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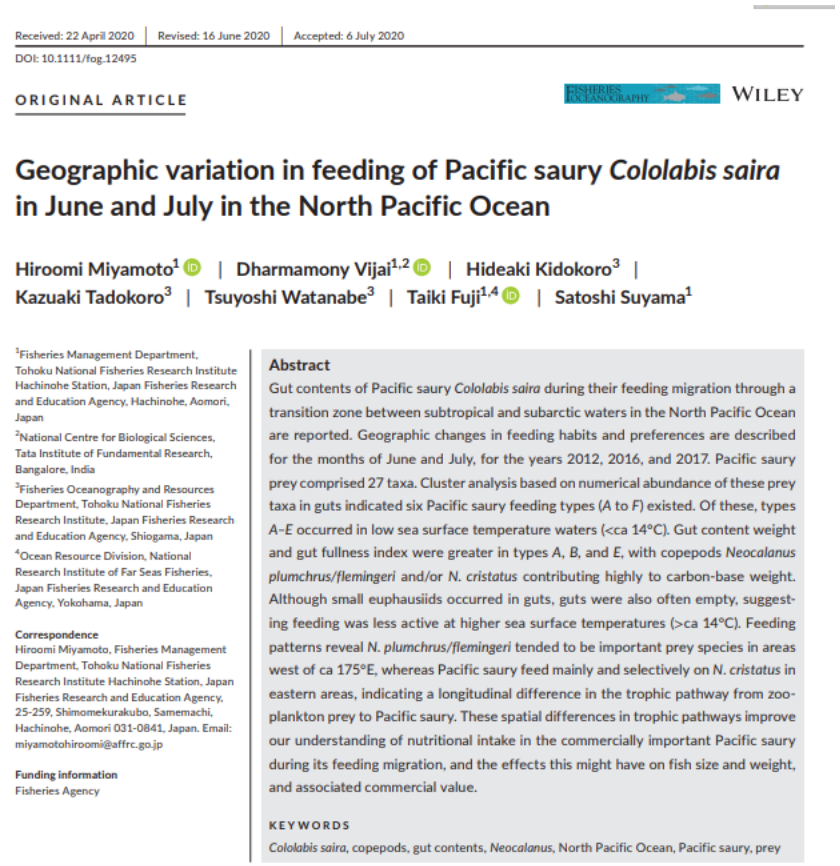
Hiroomi Miyamoto et al.



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Geographic variation in feeding of Pacific saury *Cololabis saira* in June and July in the North Pacific Ocean

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Abstract
Gut contents of Pacific saury *Cololabis saira* during their feeding migration through a transition zone between subtropical and subarctic waters in the North Pacific Ocean are reported. Geographic changes in feeding habits and preferences are described for the months of June and July, for the years 2012, 2016, and 2017. Pacific saury prey comprised 27 taxa. Cluster analysis based on numerical abundance of these prey taxa in guts indicated six Pacific saury feeding types (*A* to *F*) existed. Of these, types *A*–*E* occurred in low sea surface temperature waters (<ca 14°C). Gut content weight and gut fullness index were greater in types *A*, *B*, and *E*, with copepods *Neocalanus plumchrus/flemingeri* and/or *N. cristatus* contributing highly to carbon-base weight. Although small euphausiids occurred in guts, guts were also often empty, suggesting feeding was less active at higher sea surface temperatures (>ca 14°C). Feeding patterns reveal *N. plumchrus/flemingeri* tended to be important prey species in areas west of ca 175°E, whereas Pacific saury feed mainly and selectively on *N. cristatus* in eastern areas, indicating a longitudinal difference in the trophic pathway from zooplankton prey to Pacific saury. These spatial differences in trophic pathways improve our understanding of nutritional intake in the commercially important Pacific saury during its feeding migration, and the effects this might have on fish size and weight, and associated commercial value.

KEYWORDS
Cololabis saira, copepods, gut contents, *Neocalanus*, North Pacific Ocean, Pacific saury, prey

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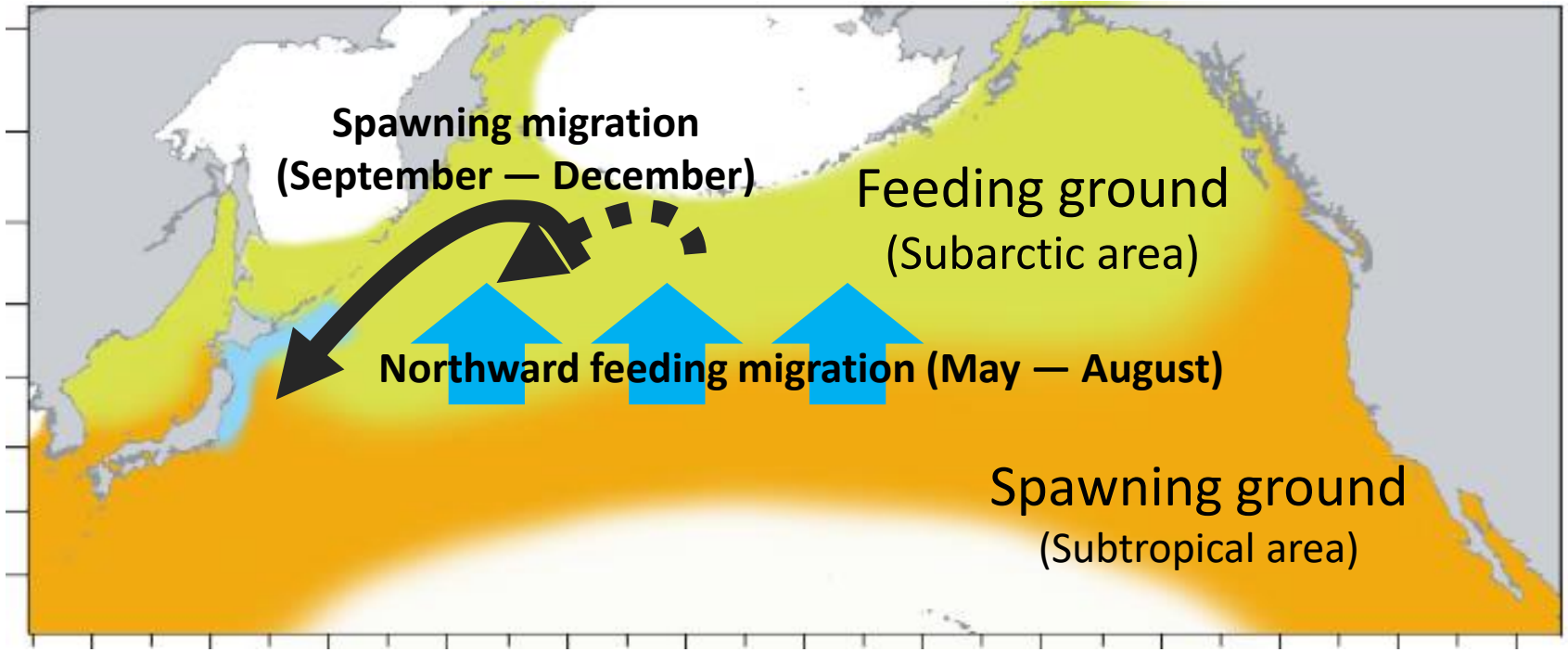
Migration of Pacific saury

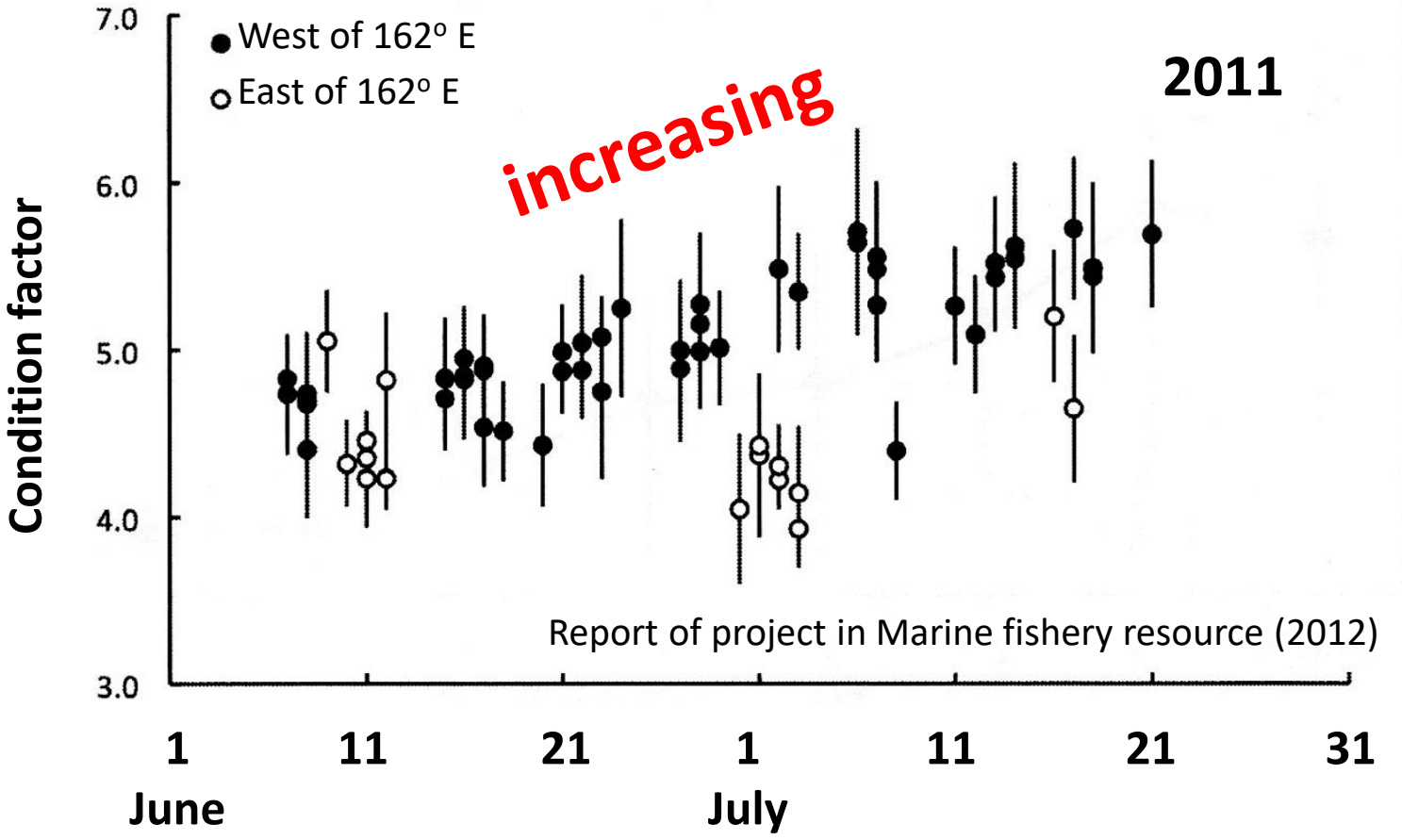


- The subarctic water is utilized as feeding ground, while subtropical region is used as spawning ground
- Pacific saury conduct the northward feeding migration from May to August
- After the northward migration, the spawning migration is shown in fall and winter

From May to August is the important season for fish growth and increasing of fatness

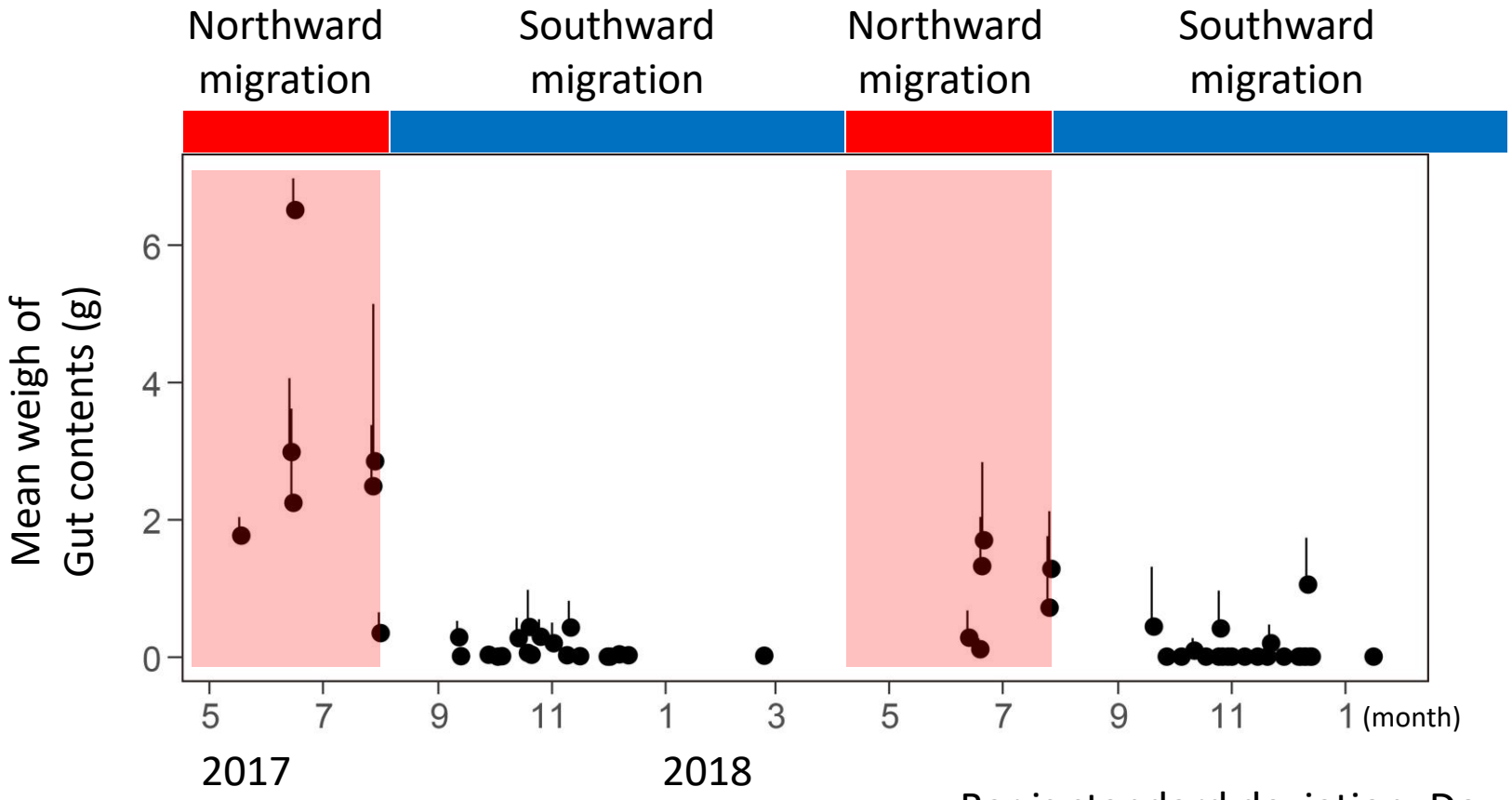
Seasonal change of condition factor (fatness)

Condition factor = weight / length^3 × 10^3



- Condition factor increases during the northward feeding migration

Seasonal change of gut content weight

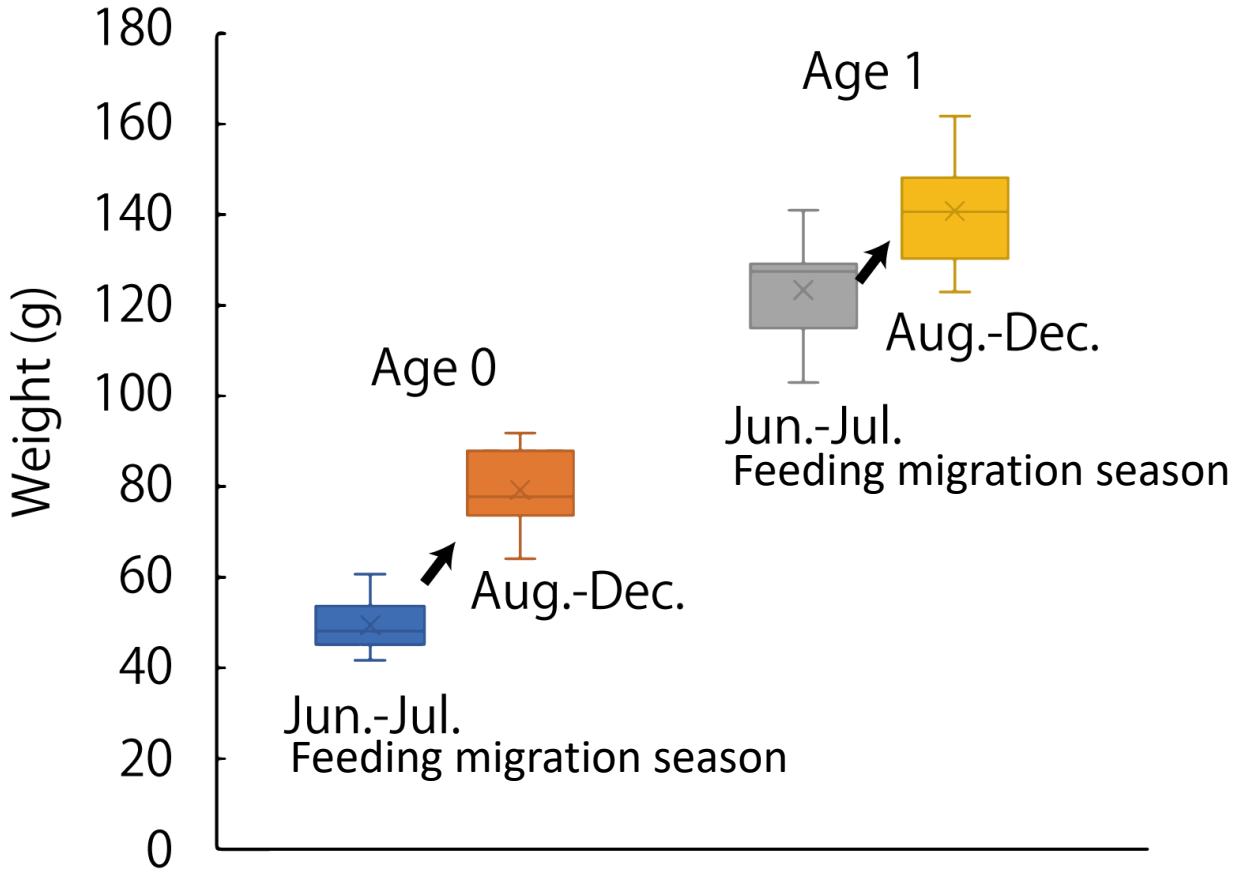


Bar is standard deviation. Down direction was omitted.

modifired Miyamoto (2020) Touhoku Suisan kenkyu letter

- Pacific saury feed on prey actively during the northward migration

Seasonal change of average weight at each age



modified Fuji et al. NPFC-2021-SSC PS07-WP10

The weight increase 40 g and 20 g from feeding migration season to post feeding migration season, respectively.

During northward feeding migration, Pacific saury abundantly feeds on prey and increase their condition factor.

However, the information for the prey taxa/species of Pacific saury during the northward migration has been limited yet.

To understand the feeding habit of Pacific saury,
We analyzed the gut contents of Pacific saury in June and July in 2012, 2016, and 2017.

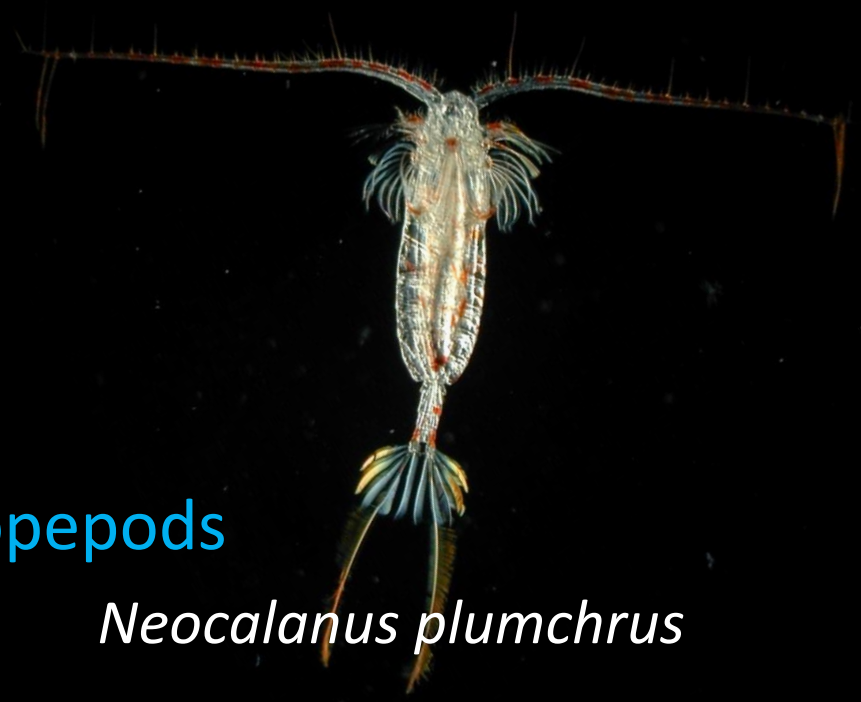
What kind of prey did Pacific saury feed on?

List of zooplankton found from their gut（27 taxa）

1. Neocalanus plumchrus (86)
2. Neocalanus cristatus (9)
3. Euphausiids (2)
4. Calanus (1.7)
5. Gastropods (0.5)
6. Amphipods (0.3)
7. Euphausiids Calyptopis larvae (0.1)
8. Unidentified copepods
9. Scolecitrichidae
10. Candaciidae
11. Cypirs larva
12. Chaetognaths
13. Ostracods
14. Pteropods
15. Unidentified crustacea
16. *Eucalanus*
17. *Clausocalanus*
18. *Metridia*
19. Unidentified Eggs
20. Gelatinous zooplankton
21. Phronimidae
22. Decapods
23. Fish larvae
24. Isopods
25. Pseudocalanus
26. Euchaeta
27. Corycaeus

※ the number of brackets represented the % Index of relative importance (%IRI).
%IRI < 0.1 in the taxa in which the %IRI are not shown.

Main prey of Pacific saury



Copepods

Neocalanus plumchrus

Copepods

Neocalanus cristatus

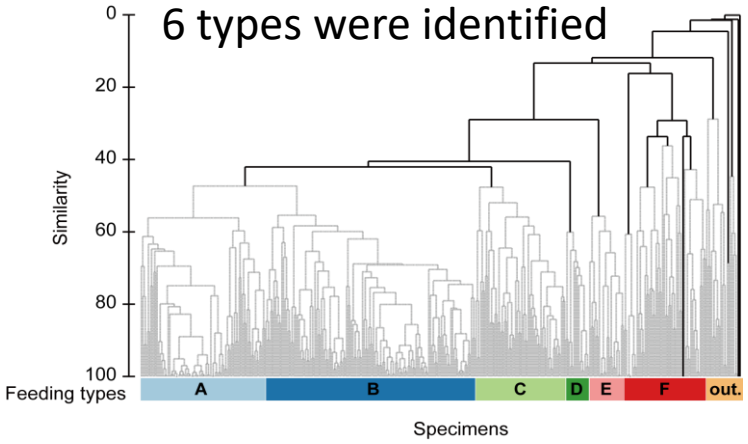
Copepods

Calanus spp.

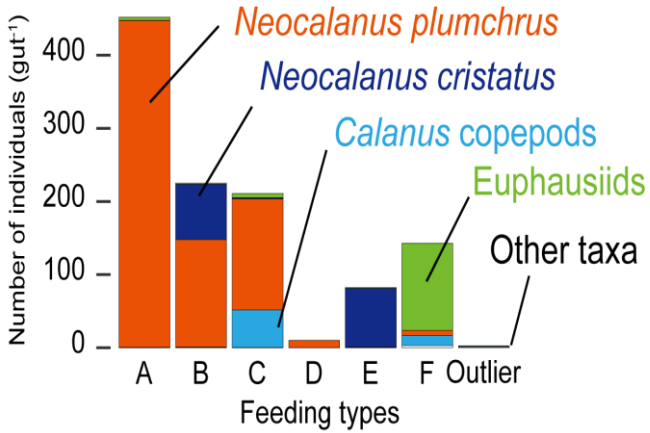
Euphausiids

Classification of prey composition in their gut and its characteristics

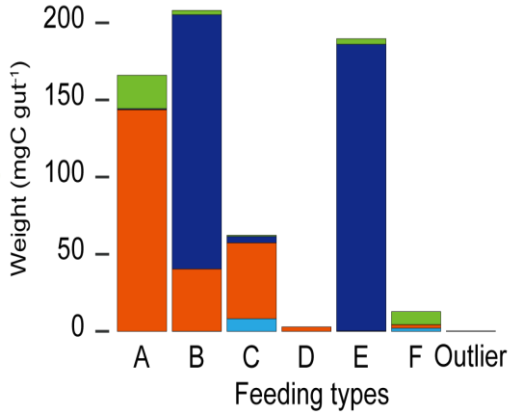
Cluster analysis based on prey composition and abundance of each prey in the gut



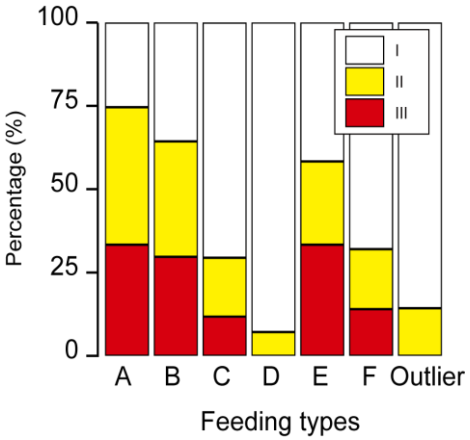
Individual base



Carbon base



Gut fullness index



III: full
II: more than half
I: less than half

Type: Main prey

A: abundant ***Neocalanus plumchrus*** **Higher gut fullness**

B: ***Neocalanus cristatus*** **&** ***N. plumchrus*** **Higher gut fullness**

C: *Calanus* & *Neocalanus plumchrus*

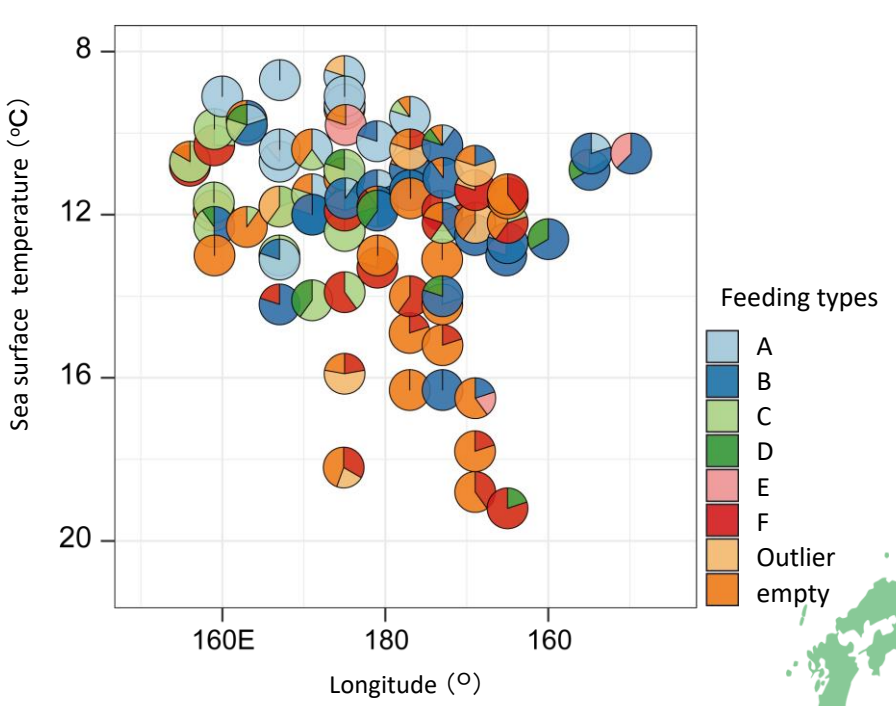
D: few *Neocalanus plumchrus*

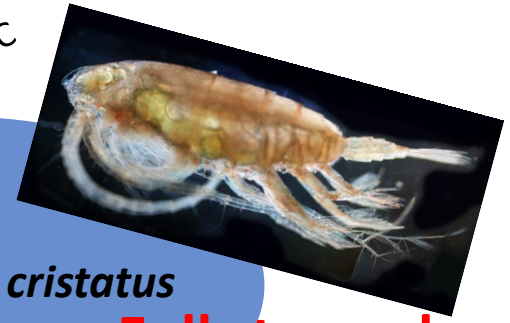
E: ***Neocalanus cristatus*** **Higher gut fullness**

F: Euphausiids

When Pacific saury fed on *Neocalanus* copepods, the gut fullness tended to be higher.

Horizontal distribution of feeding types



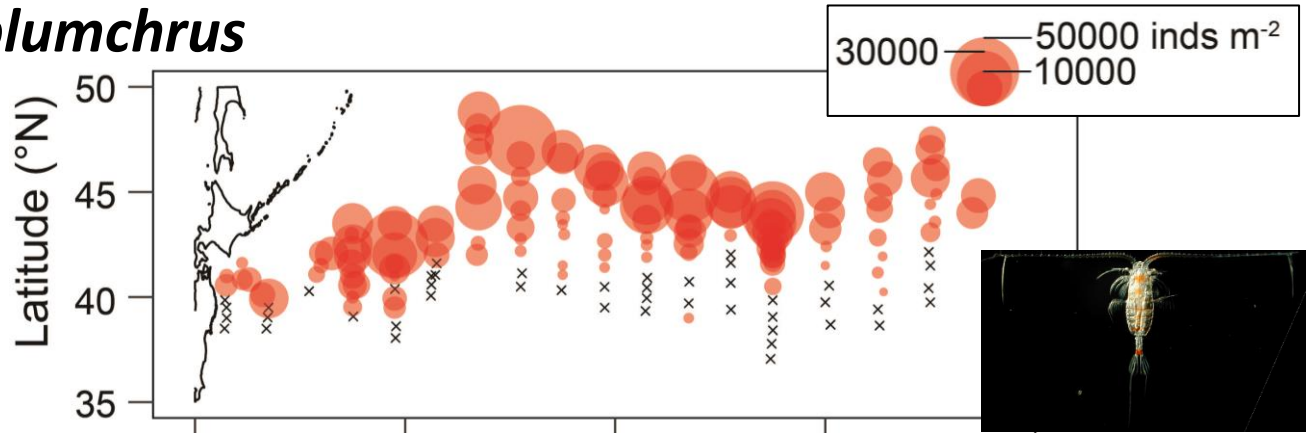


Pacific saury feeds on *Neocalanus* copepods in the cold water, subarctic water

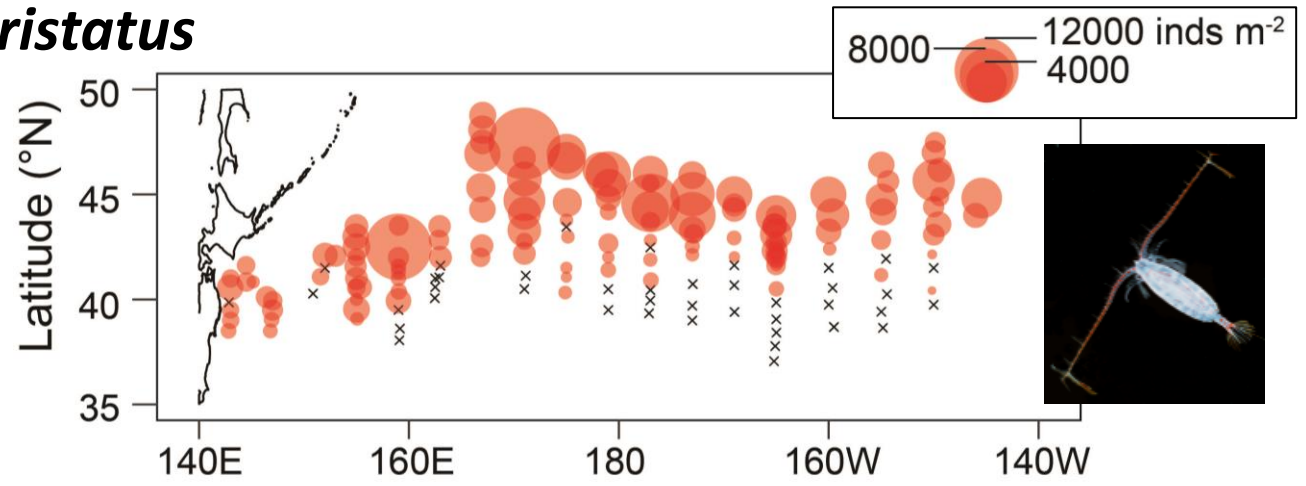
Horizontal distribution of *N. plumchrus* and *N. cristatus* in 2012 (upper 150 m layer tow of Plankton net)

NORPAC net
330 µm mesh

N. plumchrus



N. cristatus



Neocalanus copepods were mainly distributed in the north part of survey area

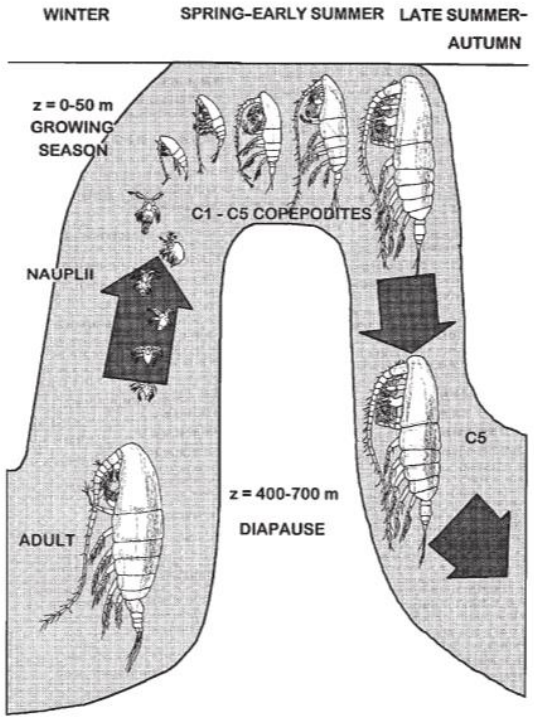
The feeding activity of Pacific saury is enhanced by encountering abundant Neocalanus in cold water.

Summary of the feeding habit of Pacific saury in early summer

- *Neocalanus plumchrus*, *N. cristatus*, *Calanus* and Euphausiids were main prey
- The gut fullness of Pacific saury was high when the fish feed on *Neocalanus* copepods
- Prey availability might be high in cold water due to *Neocalanus* copepods were mainly distributed in cold water

⇒ From May to August is important season for rapidly increasing their size by feeding on *Neocalanus* copepods abundantly.

⇒ These information might be useful for more efficient and appropriate exploitation/management strategy of Pacific saury.

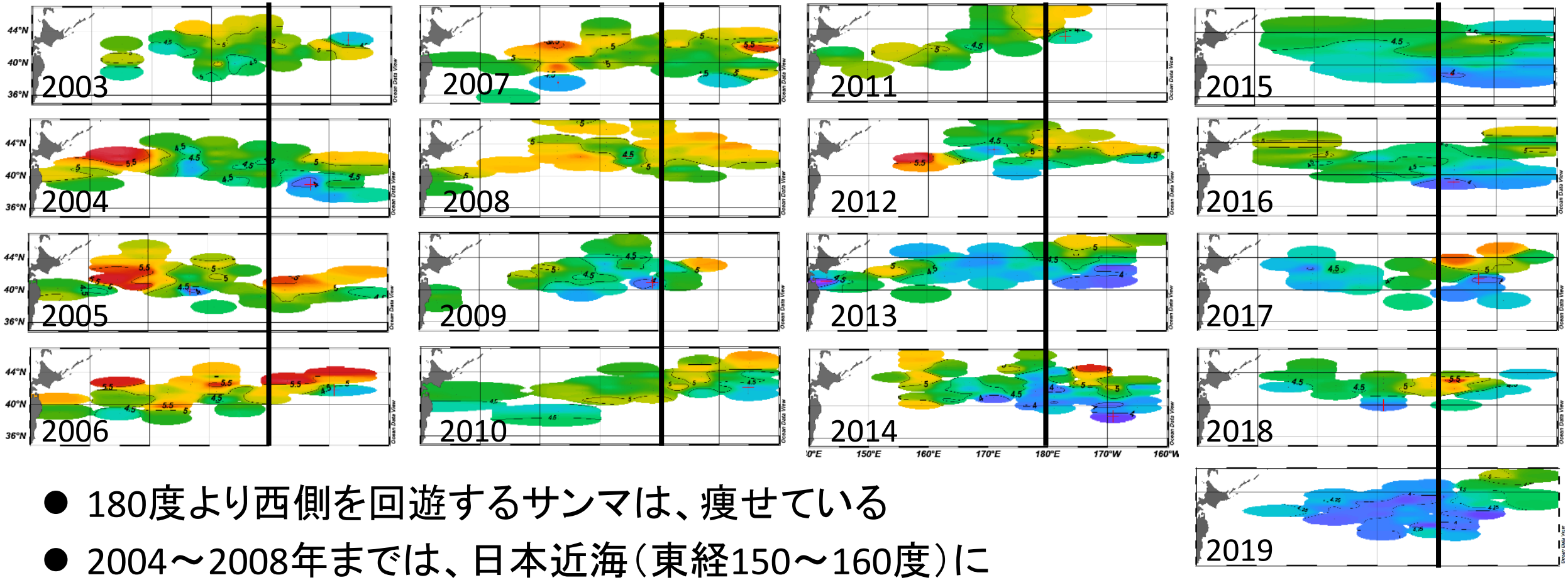


*N. plumchrus*の季節的鉛直移動

Mackas et al.1998

6～7月のサンマ資源量調査における1歳魚の肥満度の水平分布

暖色の方が寒色に比べて肥満度が高いことを示す



- 180度より西側を回遊するサンマは、痩せている
- 2004～2008年までは、日本近海（東経150～160度）に太ったサンマが出現したが最近は出現しない

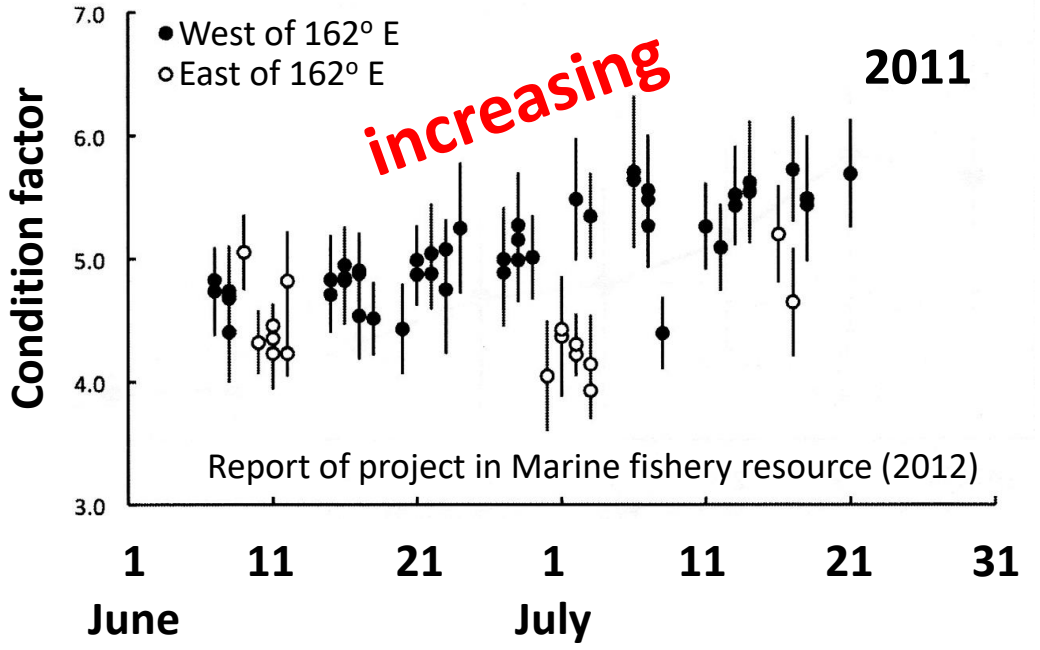
痩せてしまった要因の一つとして、食性や餌環境の変化が関連…？

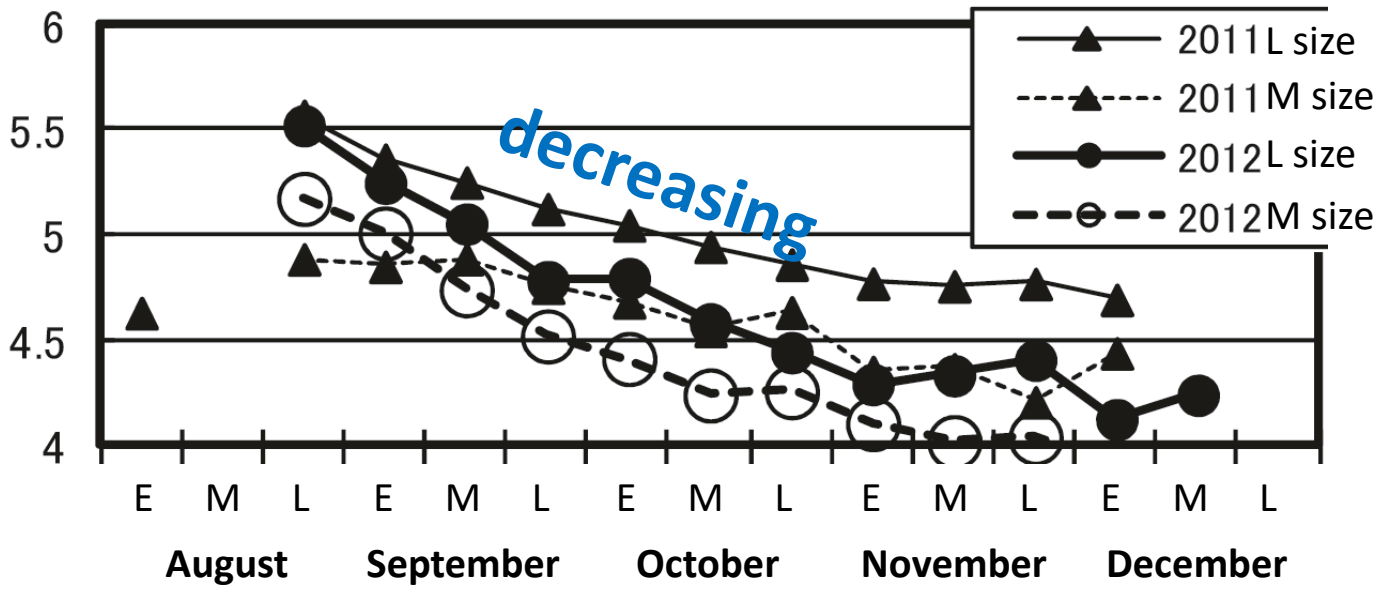
Seasonal change of condition factor (fatness)

Condition factor = weight / length^3 × 10^3

Northward feeding migration

Southward spawning migration

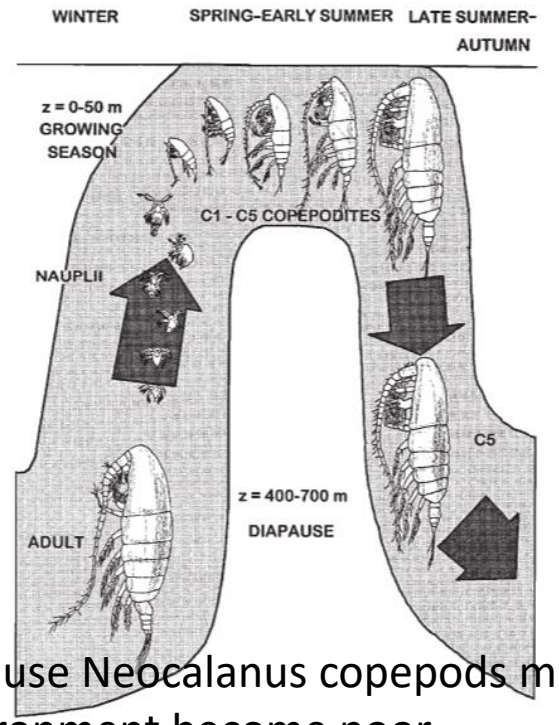


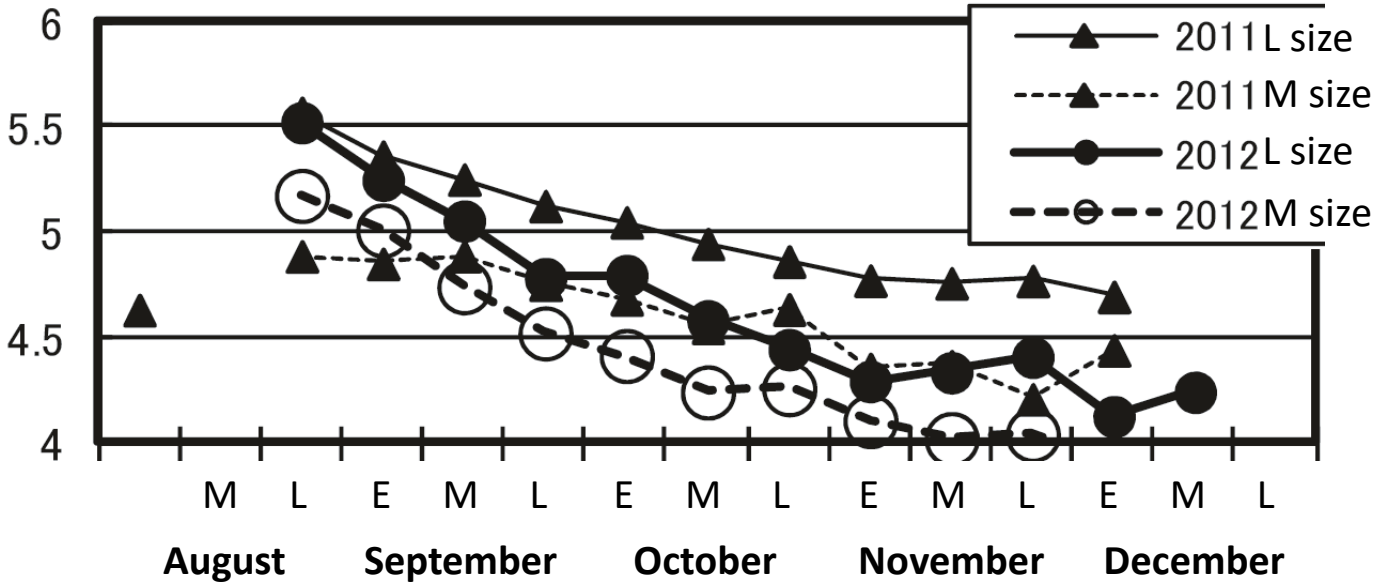


Annual Report of the research meeting on saury resource (2013)

(Fish length and weight tend to increase 2cm and 20 g from stock assessment cruise to fisheries season, respectively)

- Condition factor increases during the northward feeding migration

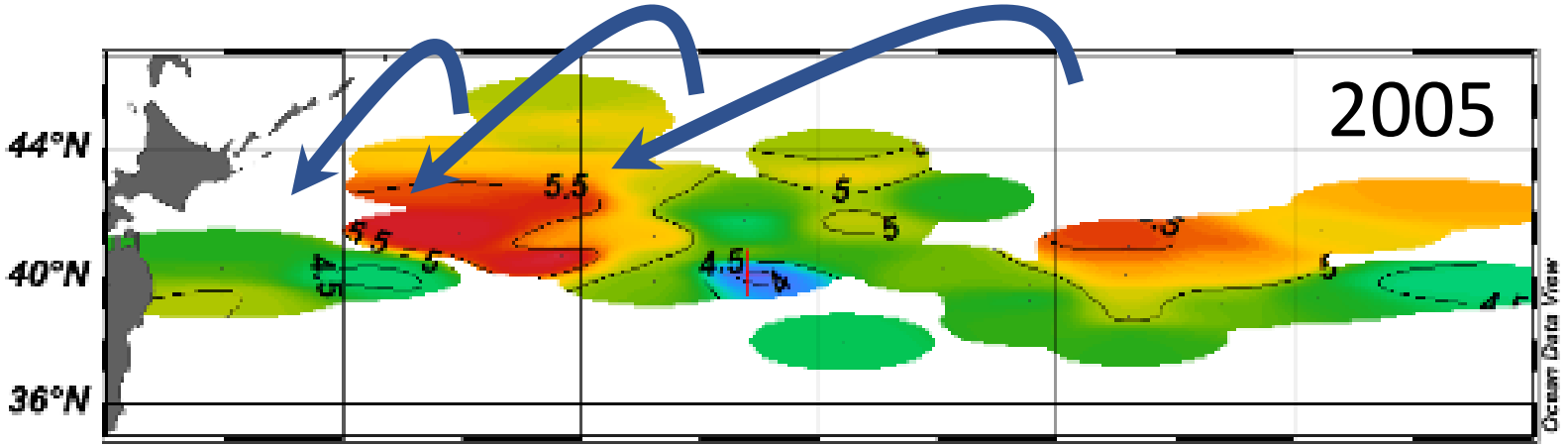




Annual Report of the research meeting on saury resource (2013)

Because Neocalanus copepods migrate to deep water, the feeding environment become poor.
After August, the growth of Pacific saury might be slow.

After August, condition factor is decreasing



Horizontal distribution of condition factor of Age1 fish in stock assessment cruise

But because this trend might be influenced by the longitudinal difference of condition factor, we need a special care to understand this trend.