ (Oy), - (Kr)	+ (Oy), ? (Kr)
Squid	+?	-

- Productivity of Oyashio will be decreased due to freshening
- More temperature rise will delay the spawning period of squid, and subsequently may cause a temporal mismatch with blooming



Phosphate concentration in Oyashio (Ono et al. 2002)

4. Adaptation (Lubchenco (2008 in Gijon), Barange et al. (2010 Oxford))

- **Adaptation by humans**
  - Technology
  - Behavior
  - Management and policy
- **Adaptation by aquatic species**
  - Distribution and migration
  - Acclimation
  - Genetic changes (evolution)
- **Create ways of adaptation for aquatic species**
  - Reduce stress
  - Protect habitats: use various types of MPAs
- **Importance of monitoring and education**
- **Common to Ecosystem Approach to Fisheries**
  - Multiple-scale objectives: adequate balance between conservation and resource use, underpinned by appropriate and focused scientific research
  - Use of wide knowledge on ecosystems
  - Conservation of biodiversity and species resiliency
  - Adaptive management with precautionary approach
  - Understandings and incentives of stakeholders