A matter of size and season: insights into planktonic food-web dynamics in a temperate coastal ecosystem

Carolina Giraldo[1*], Pierre Cresson[1], Kirsteen MacKenzie[1], Virginie Fontaine[1,2], Christophe Loots[1], Alice Delegrange[2] & Sébastien Lefebvre[2]

[1] IFREMER, HMMN – Unité halieutique Manche-Mer du Nord, 62200 Boulogne sur mer, France

[2]Univ. Lille, CNRS, Univ. Littoral Côte d'Opale, IRD, UMR 8187 – LOG – Laboratoire d'Océanologie et de Géosciences, F-59000 Lille, France

INTRODUCTION

Lower trophic levels organisms, and in particular zooplankton, are key components of marine food-webs and play an essential role in nutrient cycles, transfer of energy to upper trophic levels, and fish recruitment trough larval fish survival.

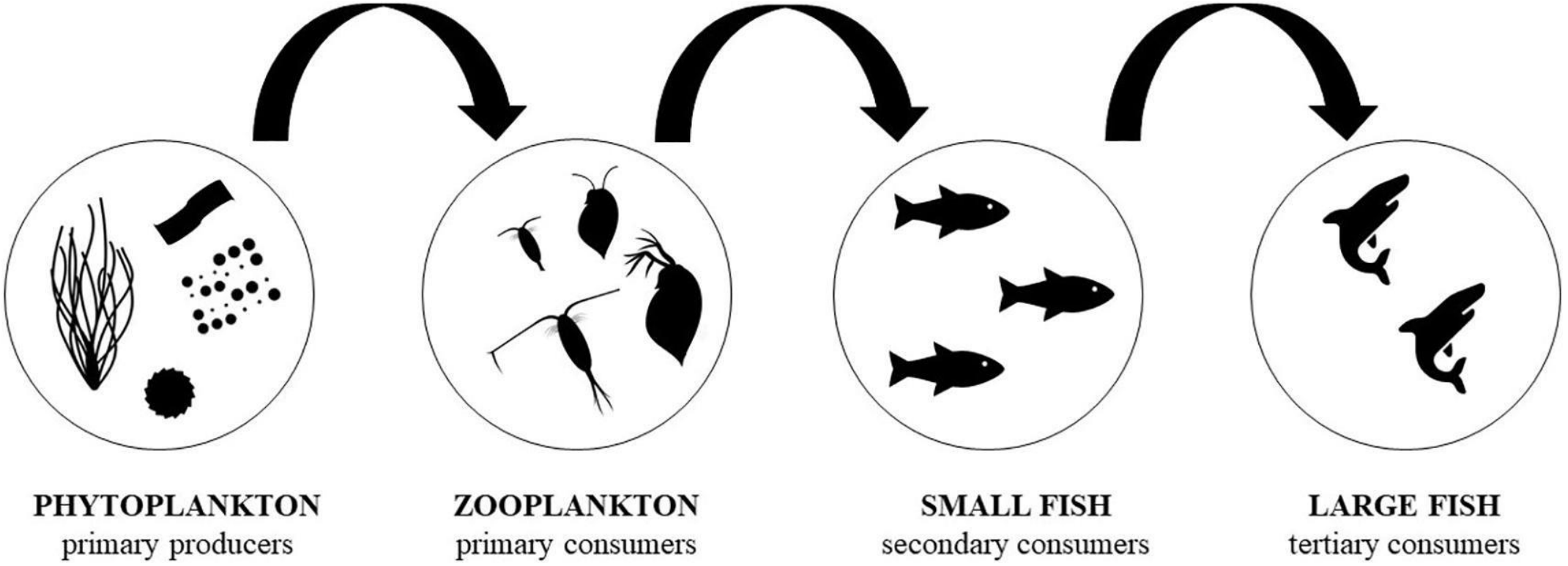
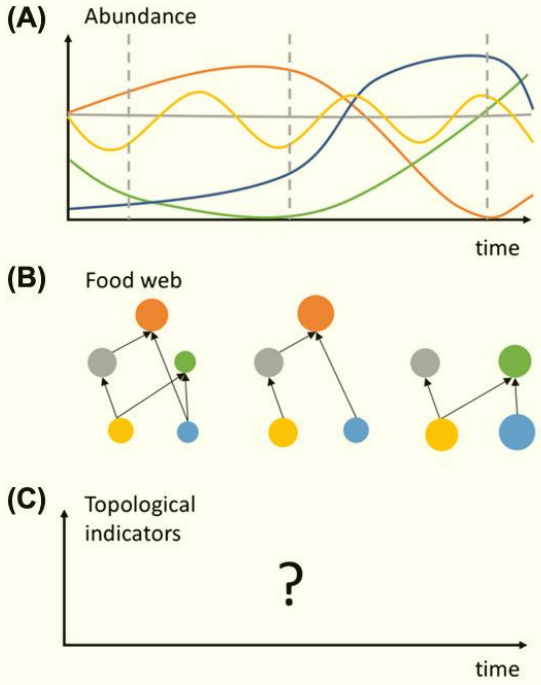


Image From: The key role of zooplankton in ecosystem services: A perspective of interaction between zooplankton and fish recruitment. Lomartire et al. (2021).

INTRODUCTION

SEASON

Seasonal fluctuations are expected to be one of the main drivers of variation within plankton food-webs

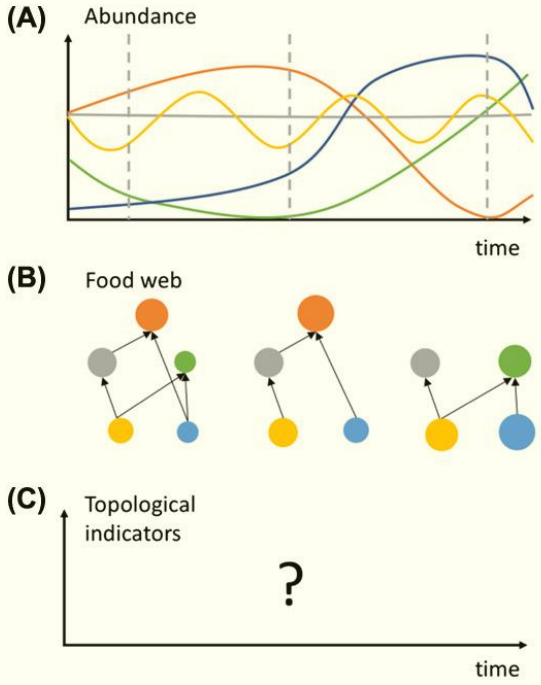


Olivier, P. et al. (2019). Exploring the temporal variability of a food web using long-term biomonitoring data. Ecography.

INTRODUCTION

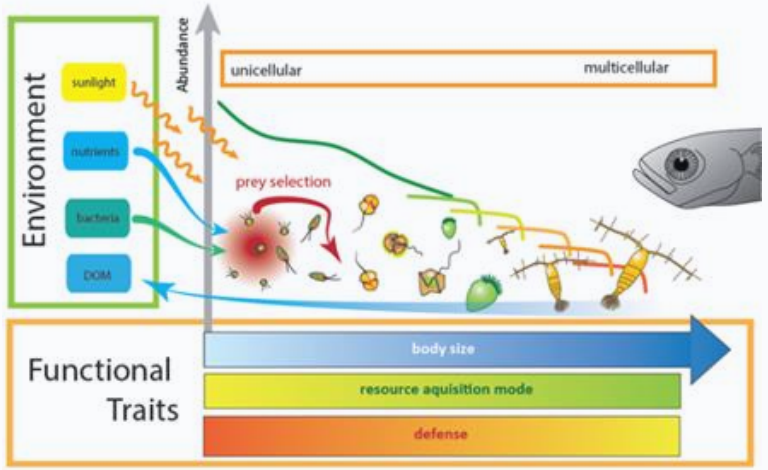
SEASON

Seasonal fluctuations are expected to be one of the main drivers of variation within plankton food-webs



SIZE

Pelagic food-webs are size-structured. Body size determines predator-prey interactions (on average predators are x10 bigger than their prey)



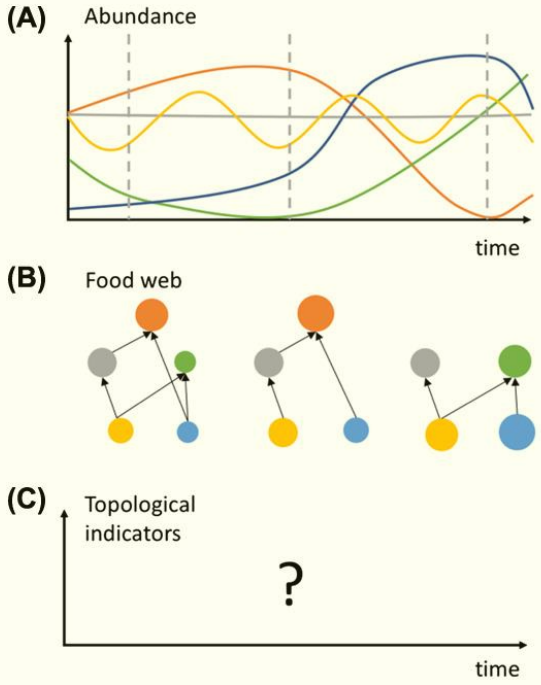
Olivier, P. et al. (2019). Exploring the temporal variability of a food web using long-term biomonitoring data. Ecography.

https://www.mecano-plankton.dk/project/community

INTRODUCTION

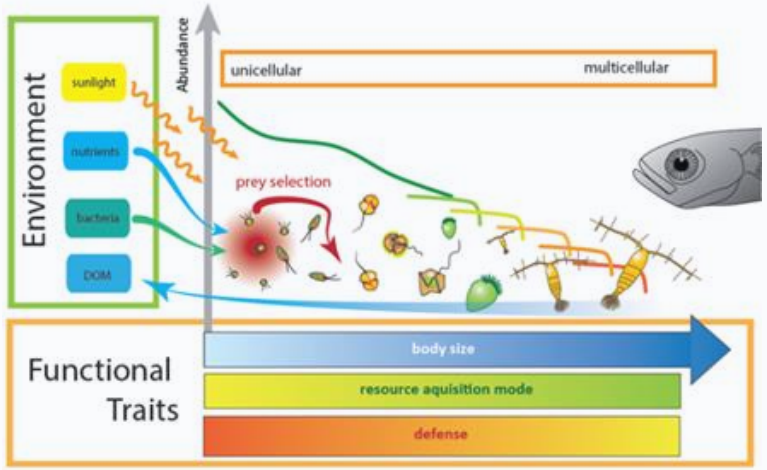
SEASON

Seasonal fluctuations are expected to be one of the main drivers of variation within plankton food-webs



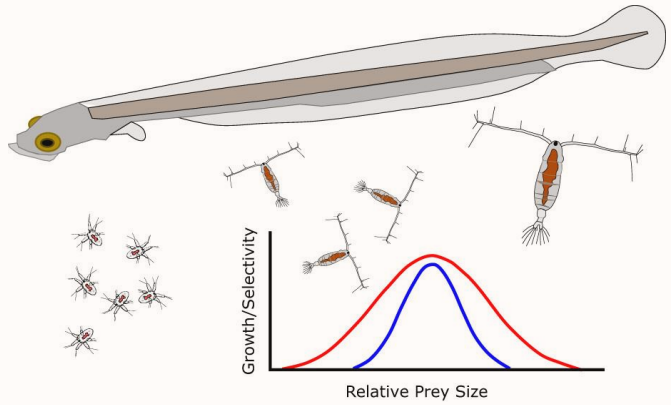
SIZE

Pelagic food-webs are size-structured. Body size determines predator-prey interactions (on average predators are x10 bigger than their prey)



FEEDING STRATEGIES

Optimal foraging in marine fish larvae Trophic divergence (varying or divergent trophic roles among different species) vs trophic similarity.



Olivier, P. et al. (2019). Exploring the temporal variability of a food web using long-term biomonitoring data. Ecography.

https://www.mecano-plankton.dk/project/community

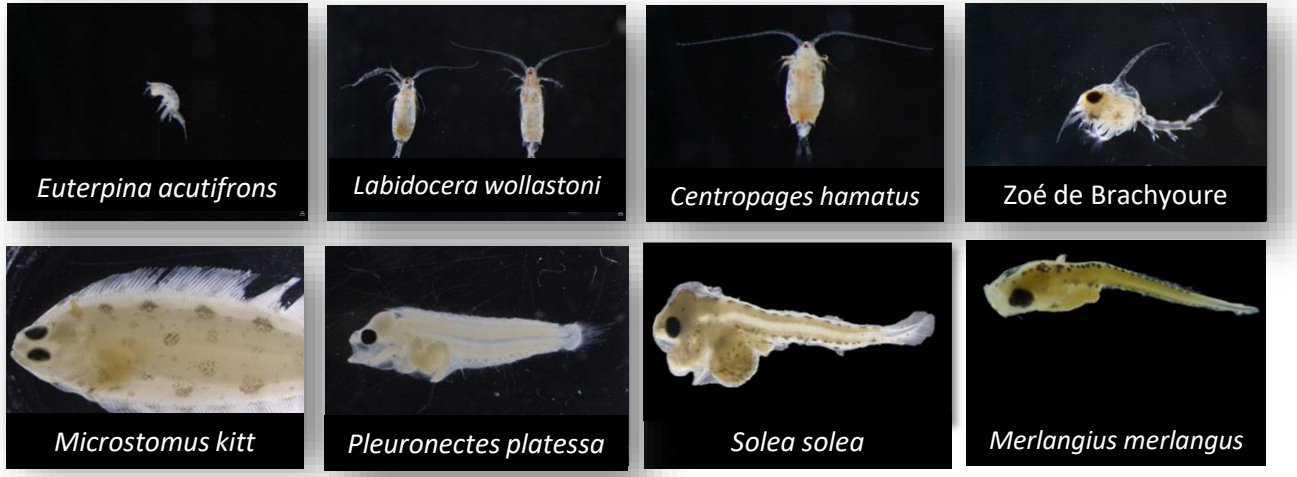
Hauss, H, Schwabe, L., & Peck, M A (2023). The costs and trade-offs of optimal foraging in marine fish larvae. Journal of Animal Ecology, 92(5), 1016-1028.

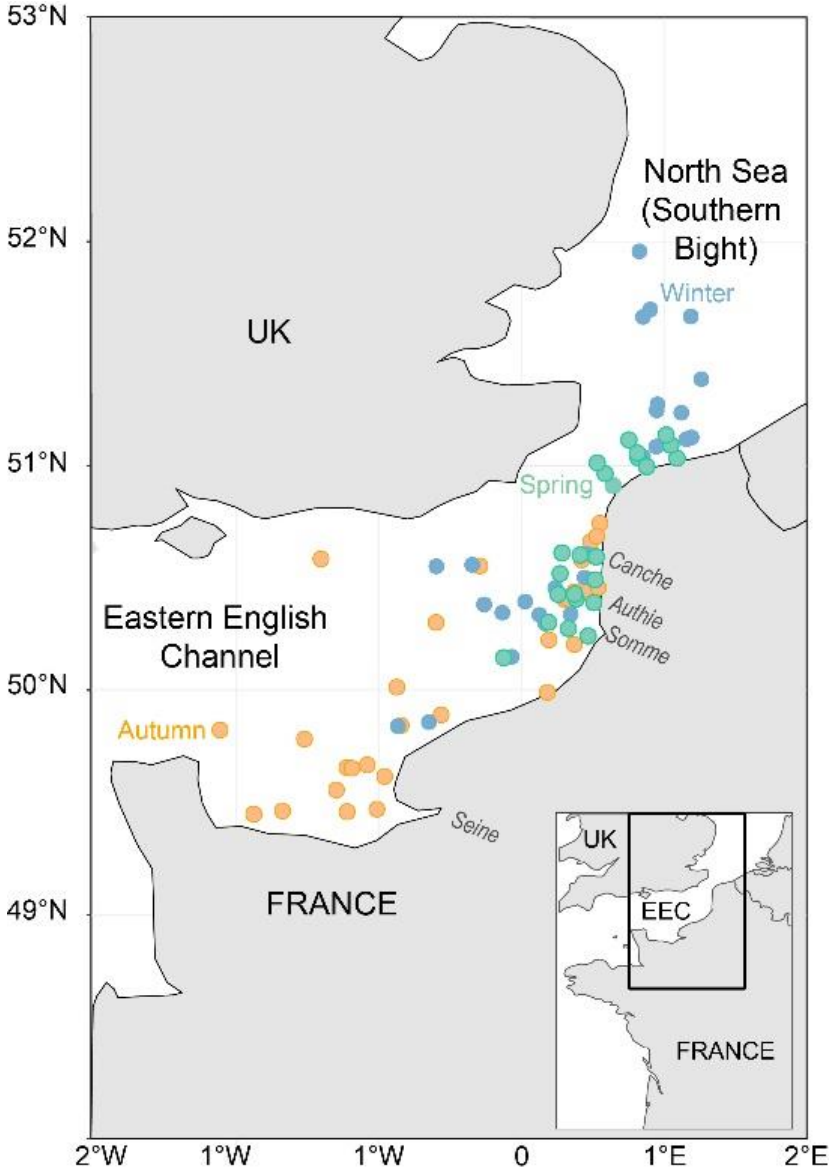
OBJECTIVES

To investigate the **seasonal dynamics of plankton food-web size-structure in a coastal ecosystem** using opportunistic sampling from oceanographic cruises

More specifically, we aimed to:

1. Explore how the planktonic food-web structure and functioning respond to changes in productivity
2. Determine how seasonal variations influence food-web topology and the main energy fluxes for predatory plankton, particularly fish larvae.





DATA: Species composition, size (mm), and stable isotopic signatures ($\delta^{13}C$, $\delta^{15}N$) for 18 taxa of mesozooplankton and 13 taxa of fish larvae collected in winter, spring, and autumn for a total of **552 measurements**.

SEASONAL VARIATIONS AND SIZE-STRUCTURE

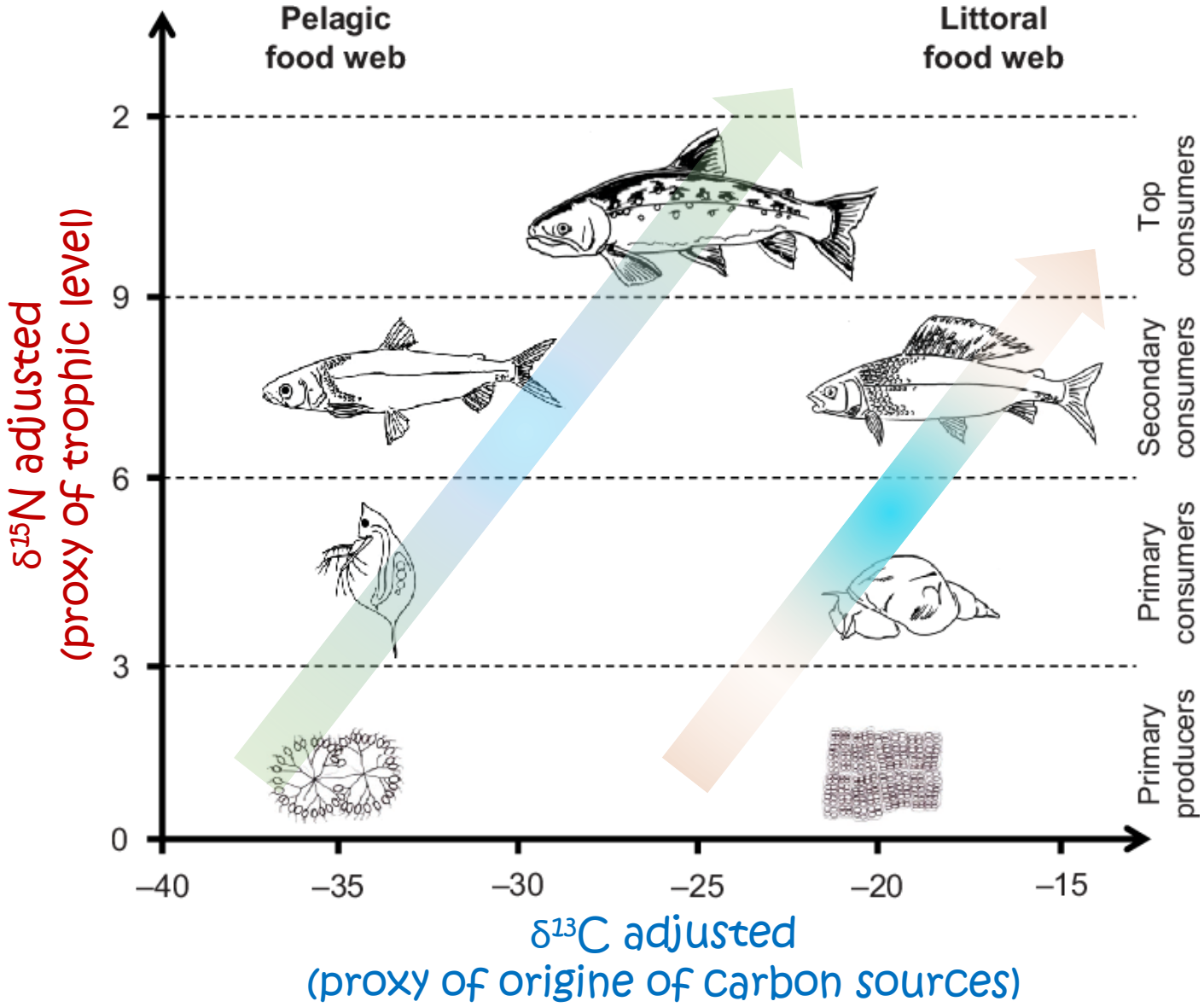


Image modified from From: Eloranta, A. (2013). The variable position of Arctic charr *(Salvelinus alpinus (L.))* in subarctic lake food webs. *Jyväskylä studies in biological and environmental science*, (261).

SEASONAL VARIATIONS AND SIZE-STRUCTURE

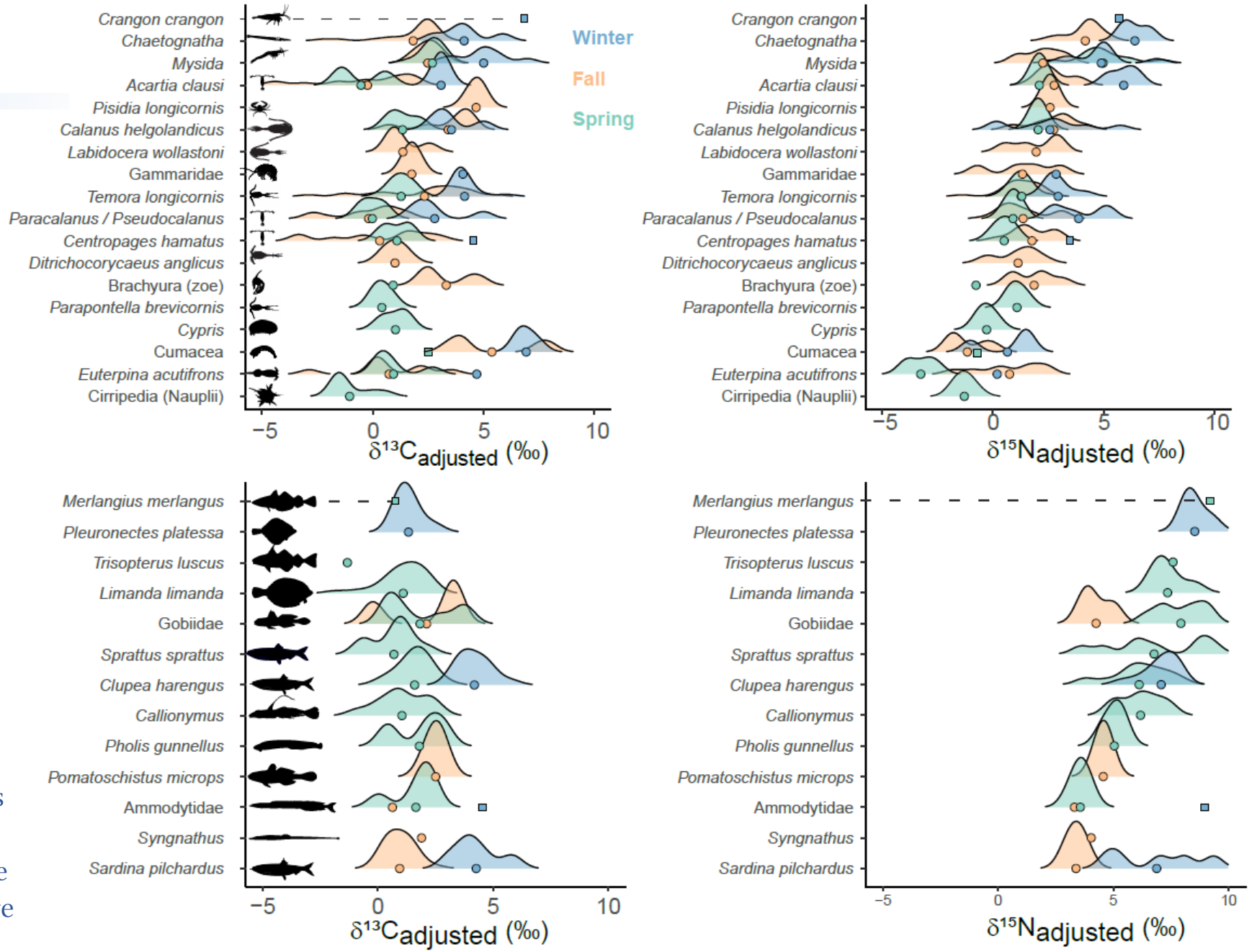


Figure 2 : Variability (seasonal, inter, and intra-specific) of plankton on baseline-adjusted isotopes values in the EEC. Species are ordered based on their averaged $\delta^{15}N_{adjusted}$ values. Seasonal mean values are illustrated by dots. Unique values (if n=1) are illustrated by squares.

NICHE SPACE: TROPHIC DIVERGENCE VS TROPHIC SIMILARITY

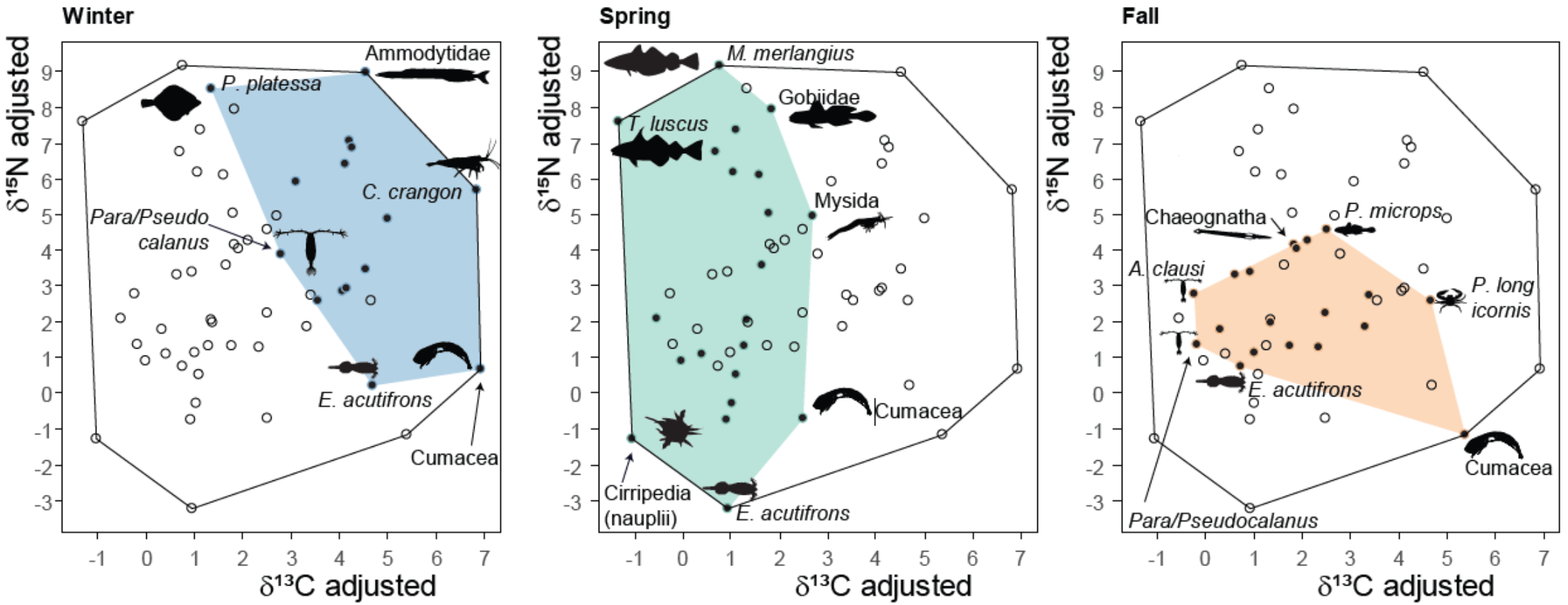


Figure 3: Seasonal variation of the isotopic niche space occupied by the plankton community in the EEC. The black polygon illustrates the overall theoretical isotopic niche space (equivalent of the richness isotopic functional diversity metric), which can be compared to the seasonal realized niches (in blue, green, and orange for winter, spring, and autumn, respectively). Seasonal data are represented as black dots, and species at the edges, reflecting those with a higher trophic divergence, are identified.

SEASONAL VARIATIONS AND SIZE-STRUCTURE

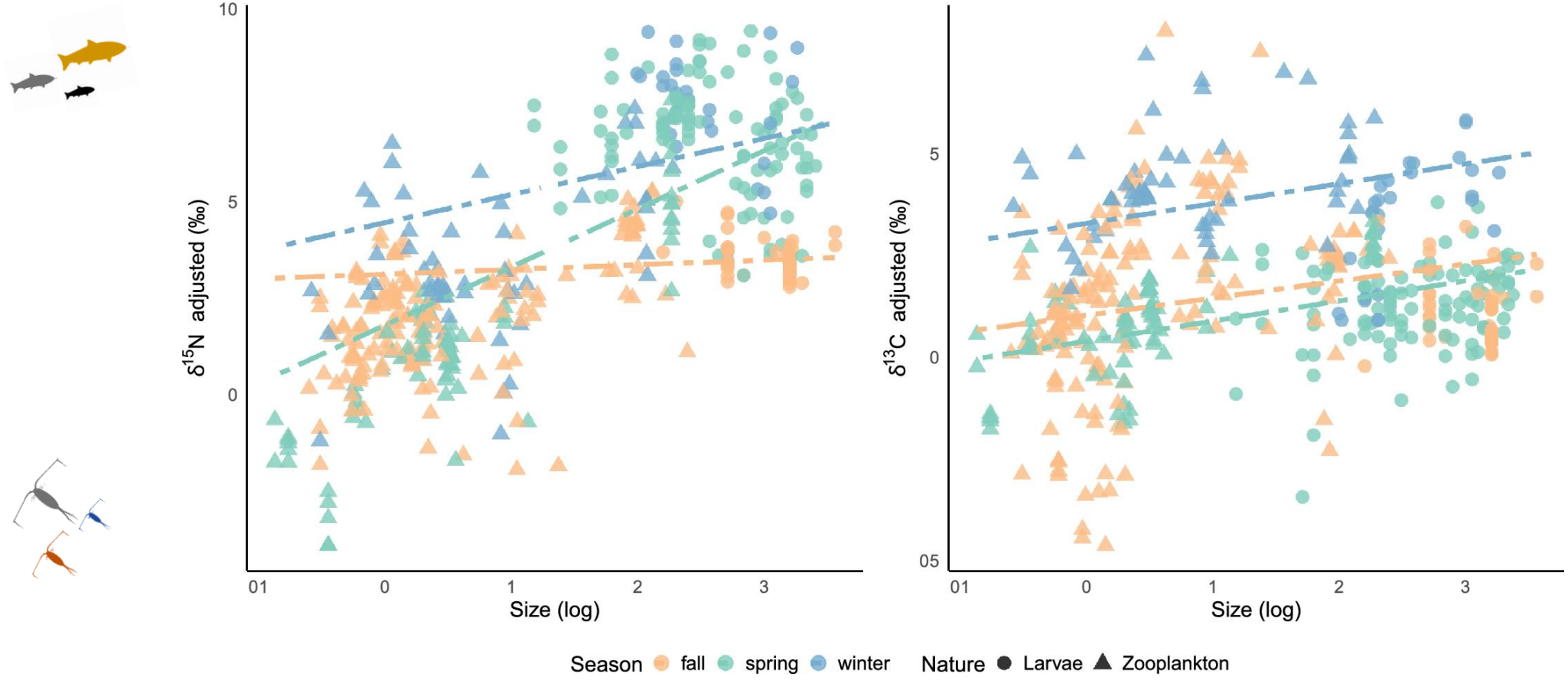


Figure 4: Seasonal and size effects on $\delta^{15}N_{adjusted}$ and $\delta^{13}C_{adjusted}$ values of the plankton community. Lines represent the predicted values of the Linear Mixed Effect Models with "*Season*" and "*size*" as fixed factors and a nested structure of "*Species/size*" as a random effect. Zooplankton values are illustrated as triangles, and fish larvae are represented as circles, colored according to the season.

FOOD-WEB TOPOLOGY AND ENERGY FLUXES

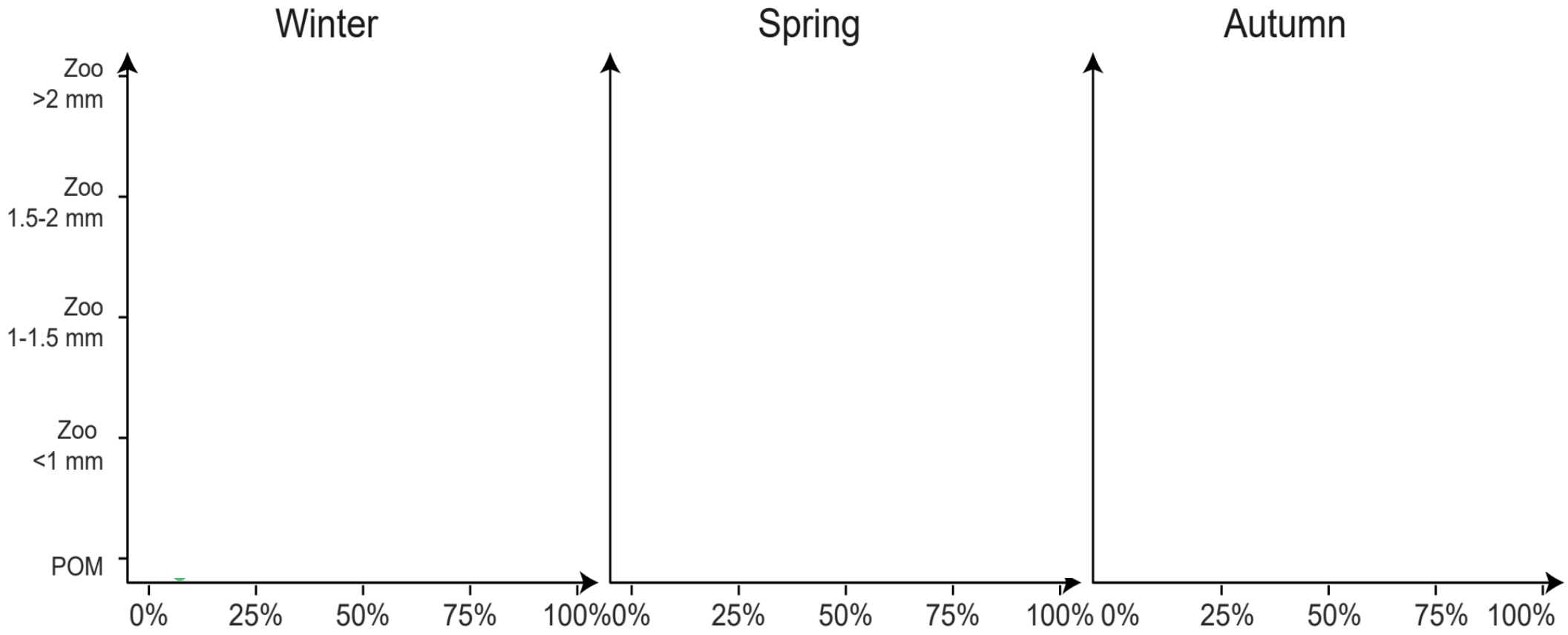


Figure 5: Diet composition (% diet) of plankton size-classes to predatory plankton. Values represent mean values and standard deviation posterior distributions of the MixSIAR Baysian models. Smooth dashed lines are for illustration purposes only and highlight main patterns or dominant size-classes to the diet.

FOOD-WEB TOPOLOGY AND ENERGY FLUXES

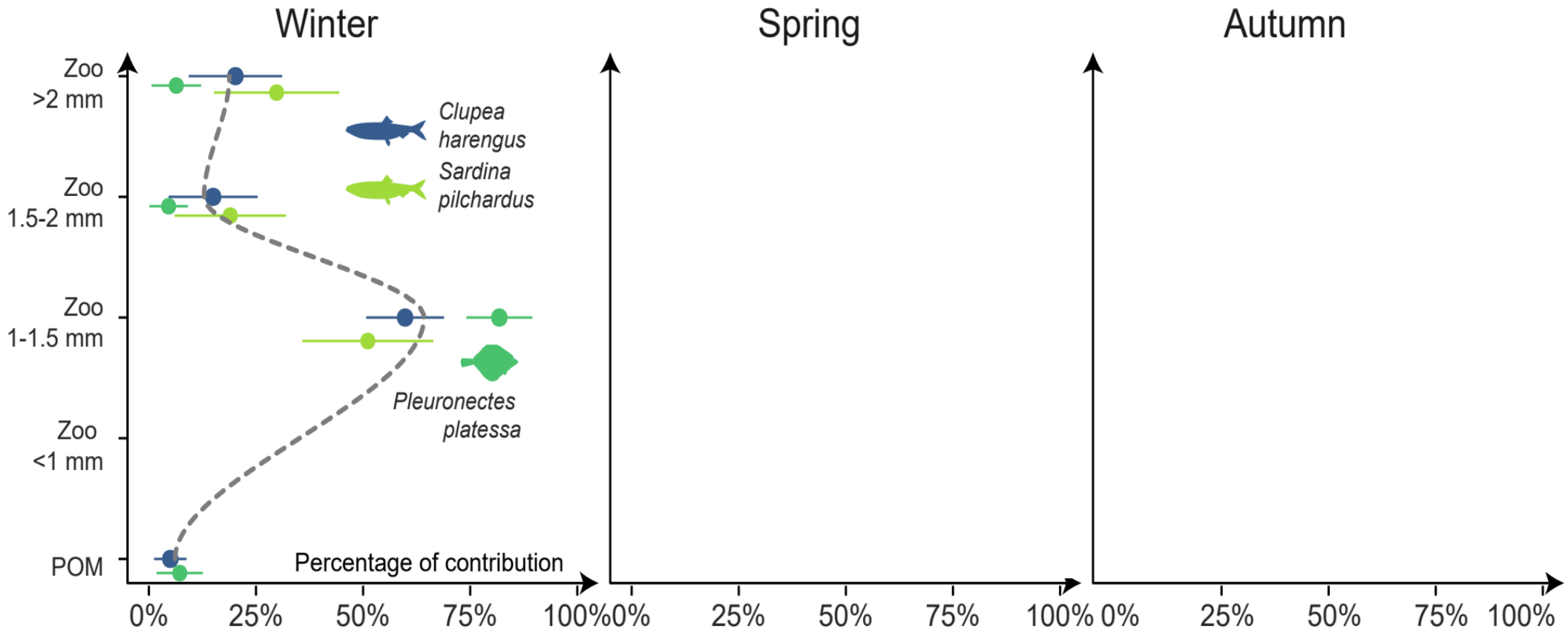


Figure 5: Diet composition (% diet) of plankton size-classes to predatory plankton. Values represent mean values and standard deviation posterior distributions of the MixSIAR Baysian models. Smooth dashed lines are for illustration purposes only and highlight main patterns or dominant size-classes to the diet.

FOOD-WEB TOPOLOGY AND ENERGY FLUXES

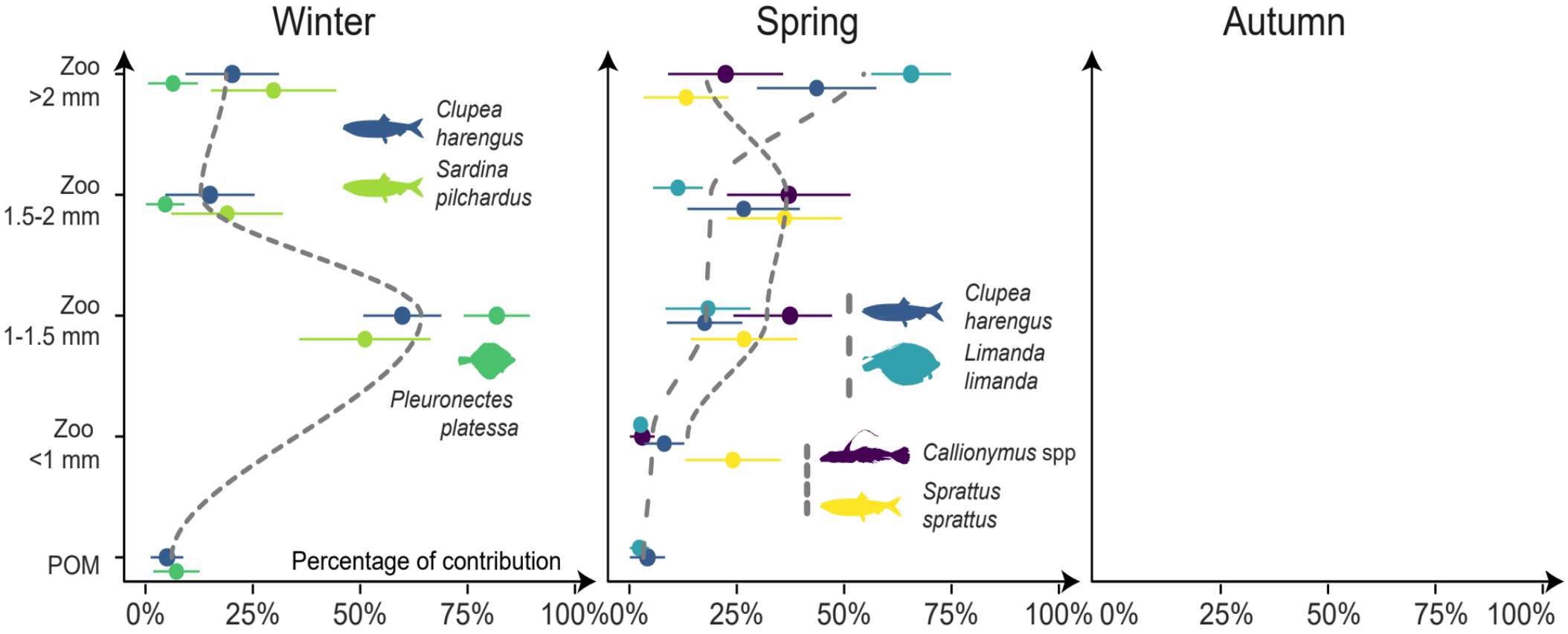


Figure 5: Diet composition (% diet) of plankton size-classes to predatory plankton. Values represent mean values and standard deviation posterior distributions of the MixSIAR Baysian models. Smooth dashed lines are for illustration purposes only and highlight main patterns or dominant size-classes to the diet.

FOOD-WEB TOPOLOGY AND ENERGY FLUXES

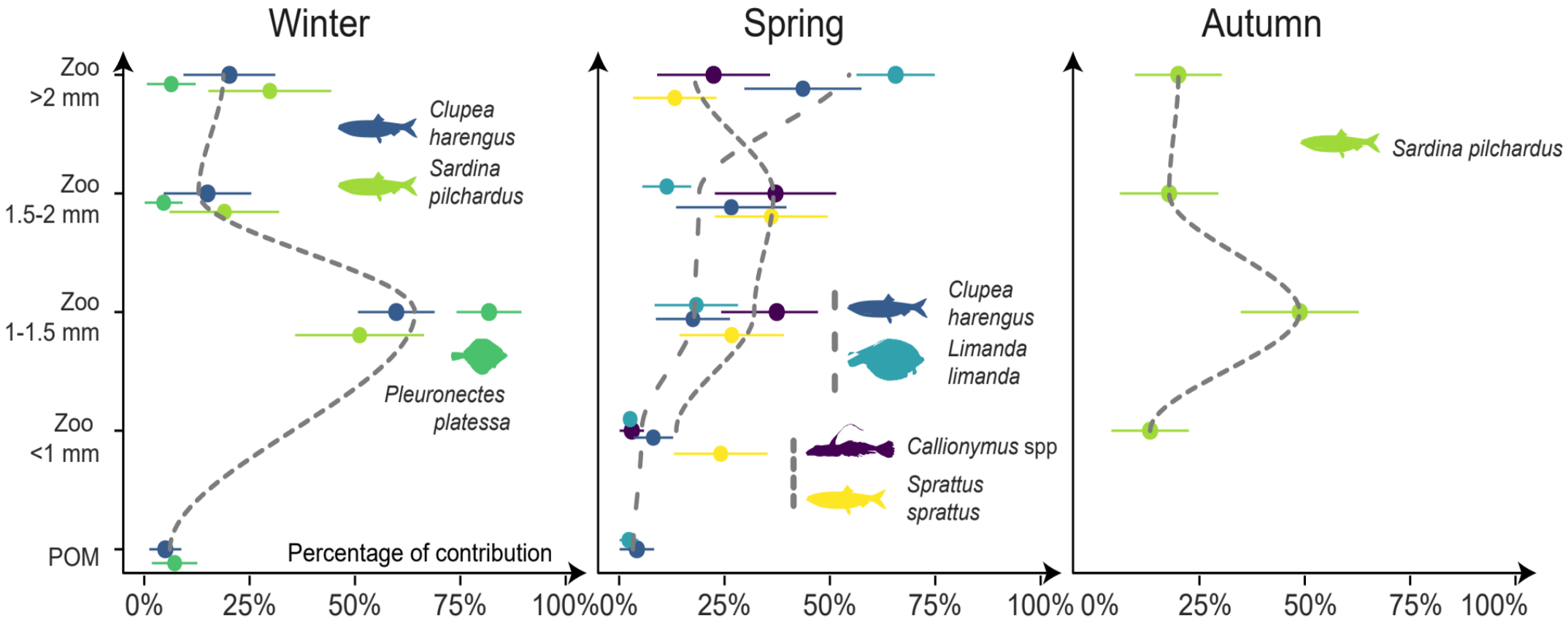
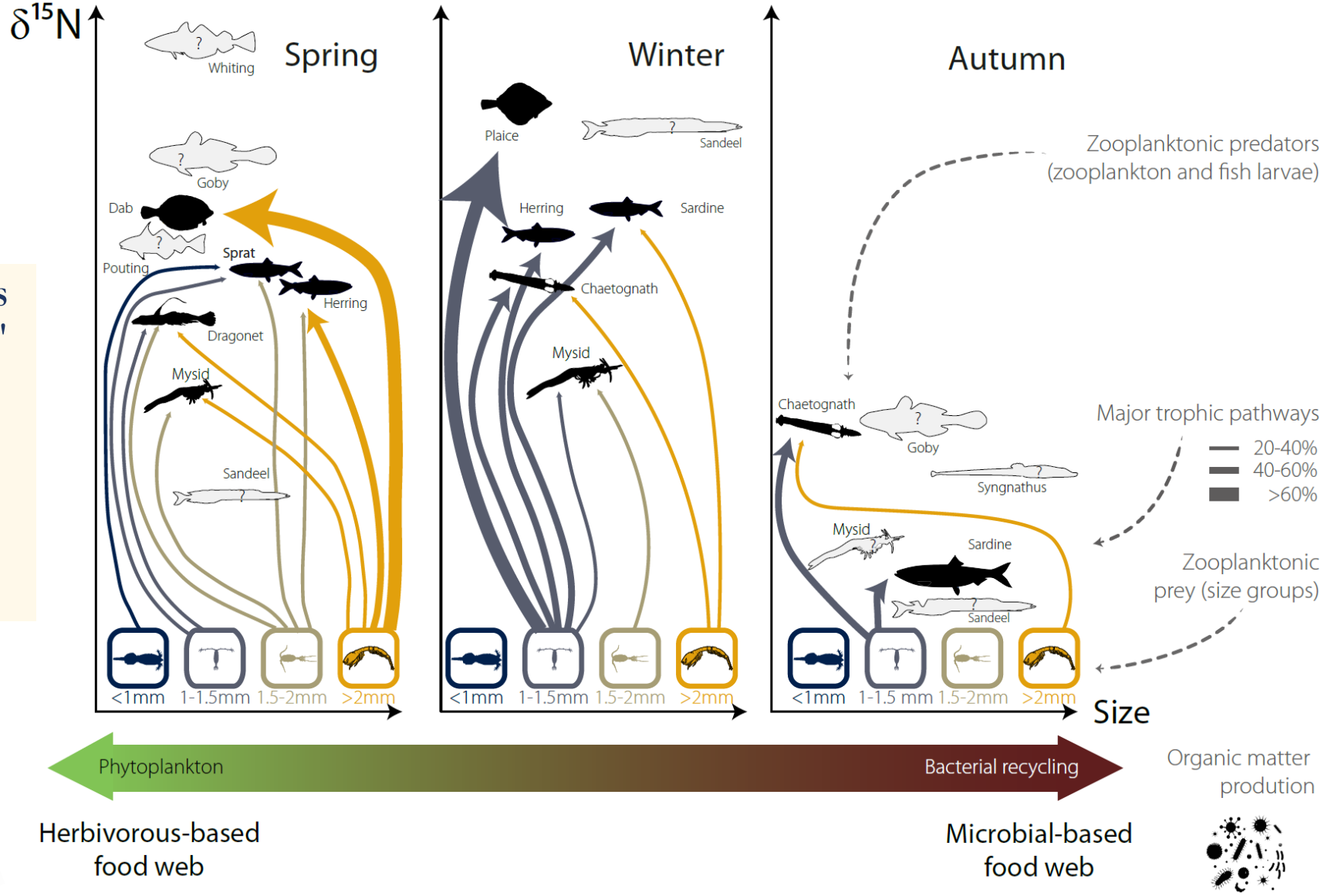


Figure 5: Diet composition (% diet) of plankton size-classes to predatory plankton. Values represent mean values and standard deviation posterior distributions of the MixSIAR Baysian models. Smooth dashed lines are for illustration purposes only and highlight main patterns or dominant size-classes to the diet.

CONCLUSION

...a continuum of trophic structures where 'herbivorous-based food-webs' vs 'microbial-based food-webs' represent only extreme configurations of the transient nature of a single planktonic food web (Legendre & Rassoulzadegan 1995).

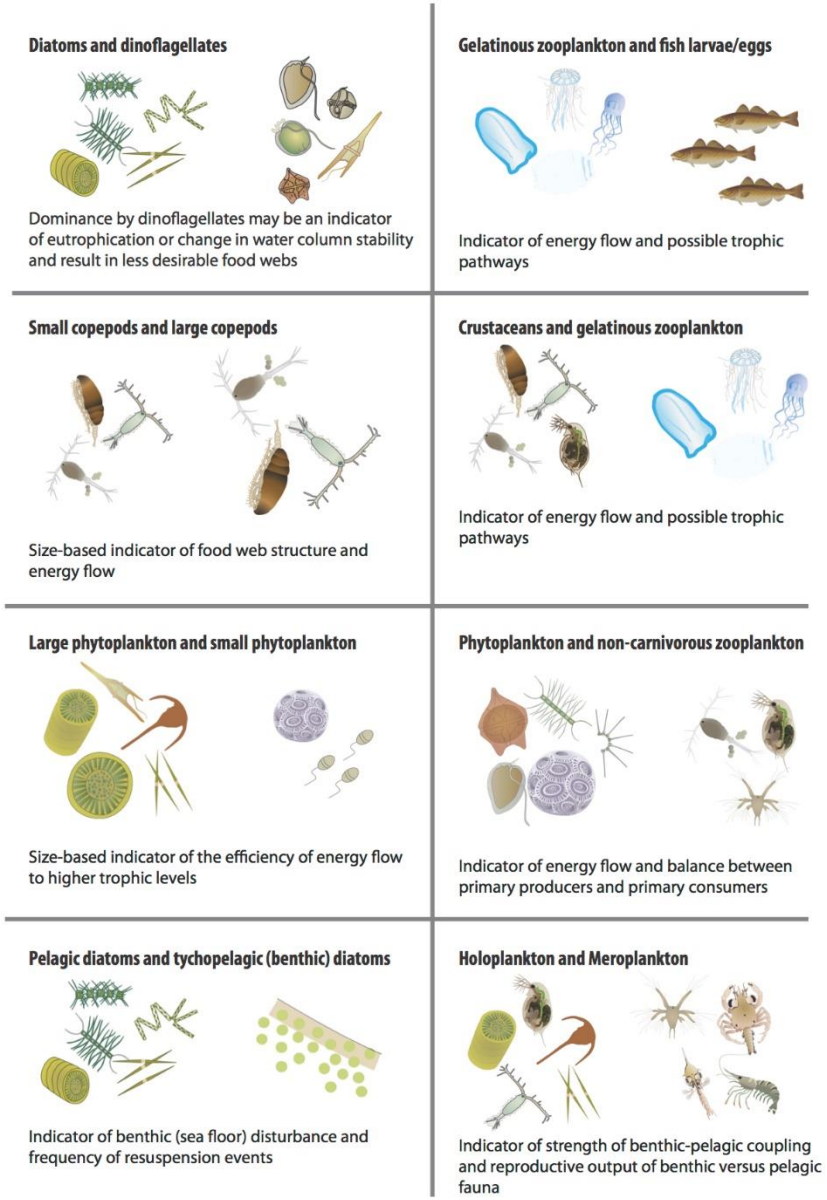


REMAINING KNOWLEDGE GAPS AND FUTURE DIRECTIONS

- Other sources of variation:
  - ✓ There are multiple sources of variation and uncertainties when using stable isotopes to elucidate trophic patterns. For instance, possible inter-annual variations on plankton stable isotopes were not explored in this study because of data limitations.
- Missing species:
  - ✓ Copepods represent the majority (~90%) of the mesozooplankton in the EEC. However, gelatinous zooplankton (Cnidaria, Ctenophora, Tunicata) are also frequently encountered, and can occasionally occur in large numbers with biomass exceeding that of fish in oligotrophic waters.

Joint information on crustaceans, gelatinous zooplankton and ichthyoplankton can be used as indicators of energy flow and trophic pathways, which should inform on how planktonic communities respond to environmental changes.

(e.g. OSPAR indicators, Marine Strategy Framework Directive-D1—Biological Diversity D4—Marine Food-webs, https://oap.ospar.org/).



Plankton lifeform pairs and ecological rationale for their selection.
Courtesy of the Integration and Application Network, University of Maryland Center for Environmental Science (ian.umces.edu/symbols/).

Thank you !

Sample sorting and preparation would not have been possible without the invaluable aid of technicians from the Trophic and Ichthyoplankton laboratories at IFREMER (**Margaux Denamiel, Josselin Caboche, Valerie Lefebvre, Fabien Lebon and Clemence Couvreur**). We would like to express our gratitude to **Dr. Elvire Antajan** for her valuable contributions to this project, including her expertise in species identification of zooplankton.

This project was founded by the IFREMER Scientific Direction through the project "FORESEA" as well as the project "MURPHY" (MUltitRoPHic biodiversity) to encourage local collaborations between the IFREMER Centre Manche Mer du Nord and the Laboratoire d'Océanologie et de Géosciences UMR 8187. Additional support was provided by the French government and the region Hauts-de-France in the framework of the projects CPER MARCO 2014–2020, the CPER IDEAL (2021-2027) and the research federation "SFR Campus de la mer". This work is also supported by the graduate school IFSEA that benefits from a France 2030 Grant (ANR-21-EXES-0011) operated by the French National Research Agency.