Increased sea ice cover disrupts food web structure in Antarctic coastal benthic ecosystem

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Sea ice in Antarctica

Sea ice is a major environmental driver of ecological processes in Antarctica

- Water column mixing
- Benthic-pelagic coupling
- Niche partitioning
- Benthic community structure
- …

Image: NASA

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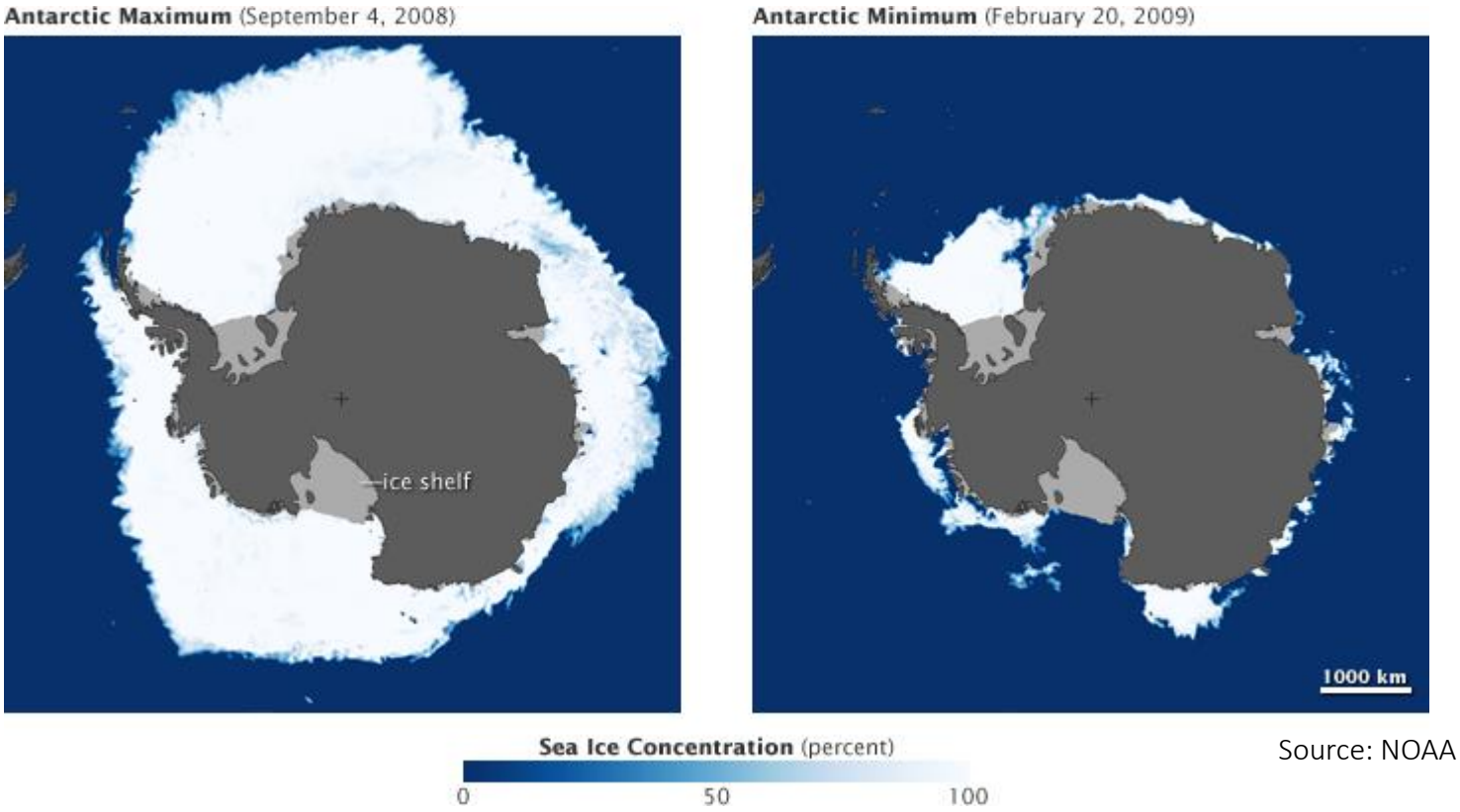
- …

Sea ice is a highly dynamic system

Image: NASA

Seasonal patterns of sea ice cover



Source: NOAA

Normal cycle:

Austral winter
Thick sea ice cover

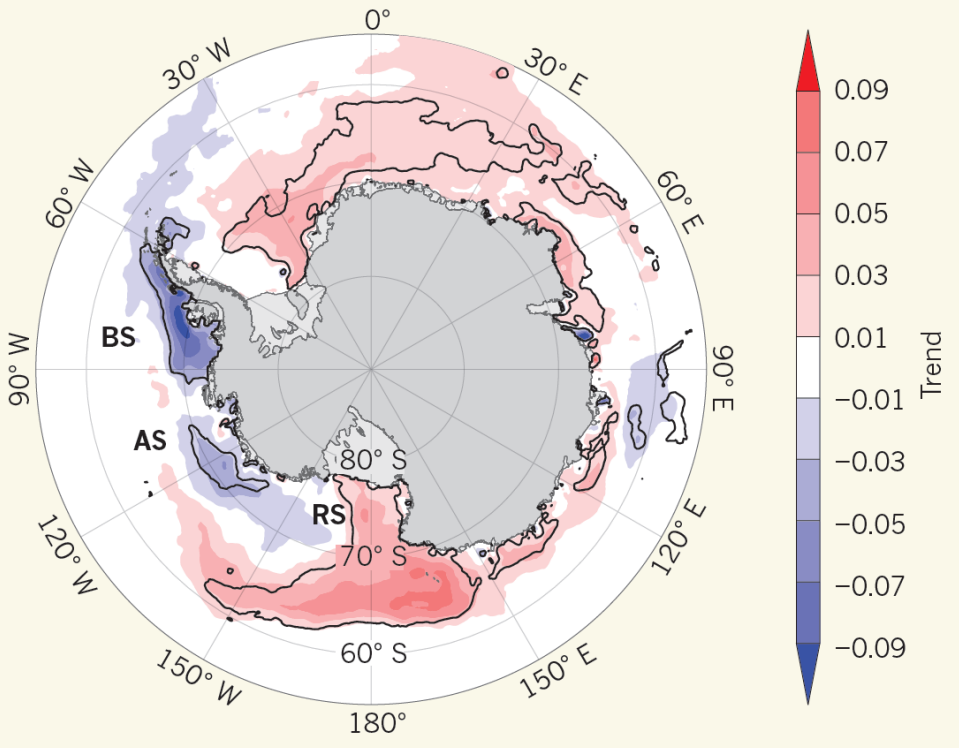
Austral summer
Thinning and breakup of sea ice

Changes in Antarctic sea ice cover

Climate change causes contrasted changes in sea ice cover in Antarctica

Spatial extent

Changes in sea ice concentration



From King (2014), Nature 505: 491-492.
(Data 1979-2012)

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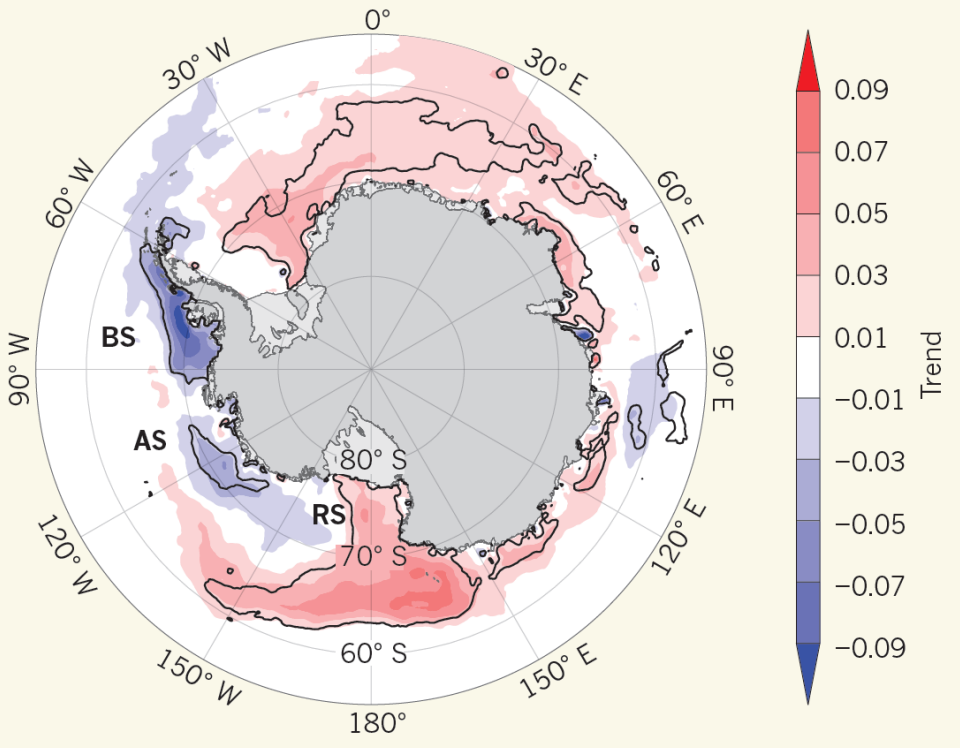
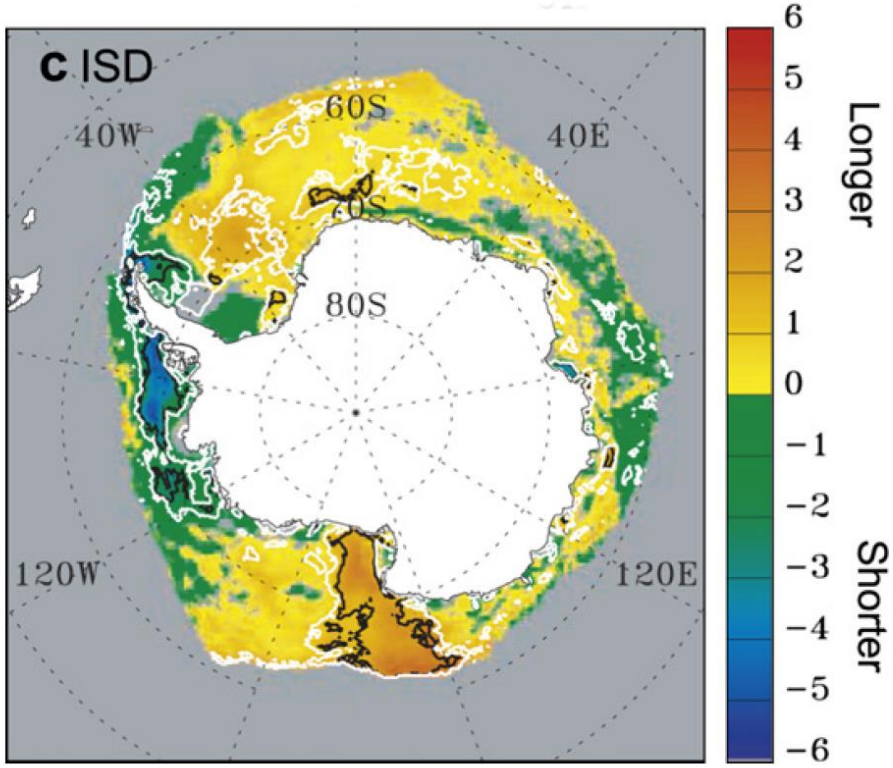


From King (2014), Nature 505: 491-492.
(Data 1979-2012)

Temporal extent

Changes in sea ice season duration



From Massom & Stammerjohn (2010), Pol . Sci. 4: 149-186
(Data 1979 -2004)

Study site: Dumont d'Urville station

East Antarctica, Adélie Land
Petrels Island

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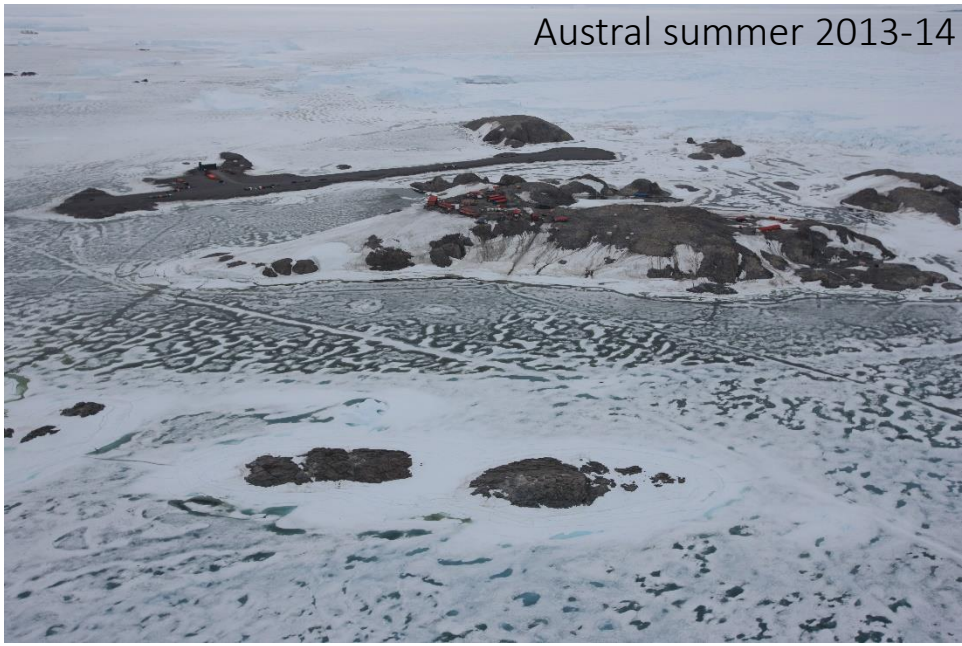
East Antarctica, Adélie Land
Petrels Island

2013-2015: Event of high spatial and temporal sea ice coverage

No seasonal breakup during austral summers 2013-14 and 2014-15



Study site: Dumont d'Urville station

Time of sampling : Austral summer 2014-15

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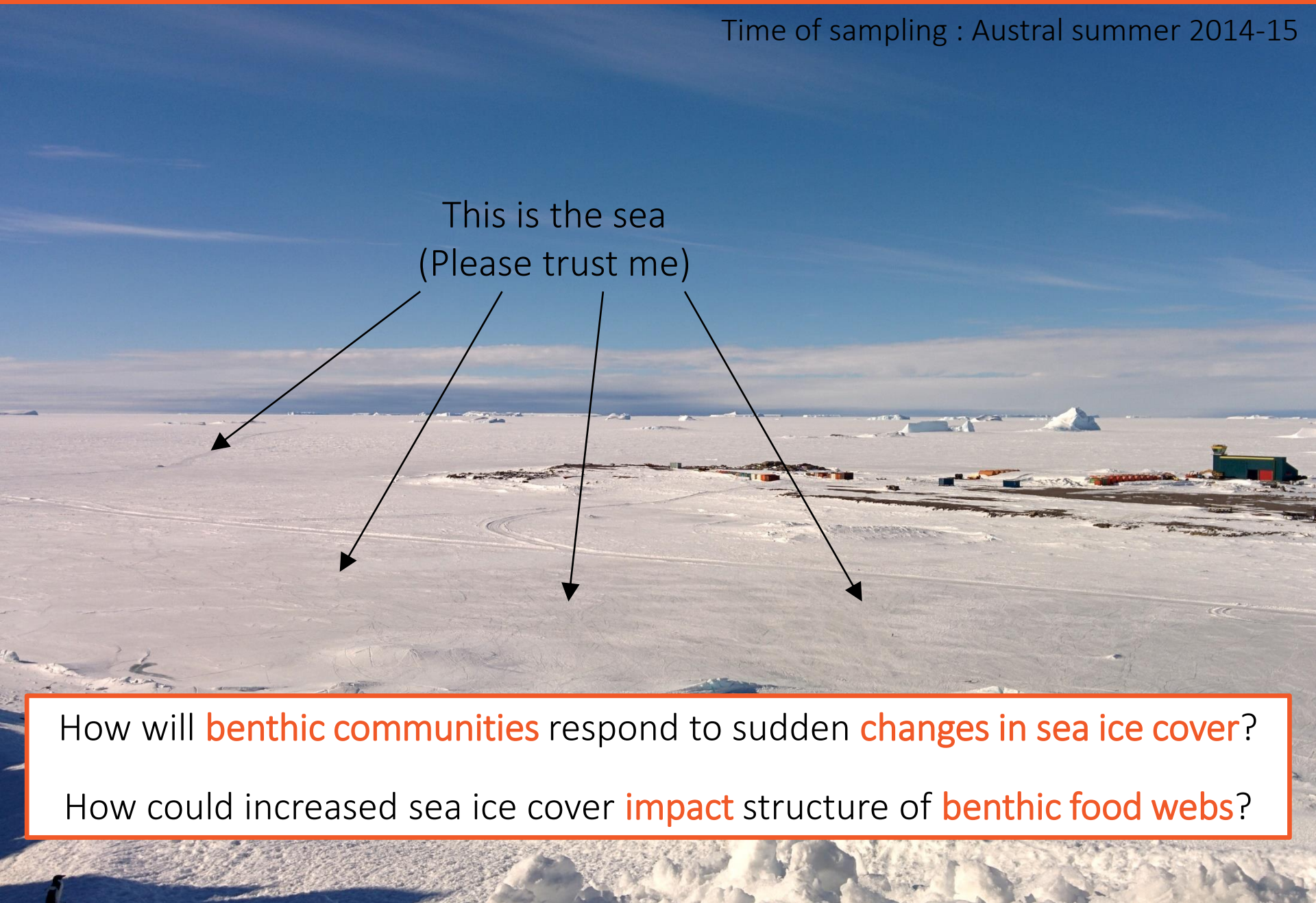
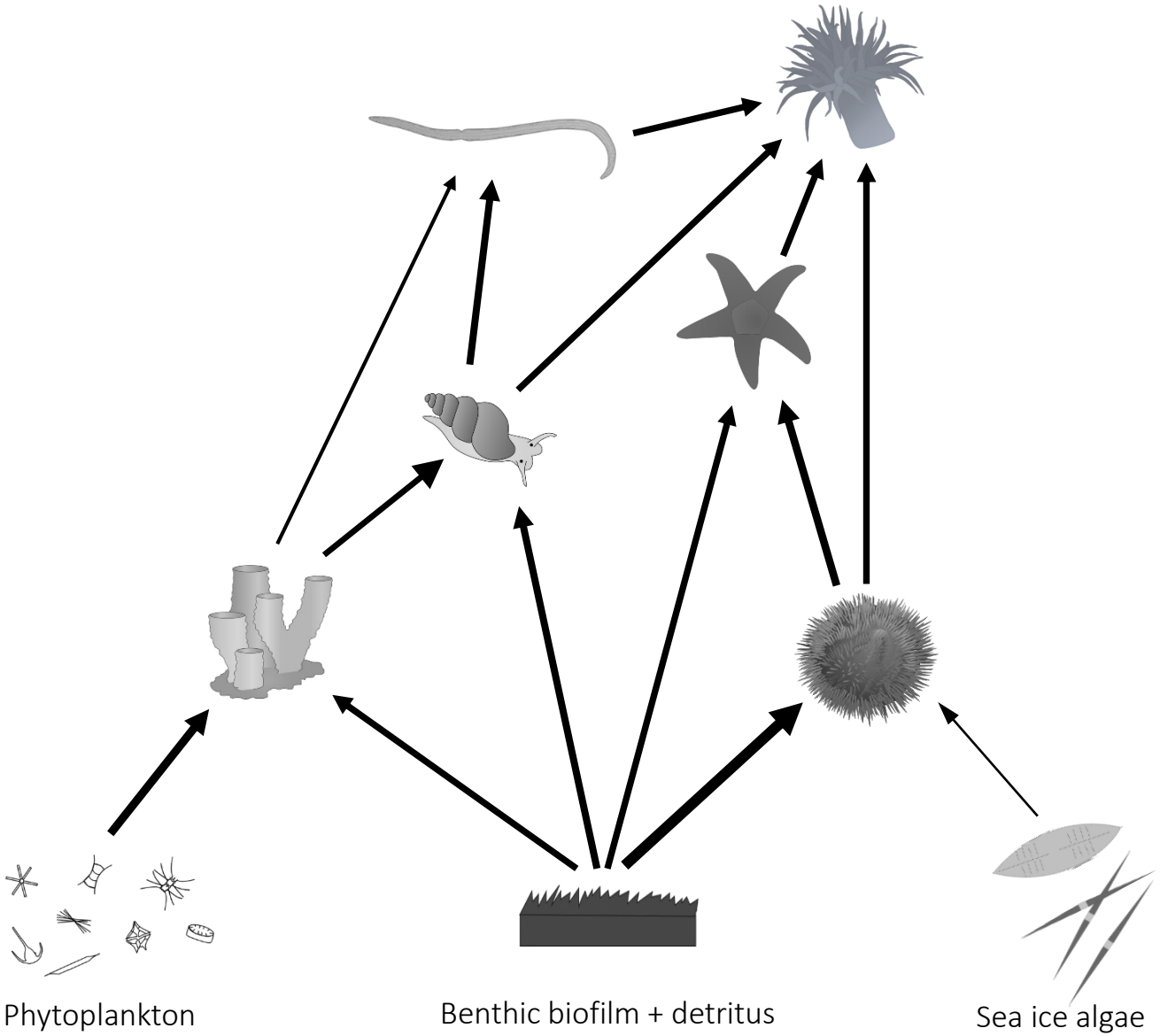


How will benthic communities respond to sudden changes in sea ice cover?

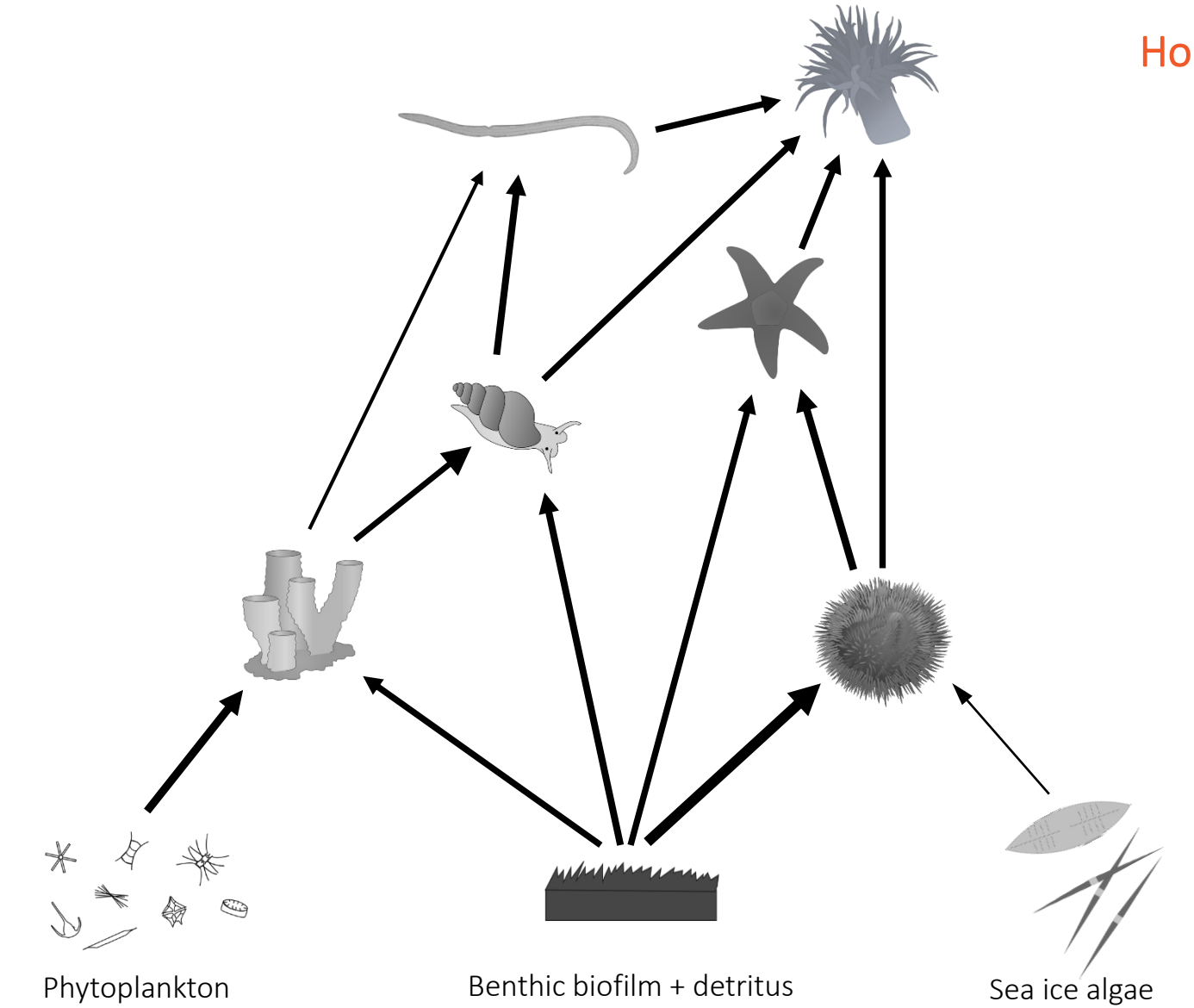
How could increased sea ice cover impact structure of benthic food webs?

Food web structure in marine ecosystems



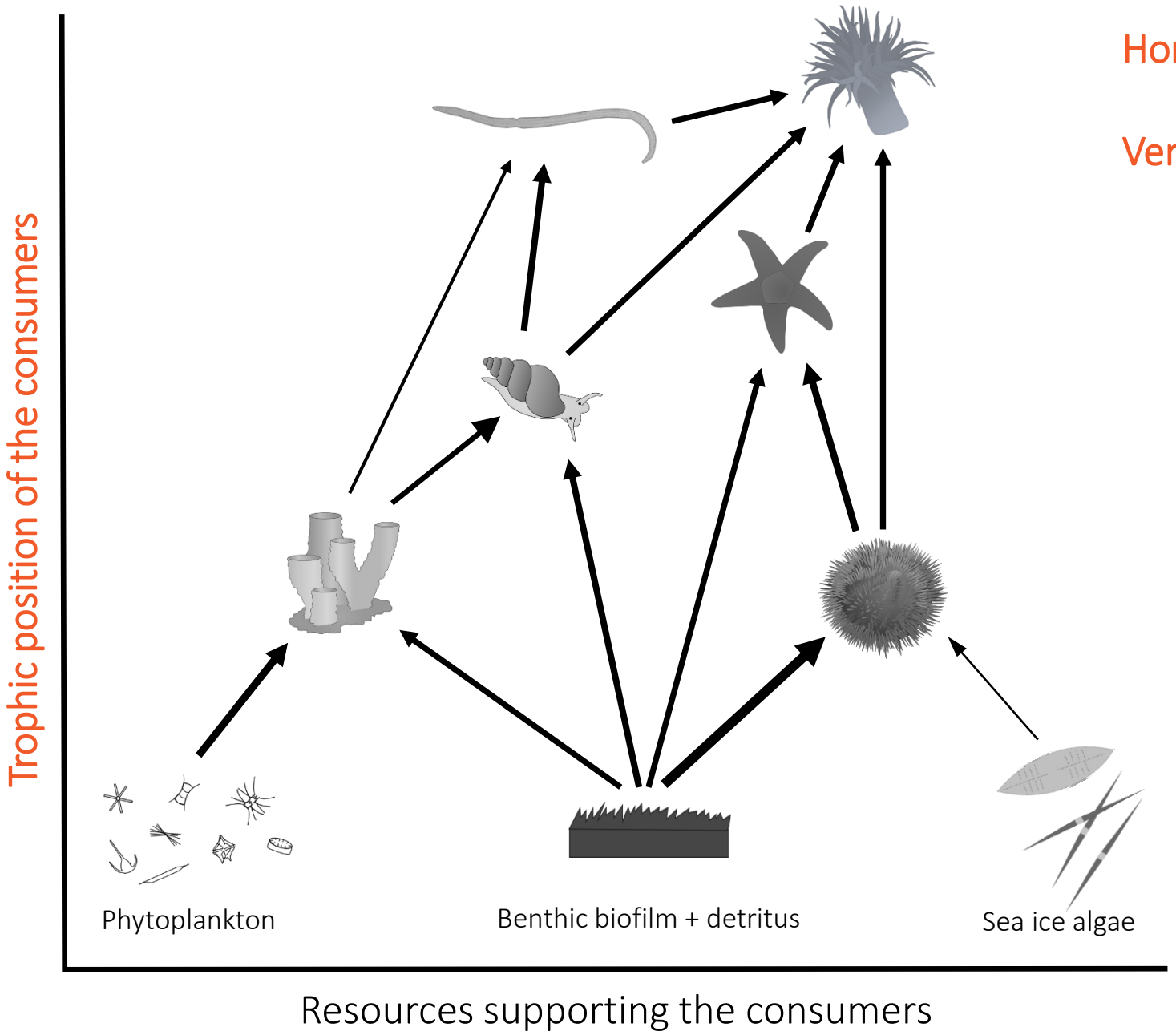
Food web structure in marine ecosystems

Horizontal dimension

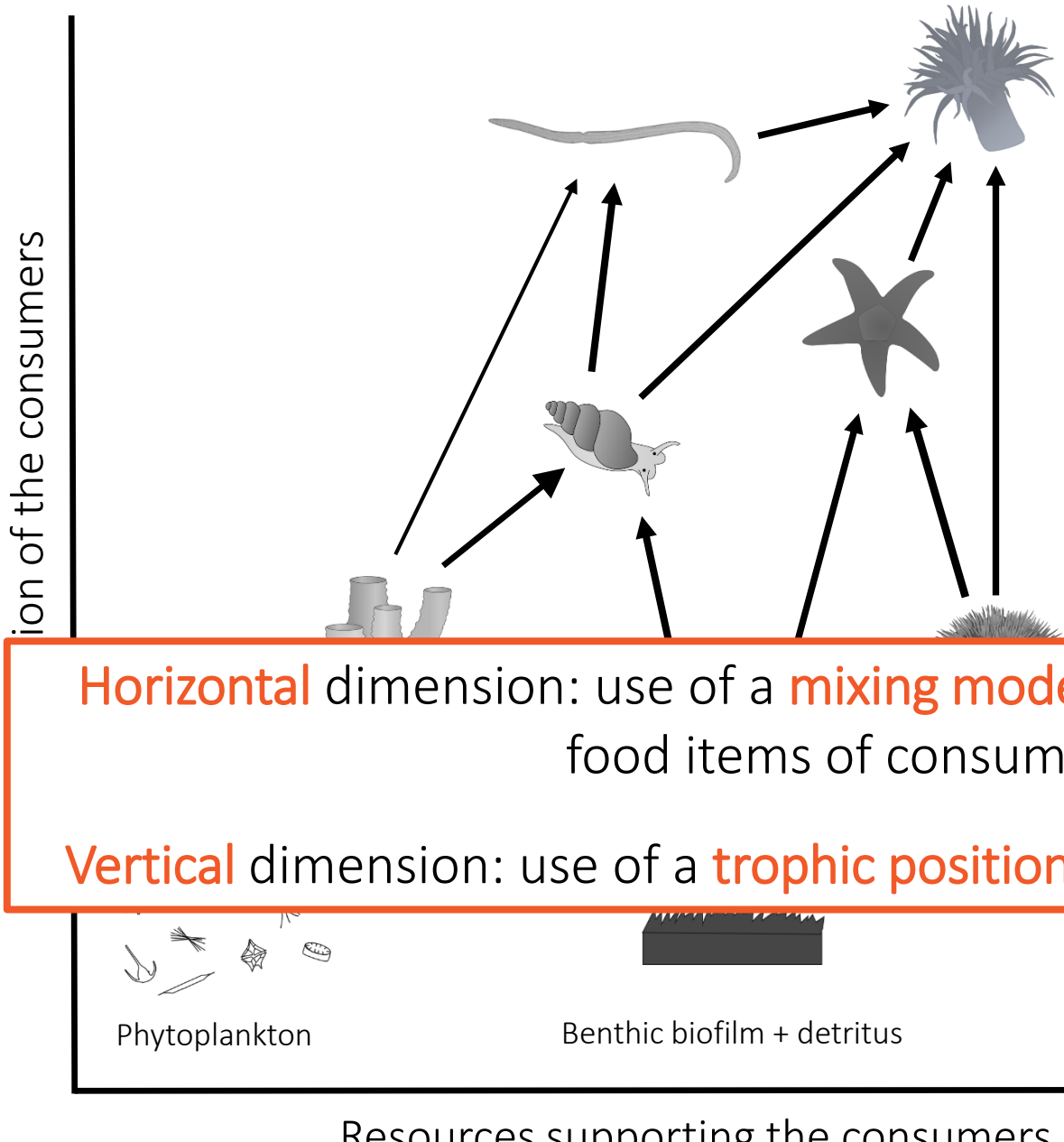


Resources supporting the consumers

Food web structure in marine ecosystems



Food web structure in marine ecosystems



Horizontal dimension

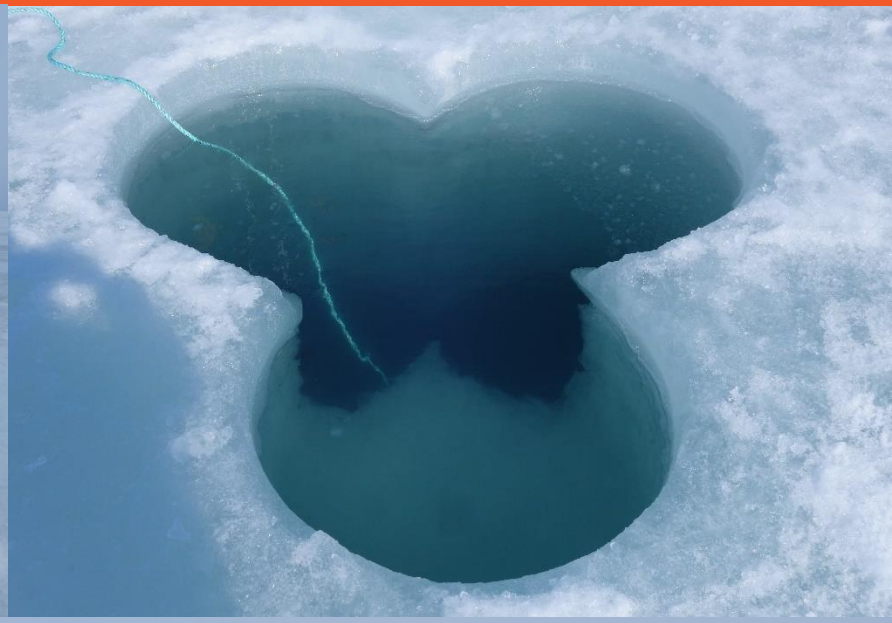
Vertical dimension

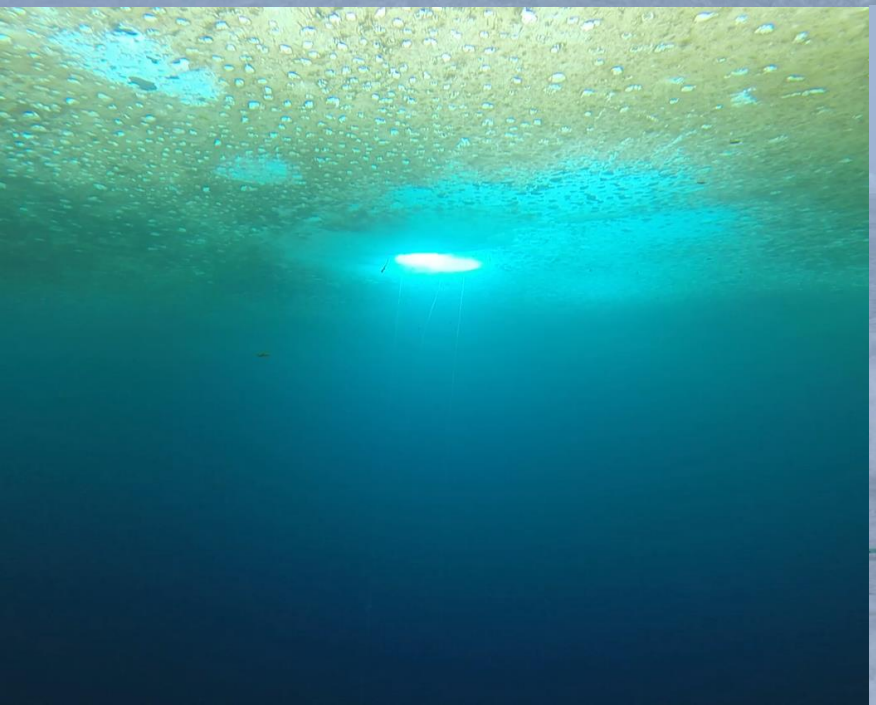
Here: models based on trophic markers (stable isotope ratios) were used to as proxies of both food webs dimensions

Horizontal dimension: use of a mixing model (SIAR) to identify main food items of consumers

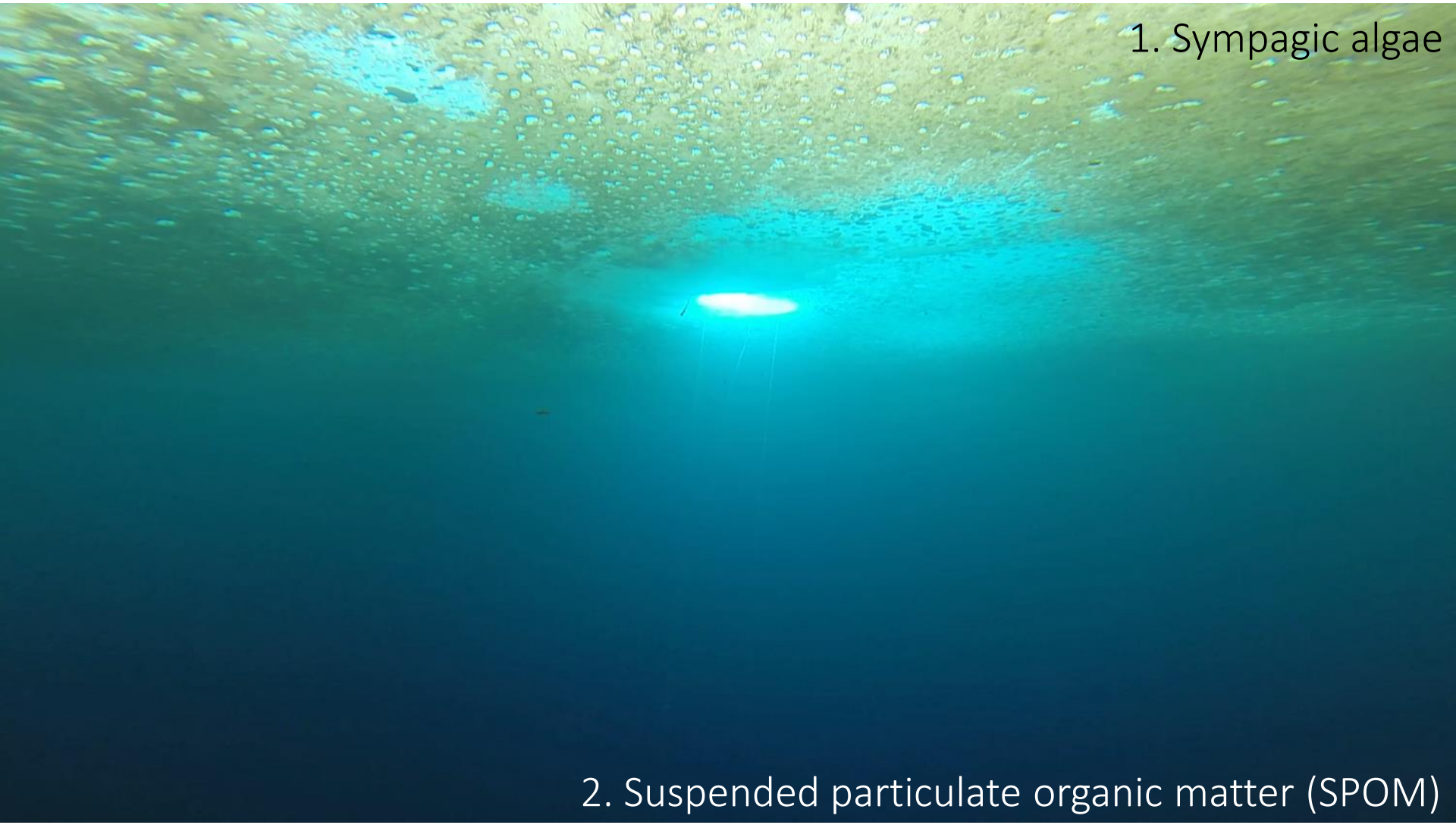
Vertical dimension: use of a trophic position model (tRophicPosition)

Sampling: under ice SCUBA diving





Sampling: food items

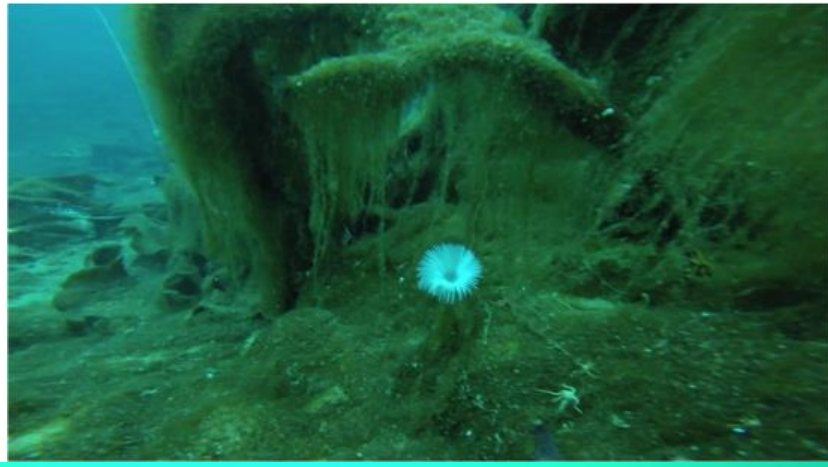


Sampling: food items

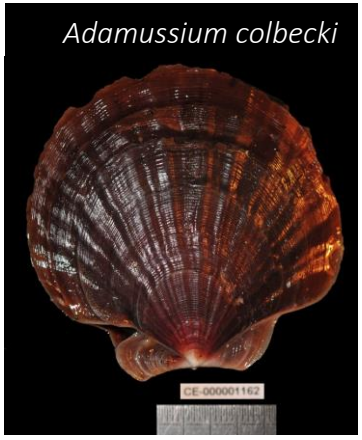
3. Benthic brown algae *Himantothallus grandifolius*

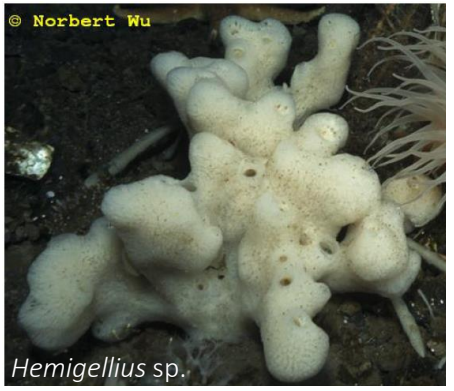
Sampling: food items

4. Benthic biofilm
(heterogeneous mix of microalgae, bacteria, amorphous material and detrital items)



Some sampled consumers





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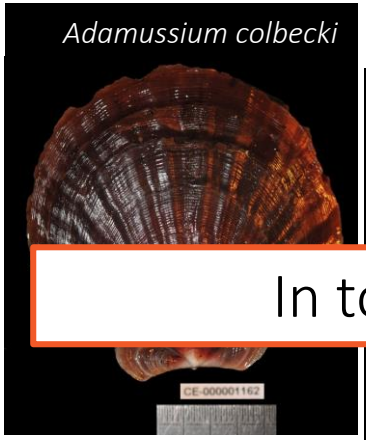
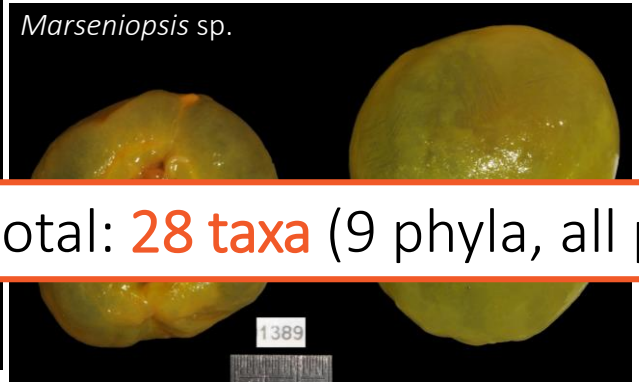
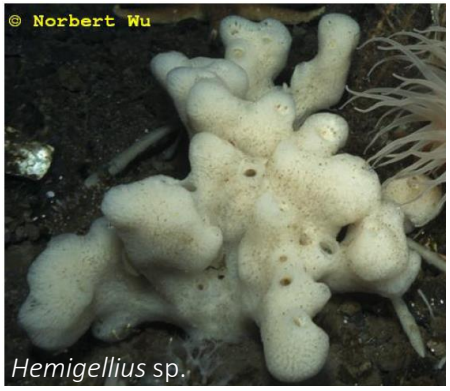


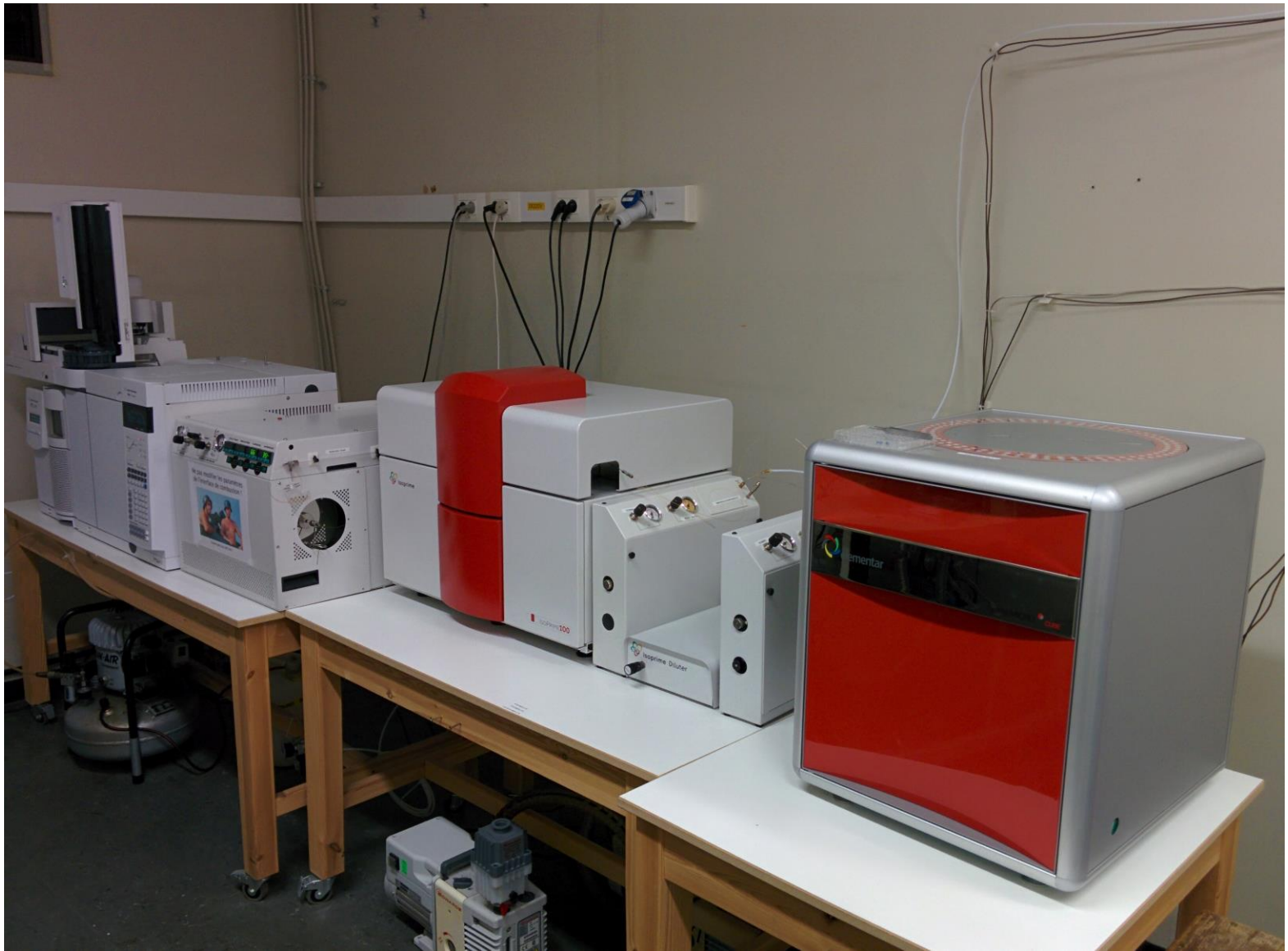


In total: 28 taxa (9 phyla, all present functional guilds)

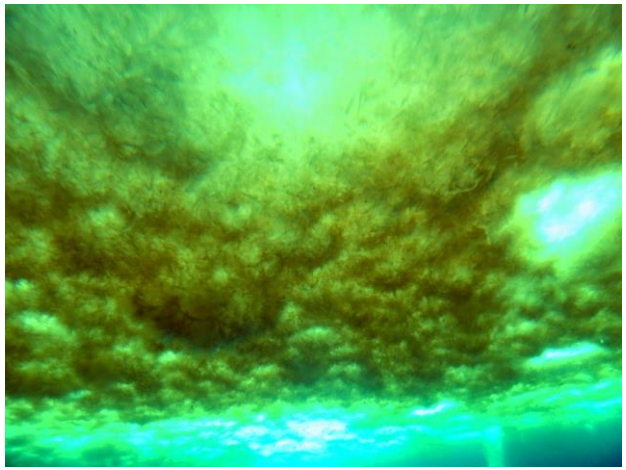


Material & methods: analysis

University of Liège's setup:
Vario MICRO cube EA coupled to an Isoprime 100 IRMS



Horizontal dimension – mixing model



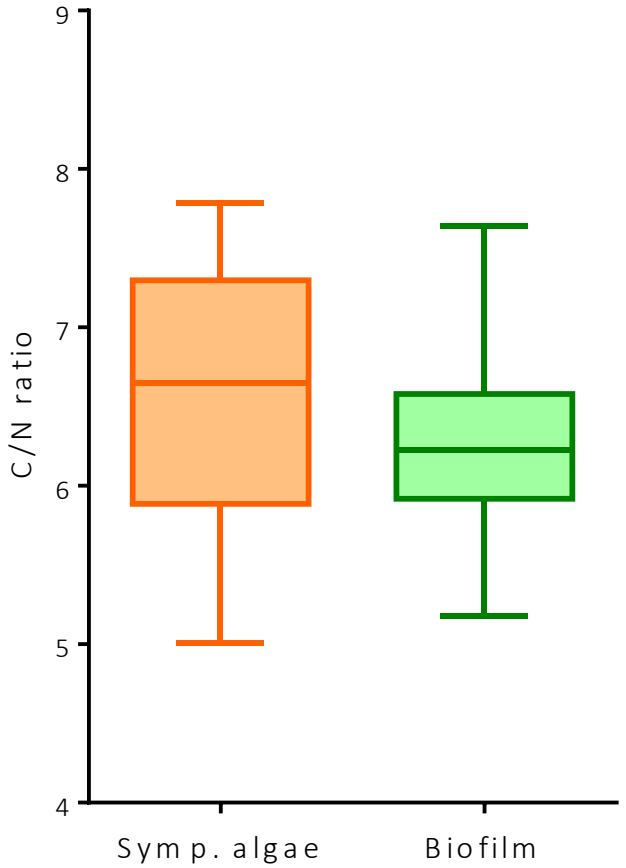
High reliance of many benthic invertebrates on sympagic material exported to the seafloor

Main food item of 8 out of 14 primary consumers / omnivores (up to 80% of diet)

Why is it preferred by many consumers over more abundant food items such as biofilm?

Better nutritional value? Unlikely… ➔

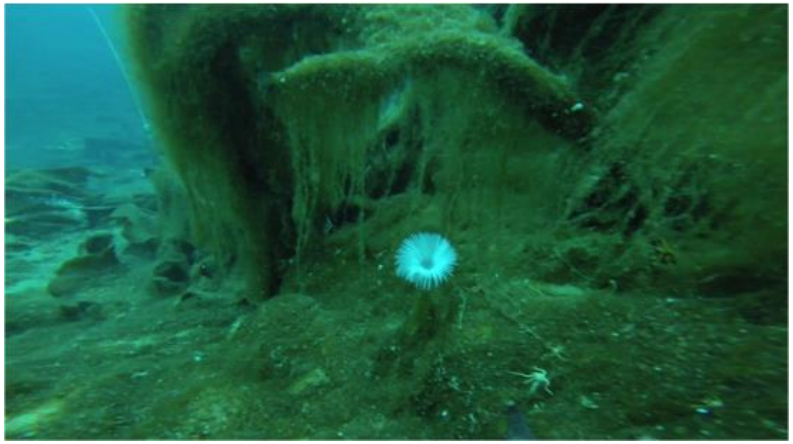
Better palatability? Pure aggregates of microalgae…



Horizontal dimension – mixing model

Preliminary microscopic examination:

Benthic biofilm = heterogeneous mix of microalgae, bacteria, amorphous material and detrital items



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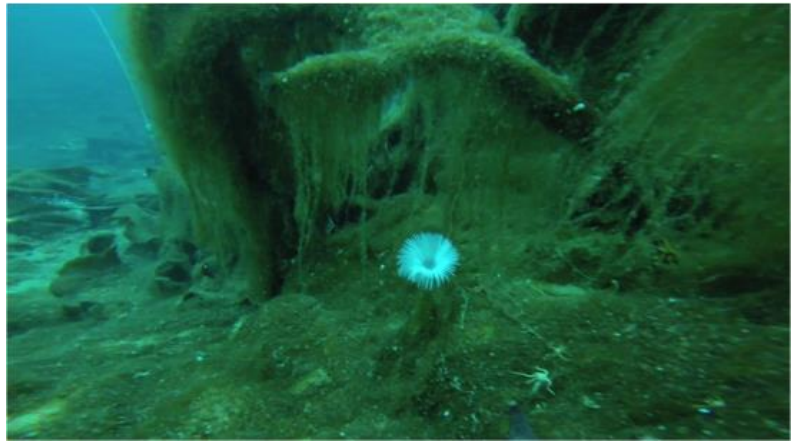

Yannick LARA – Poster nr. 28
Session 1.2 (Tuesday)

Horizontal dimension – mixing model

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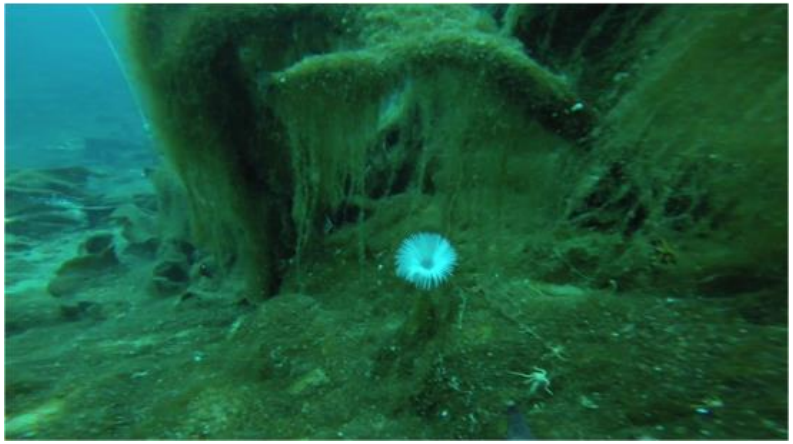
Here: importance of benthic biofilm in food web comparatively limited despite high abundance



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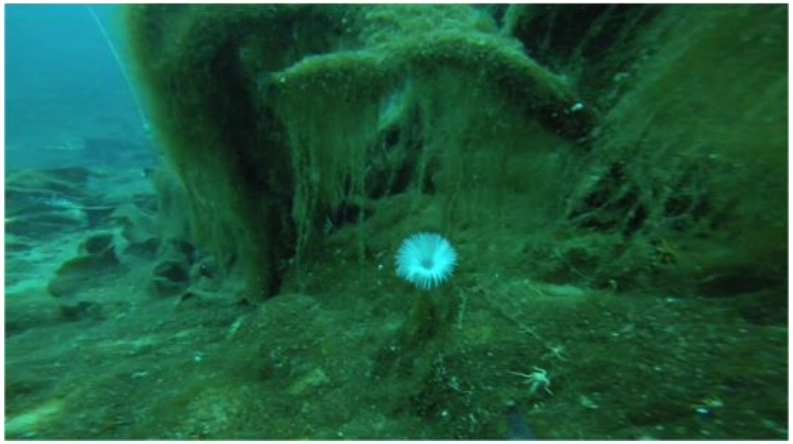

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Ross Sea: Benthic invertebrates consume more detritic matter in sea-ice influenced locations
(Norkko et al. (2007), Ecology 88: 2810-2820)

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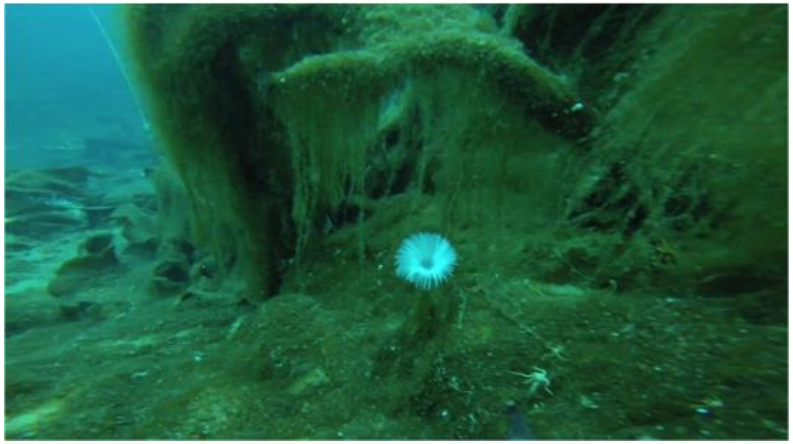

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Ross Sea: Benthic invertebrates consume more detritic matter in sea-ice influenced locations
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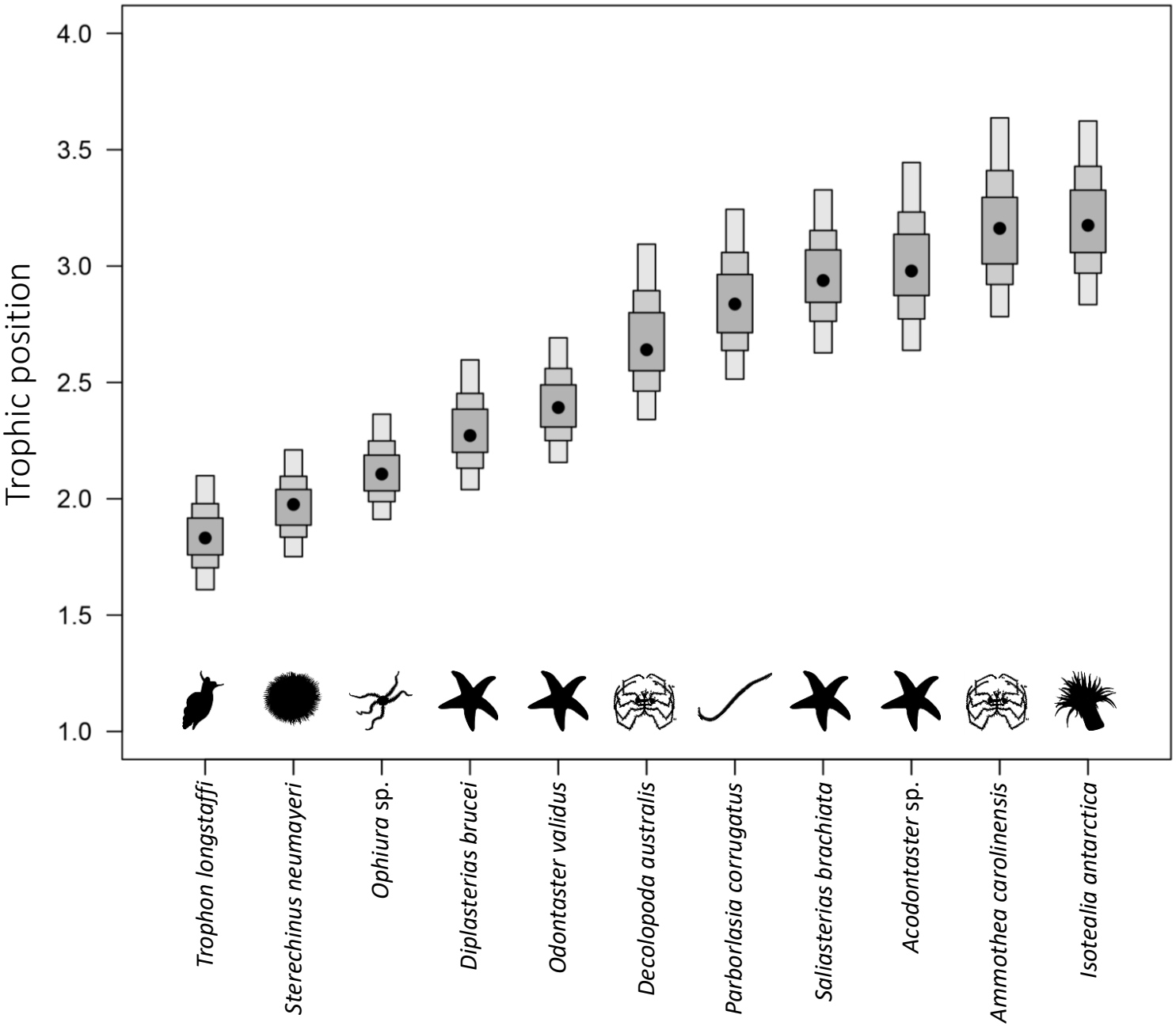
Important variation in benthic ecosystem response to sea ice: sudden changes vs. stable conditions?

However: no data about dynamics of biofilm accumulation!

Here: long-lived benthic invertebrates with low metabolic rates ➔ low isotopic turnover? Is isotopic equilibrium reached?

Our model could underestimate actual biofilm importance for invertebrate feeding

Vertical dimension – Trophic position modelling



Overall: low trophic positions compared to literature

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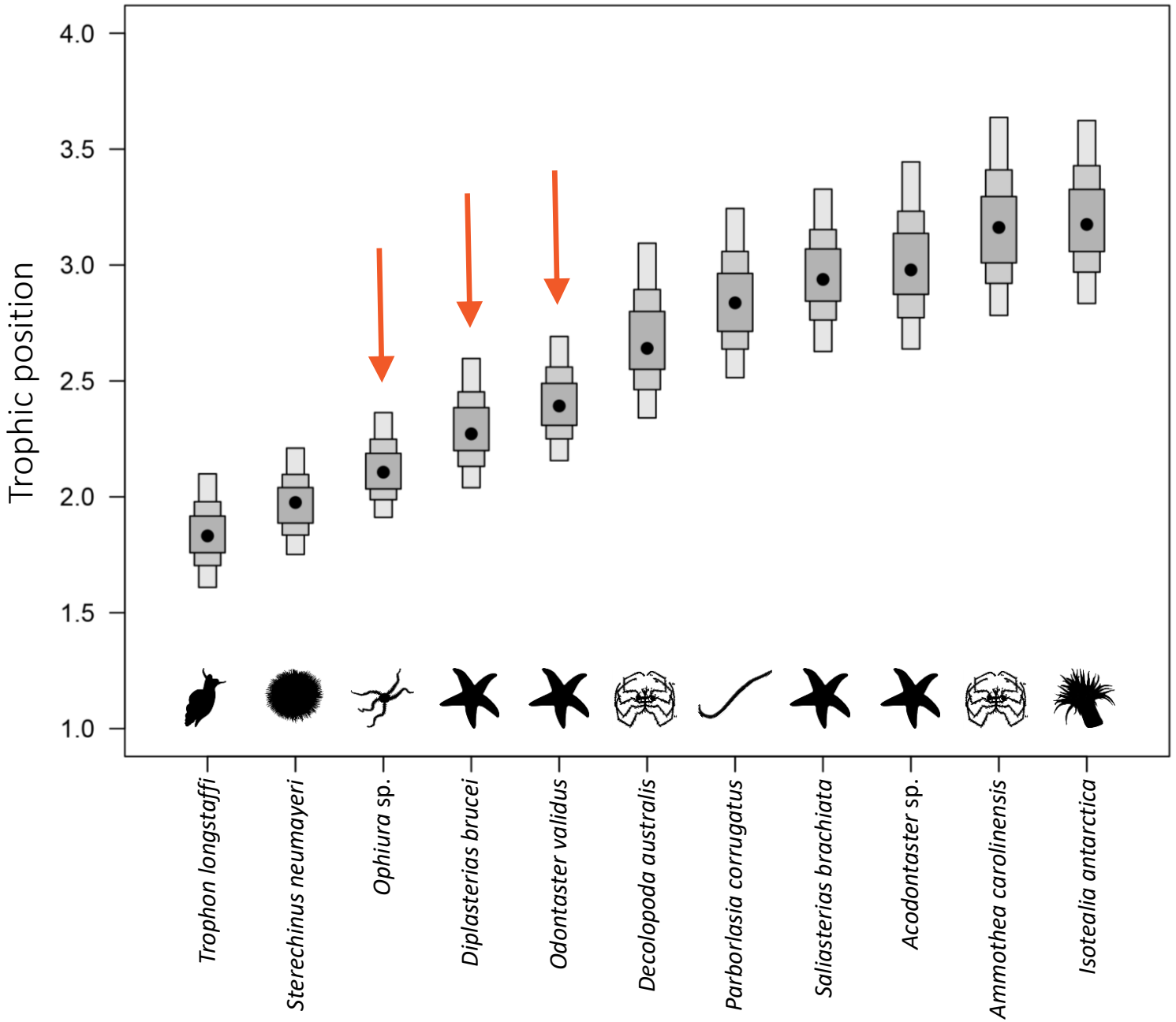
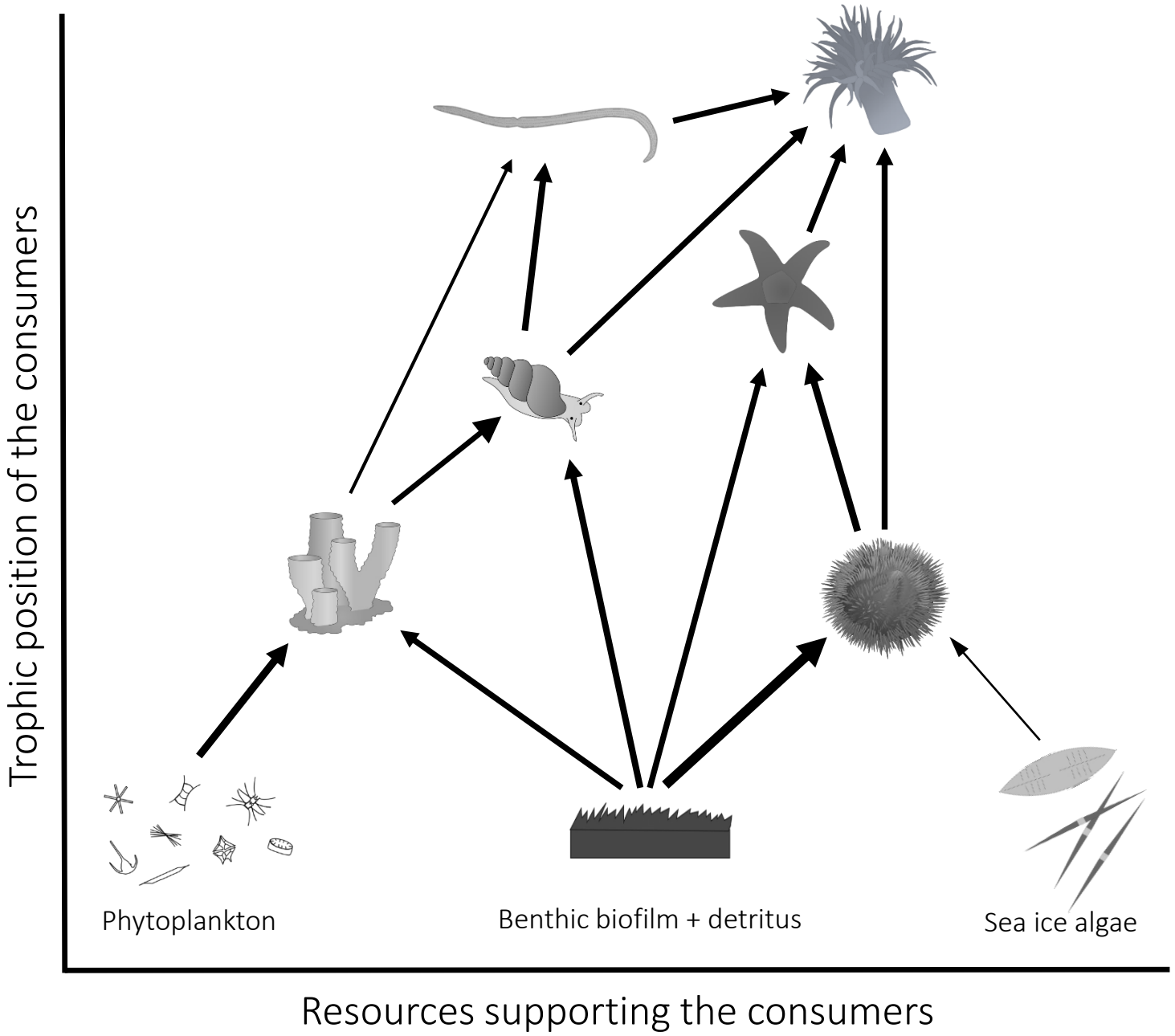


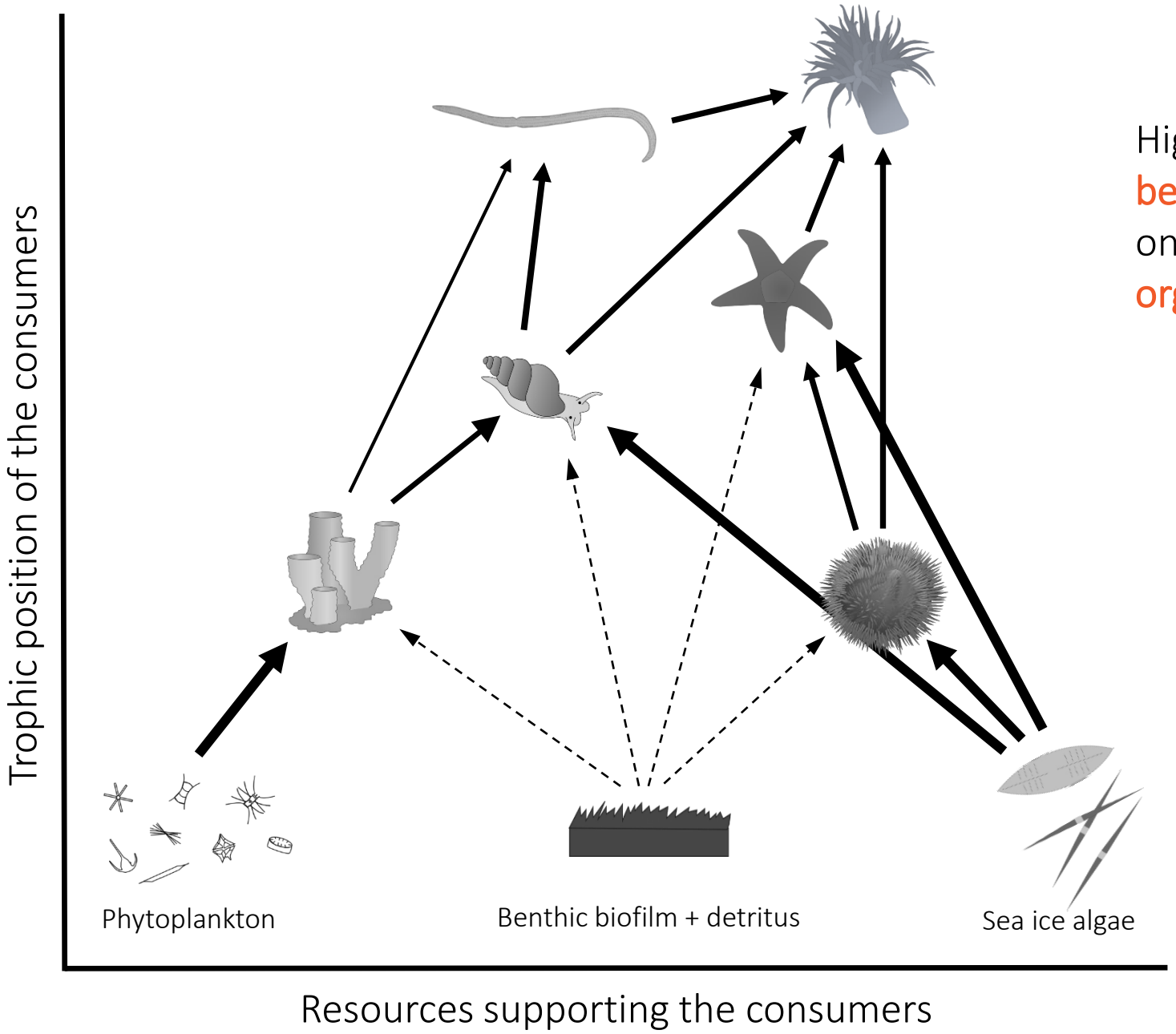
Overall: low trophic positions compared to literature

Dominant omnivore taxa: very low trophic levels, mostly feeding directly on primary producers

The food web we expected



Shift in resources supporting consumers



High dependency of benthic invertebrates on sea ice-derived organic matter

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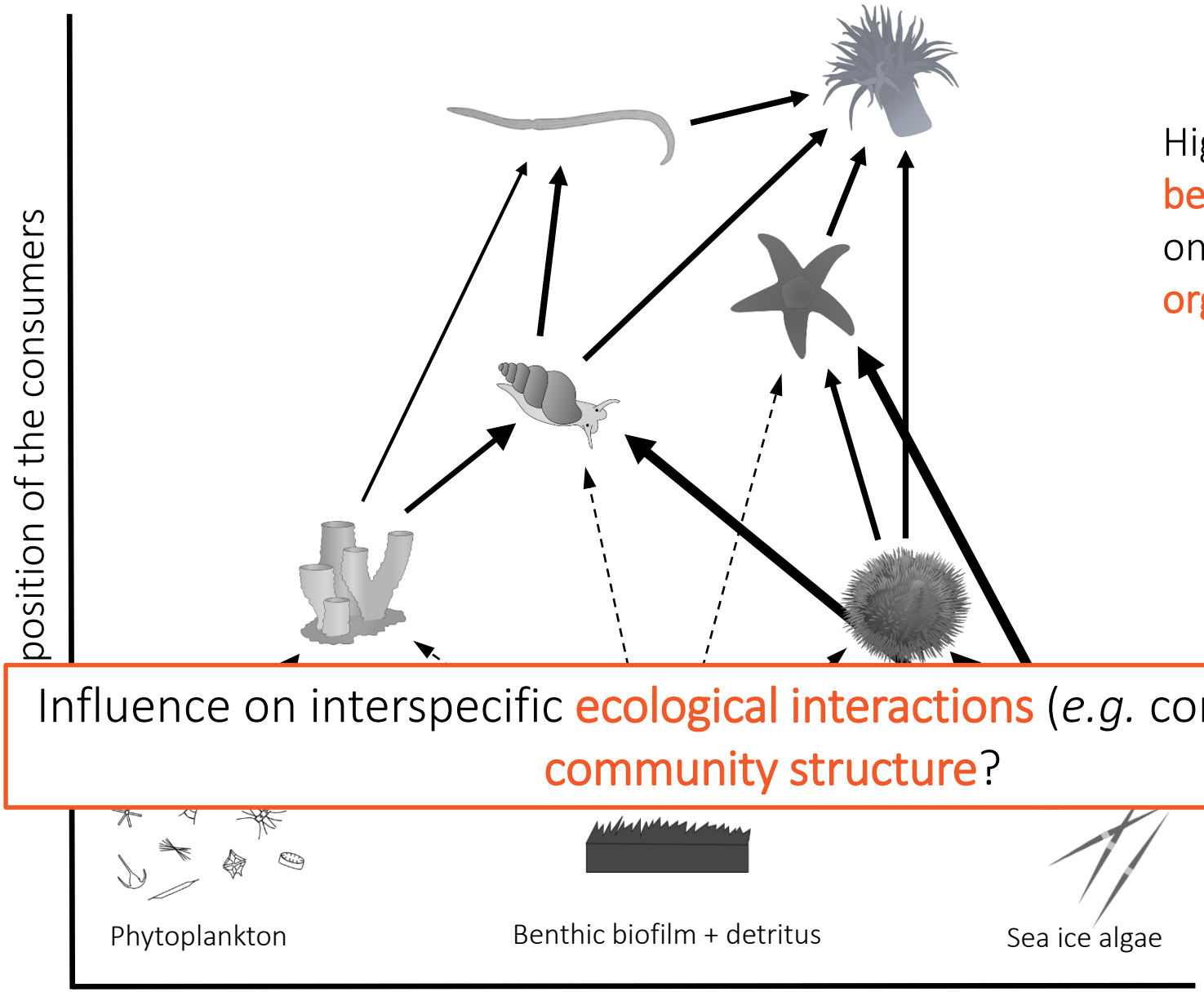
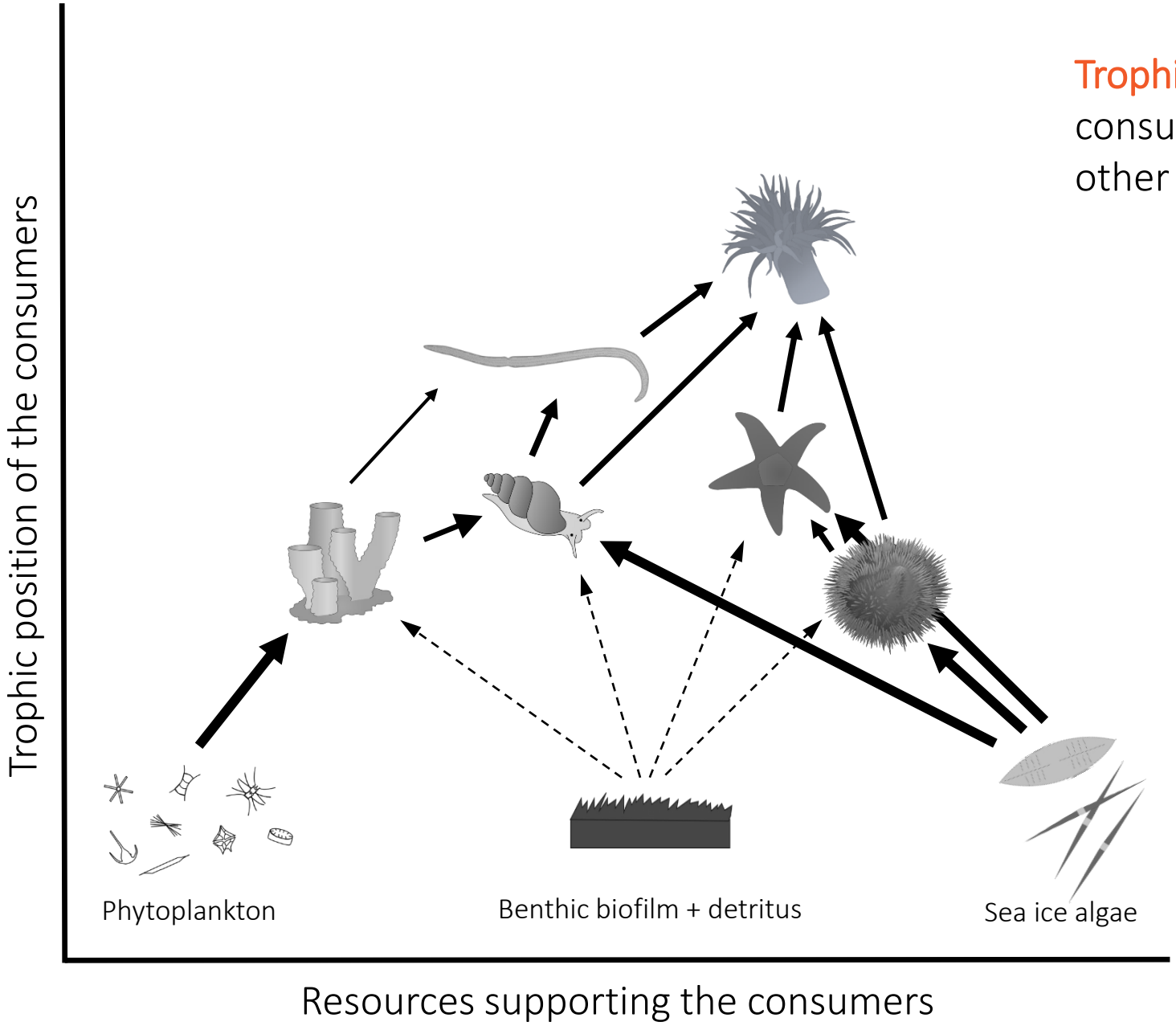


High dependency of benthic invertebrates on sea ice-derived organic matter

Influence on interspecific ecological interactions (*e.g.* competition) and community structure?

Shift in trophic position of consumers

Trophic positions of many consumers **lower** than in other studies



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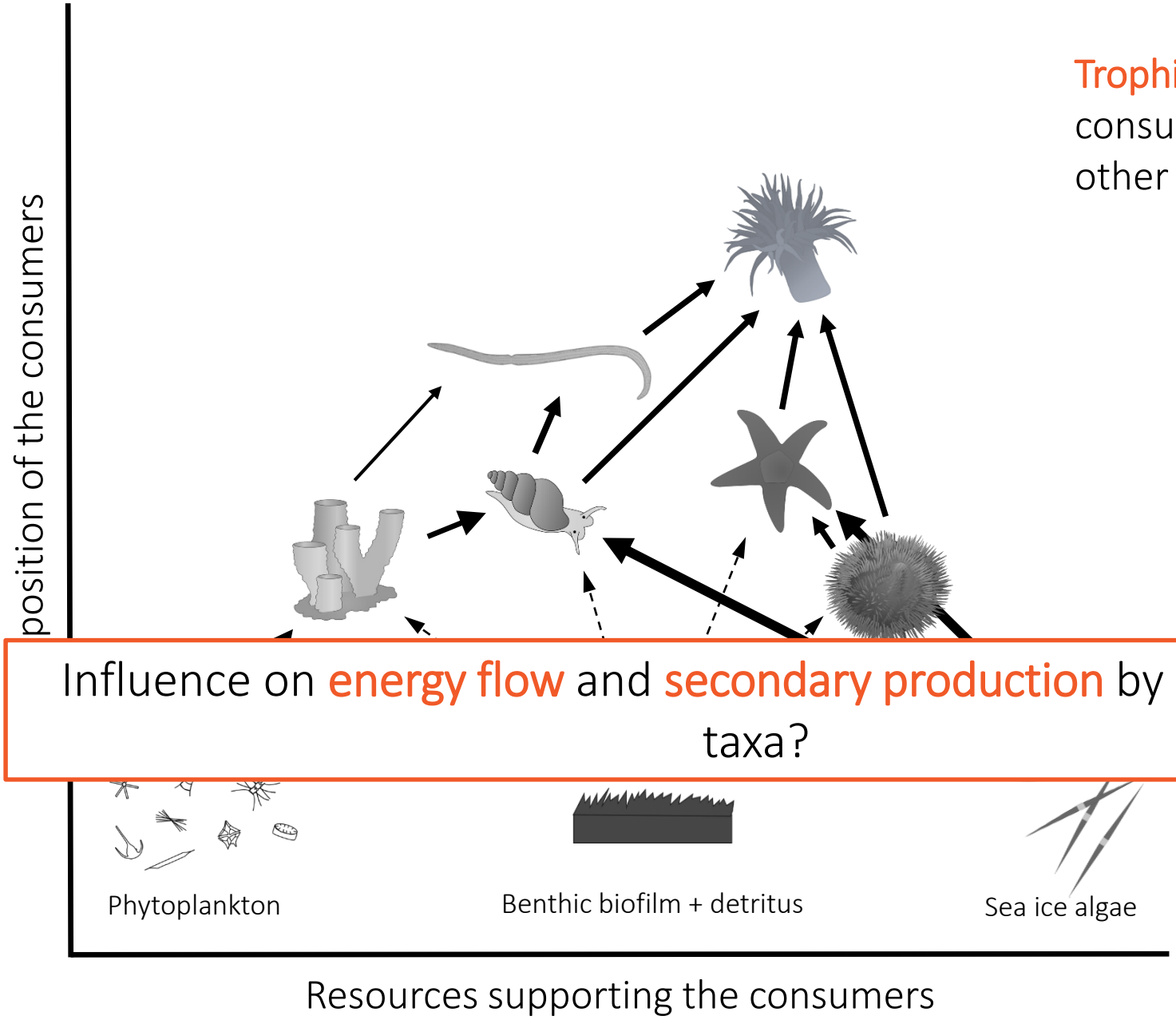
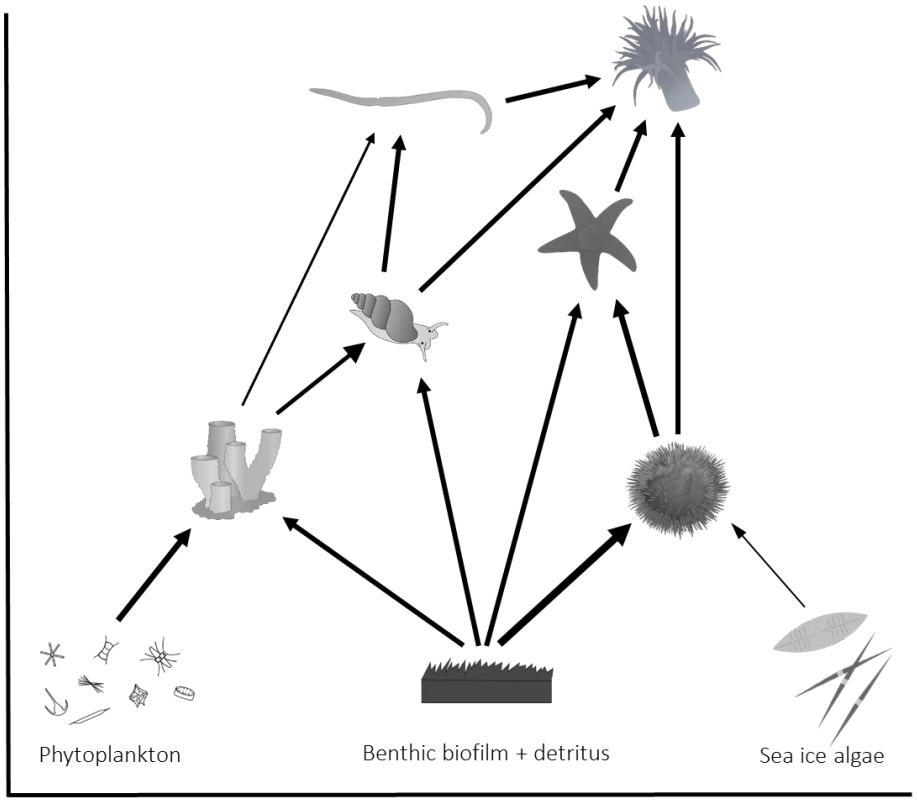
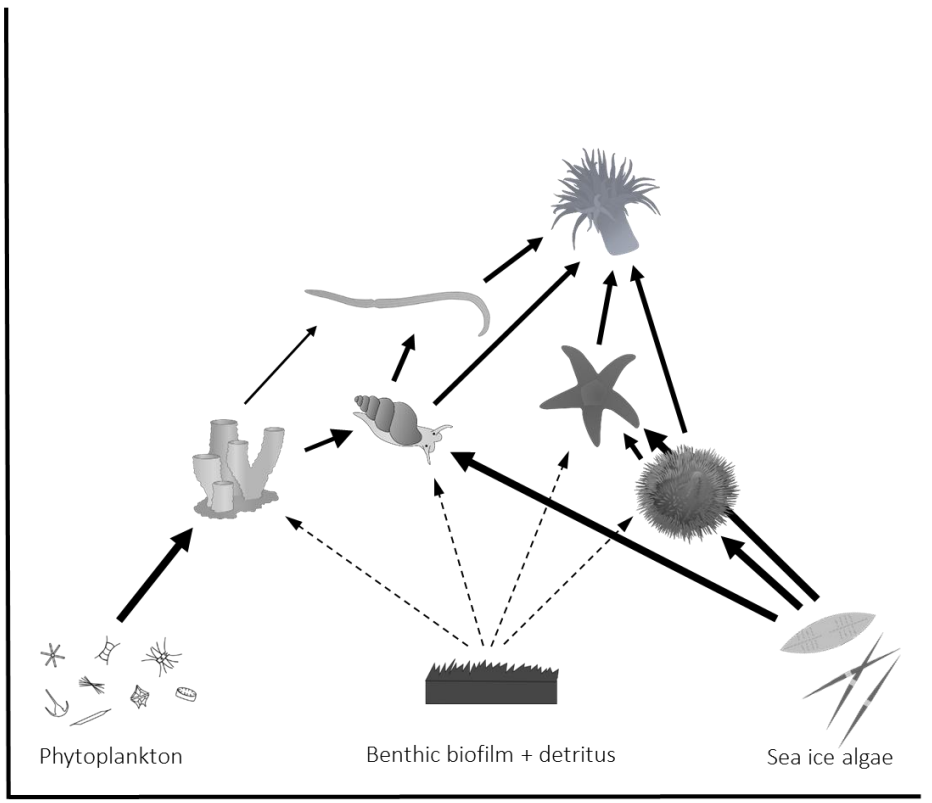


Influence on energy flow and secondary production by key omnivore taxa?

Sea ice & food web structure



Expected food web



Increased sea ice conditions

Increase of sea ice cover strongly influences the benthic food web by modifying both its horizontal and its vertical structure

Take home message

- Important sea ice cover is linked with high reliance of coastal benthic invertebrates on sympagic algae

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Take home message

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- Interpretation of results is complicated by lack of background data ("normal" conditions) and by physiological features of studied organisms

Take home message

- Important sea ice cover is linked with high reliance of coastal benthic invertebrates on sympagic algae
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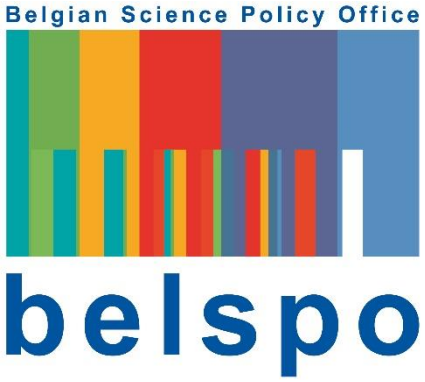
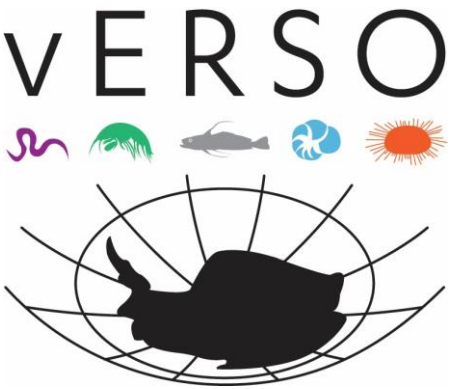
- Interpretation of results is complicated by lack of background data ("normal" conditions) and by physiological features of studied organisms

Despite being interpreted as a positive signal by mainstream media, local or large-scale trends of sea ice increase in Antarctica could actually have strong impacts on benthic ecosystems

Funding





Belgian Federal Science Policy Office (BELSPO)

vERSO (Ecosystem Resilience in Southern Ocean) and RECTO (Refugia and Ecosystem Tolerance in the Southern Ocean) projects

French Polar Institute (IPEV)

Thanks for your attention

Download this presentation: http://hdl.handle.net/2268/212612

Horizontal dimension: mixing model

Mixing law: "You are what you eat"

An animal's stable isotope composition is a proportional mix of its food items' stable isotope compositions

Horizontal dimension: mixing model

Mixing law: "You are what you eat"

An animal's stable isotope composition is a proportional mix of its food items' stable isotope compositions

Analysis of stable isotope composition of consumers and potential food items

Use of SIAR (Stable Isotope Analysis in R) mixing model

↓

Quantitative estimates of contributions of each food item to each consumer diet

Identifications of resources supporting each consumer's populations

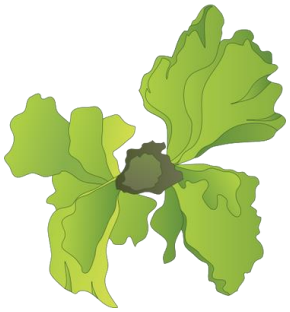
OPEN ACCESS Freely available online PLoS one

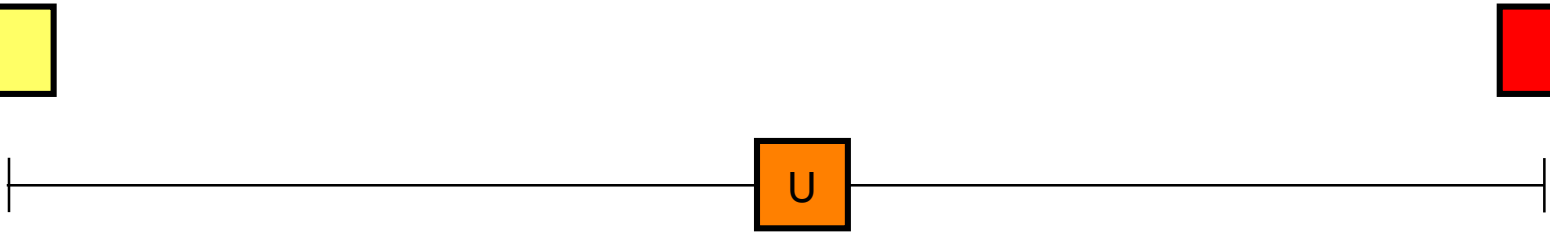
Source Partitioning Using Stable Isotopes: Coping with Too Much Variation

Andrew C. Parnell[1], Richard Inger[2], Stuart Bearhop[2], Andrew L. Jackson[3]*

Stable isotopes: you are what you eat

Mixing law: an animal's stable isotope composition is a proportional mix of its food items' stable isotope compositions





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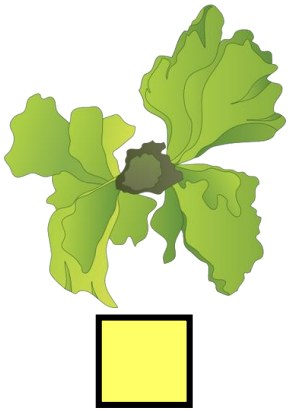
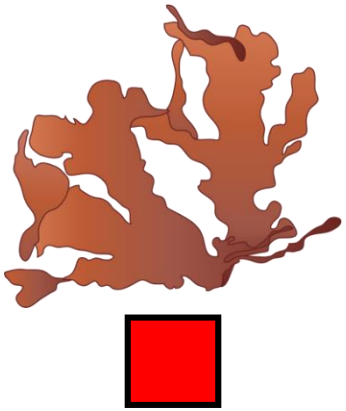
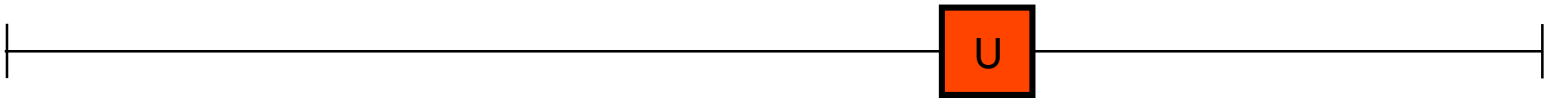




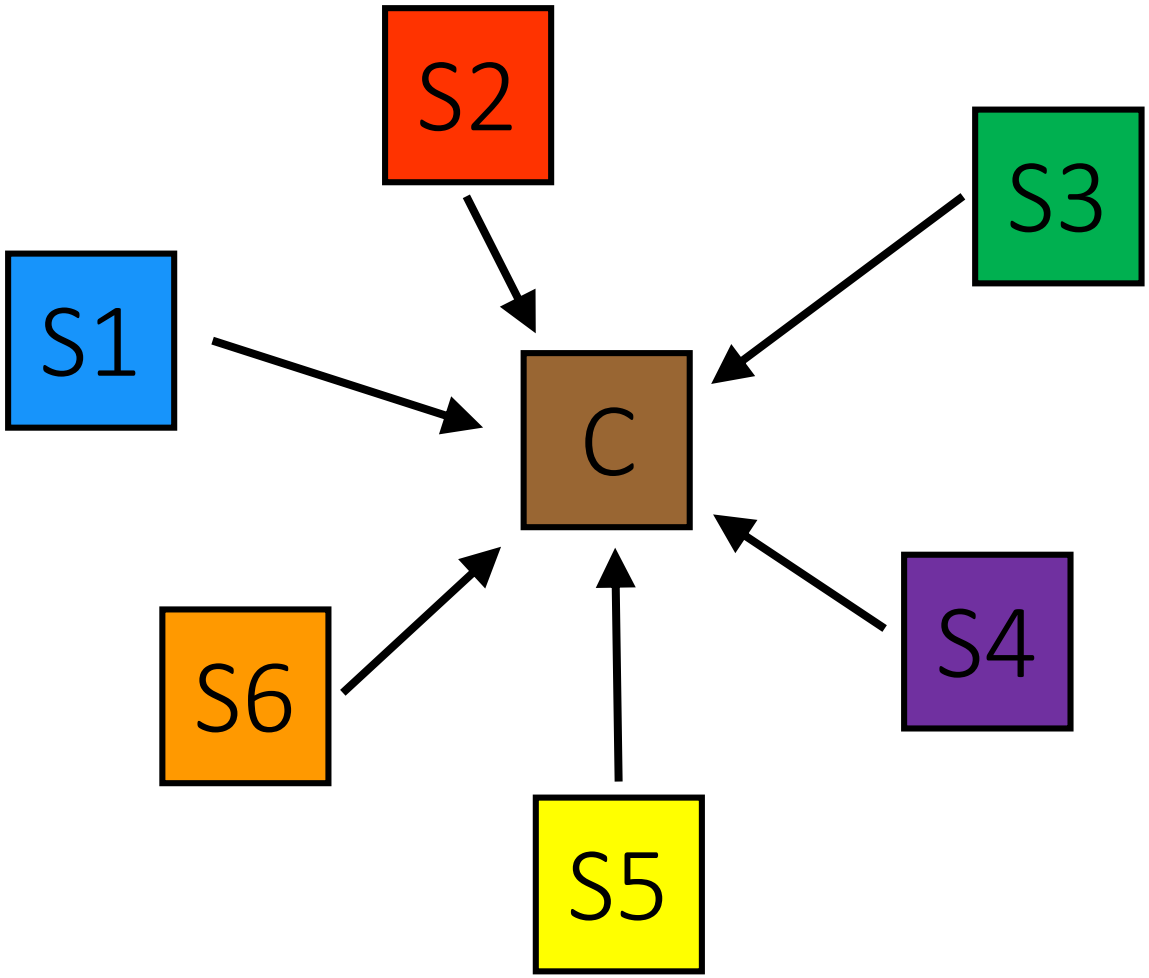


Analysis of stable isotope composition of a consumer and those of its potential food items through mass spectrometry

Estimation of contributions of each item to consumer diet

Stable isotopes: you are what you eat

Real-life ecosystems : many potential food items + natural variability of isotopic compositions



Necessity of complex mathematical tools: mixing models (SIAR – Stable Isotope Analysis in R)

SIAR parameters

SIAR 4.2 in R 3.2.2

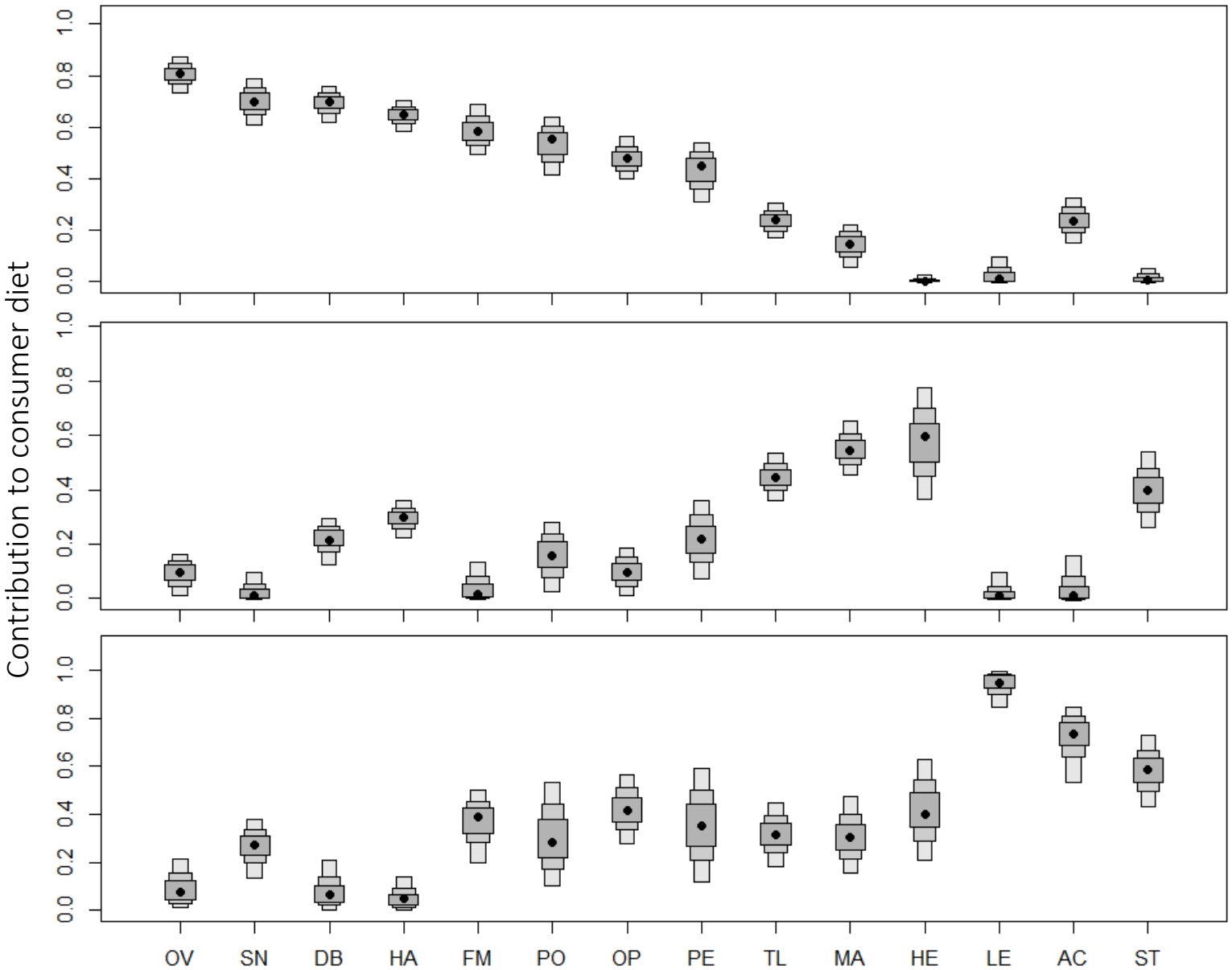
No concentration dependencies

TEFs: $\Delta^{13}C = 0.40 \pm 1.20$ ‰; $\Delta^{15}N = 2.30 \pm 1.61$ ‰ (mean ± SD; TEFs for aquatic consumers from McCutchan *et al.* 2003 Oikos 102: 378-390)

10^6 iterations

Burn-in size: 10^5

Results - SIAR modelling



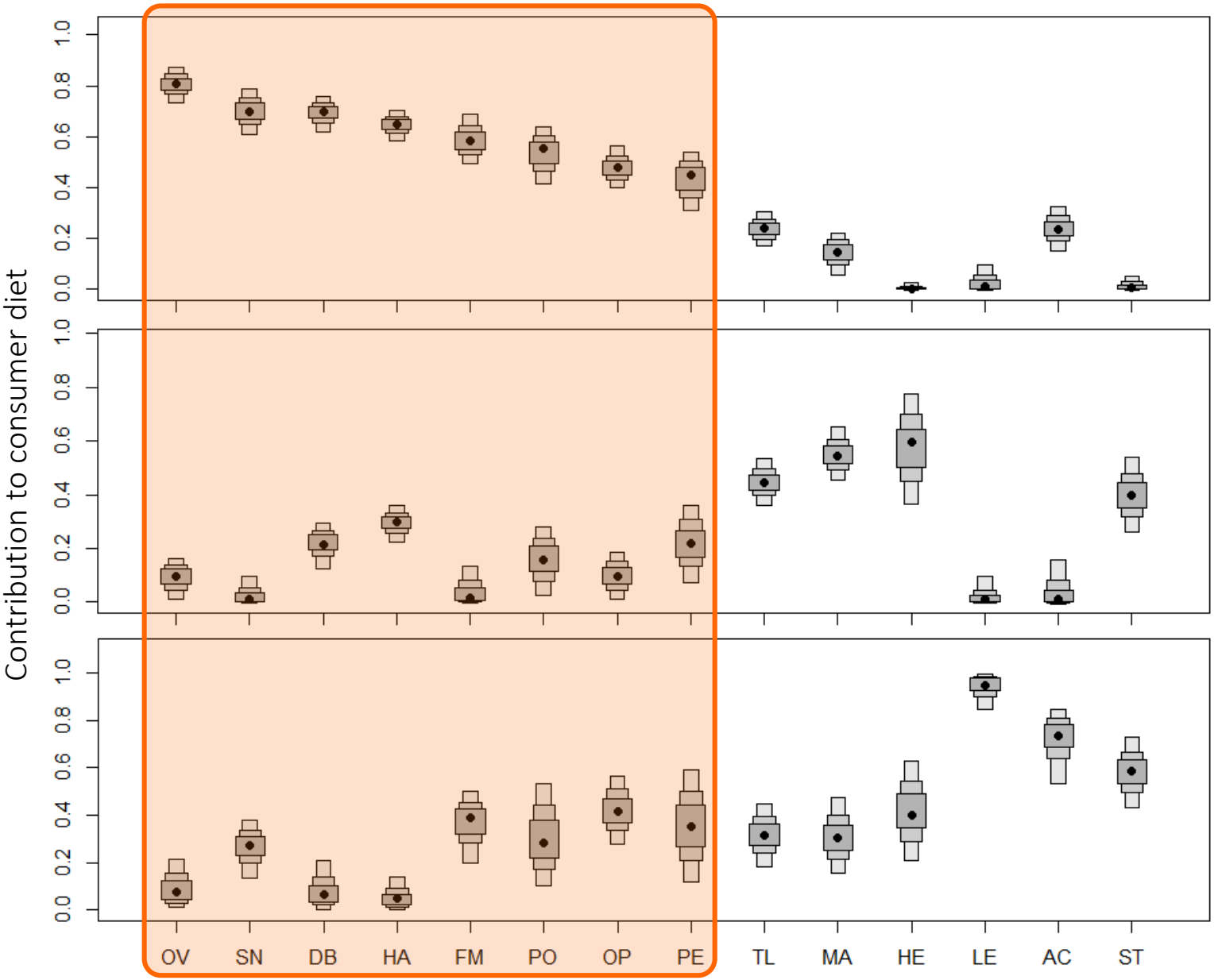
Sympagic algae

Suspended Particulate Organic Matter (SPOM)

Benthic algae + Biofilm

OV: *O. validus*; SN: *S. neumayeri*; DB: *D. brucei*; HA: *Harmothoe* sp.; FM: *F. mundata*; PO: *Polycirrus* sp.; OP: *Ophiura* sp.; PE: *Perkinsiana* sp.; TL: *T. longstaffi*; MA: *Marsienopsis* sp.; HE: *Heterocucumis* sp.; LE: *Laternula elliptica*; AC: *Adamussium colbecki*; ST: *Staurocucumis* sp.

Results - SIAR modelling



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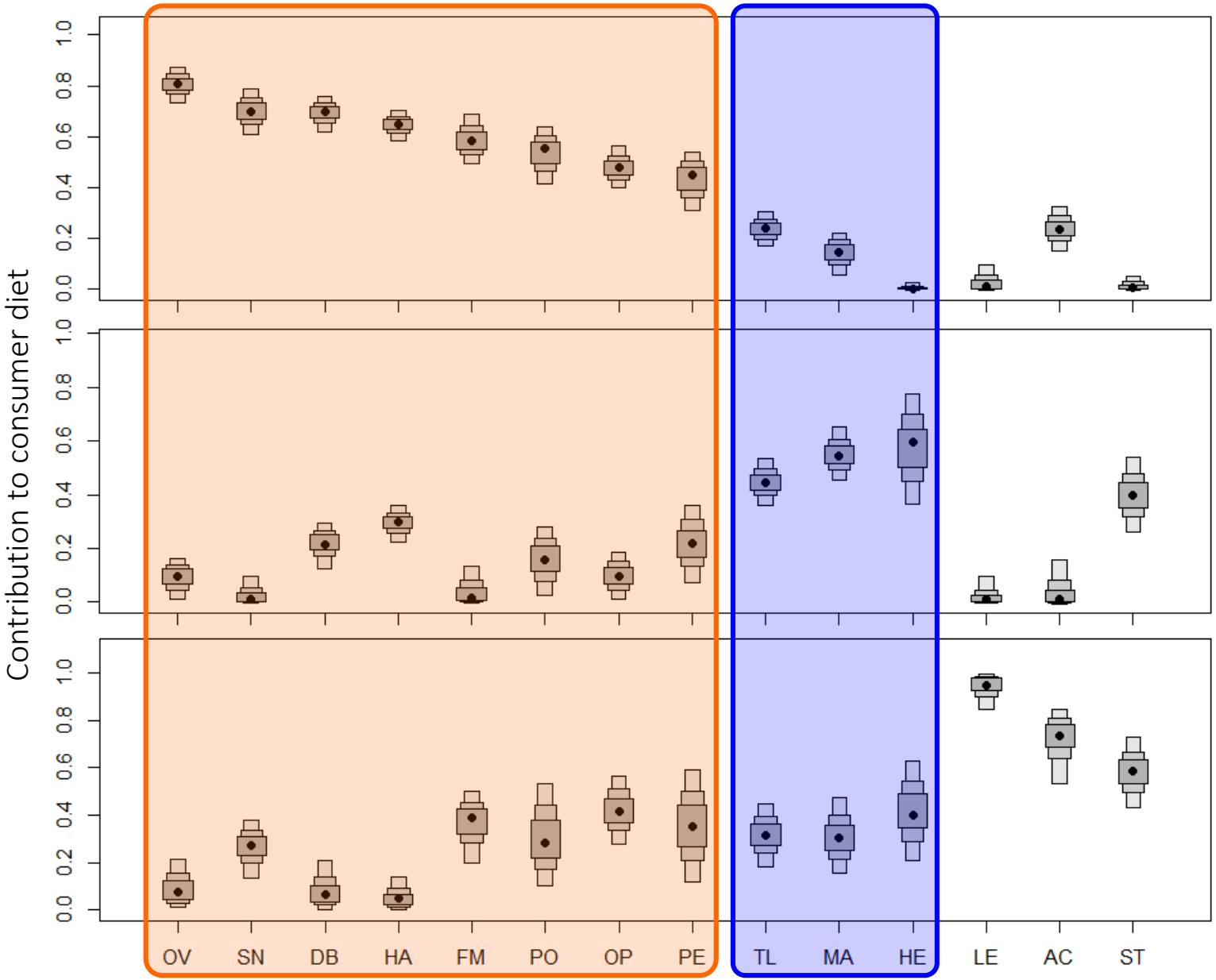
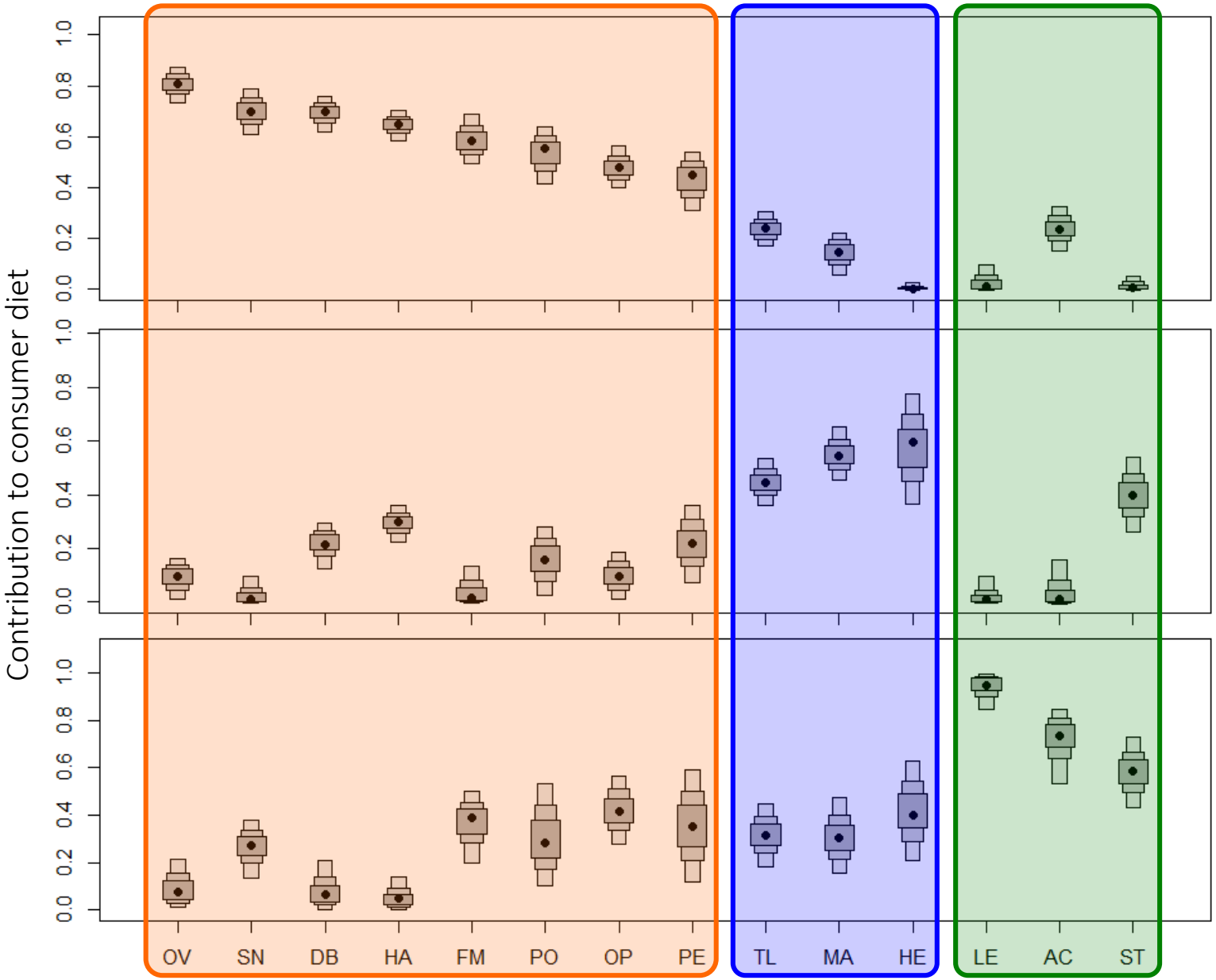
Results - SIAR modelling



OV: *O. validus*; SN: *S. neumayeri*; DB: *D. brucei*; HA: *Harmothoe* sp.; FM: *F. mundata*; PO: *Polycirrus* sp.; OP: *Ophiura* sp.; PE: *Perkinsiana* sp.; TL: *T. longstaffi*; MA: *Marsienopsis* sp.; HE: *Heterocucumis* sp.; LE: *Laternula elliptica*; AC: *Adamussium colbecki*; ST: *Staurocucumis* sp.

Results - SIAR modelling



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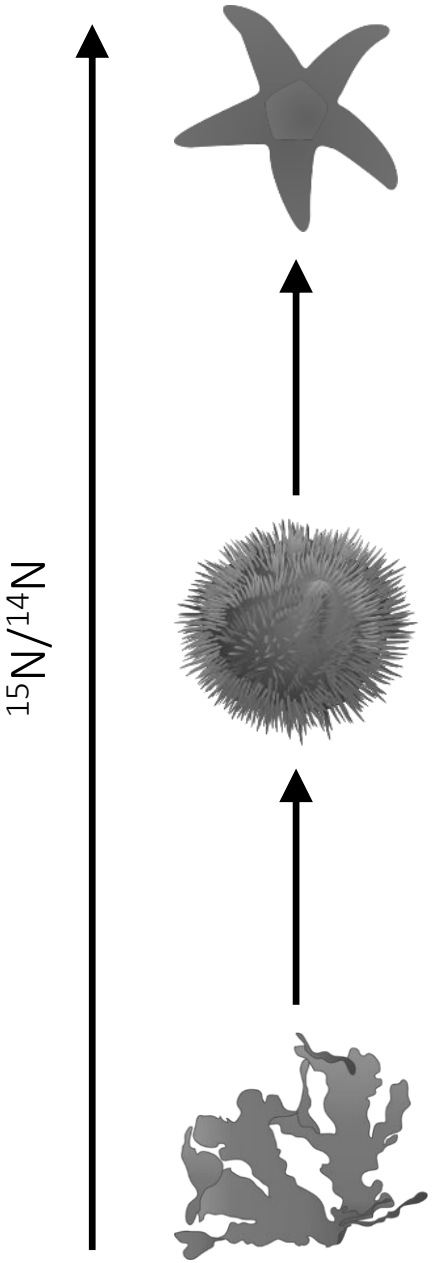
Vertical dimension: trophic position model



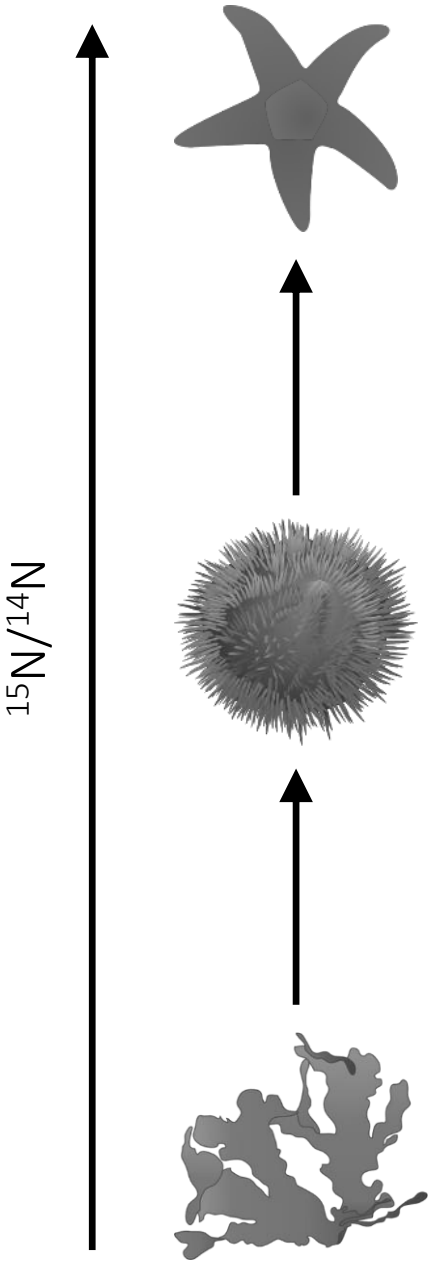
Secondary consumers
TL = 3

Primary consumers
TL = 2

Primary producers
TL = 1

The heavy nitrogen stable isotope (^{15}N) follows a predictable stepwise enrichment pattern with increasing trophic level

Vertical dimension: trophic position model



Secondary consumers
TL = 3

Primary consumers
TL = 2

Primary producers
TL = 1

The heavy nitrogen stable isotope (^{15}N) follows a predictable stepwise enrichment pattern with increasing trophic level

Measurement of stable isotope composition of consumers and baseline items (primary producers)

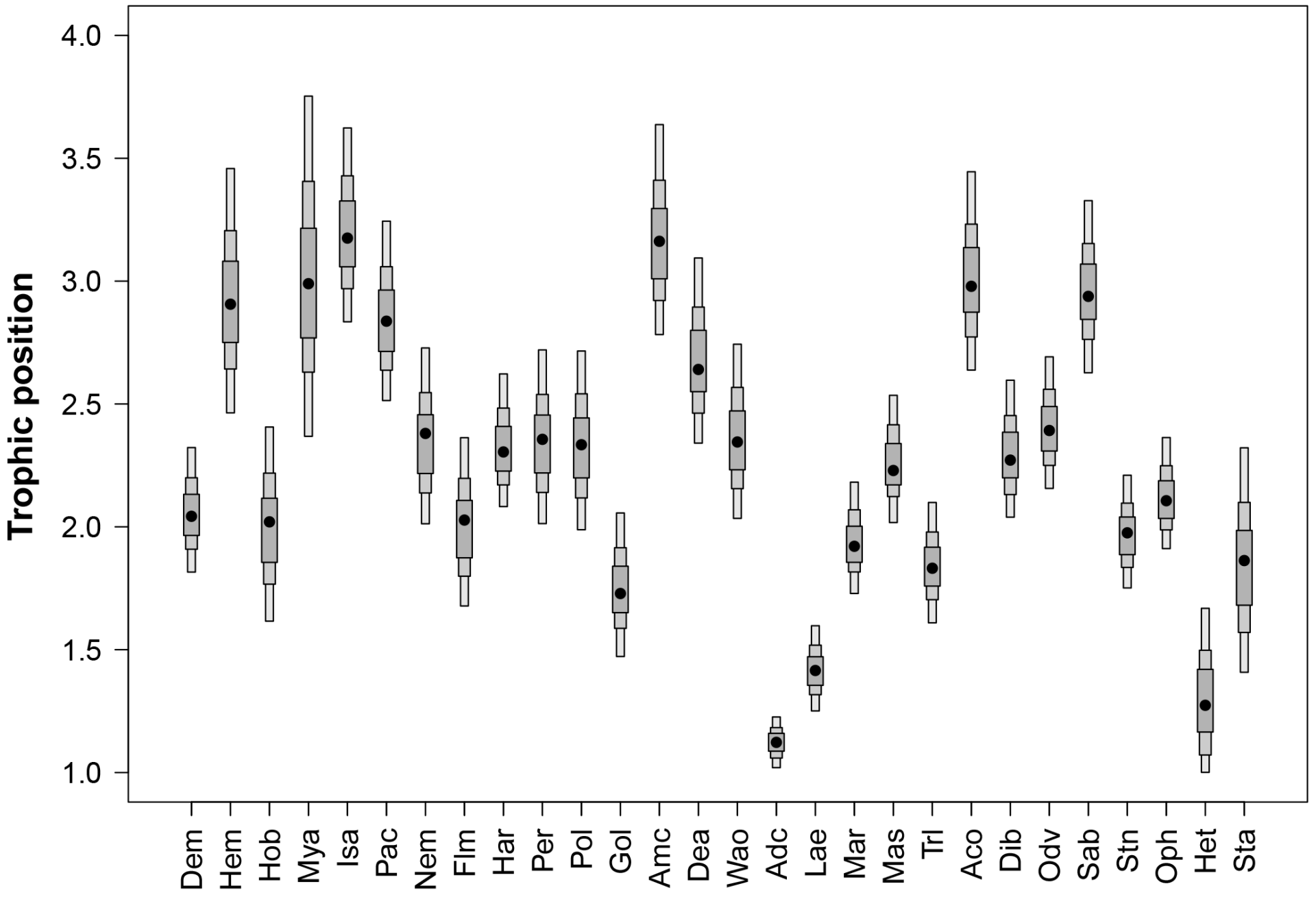
Use of tRophicPosition model to infer trophic level of animals

A guide to the use of tRophicPosition

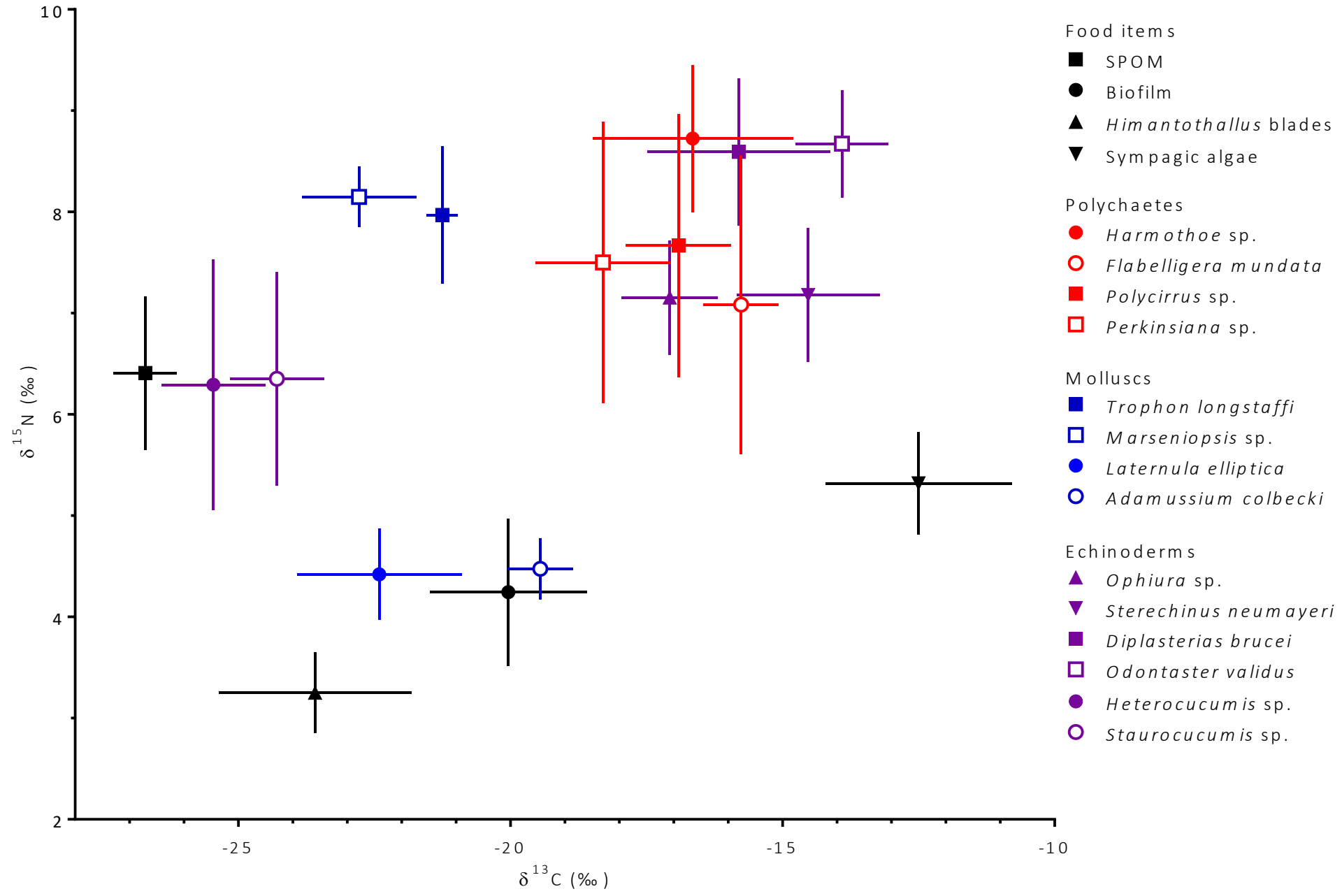
Claudio Quezada-Romegialli, Andrew L Jackson & Chris Harrod

https://github.com/clquezada/tRophicPosition

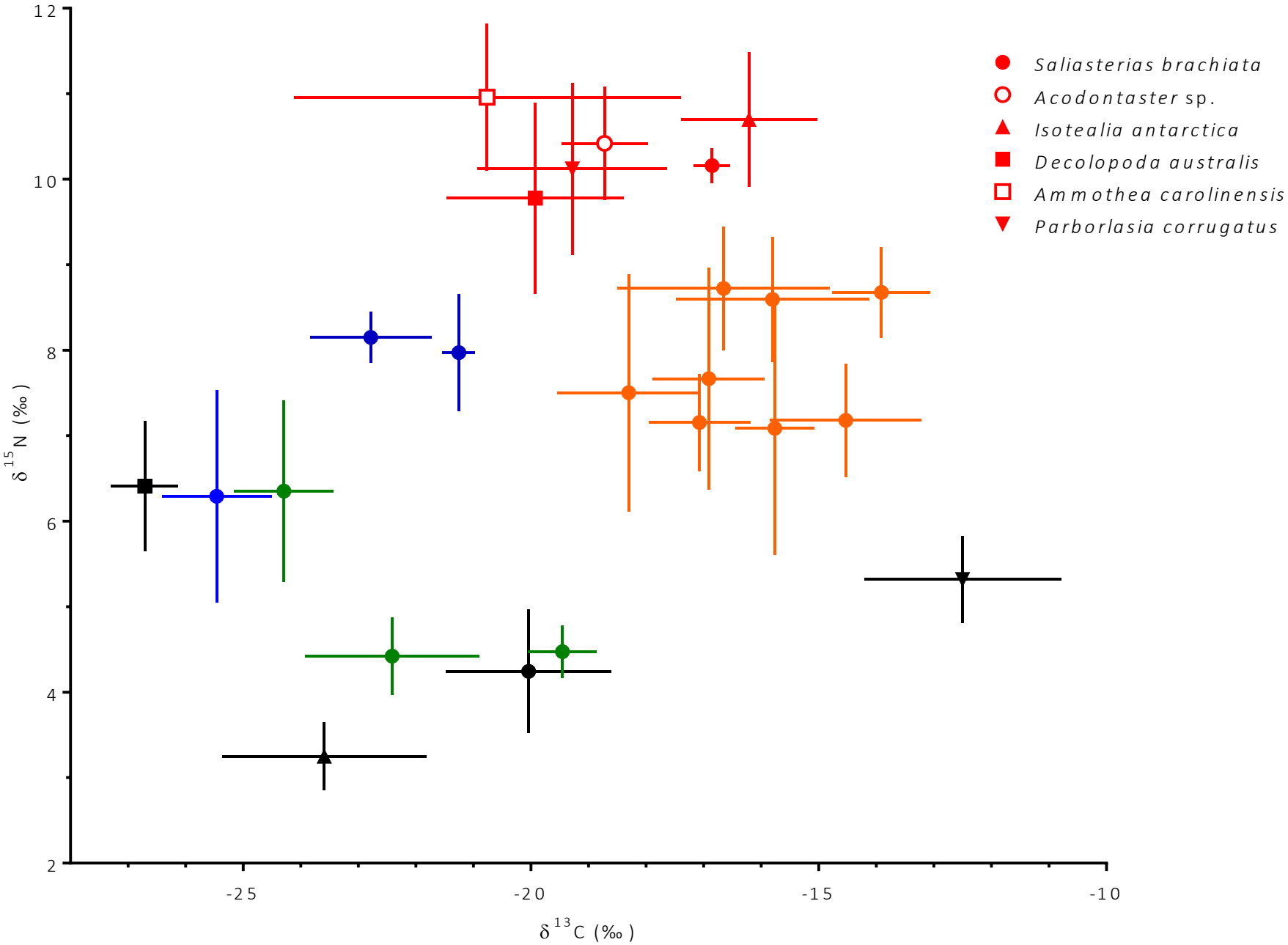
Low trophic positions of consumers



Results: food sources and primary consumers



Results: secondary consumers



Inter-annual change in isotopic compositions