Forecasting Fish Species Alternation:

Results of SUPRFISH Programme and Remaining Issues

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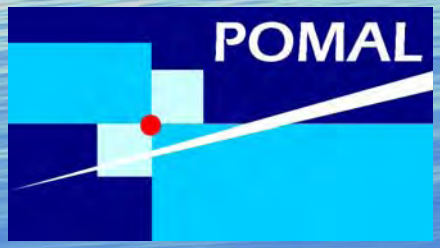
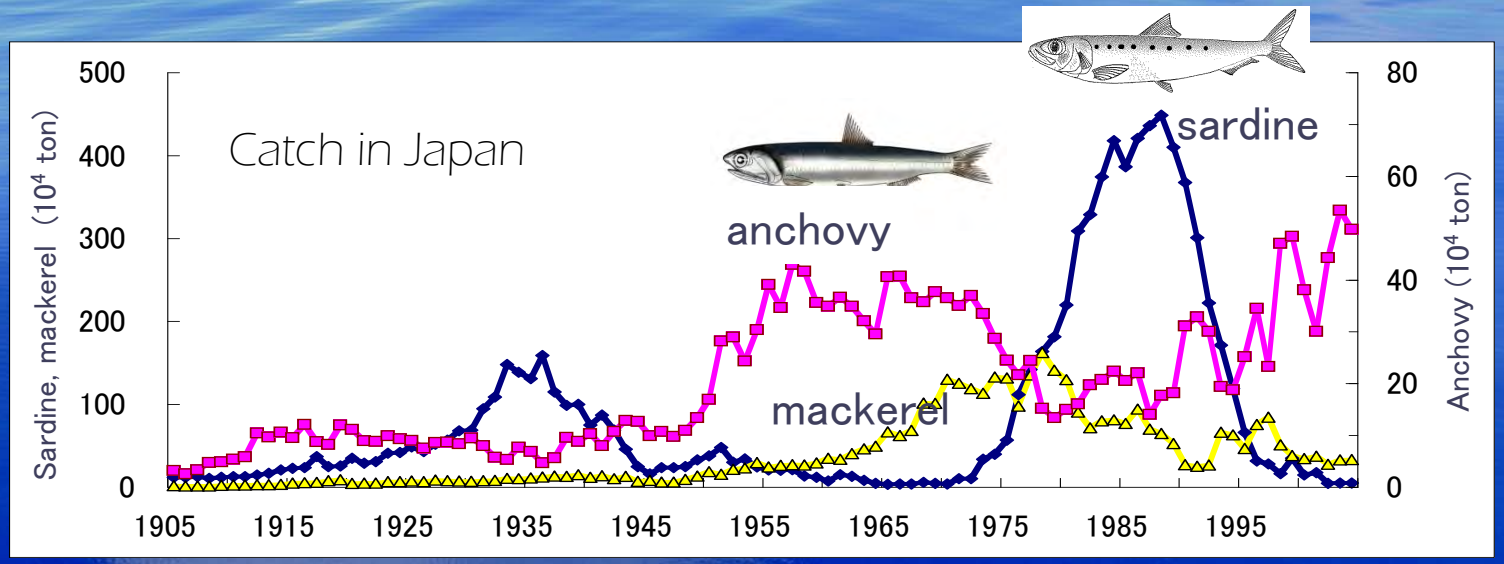


SUPRFISH (Studies on Prediction and Application of Fish Species Alternation) is a sub-programme of POMAL (Population Outbreak of Marine Life), funded by AFFRC (FY 2007-2011). IMBER-JAPAN programme.

Selected results and remaining issues after 3-years of SUPRFISH

Fish Species Alternation (FSA)



Sardine landing in Japan:

1960s: 10^4 -10^5 ton

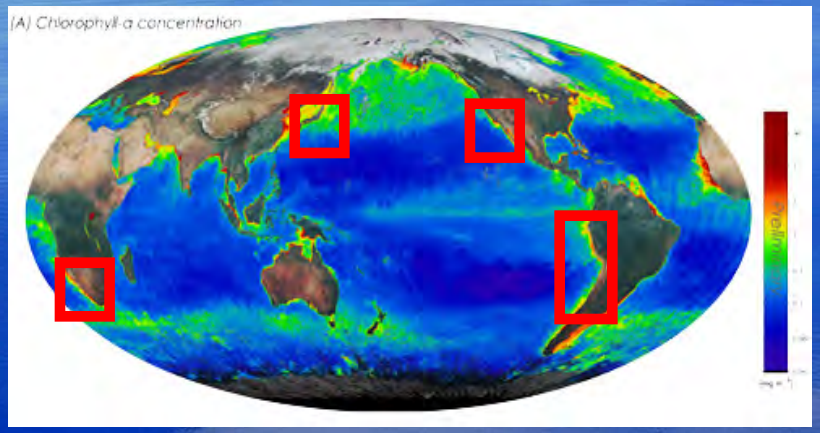
mid 1980s : >4 x 10^6 ton

1988: start declining

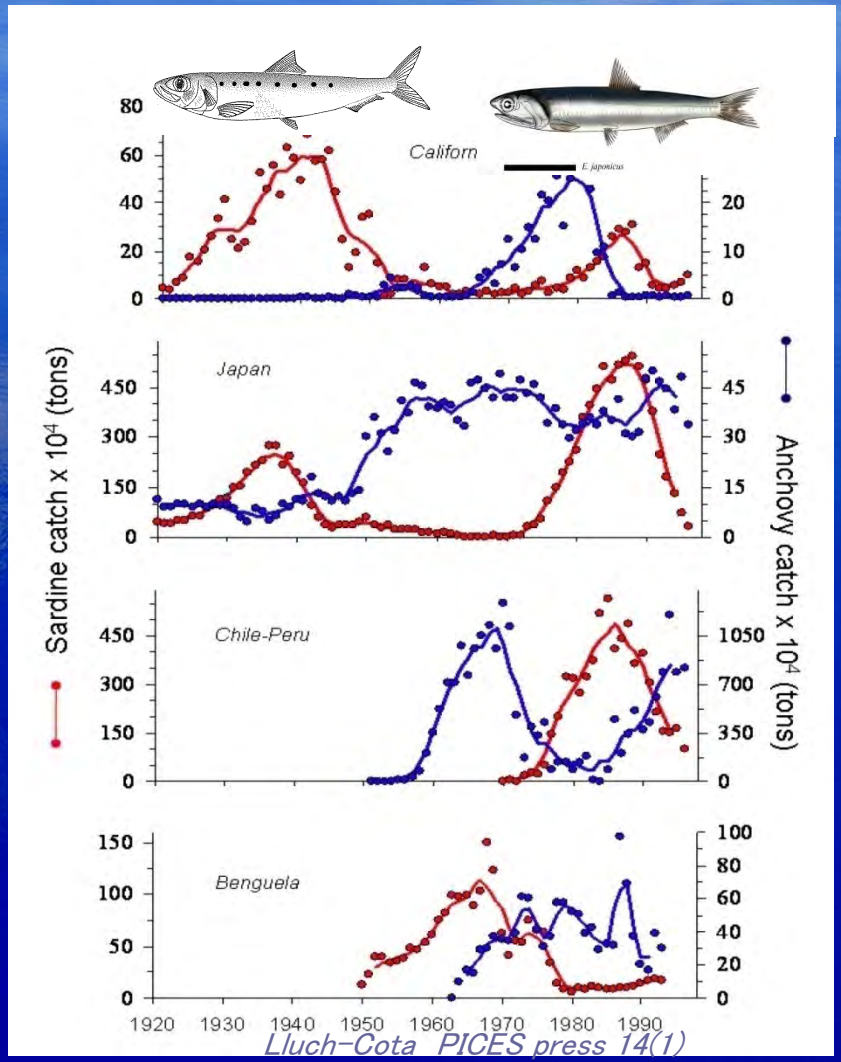
2000- : ~ 10^5 ton

Anchovy landing increased after the sardine stock collapse

Fish Species Alternation (FSA)

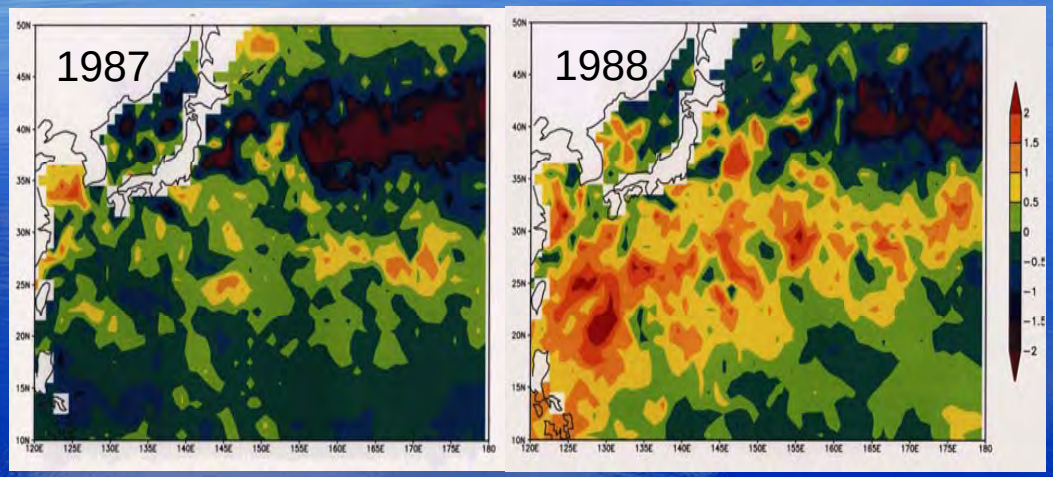


- Synchronization in FSA between remote populations indicates that FSA is climate induced phenomenon
- Overfishing is not the direct factor inducing FSA

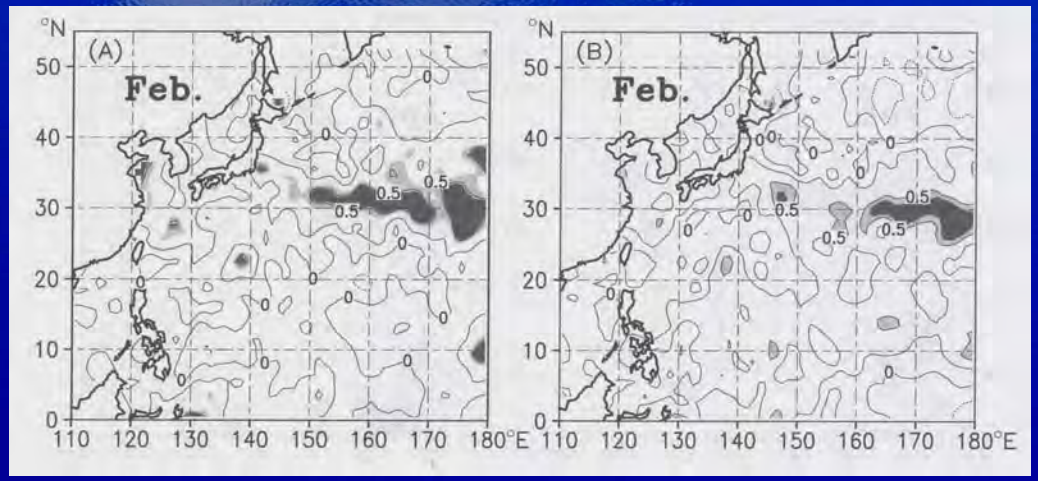


What is the trigger of the FSA?

SST anomaly

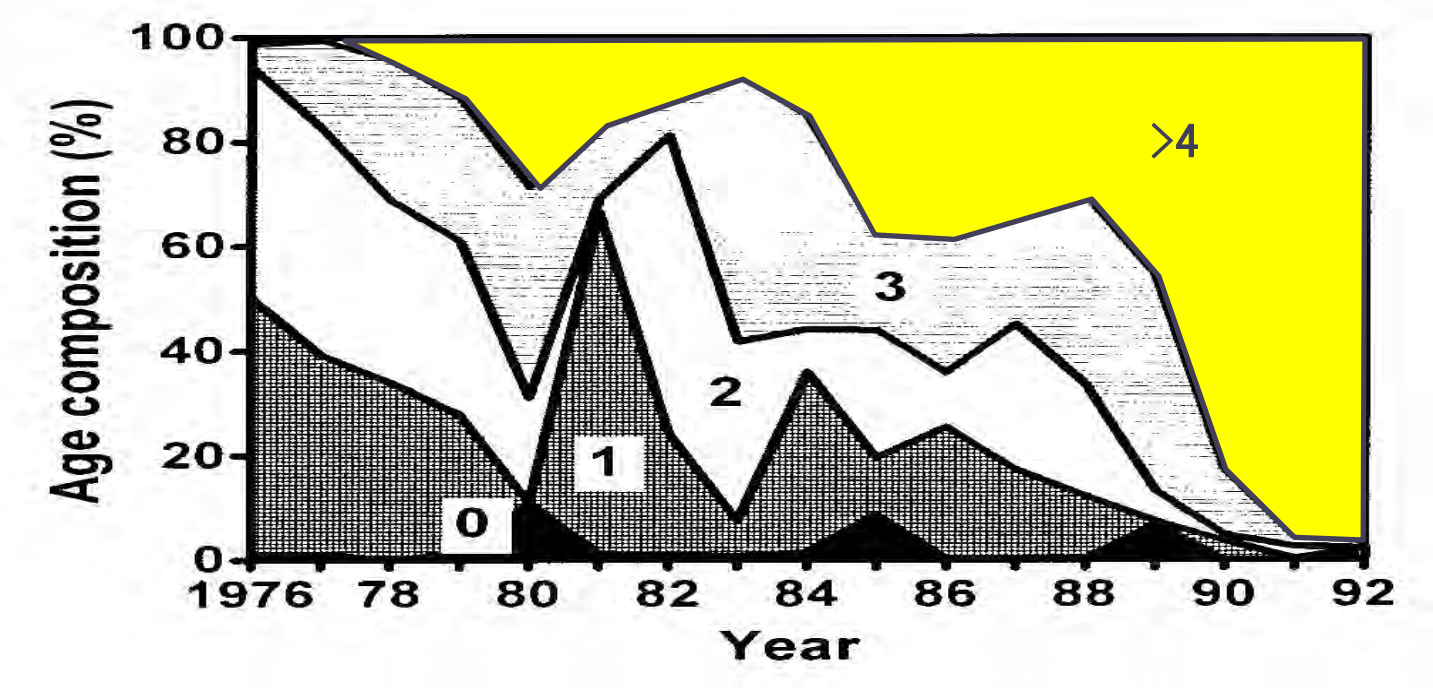


Correlation between SST anomaly and larval mortality rate



Noto &Yasuda 1999

Age composition of sardine



Watanabe

Recruitment failure after 1988 even high egg production (>10^{15} eggs)

Continuous failure of recruitment induced the sardine stock collapse

Fish Species Alternation

We know there is a correlation between climate regime shift & FSA

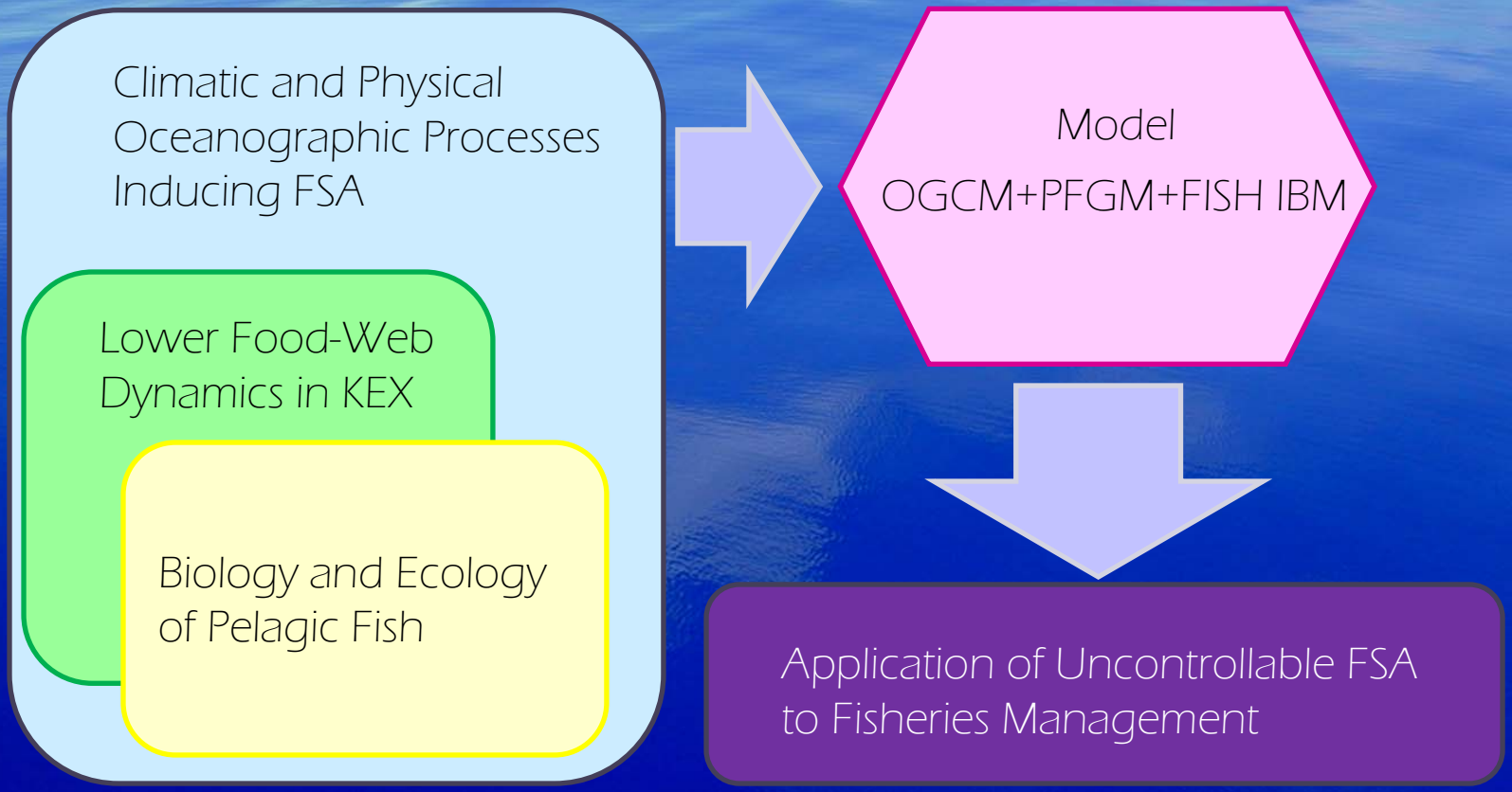
- SST change (～1℃) is not enough to induce the recruitment failure by itself.
- Intervals in climate regime shift (10-20years) and FSA (50-60 years) are different each other

We don't know the mechanisms connecting climate regime shift with FSA

Goal of SUPRFISH

Understanding the mechanisms of FSA induced by natural climate change and forecasting FSA to sustainable use of fish resources.

Structure of SUPRFISH



Establishing an Interdisciplinary Scientists Group [20 PIs, 60 Scientists]

Is FSA Predictable?

Understanding the mechanisms of FSA induced by natural climate change and forecasting FSA to sustainable use of fish resources.

A few years - 20 years forecasting of climate is unable.

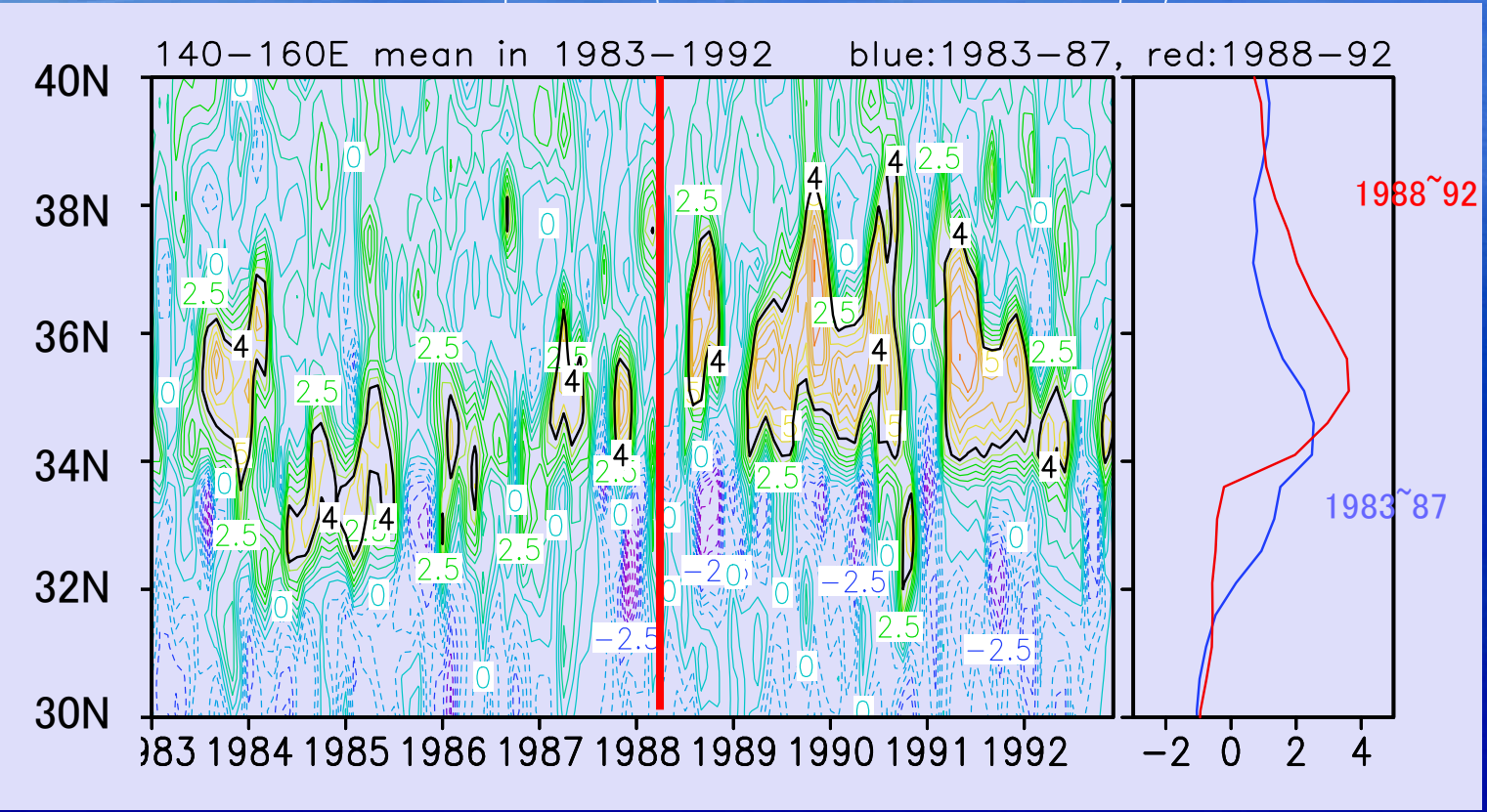
Are there any precursors of FSA?

Retrospective analysis of KEX using eddy resolving GOCM "OFES"

Kuroshio Extension (KEX)

Eddy resolving GOCM OFES

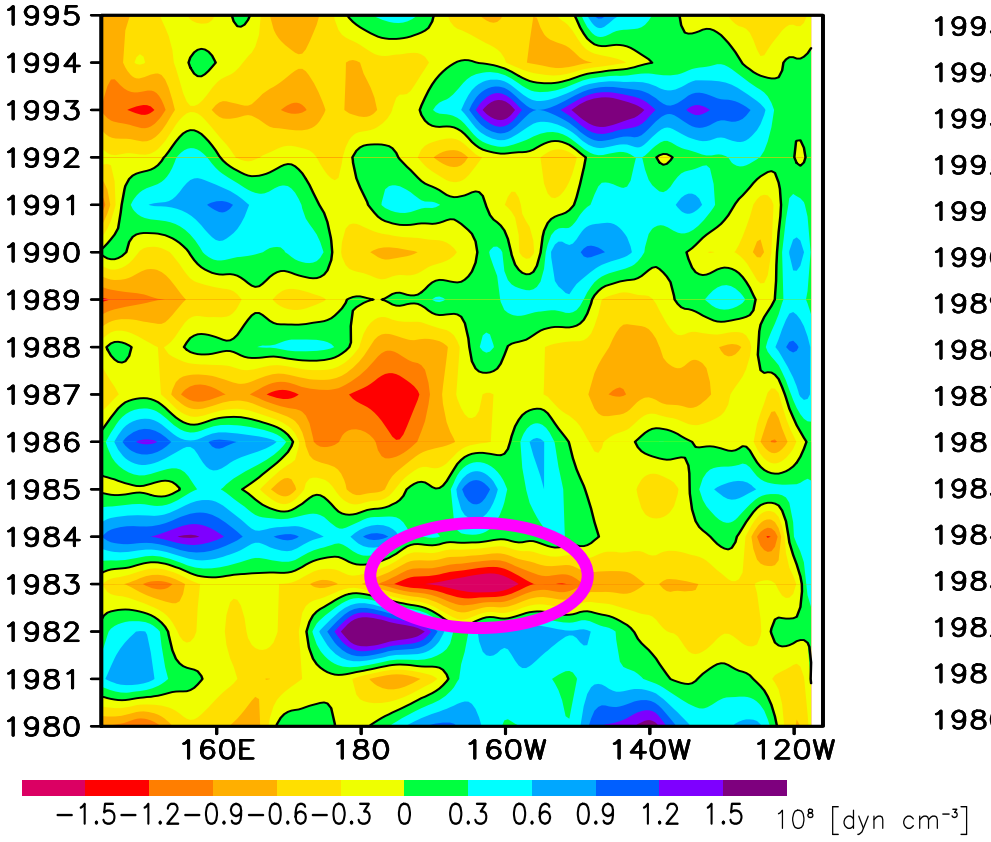
Eastward current speed (140-160 E average)



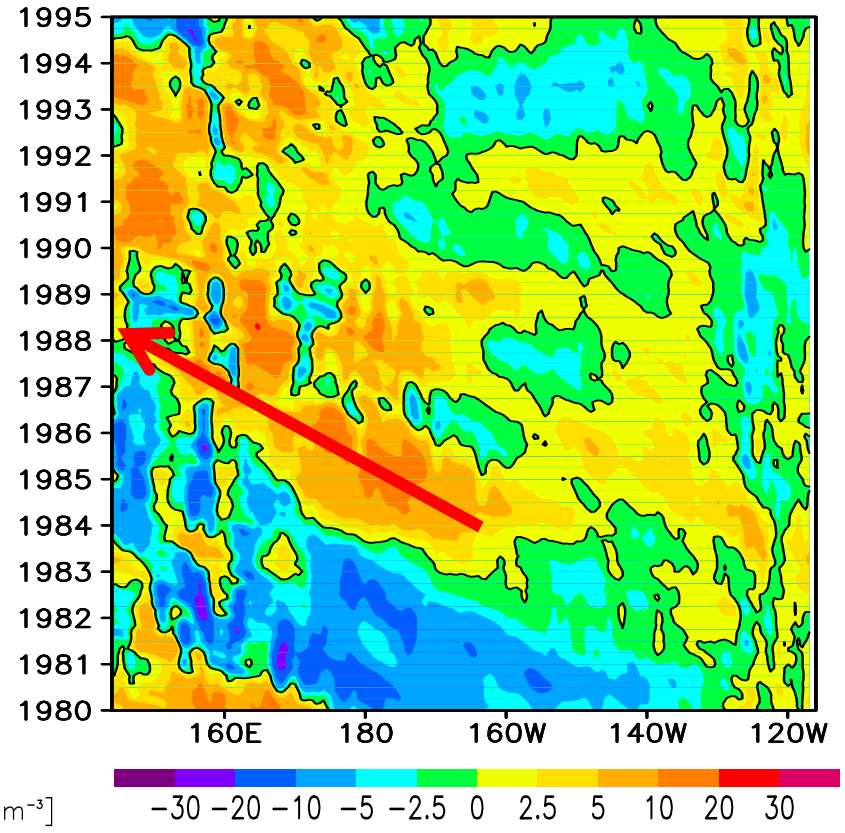
Acceleration and northward shift in KEX axis in 1988

Wind curl and SSH anomaly (N32)

Wind curl anomaly(Dec-Feb)

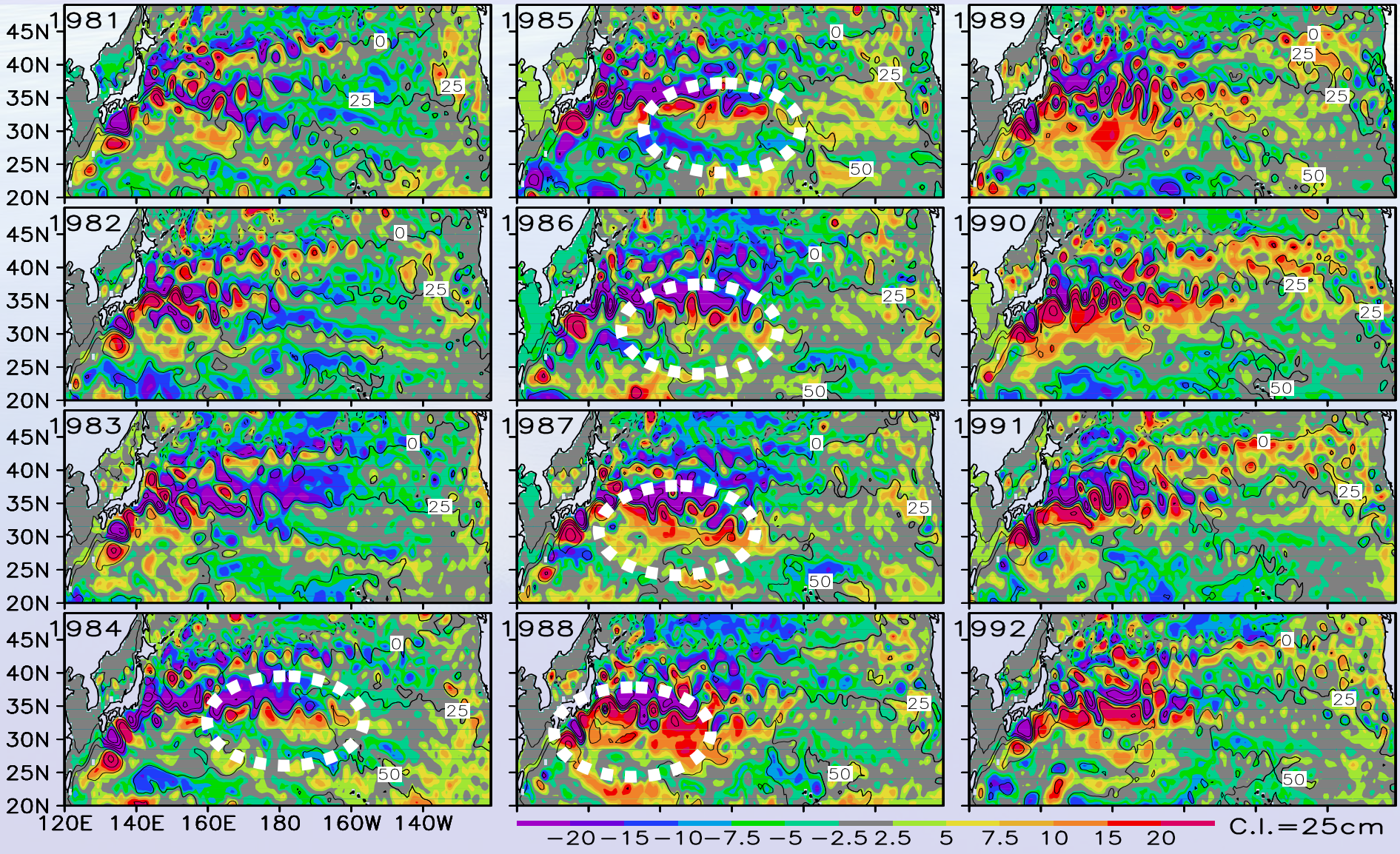


SSH anomaly (13 mo rm)



- Negative wind curl induced positive SSH anomaly
- Positive SSH anomaly propagated westward and reached to the KEX region after 3-4 years

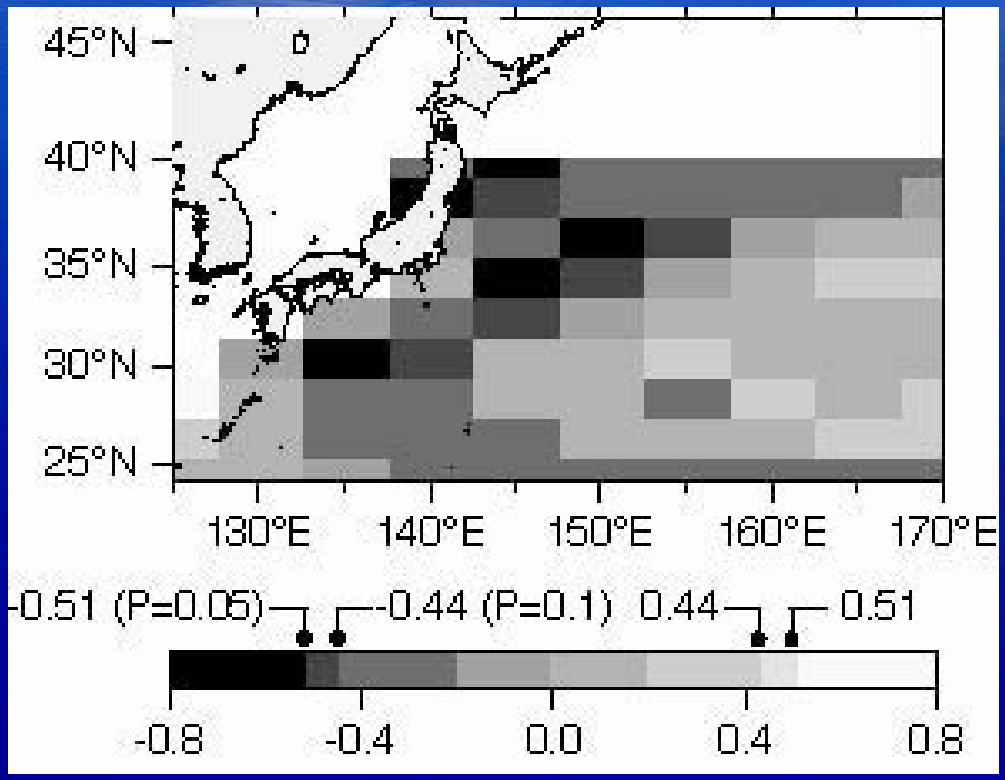
SSH anomaly (OFES)



Positive SSH anomaly appeared in 1984 in the central North Pacific and propagated westward. After 1988, KEX was intensified

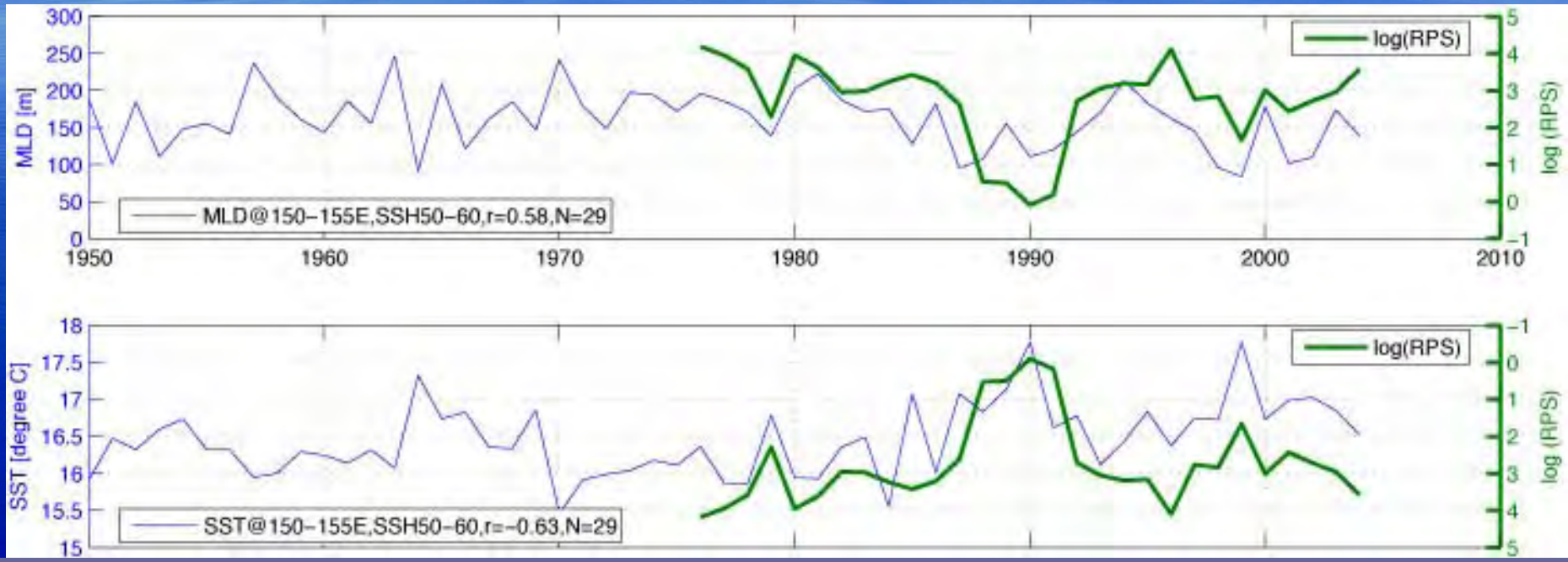
Ecosystem response after reaching high SSH anomaly to the KEX region

[Nishikawa and Yasuda 2008]
Negative correlation between winter MLD and the index of sardine recruitment success (logarithm of recruitment per spawning: RPS)



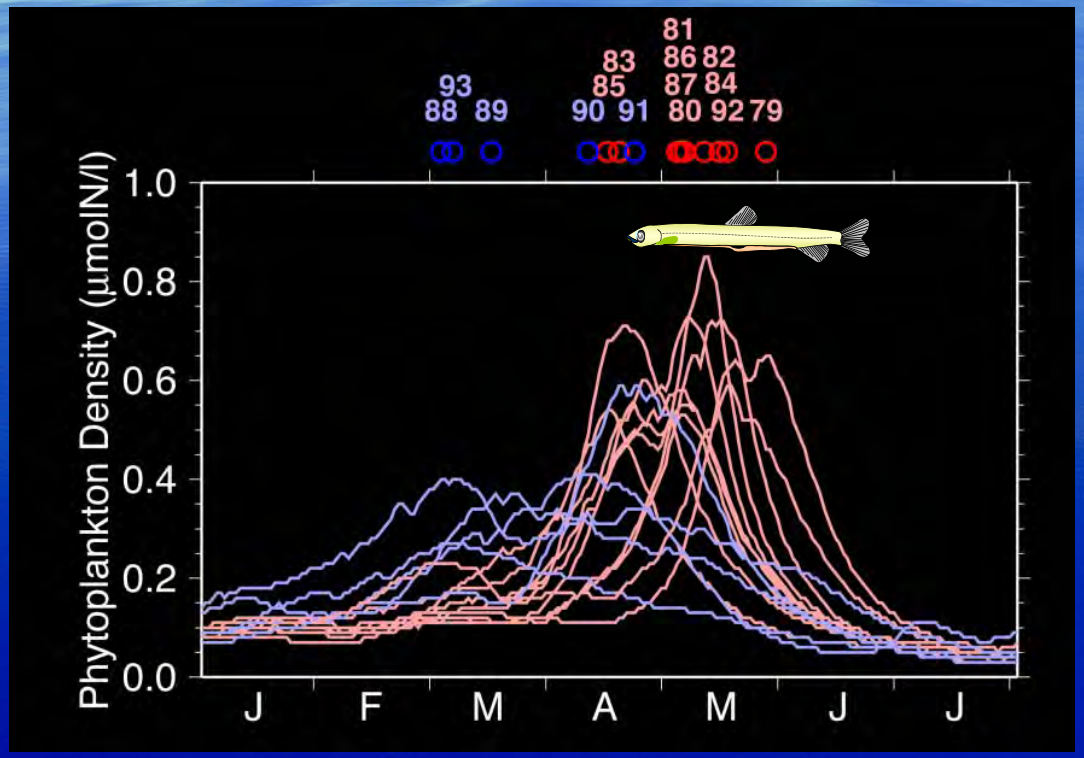
Recruitment failure in the years of shallow MLD in KEX (Feb-Mar)

Annual variations in MLD, SST in the KEX (OFES) and RPS Recruitment per spawner



Recruitment failure in the yeas of shallow MLD and high SST

Seasonal change in phytopl. (model)

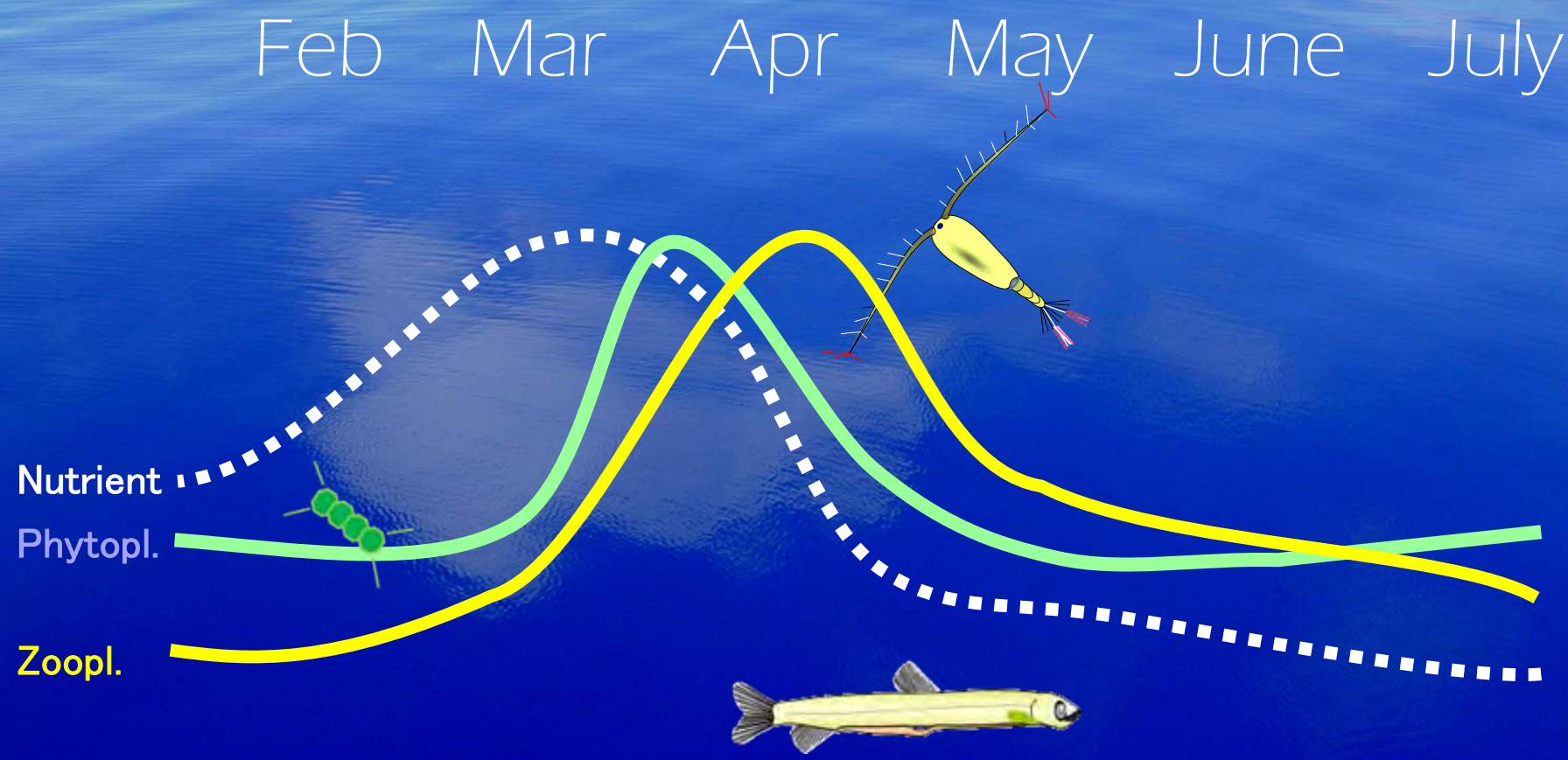


1988-91,93 (blue):

years of MLD<170m

Spring bloom in shallow MLD years (1988-1991、93):
Early initiation, low magnitude, early termination (except for 1991)

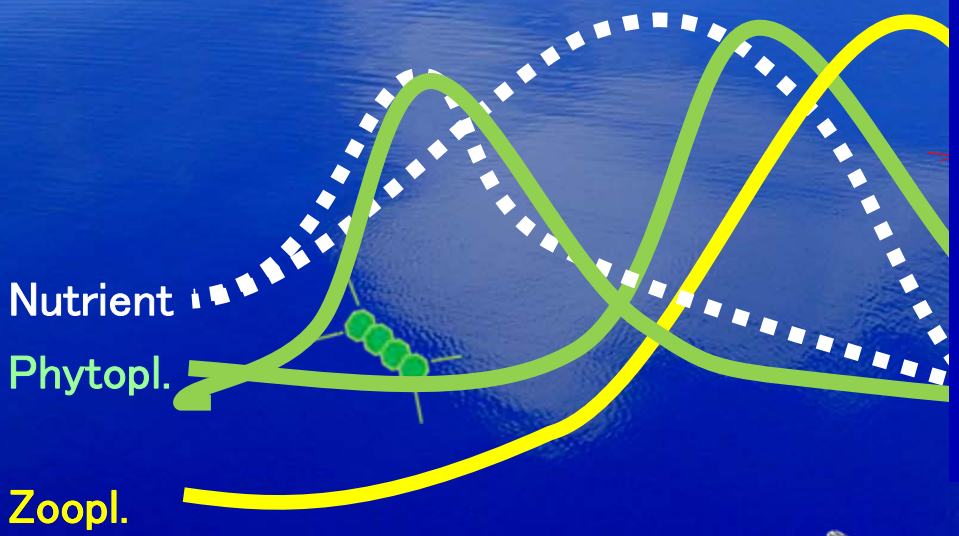
Proposed scenario



larval sardine trans-
portation (Apr-May)

Proposed scenario

Feb Mar Apr



In the years of shallow MLD:

- Low growth rate due to low food conc.
- Resultant increase in mortality

"Mismatch" induced by the change in wind curl anomaly in the central N. Pacific

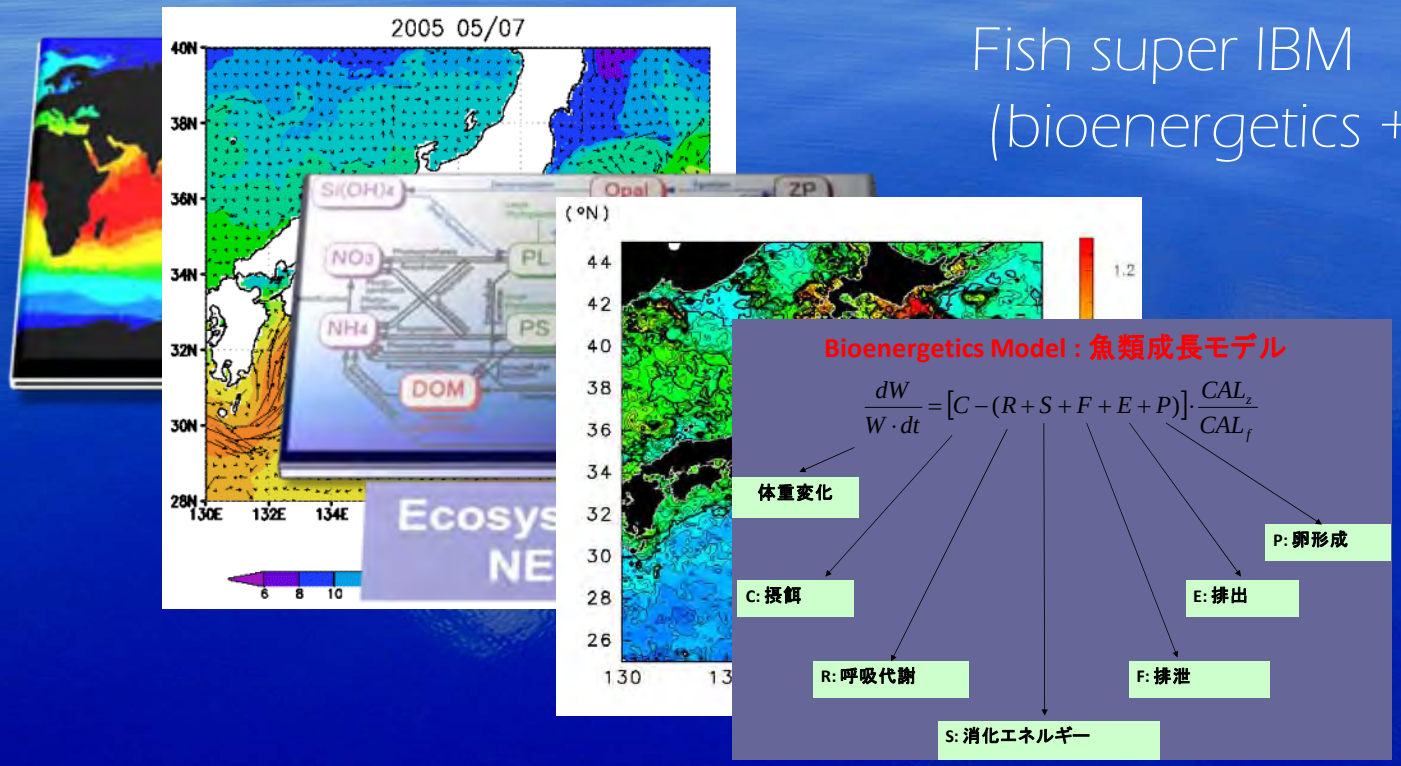
larval sardine trans-portation (Apr-May)

Intermediate conclusions

- FSA is suggested to be induced by the shift in wind curl field in the central-eastern North Pacific. The resultant shift in SSH anomaly propagated to KEX region after 3-4 years. The SSH anomaly shift is available to use as the precursor of FSA.
- Sardine resource responds to the ecosystem change after 2-3 years (life cycle ~6-7 years, maturation age 3 or 2 years). Thus, we are potentially able to forecast FSA 6-7 years in advance of substantial change.
- SSH anomaly shift in the central-eastern North Pacific is possible to attenuate by climate event/shift. The monitoring of the Rossby wave propagation of SSH anomaly by satellite remote sensing is essential for the forecast of FSA.

FSA Model (Okunishi et al2009 Ecol. Model.)

Structure : GOCM
PFGM
Fish super IBM
(bioenergetics + migration)



FSA model

Coupling of sardine and anchovy IBMs with interactions (i.e., species competition) is on going....

SUPRFISH FSA scenario after 3-years

- Negative wind curl induced positive SSH anomaly in the central-eastern N. Paciic
- Positive SSH anomaly propagated westward and reached to the KEX region after 3-4 years
- KEX is accelerated and KEX axis shifted northwardly
- These induced shallow MLD in winter in the region along the KEX
- Larval sardine reached to the KEX region mismatched to the early and weak spring bloom after 1988
- Continuous failure of the recruitment

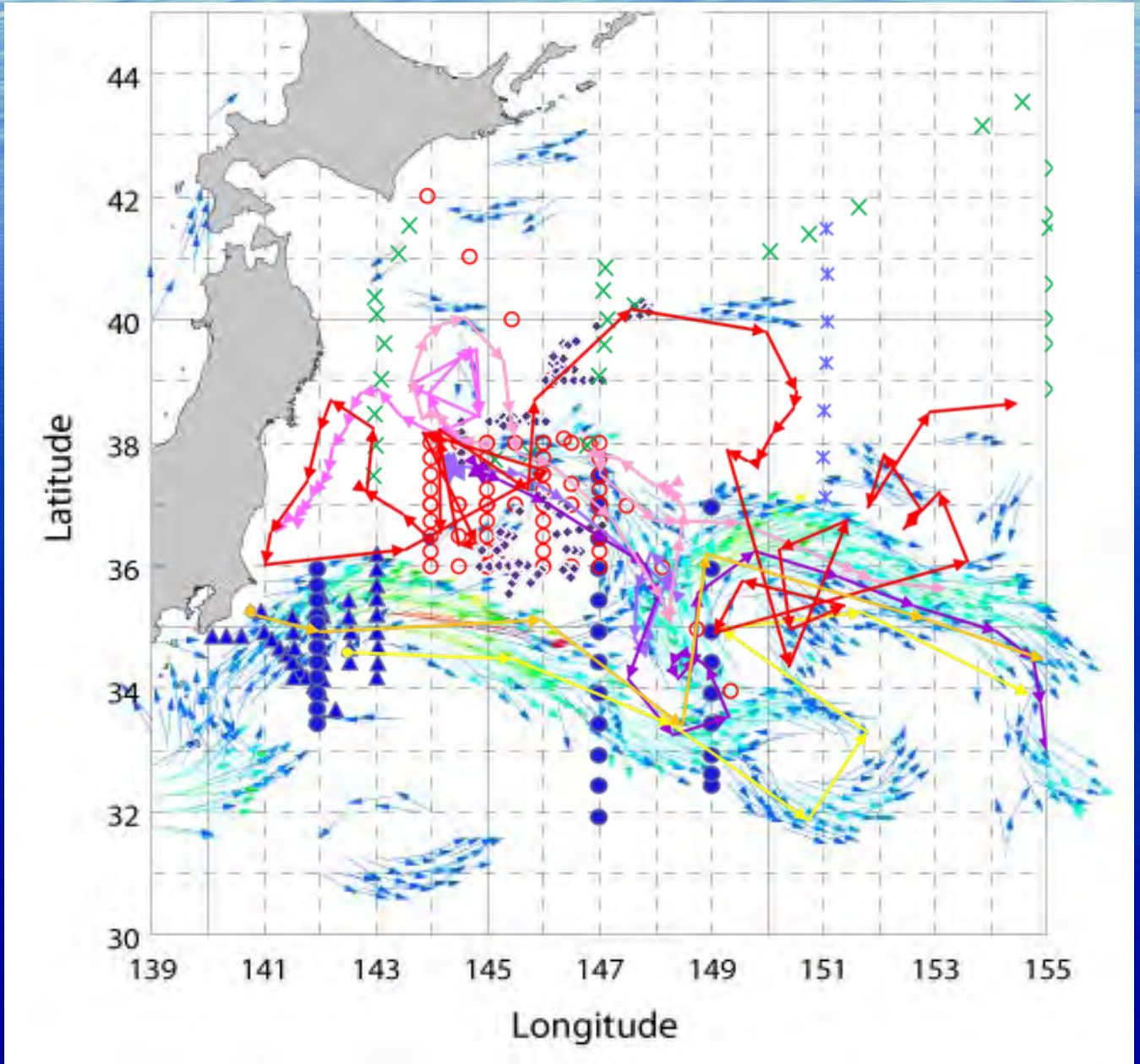
Remaining issues

- Mechanisms of the KEX axis shift and shoalling winter MLD at the positive SSH anomaly propagation to the KEX region

  The Rossby wave propagation of high SSH anomaly can not explain the northward shift of KEX axis and shoalling of winter MLD —— mesoscale eddies?

- Prey zooplankton response to the physical oceanographic shift in the KEX region

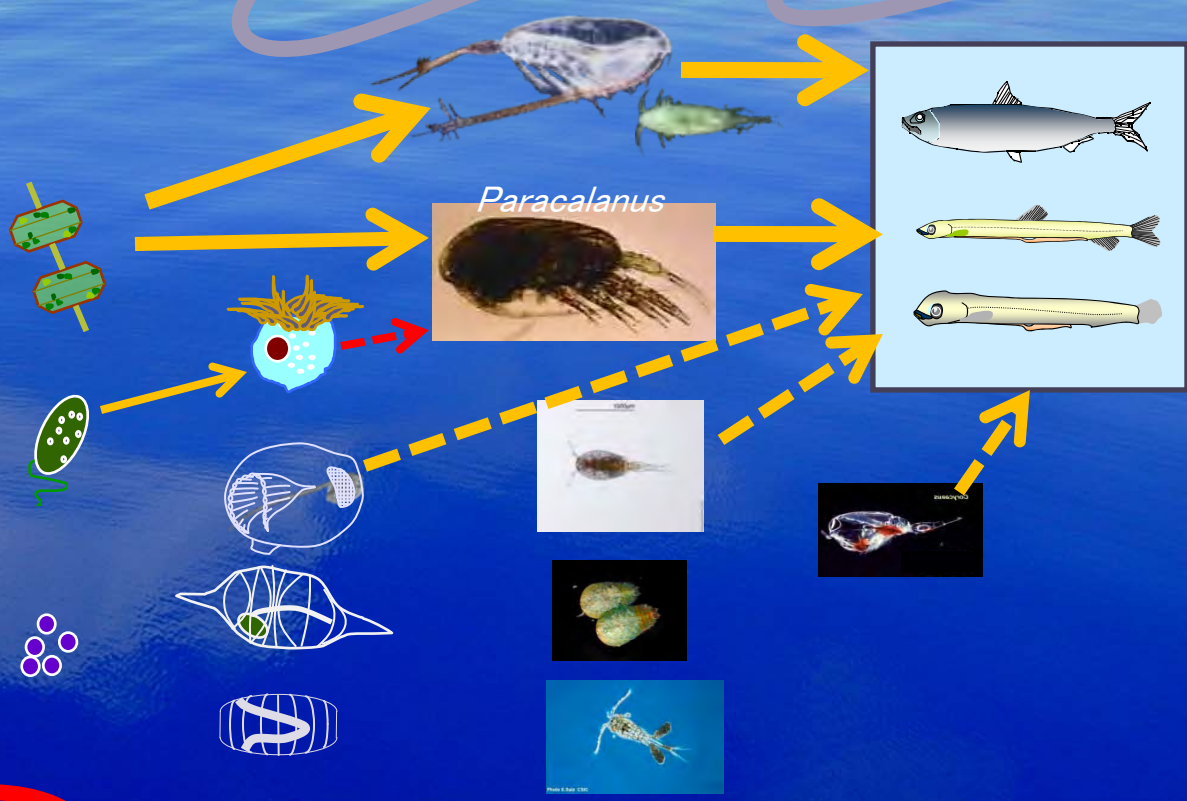
SUPRFISH Field Campaigne - 2008



KEX Ecosystem (before-SUPRFISH)

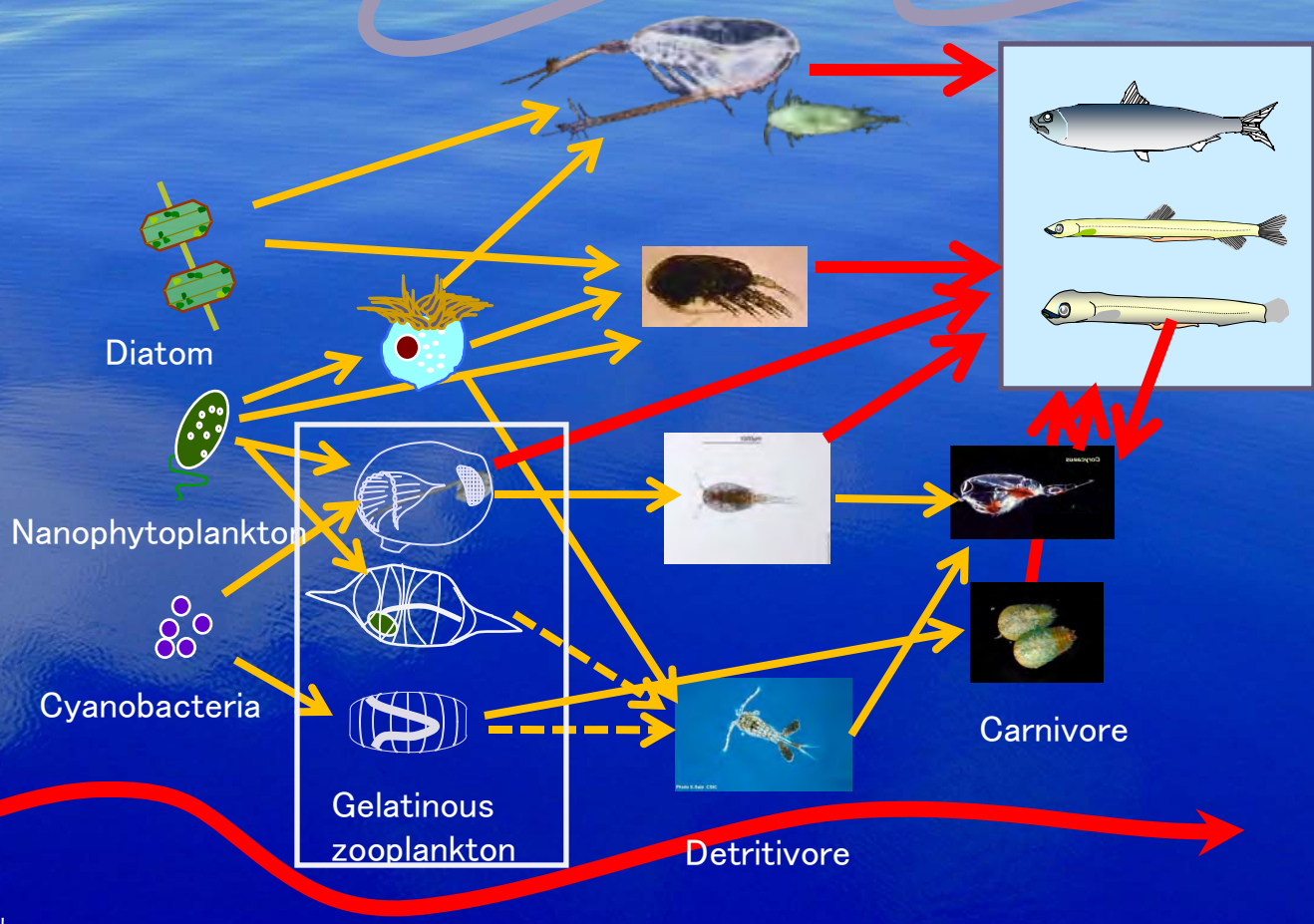
Diatoms→Copepods
→Fish larvae

Paracalanus is key species.



KEX Ecosystem (during-SUPRFISH)

- Nutrient supply by Oyashio water
- Iron-limitation prevents NO_3 utilization for phytoplankton in early summer
- Various prey species
- Complex prey-predator interaction
- Non-prey zooplankton (gelatinous) influence seasonal change in the ecosystem structure and production



Remaining issues

- Factors inducing continuous success of sardine recruitment (population outburst of Japanese sardine)
  - Different factor(s) from the stock collapse?
  - Need biomass accumulation?
  - Need age-structure change?
  - Time-lag from the climate shift to apparent increase in the stock size?
  - etc.

Acknowledgements:

- SUPRFISH members
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- Fisheries Research Agency (FRA)