

**Spatio-temporal distribution of planktonic copepods  
and planktonic stages of small pelagic fishes:  
Copepod community structure and species diversity  
in egg- and larvae-rich Kuroshio and Kuroshio  
Extension area**

Sayaka **Sogawa**<sup>1</sup>, Kiyotaka Hidaka<sup>1</sup>, Yasuhiro Kamimura<sup>1</sup>,  
Masanori Takahashi<sup>1</sup>, Hiroaki Saito<sup>1,a</sup>, Yuji Okazaki<sup>1</sup>,  
Yugo Shimizu<sup>1</sup>, Takashi Setou<sup>1</sup> and Ichikawa Tadafumi<sup>1</sup>

<sup>1</sup> Japan Fisheries Research and Education Agency

<sup>a</sup> Atmosphere and Ocean Research institute, University of Tokyo

## Introduction

- Ecologically and fishery importance of copepods and small pelagic fishes
- Relation among size and developmental stages
- Spawning grounds of mackerels and Japanese sardine during spring

## Results and Discussion

- Hydrography
- Geographical distribution
  - Eggs and larvae of mackerels and Japanese sardine
  - Copepod communities
  - Comparison of ichthyoplankton and copepod community
- Detail of fish egg- and larva-rich copepod community
  - Abundance and diversity
  - Community composition
  - Community assembly

# Ecologically & fishery importance of **copepods**

- **Copepods** are crustaceans that comprise one of the most abundant metazoan groups, and ca. 11,500 species are described in the world.  
*(Humes 1994; the world of Copepods)*
- **Planktonic copepods** play **various roles in the marine food web** as **herbivores, omnivores/detritivores** and **carnivore**, linking primary production and higher trophic level organisms such as fishes.  
*(Ohtsuka & Nishida 1997; Turner et al. 2004; Sano et al. 2013)*



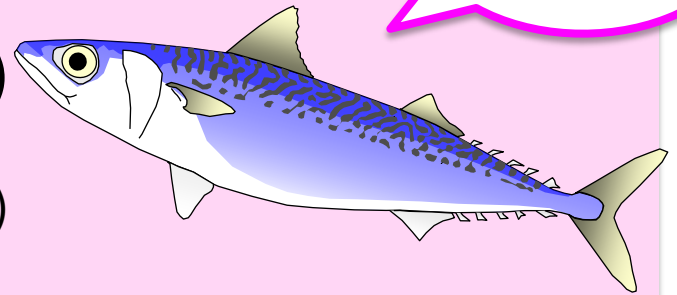
# Ecologically & fishery importance of small pelagic fishes

Small pelagic fishes are ...

- main fishery species in Japan:

- 1<sup>st</sup> **Mackerels (503,000 tons)**
- 2<sup>nd</sup> **Japanese sardine (378,000 tons)**
- 5<sup>th</sup> Japanese anchovy (171,000 tons)
- 7<sup>th</sup> Japanese jack mackerel (125,000 tons)
- 8<sup>th</sup> Pacific saury (114,000 tons)
- 10<sup>th</sup> Round herring (98,000 tons)

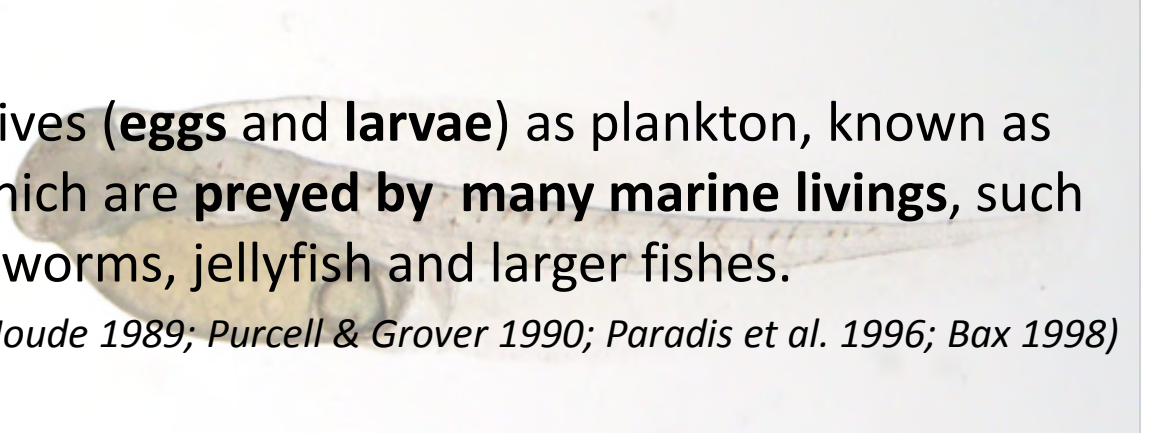
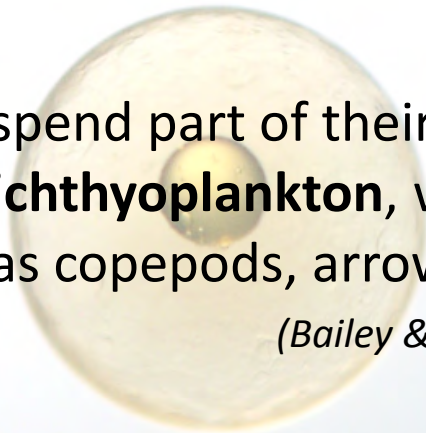
*(Fishery and aquaculture production statistics for fiscal 2016, MAFF)*



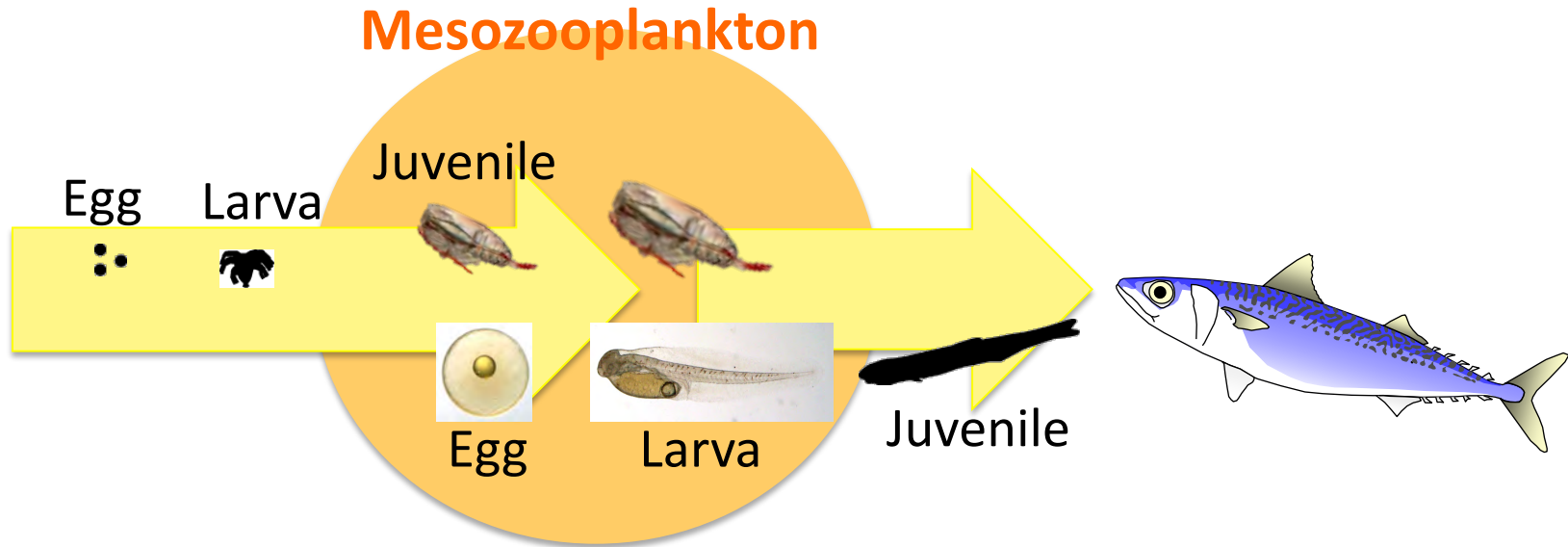
top 10 fish catches

- spend part of their lives (**eggs and larvae**) as plankton, known as **ichthyoplankton**, which are **preyed by many marine livings**, such as copepods, arrow worms, jellyfish and larger fishes.

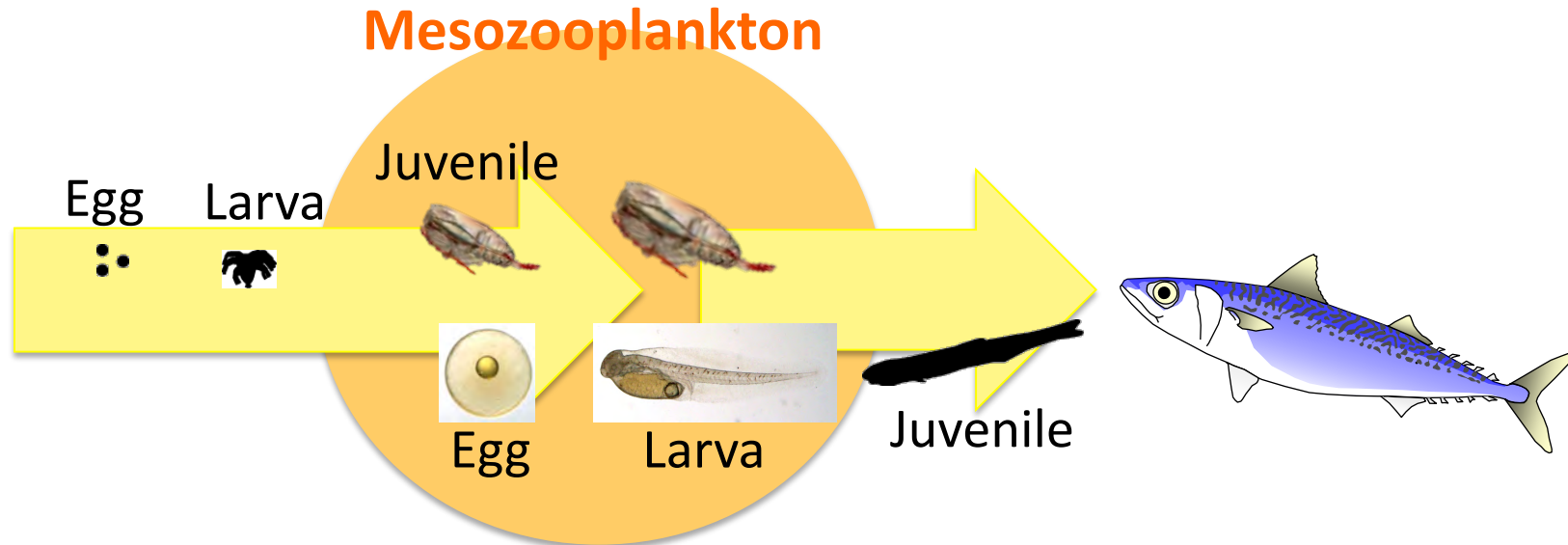
*(Bailey & Houde 1989; Purcell & Grover 1990; Paradis et al. 1996; Bax 1998)*



# Size and developmental relation planktonic copepods and small pelagic fishes

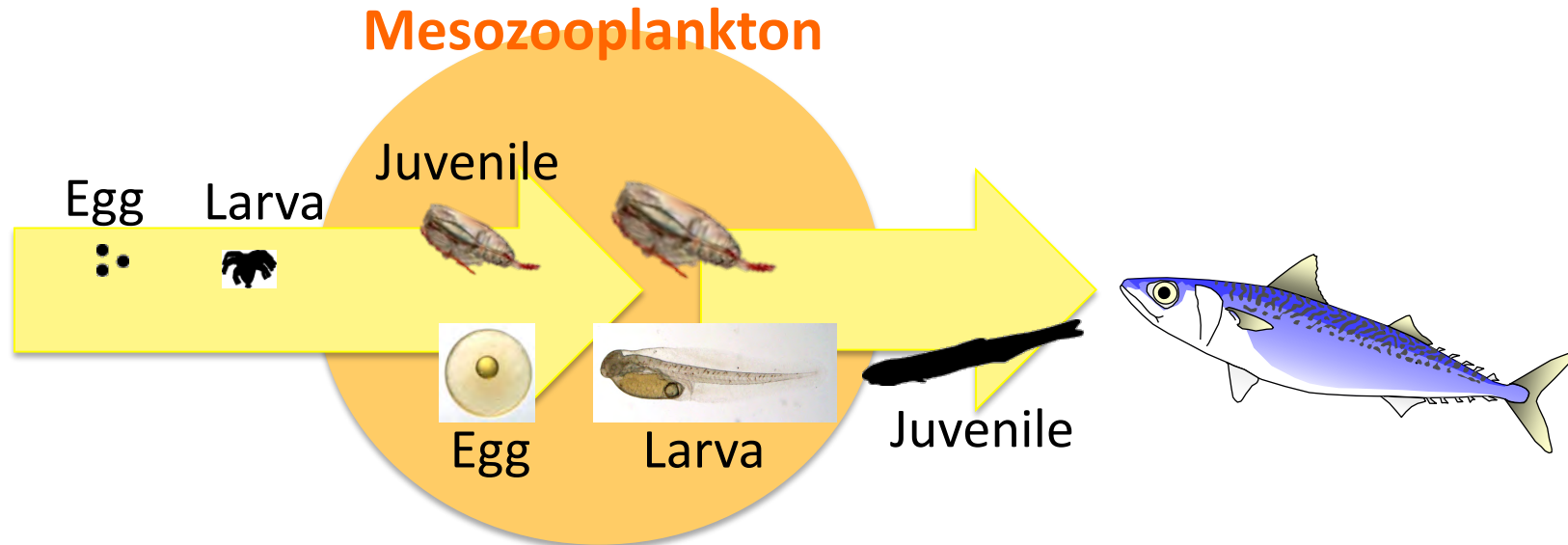


# Size and developmental relation planktonic copepods and small pelagic fishes



- Coastal/shelf-water **copepods are important food for small pelagic fishes** around Japan. (Fish larvae prey on copepod eggs and larvae.)  
*(Nakata 1990; Uye 2000; Hirai et al. 2017)*
- Some carnivorous **copepods prey on fish eggs and larvae.**  
*(Lillelund & Lasker 1971; Bailey & Yen 1983; Turner et al. 1985)*
- **Competition between copepods and fish larvae** for food.  
*(Amber & Frost 1974; Turner et al. 1984; Yen 1985)*

# Size and developmental relation planktonic copepods and small pelagic fishes



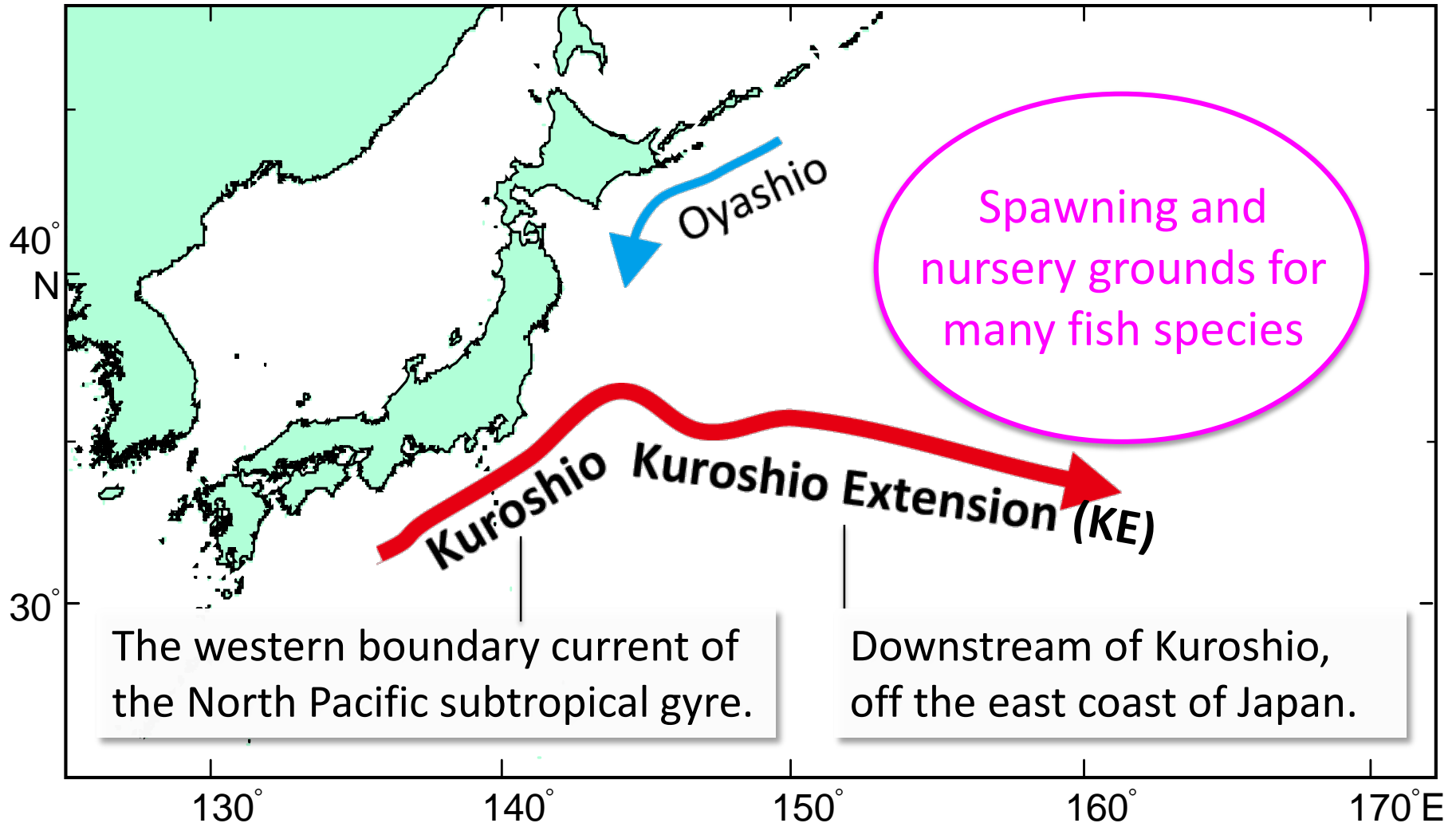
- Coastal/shelf-water copepods are important prey for small pelagic fishes around Japan. (Fish larvae prey on copepod eggs and larvae.)

The **abundance** and **community structure** of copepods directly affect the dynamics of the fishery resources.

- Competition between copepods and fish larvae for food organisms.

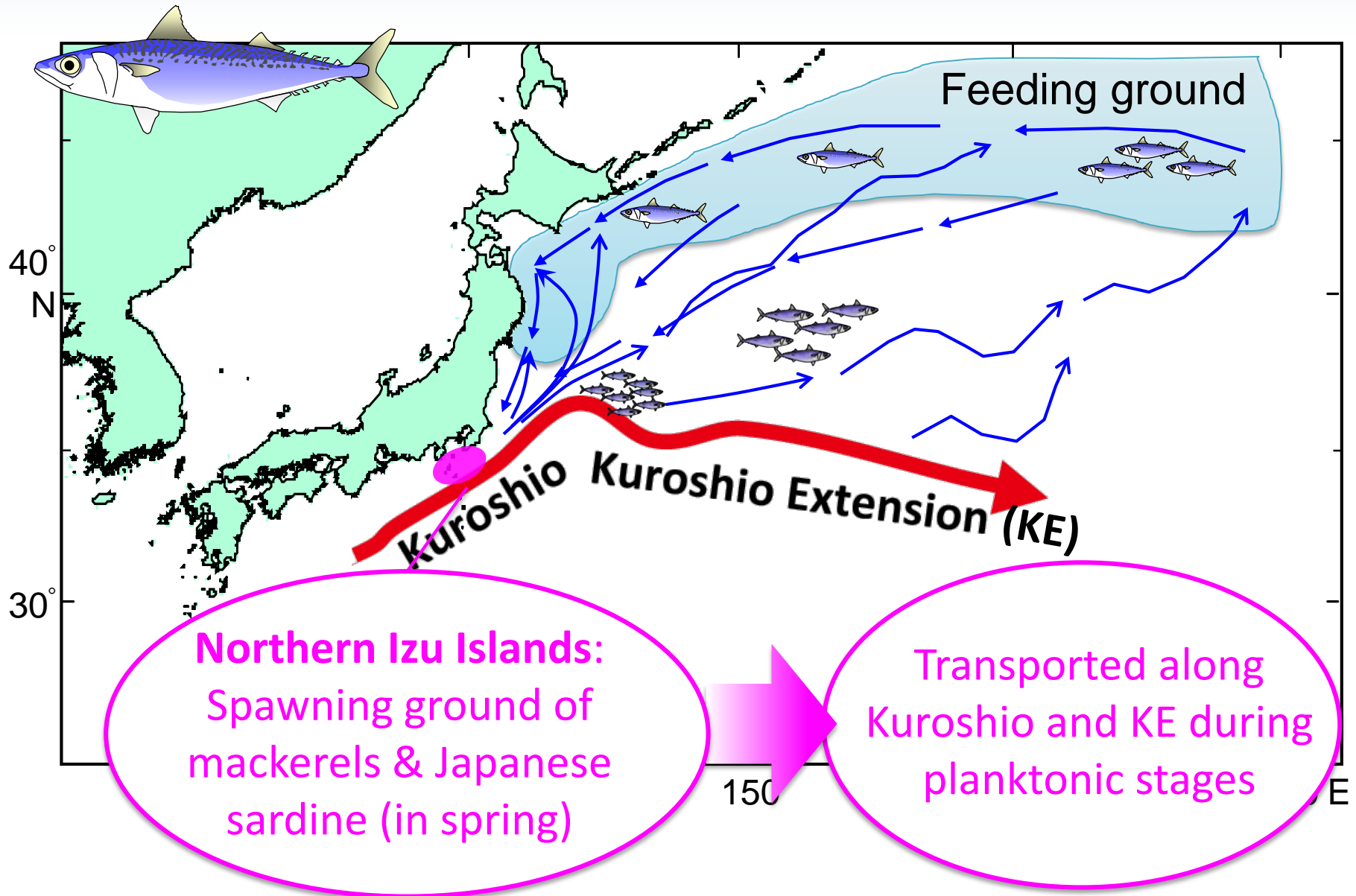
(Amber & Frost 1974; Turner et al. 1984; Yen 1985)

# Kuroshio and Kuroshio Extension





# Spawning grounds and migration path



# Survey periods and methods

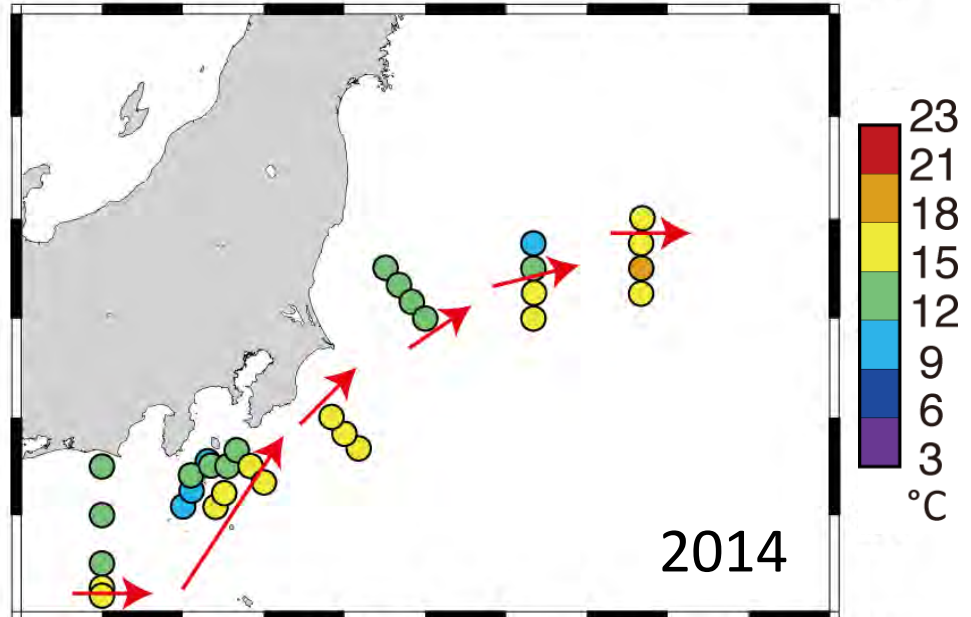
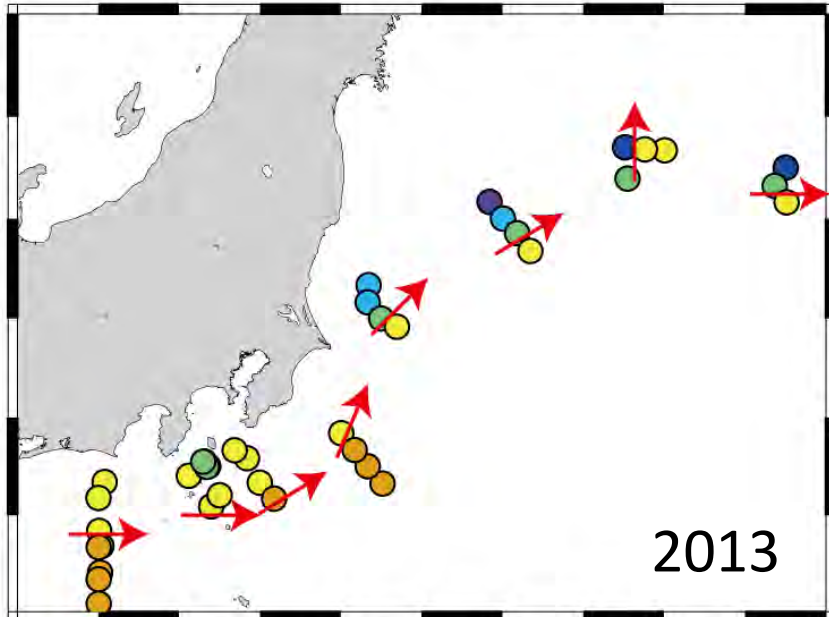
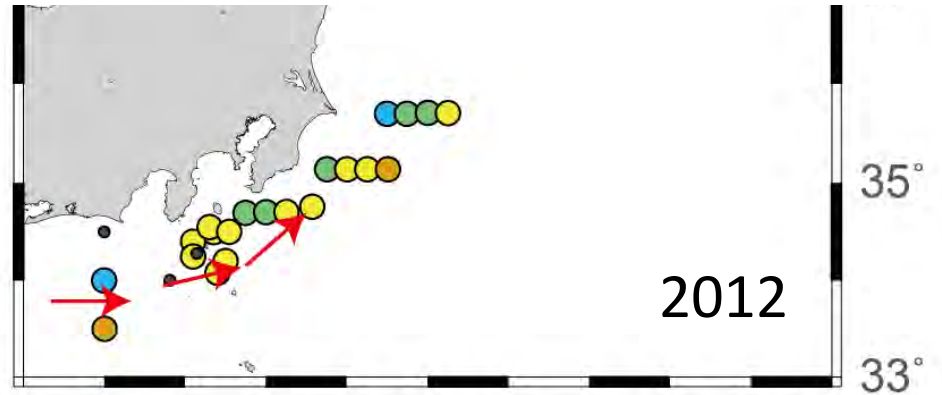
- Survey periods
  - April 11–24th, **2012 (22 stations)**
  - April 17–30th, **2013 (38 stations)**
  - May 10–20th, **2014 (33 stations)**
- Methods
  - R/V **Soyo-maru** and training vessel **Hokuho-maru**
  - Plankton samples: **NOPRAC net** (0.3mm), 0–150m
  - Temperature data: **CTD**



# Variation of temperature (150m depth) and Kuroshio & KE

Kuroshio took **non-large meander** path during 2012–2014, but **temporary go south** ( $31.5^{\circ}$  N) in 2013 April.

*(Japan Meteorological Agency)*



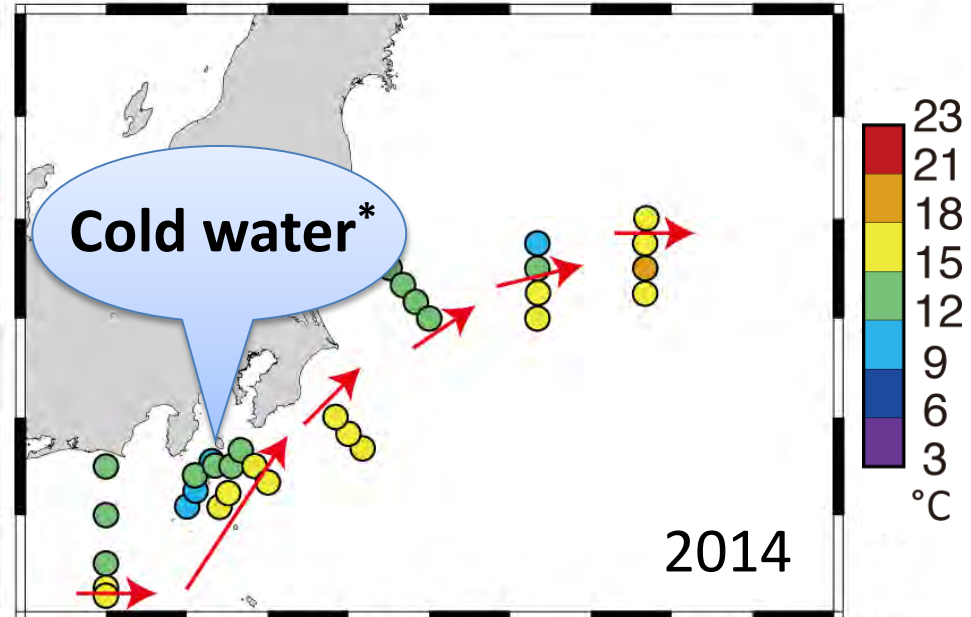
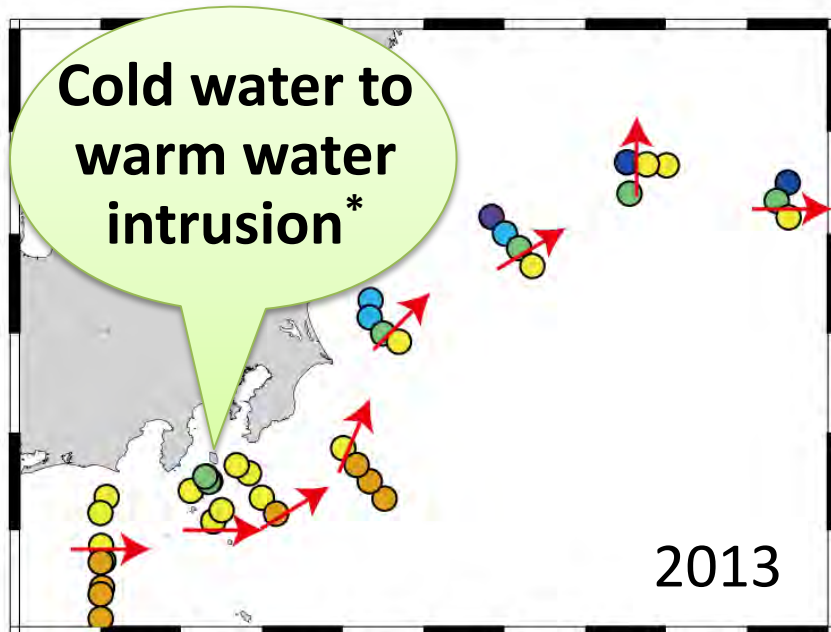
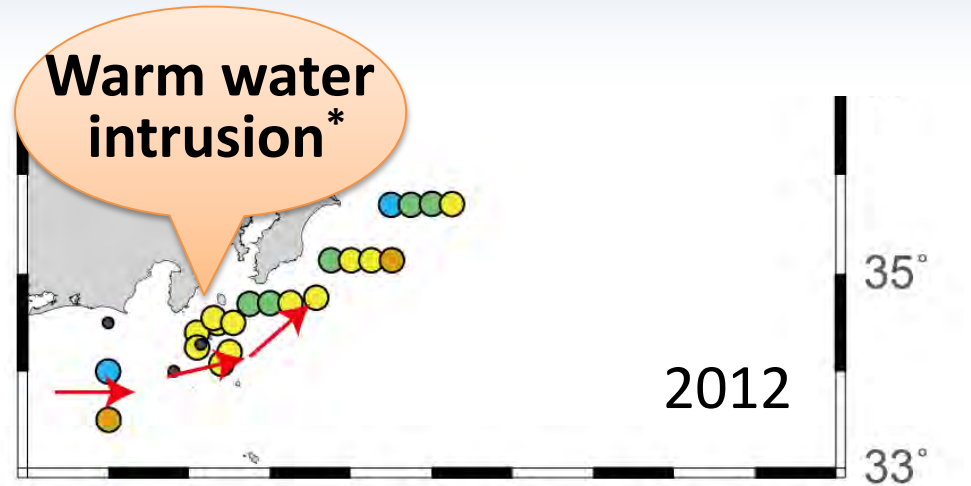
137° 139° 141° 143° 145° 137° 139° 141° 143° 145° 147°E

(\*Flash report on hydrographic condition of Kanto-Tokai, Kanagawa Prefectural Fisheries Technology Center)

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# Geographical distribution of eggs & larvae of small pelagic fishes

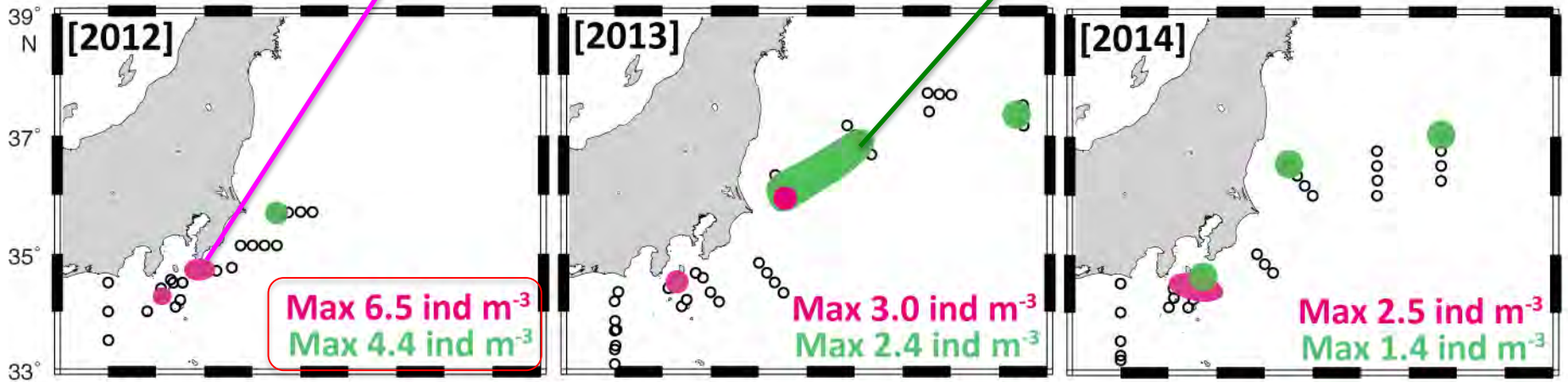
## Mackerels



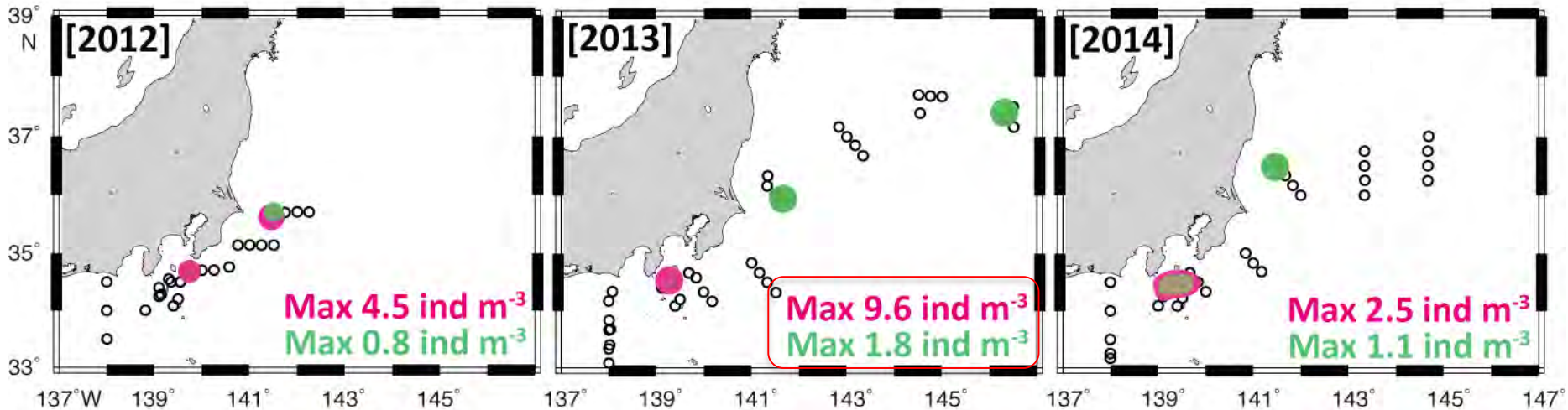
Abundant eggs  
(> 50% of max abundance)



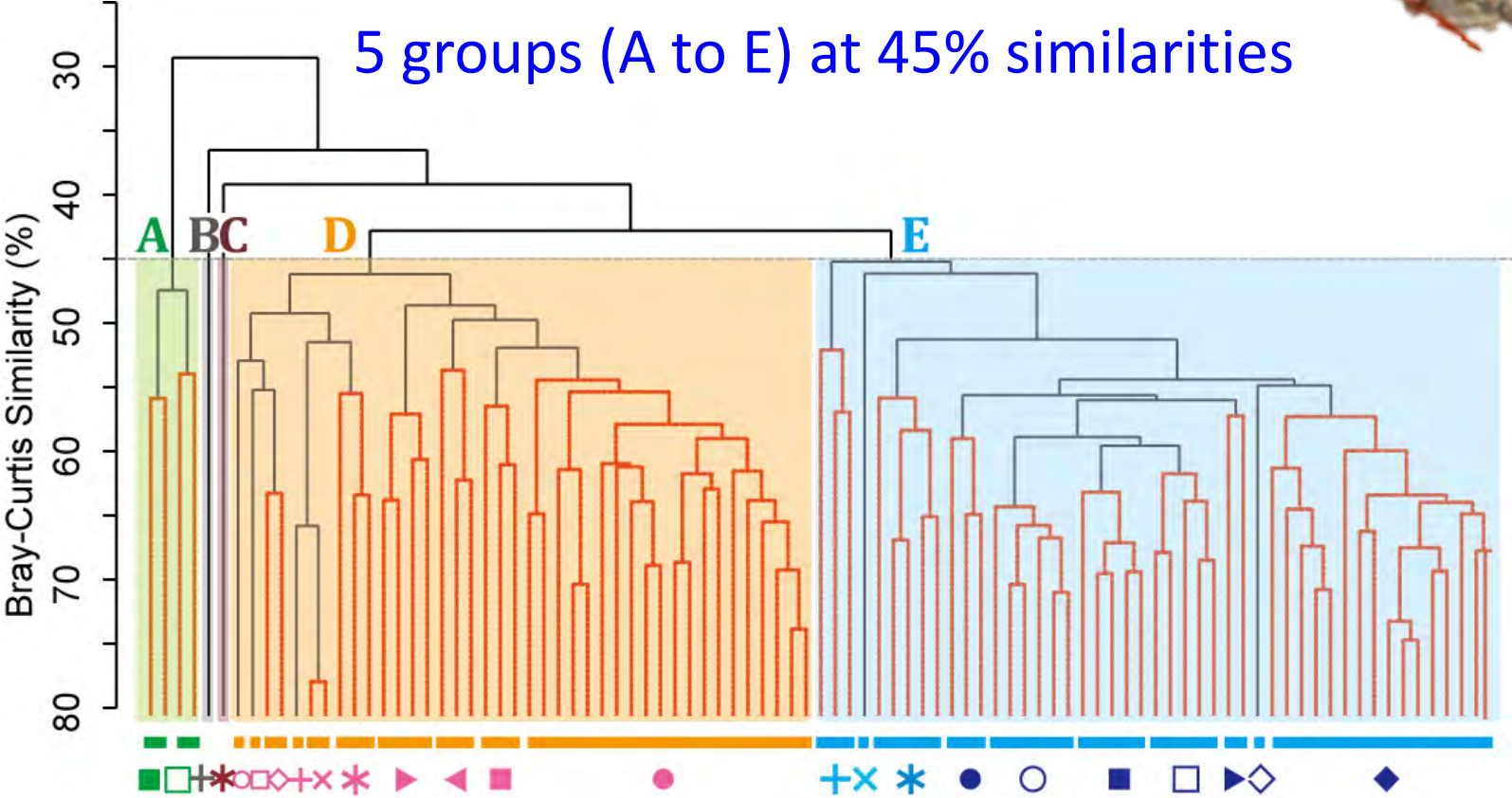
Abundant larvae  
(> 50% of max abundance)



## Japanese sardine

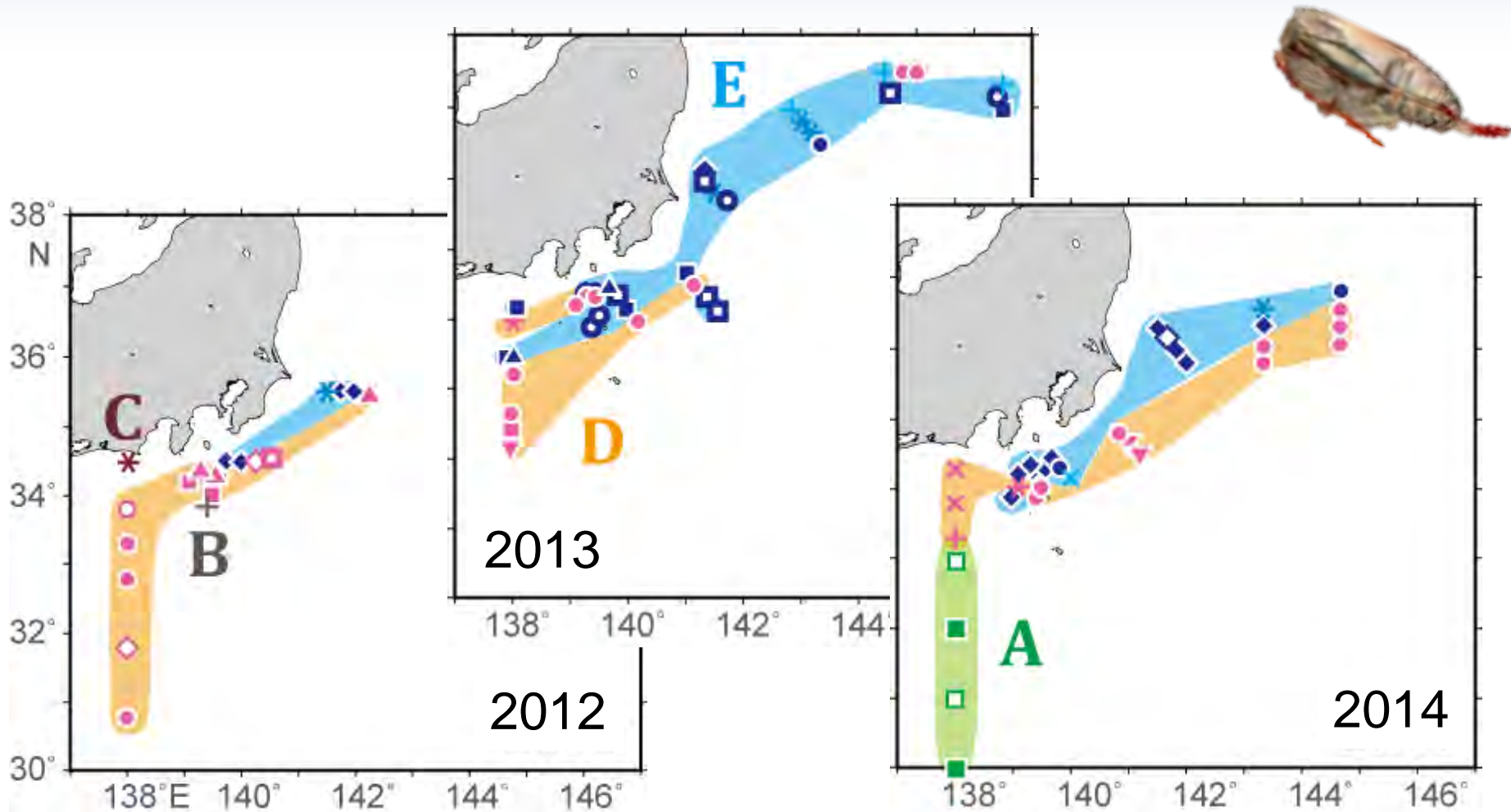


# Community structure analysis of 172 copepod species



24 communities by SIMPROF test

# Geographical distribution of copepod communities



Group **D** and **E**: all years, but distribution patterns varied among years



# Geographical distribution of eggs & larvae of small pelagic fishes

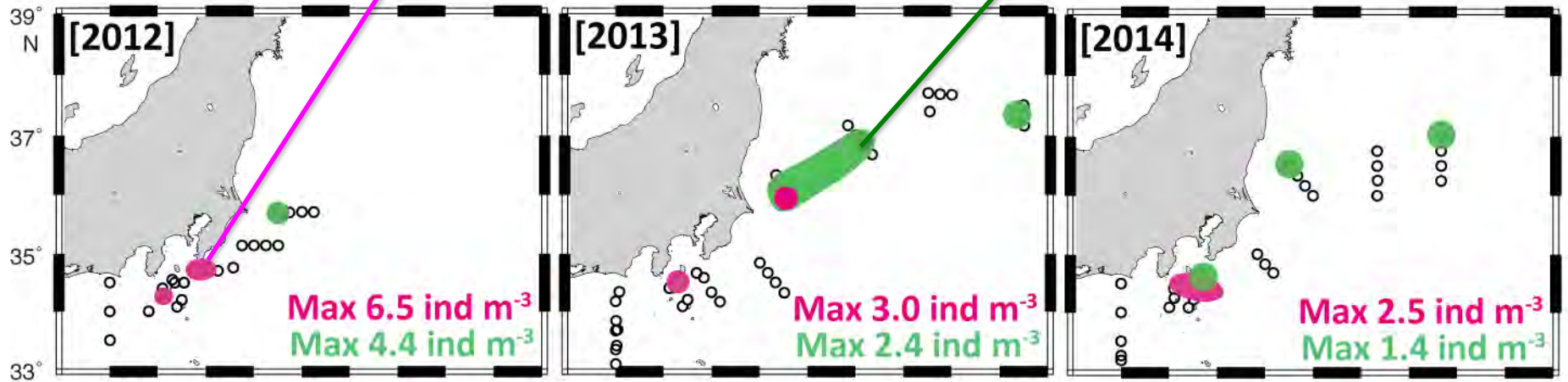
## Mackerels



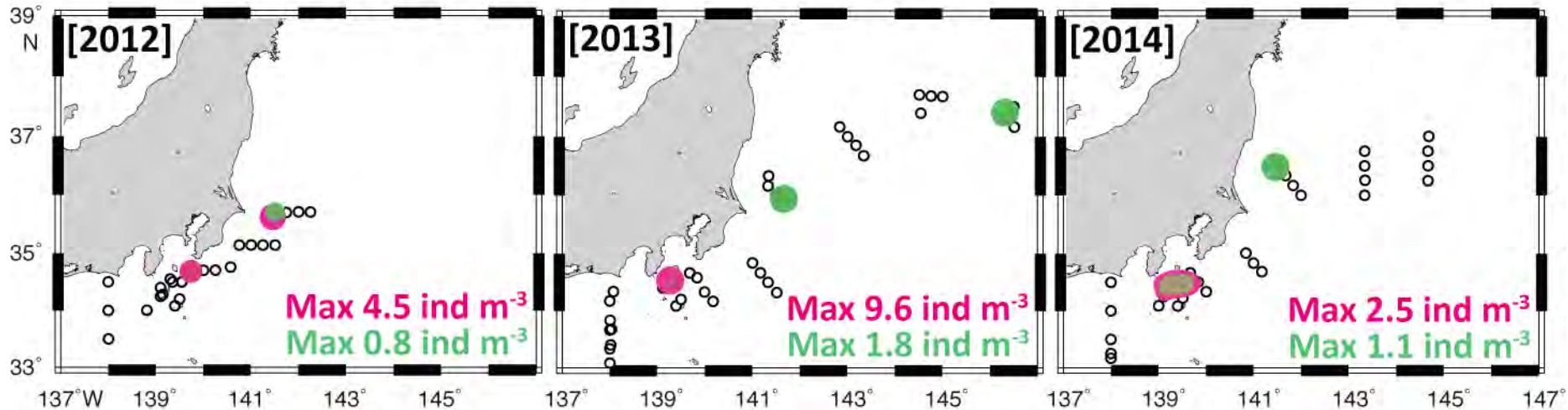
Abundant eggs  
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Abundant larvae  
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## Japanese sardine



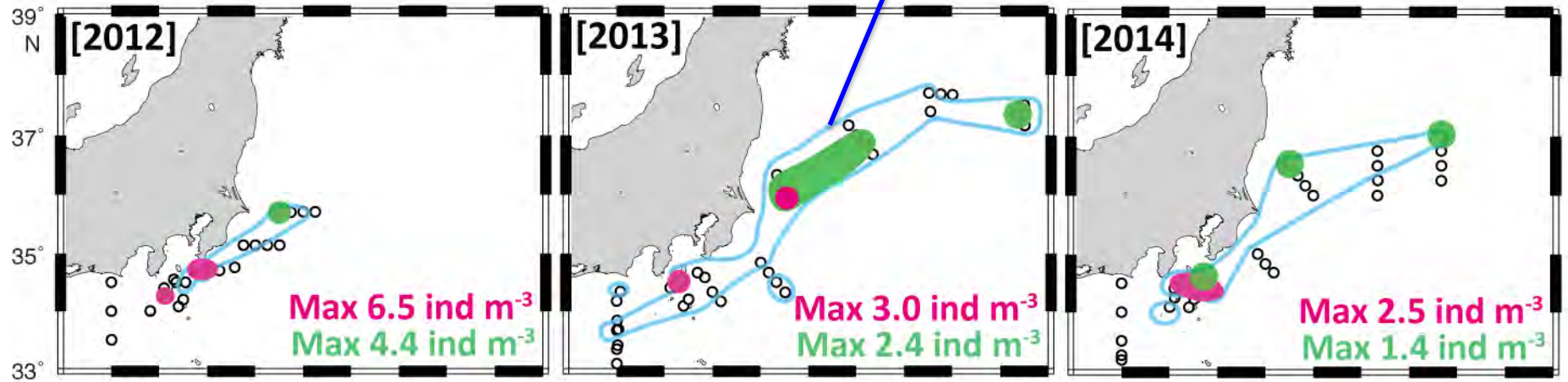


# Fish egg- and larvae-rich copepod community

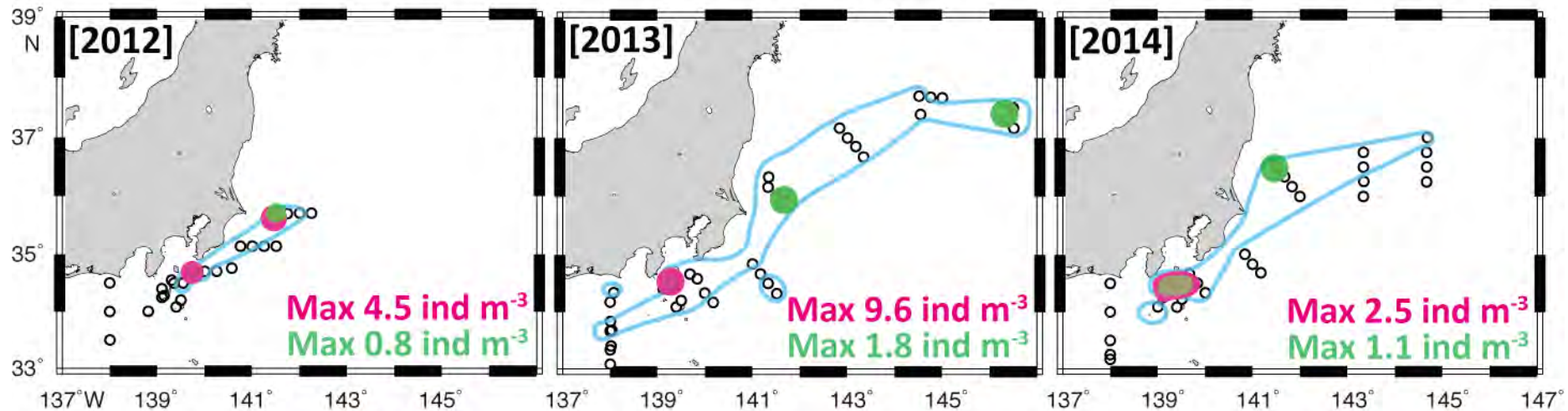


## Mackerels

Copepod community "E"

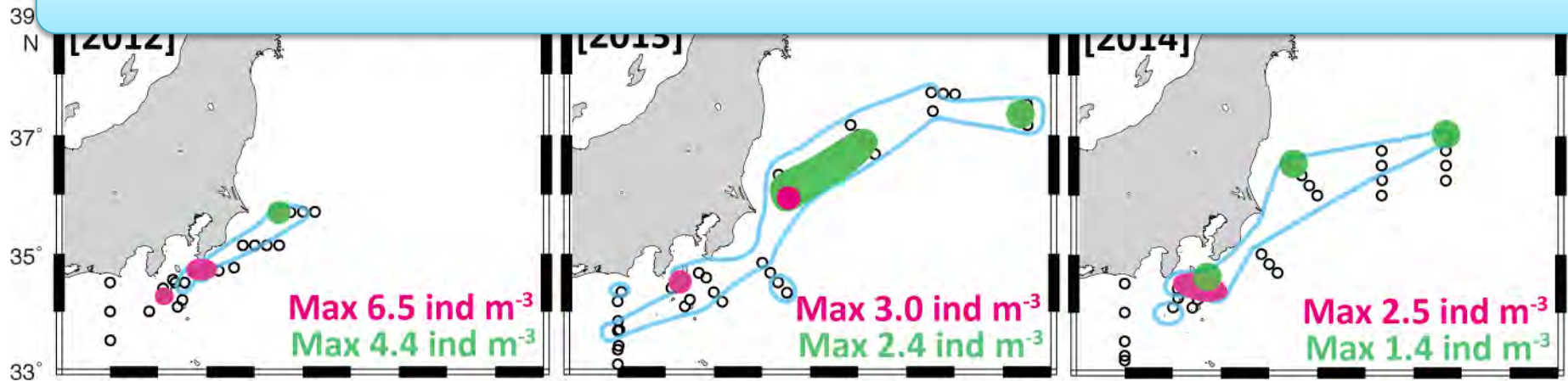


## Japanese sardine

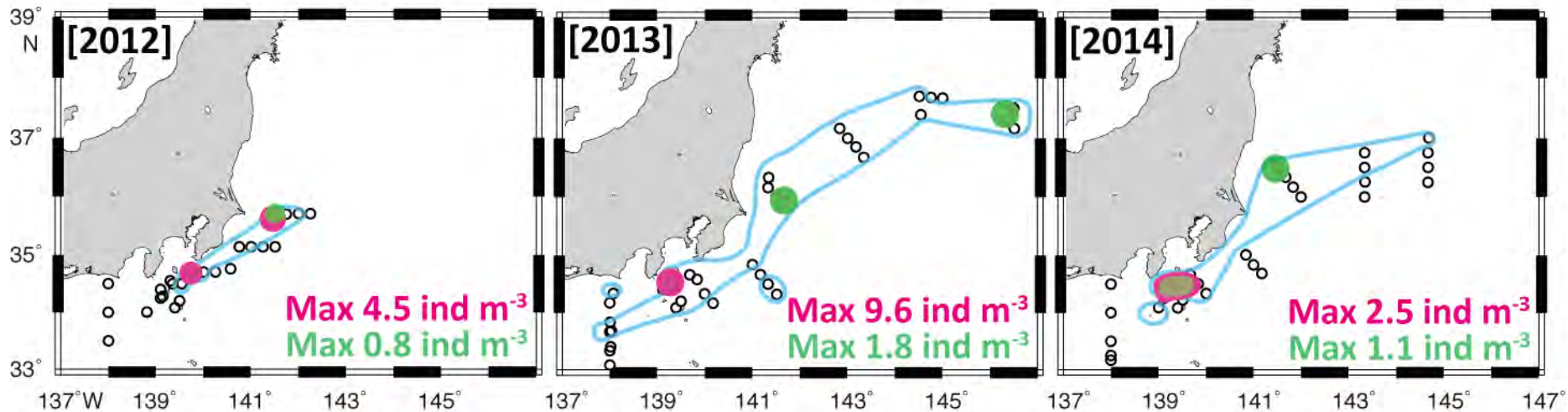


# Fish egg- and larvae-rich copepod community

Recruitment of fishes depend on survival rate of larvae (e.g., Leiby 1984).



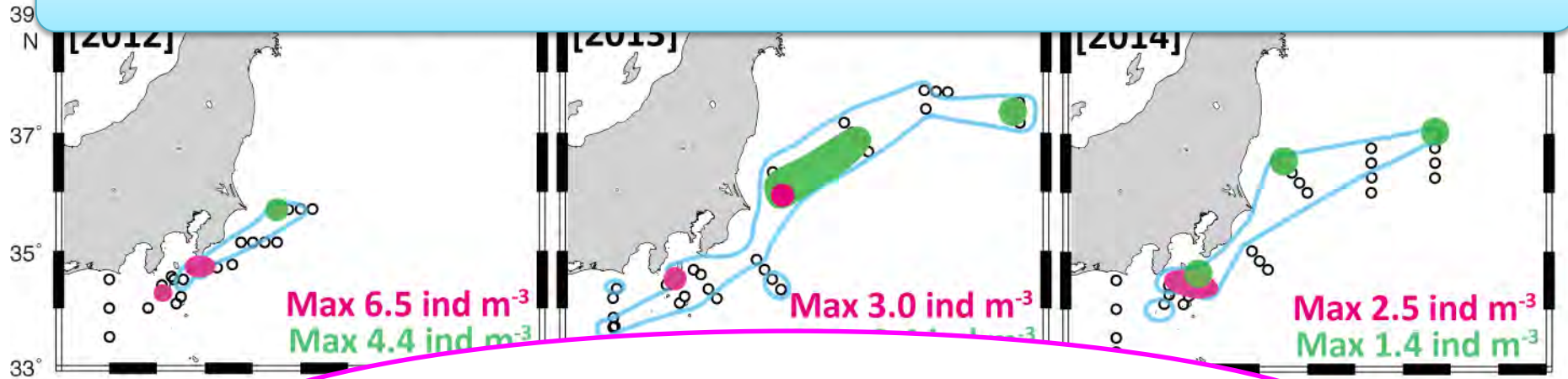
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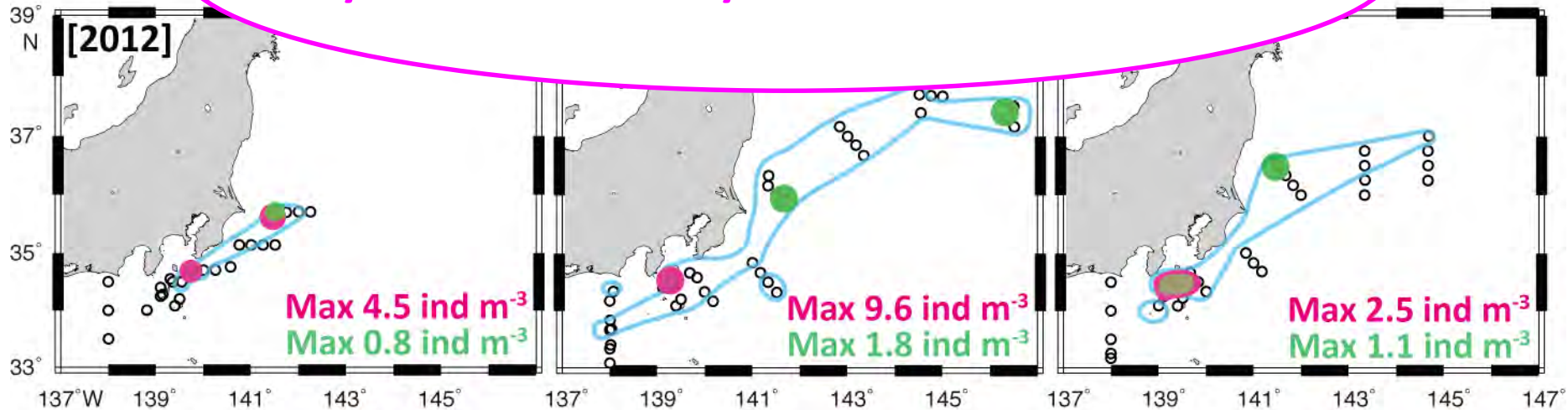
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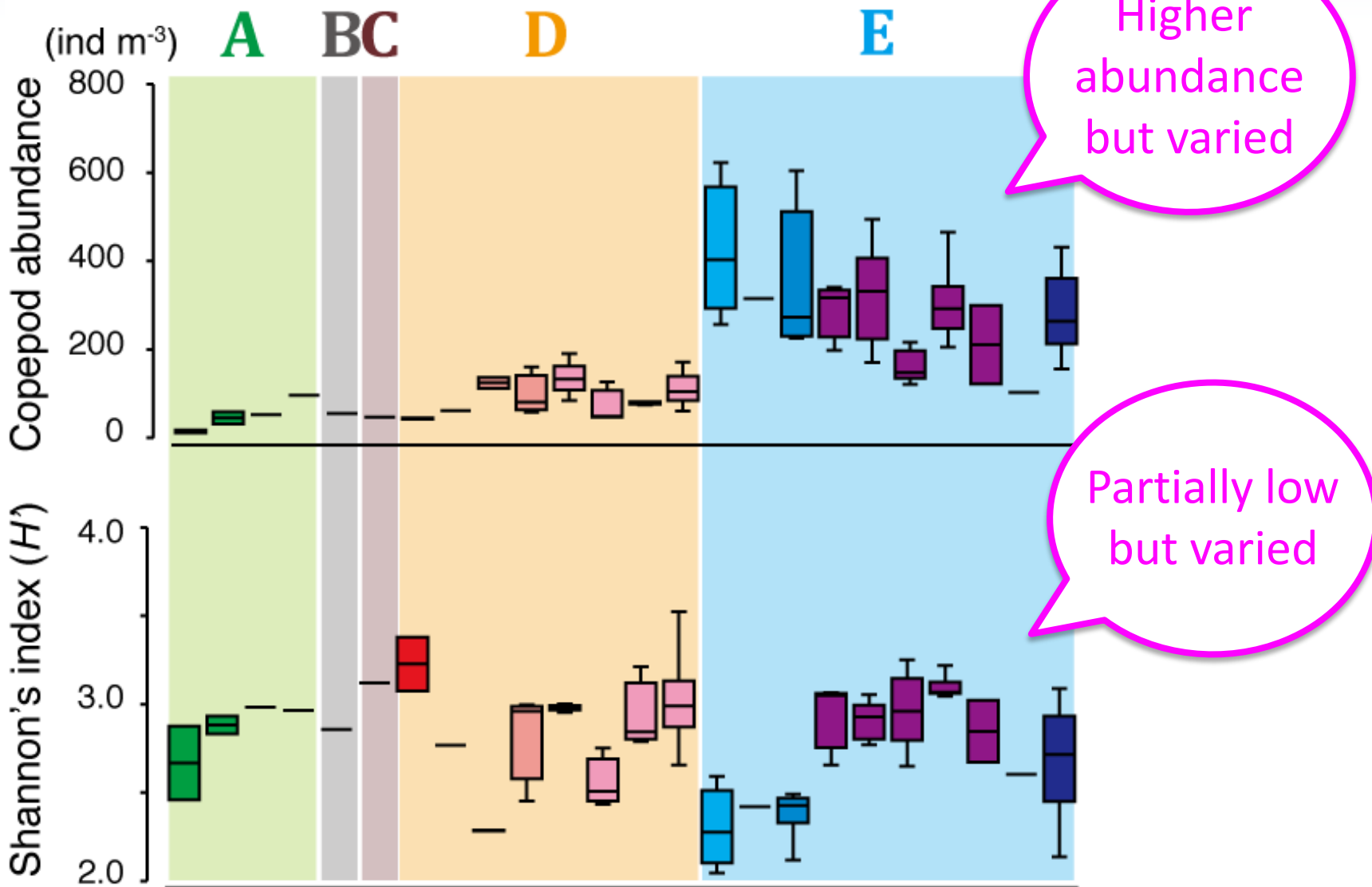
Japan

Key community for recruitment ?



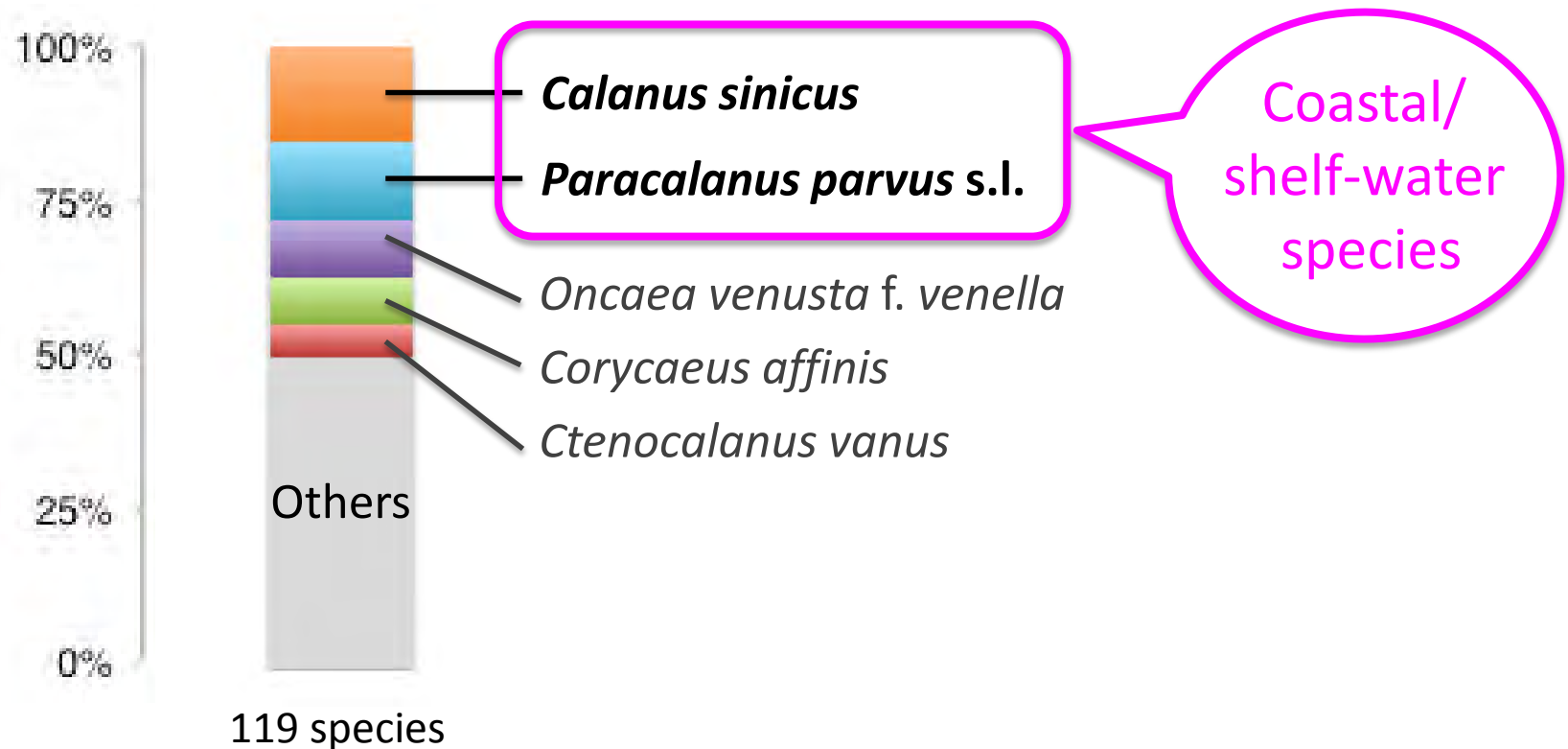
# Characteristics of copepod community "E"

## Abundance & diversity



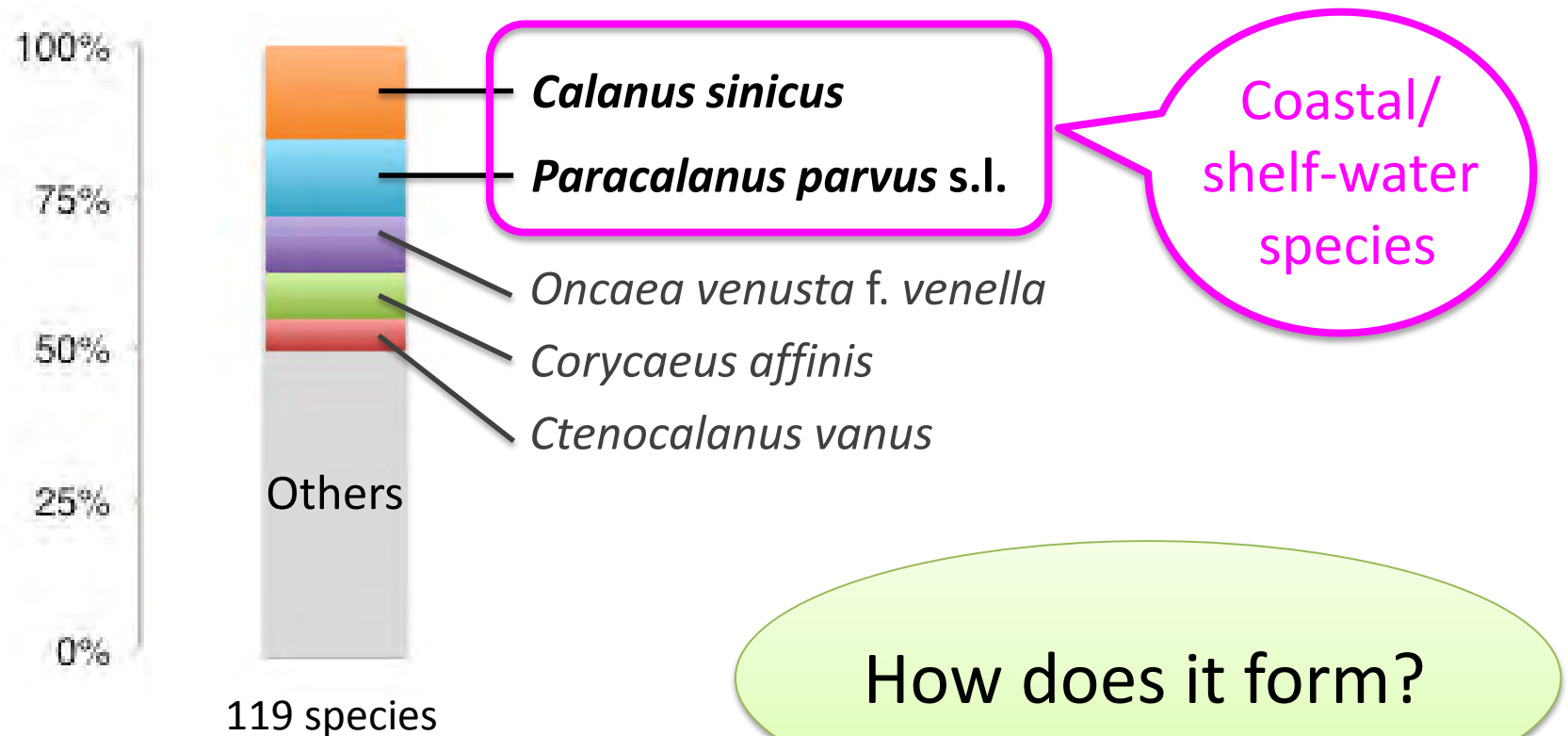
# Copepod community composition of group “E”

- Top 5 species account for >50%
- Top 2 species account for >25%



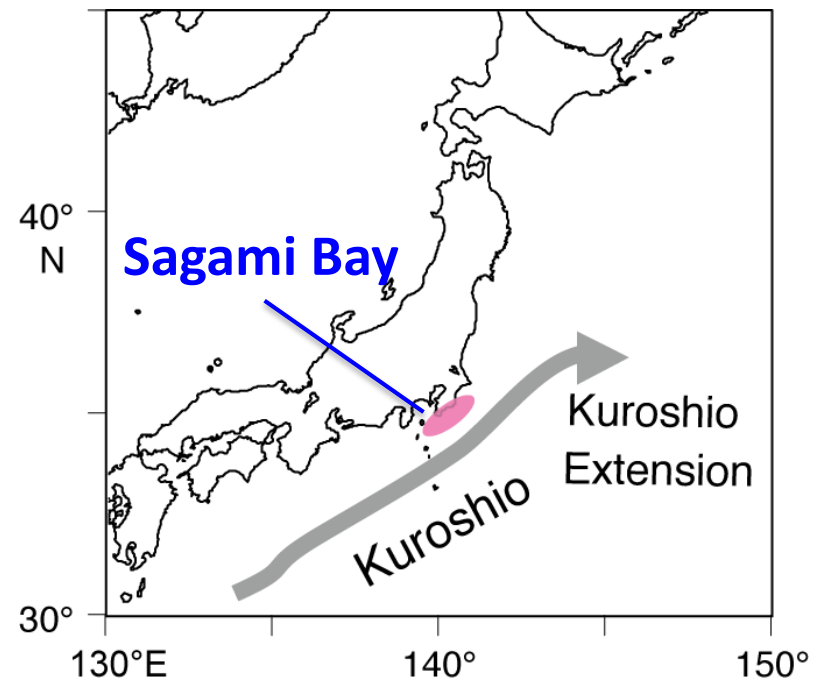
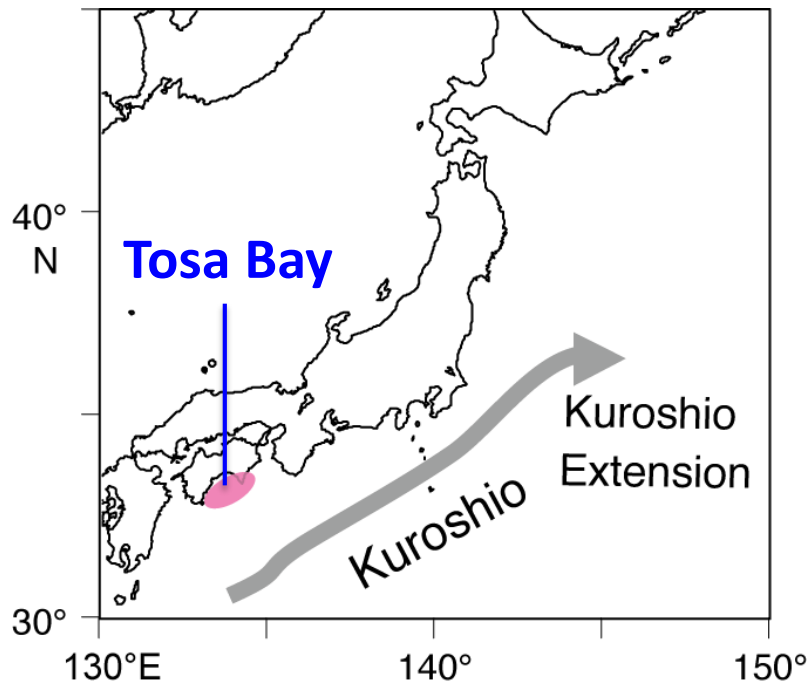
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# Previous researches

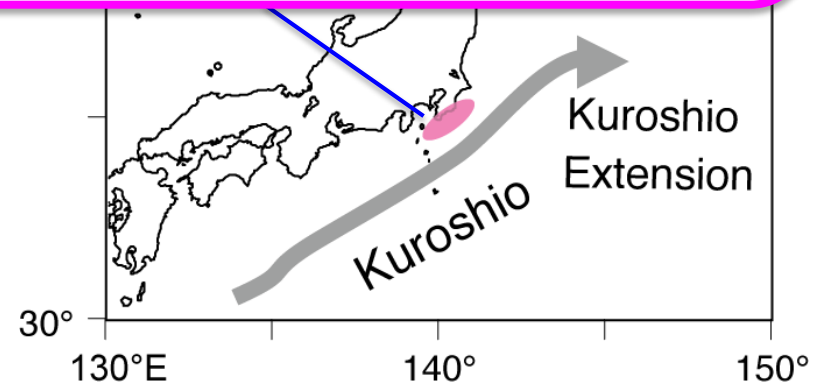
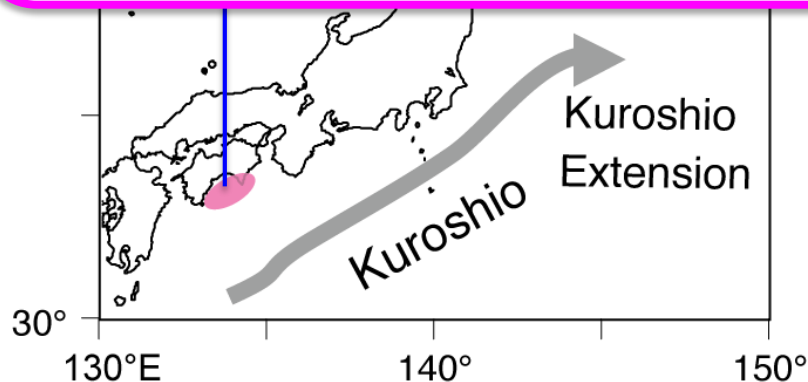
- **Selective feeding** of Japanese sardine larvae on the eggs and larvae of *Calanus sinicus* and *Paracalanus parvus* s.l. in the **Tosa Bay** along the Pacific Coast of Japan (*Hirai et al. 2017, MEPS*).
- Abundant *Calanus sinicus* was assumed to be **transported from Sagami Bay** as Kuroshio left the shore (*Sogawa et al. 2017, JO*).



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Expansion of coastal/shelf-water copepods along the Kuroshio variation from open-type bay could be the key for the assembly of fish egg- and larvae-rich copepod community.





# Summary

- Abundant eggs and larvae of mackerels and Japanese sardine was observed in distribution area of **particular copepod community (E)**, which would be the **key for the recruitment**
- Expansion of coastal/shelf-water species to offshore would be the key for the **assembly of this community**

Understanding the **community assembly process** could lead to improvement of recruitment prediction, which is a key element for prudent resource management.

# Acknowledgement

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Data sets of fish eggs and larvae were provided by Dr. Akinori Takasuka and his laboratory members (National Fisheries Research Institute).

We gratefully acknowledge the captains, crews and all participants for their cooperation during the cruise of training vessel Hokuho-Maru (Office of Education Hokkaido Government) and R/V Soyo-Maru (Japan Fisheries Research and Education Agency).

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