TROPHIC ECOLOGY OF SEA STARS OF THE SOUTHERN OCEAN

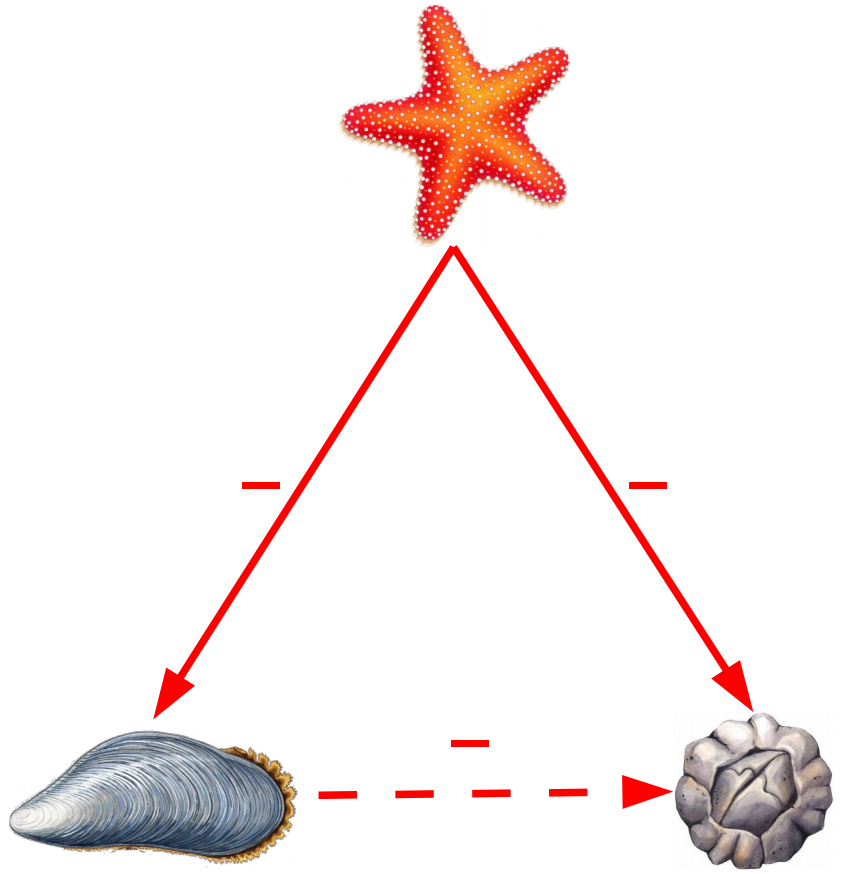
Influence of environmental drivers and subsequent resource availability on trophic diversity

Baptiste Le Bourg

?

Sea stars as a keystone taxon

- 235 species (*ca* 12 % of the known sea star species) in the Southern Ocean
- Keystone taxon: top-down influence on lower trophic levels
- Paine, 1966: Sea star removal experiment



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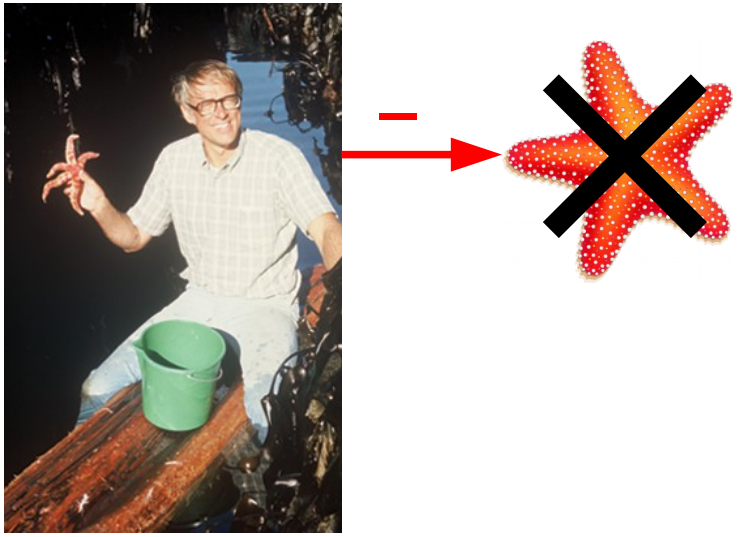
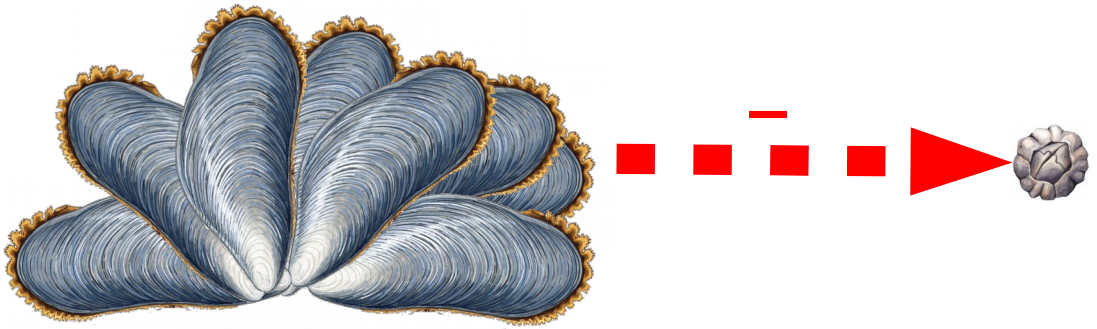


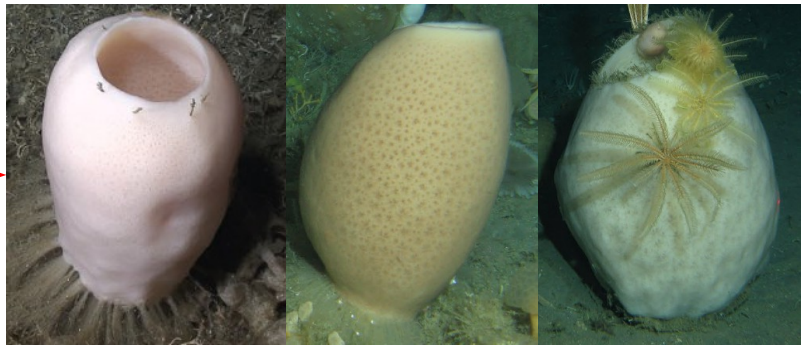


Antarctic sea stars

- Dayton et al., 1974: Sea stars controlling Antarctic sponge communities → keystone species?

Mycale acerata

Rosselid sponges



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Acodontaster conspicuus

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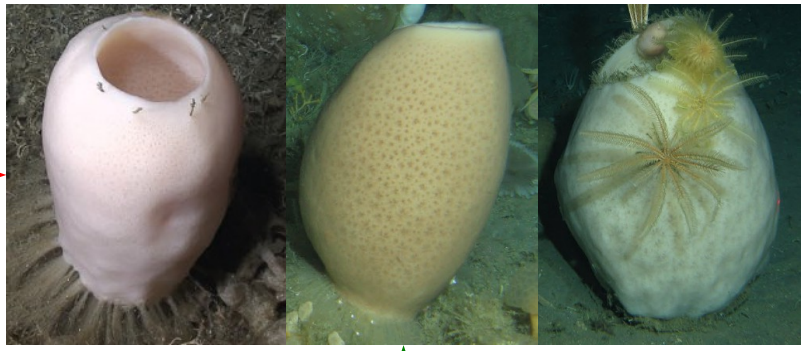

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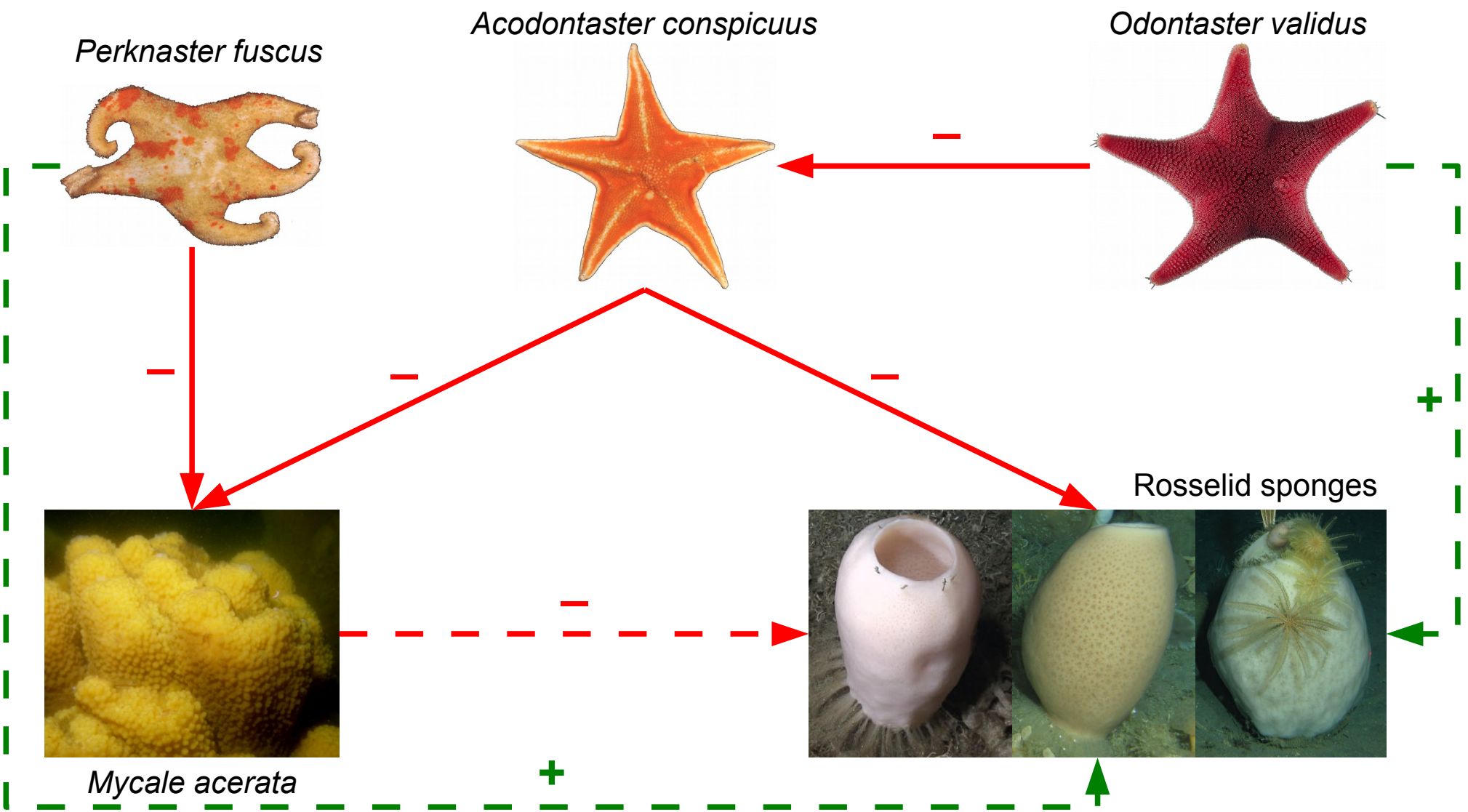

Sea star trophic groups

Predators of
active prey
Labidiaster annulatus

Sea star trophic groups

Predators of active prey

Labidiaster annulatus

Predator of large sessile prey

Perknaster sp.

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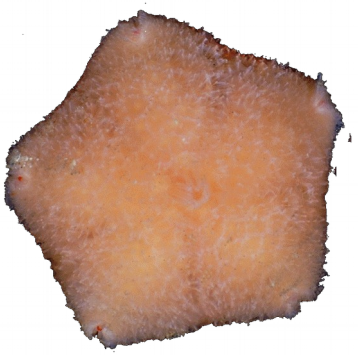

Predators of encrusting prey

Pteraster sp.

Sea star trophic groups

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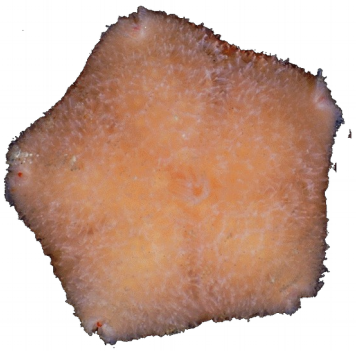

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Suspension feeders

Odinella nutrix

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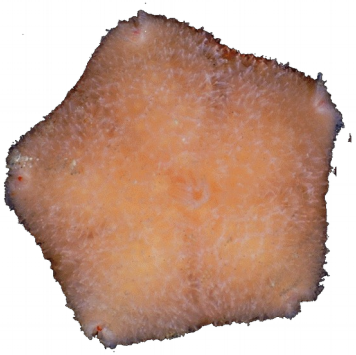

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Sediment feeders

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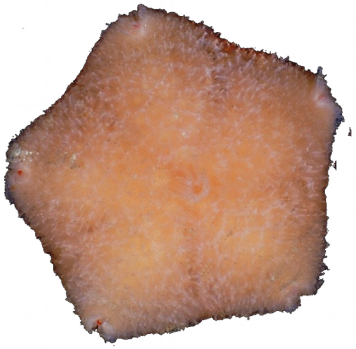

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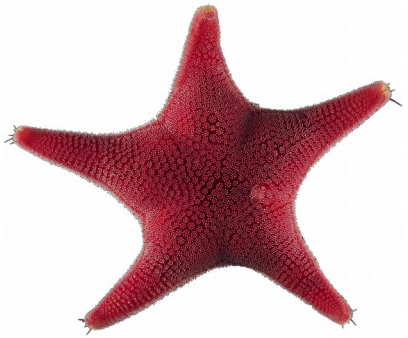

Omnivores

Odontaster validus

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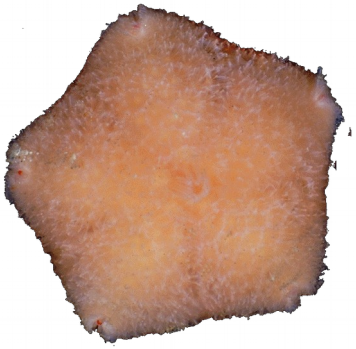

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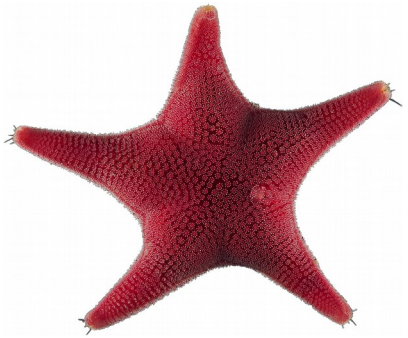

Omnivores

Odontaster validus

Pelagos-based omnivores

Notasterias bongraini

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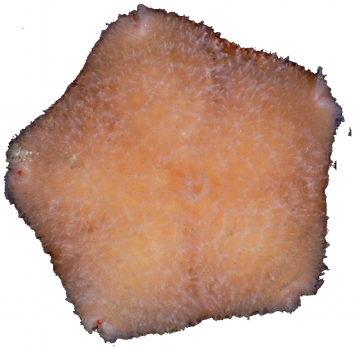

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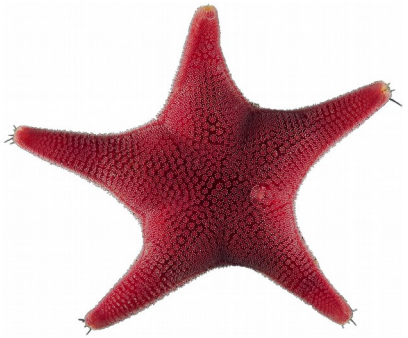

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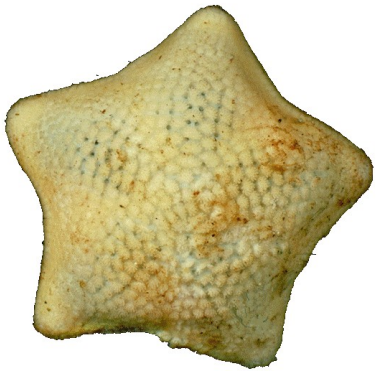
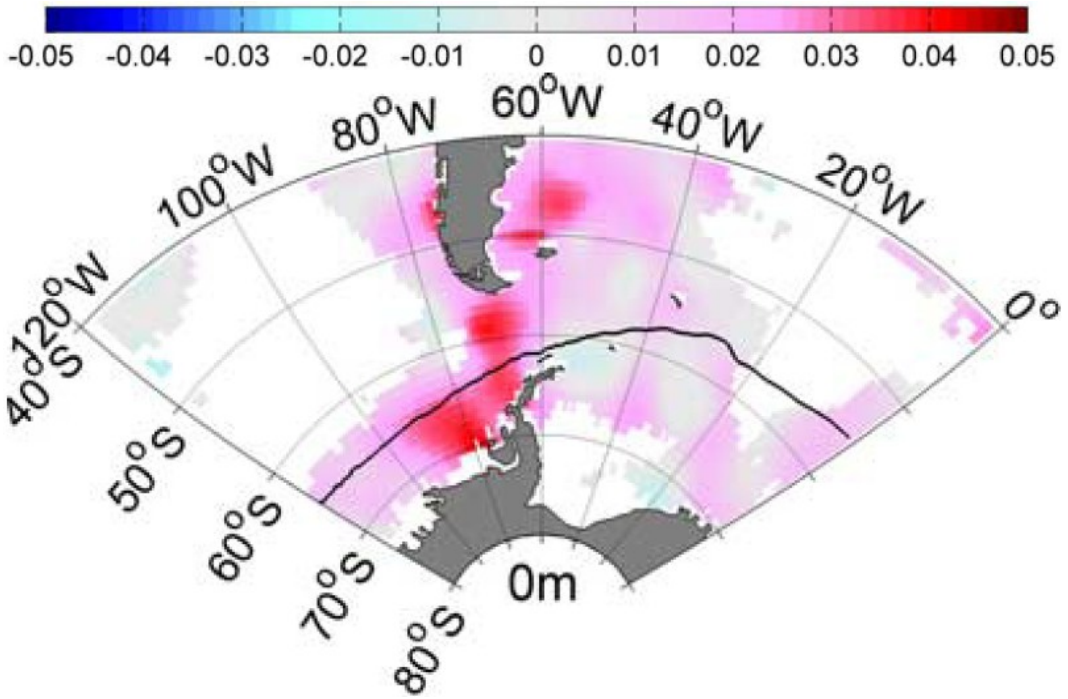


Unknown trophic group

Kampylaster incurvatus

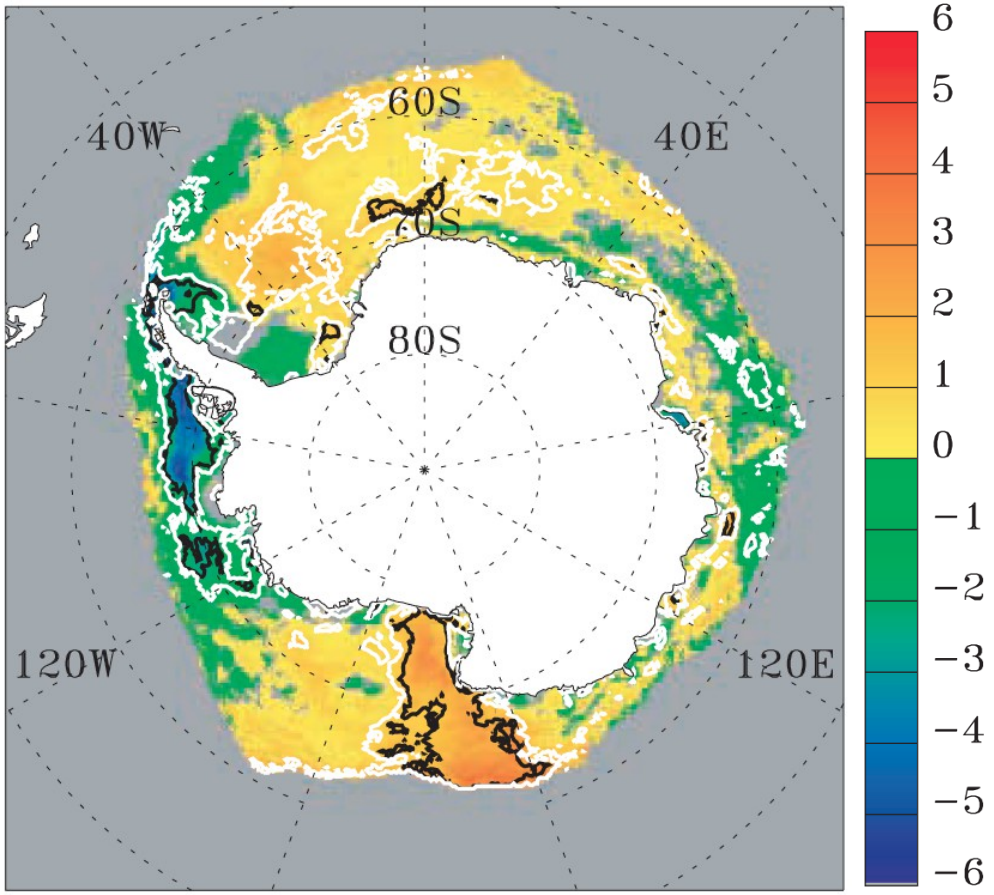
Climate change in the Southern Ocean

Ocean temperature trend
(°C/yr, 1955-1998)



Meredith and King, 2005

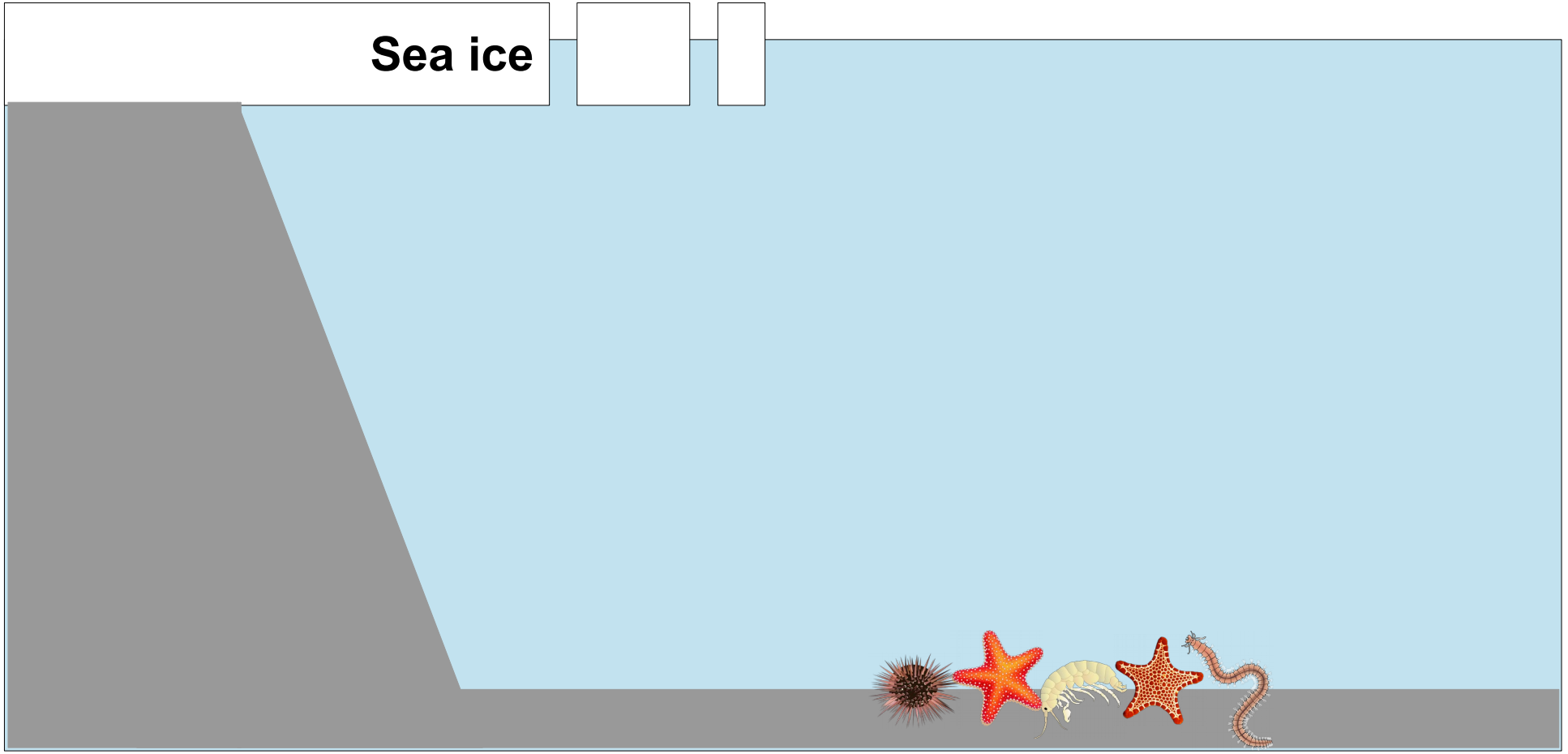
Ice season duration trend
(days/yr, 1979-2004)



Stammerjohn et al., 2008

- Increasing sea water temperature in Western Antarctic Peninsula
- Regional variations in changes of sea ice extent and ice season duration

Climate change and sea stars



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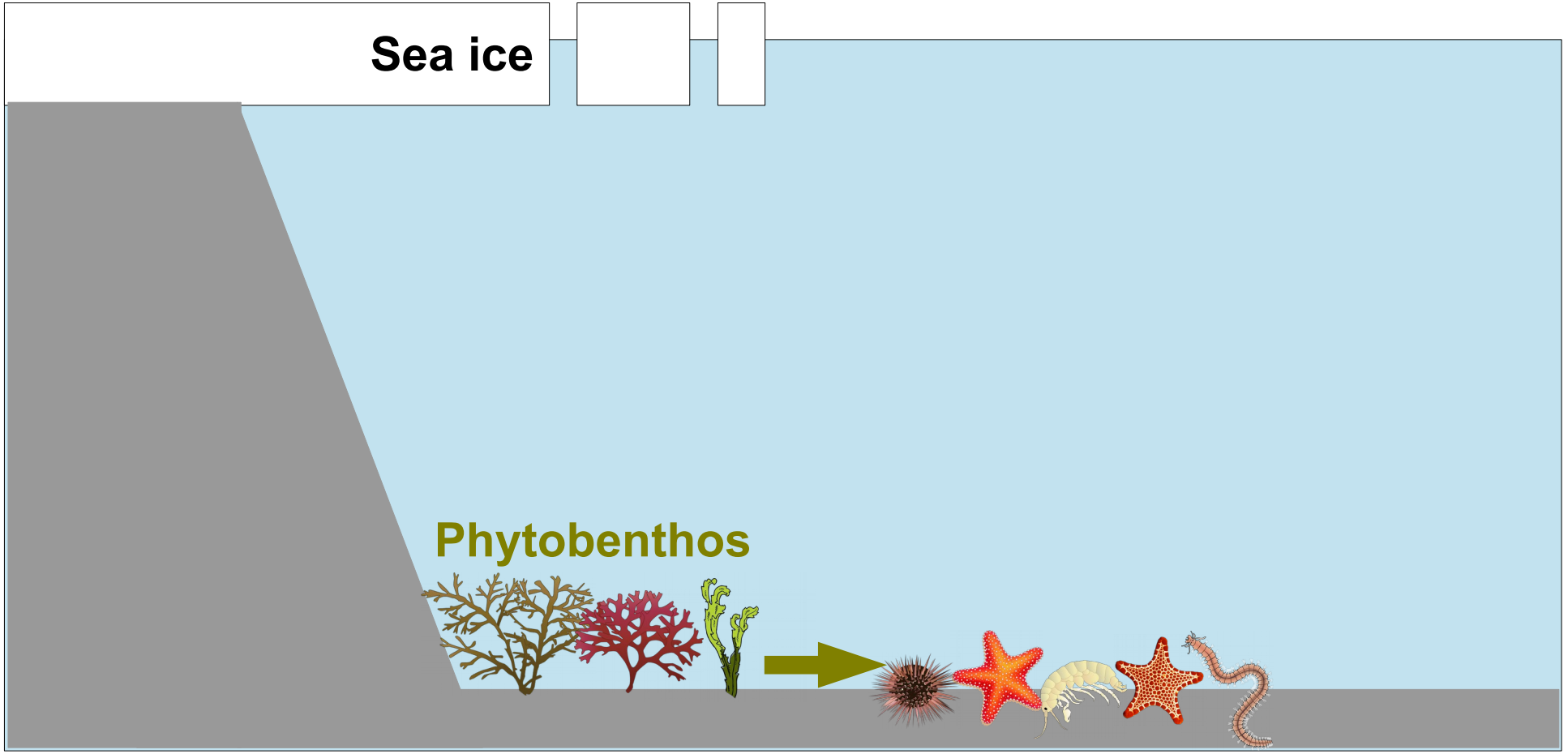

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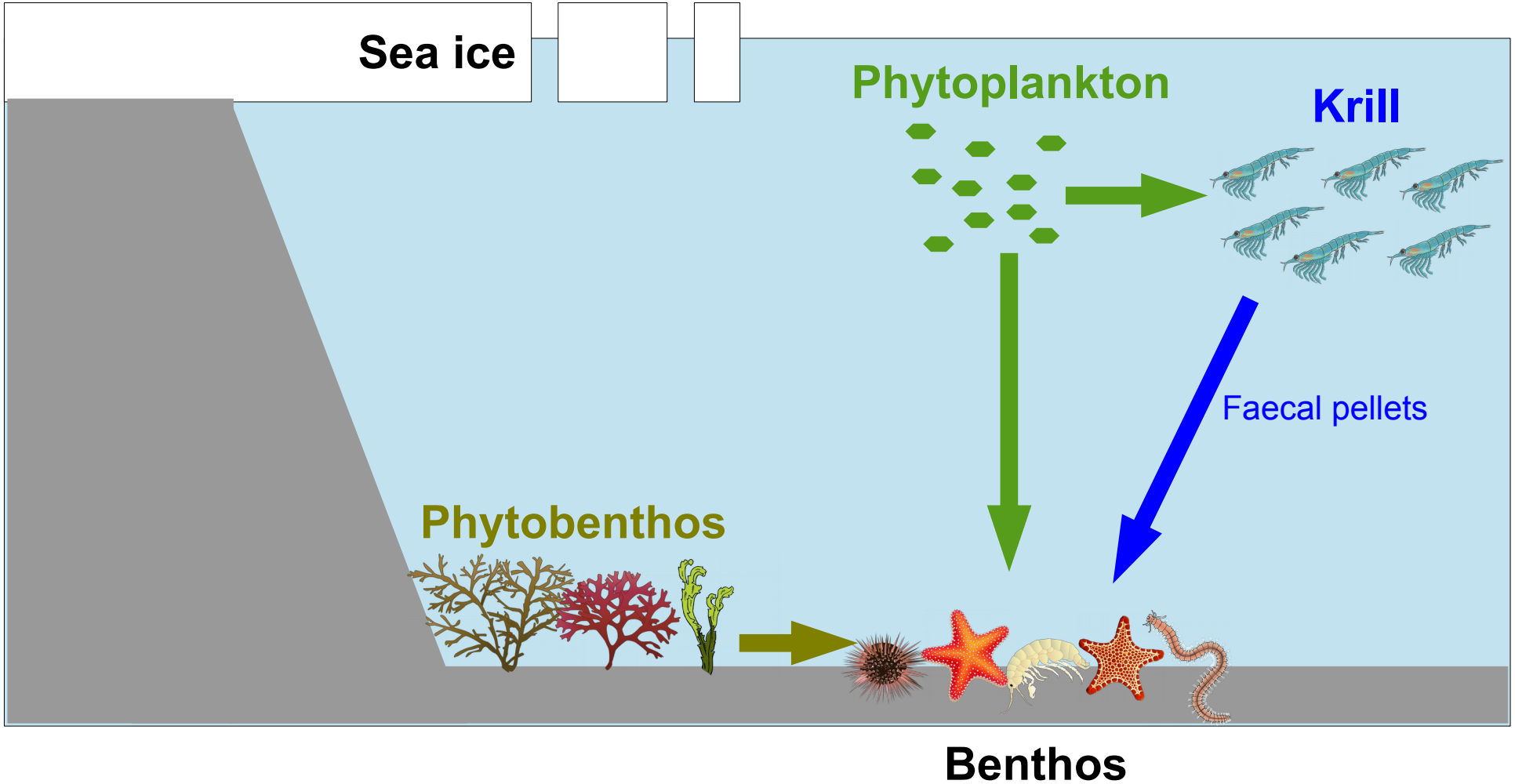

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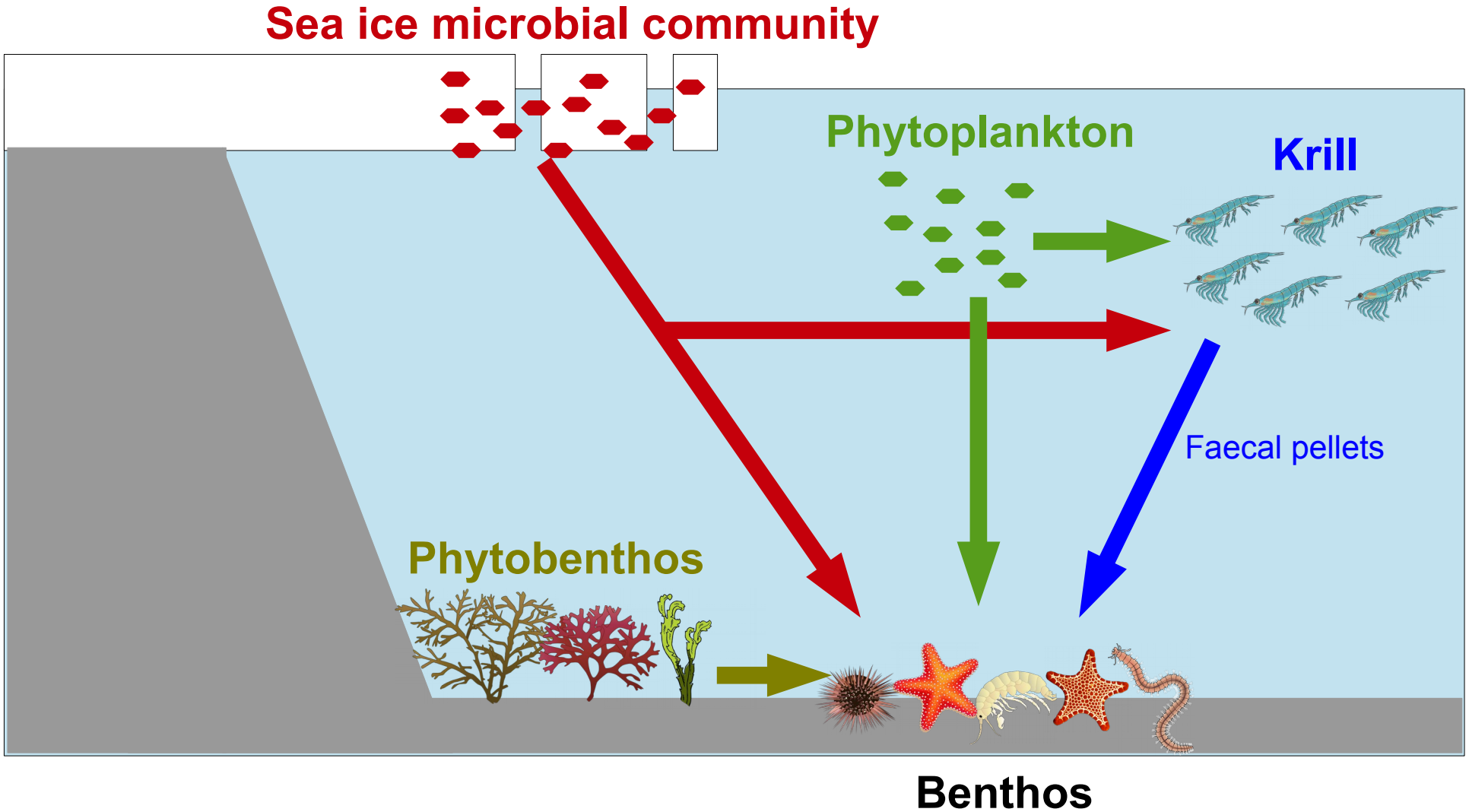

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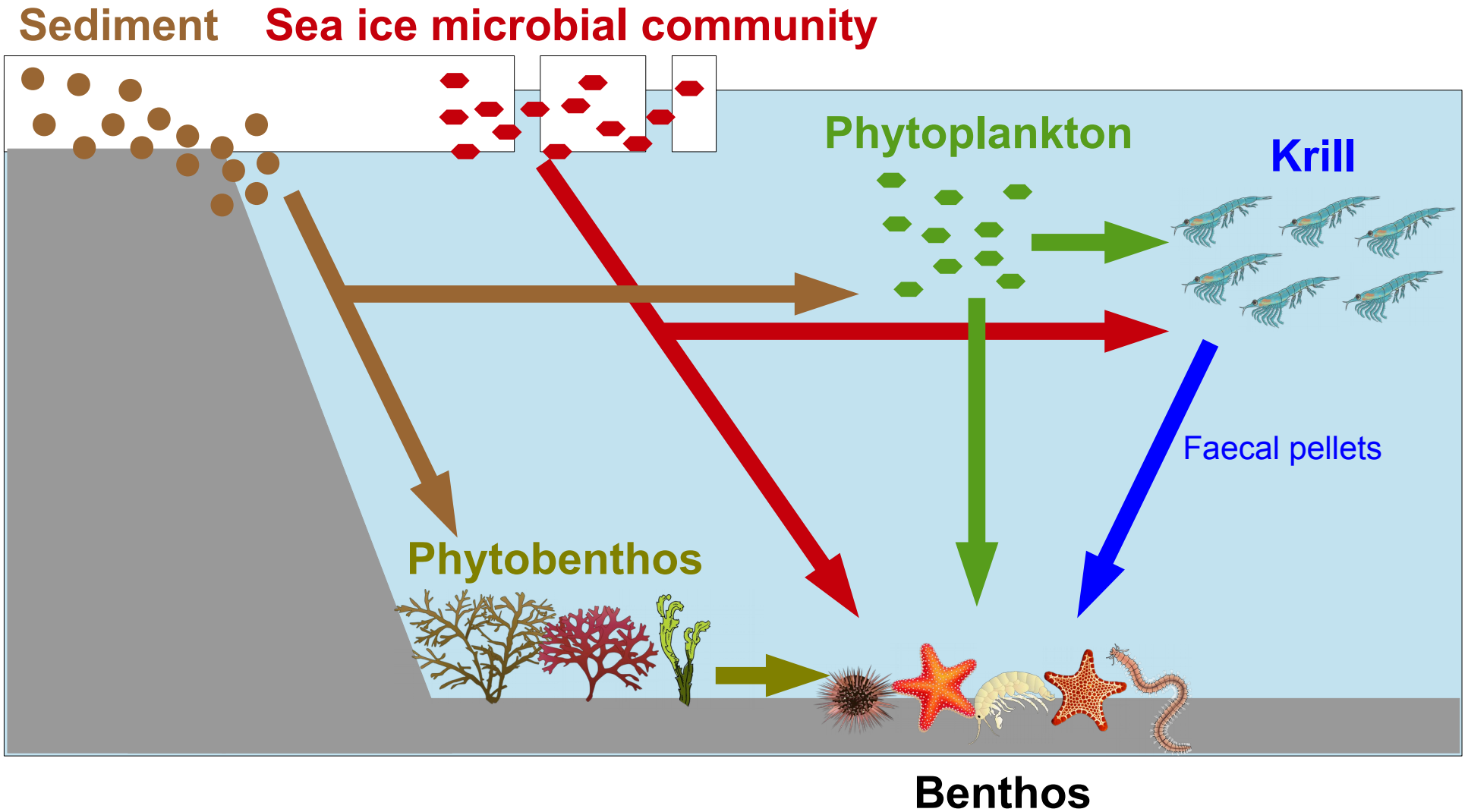

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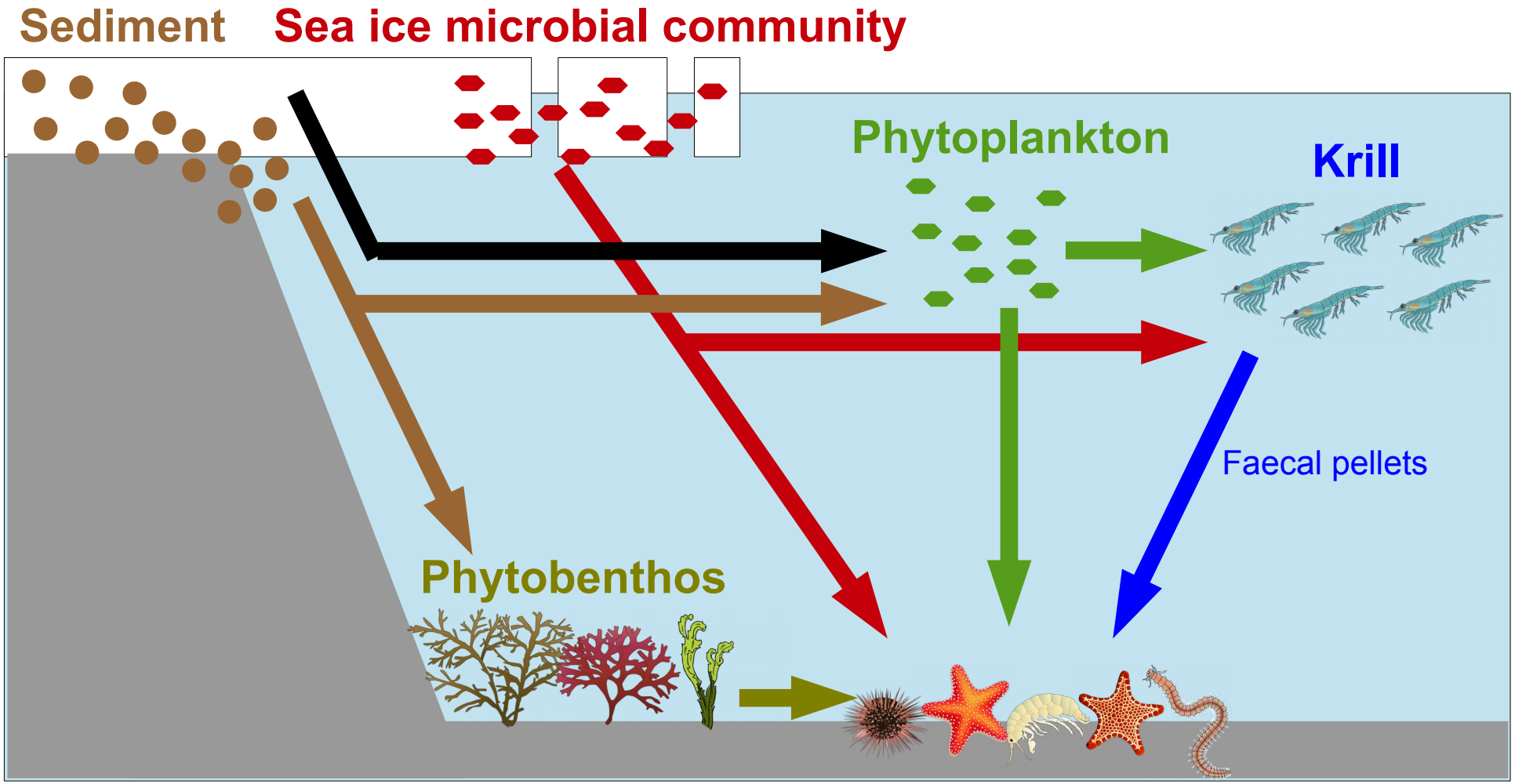

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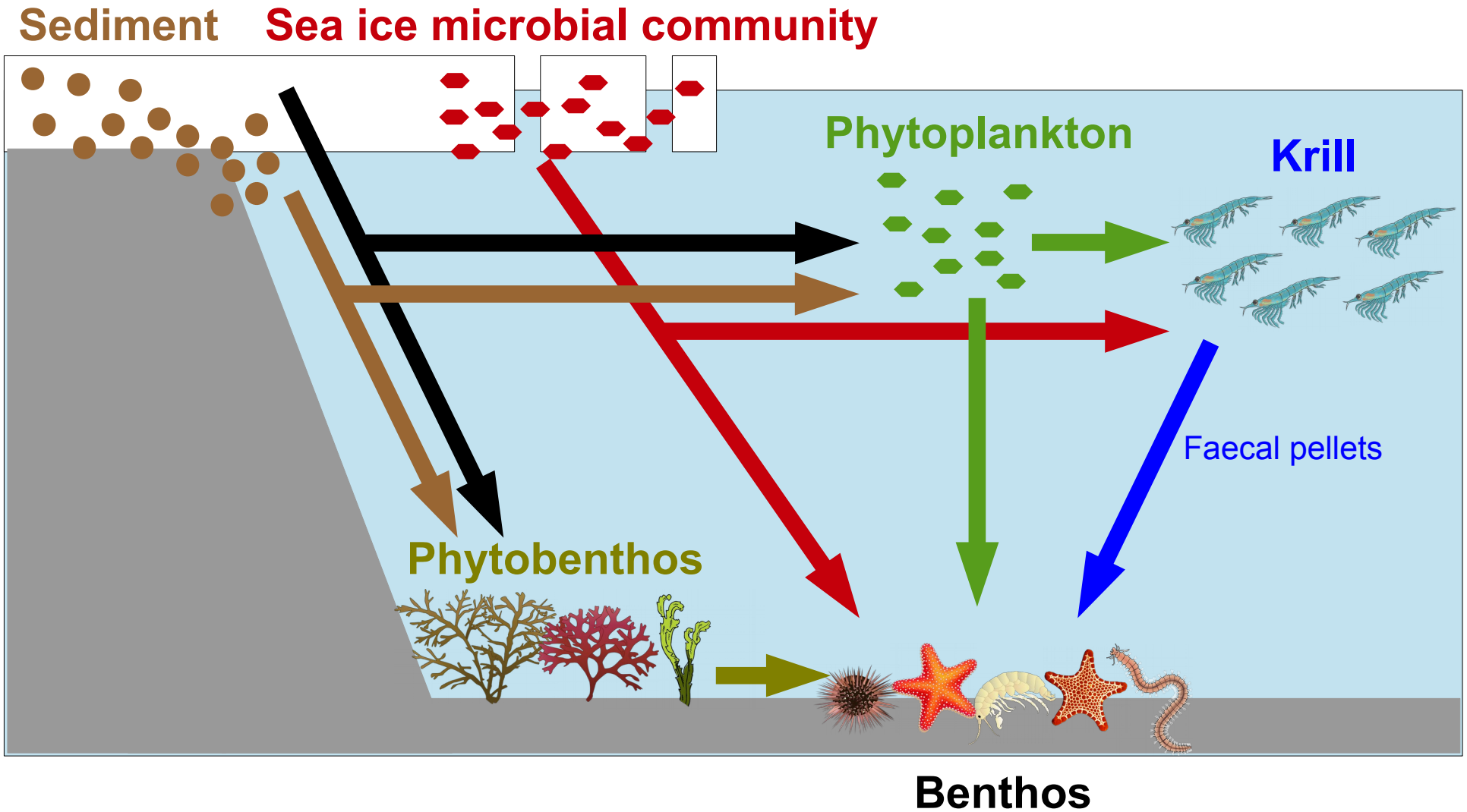

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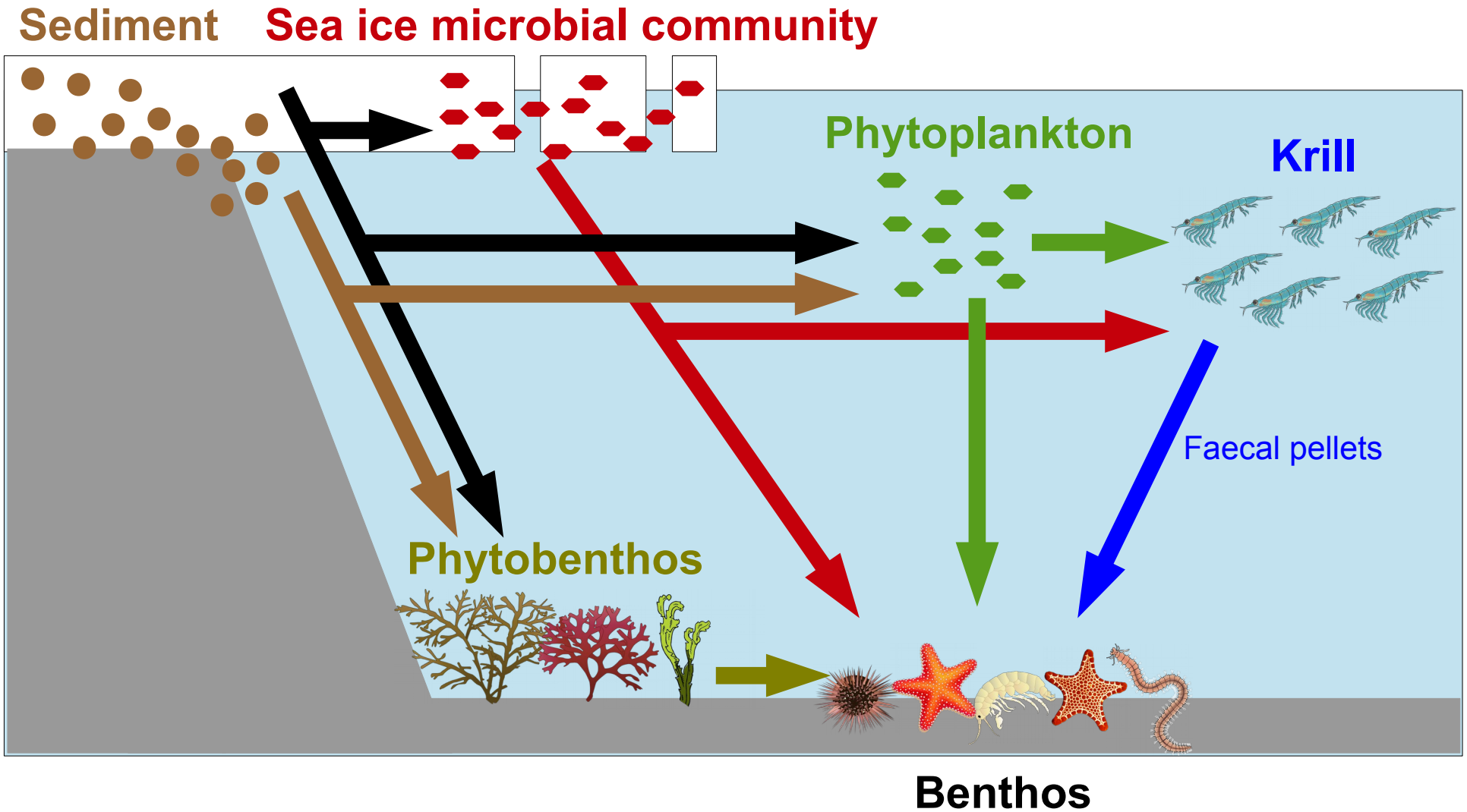

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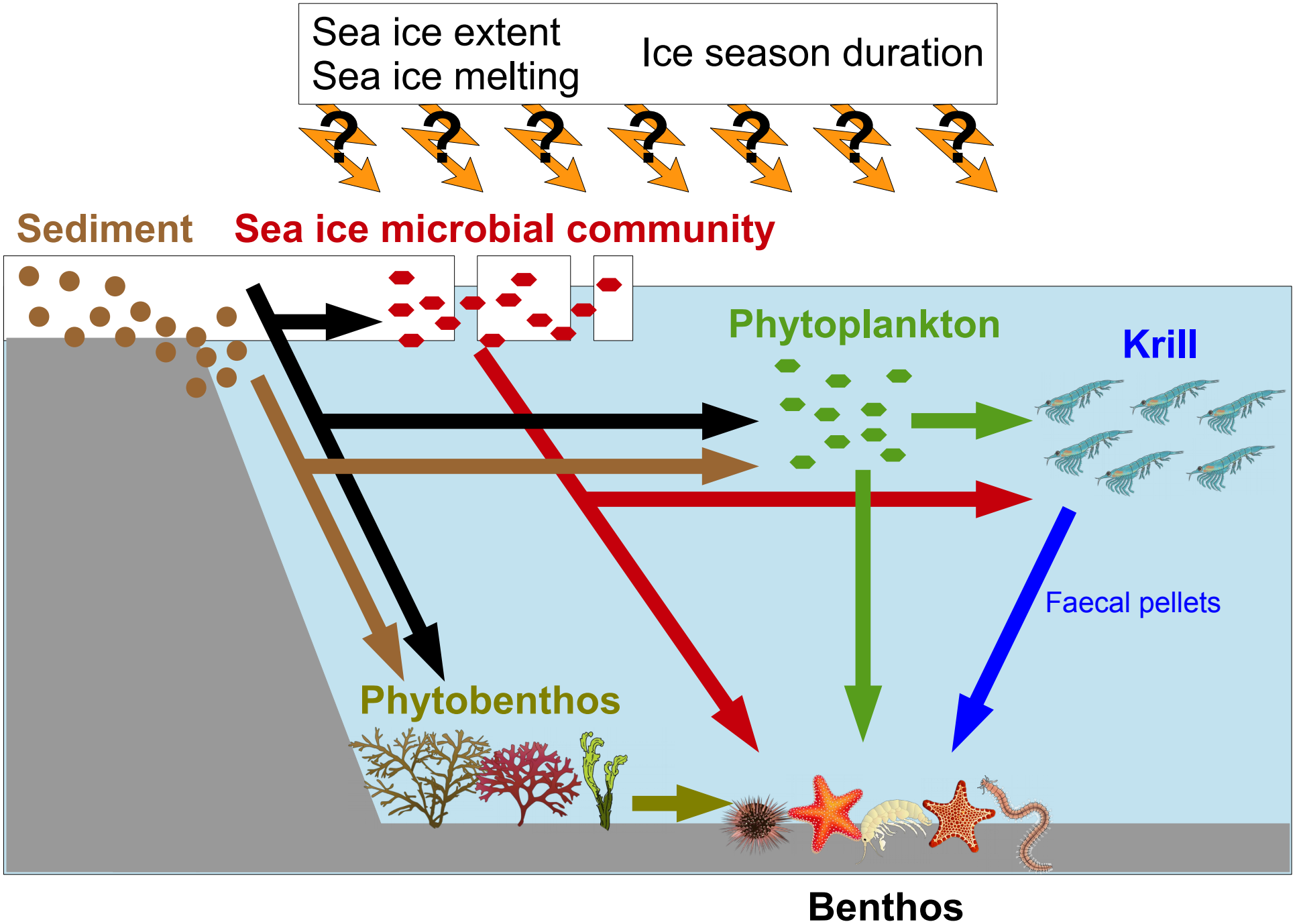


Study objectives

In the Southern Ocean:

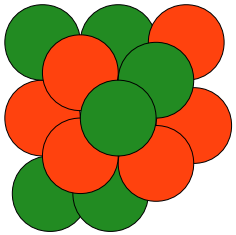
→ What is the extent of trophic diversity between sea stars?

→ How does ice impact the trophic ecology of sea stars?

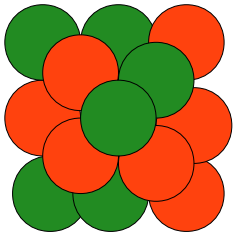
Stable isotopes in trophic ecology

- $^{13}C/^{12}C \rightarrow \delta^{13}C$
- $^{15}N/^{14}N \rightarrow \delta^{15}N$
- $^{34}S/^{32}S \rightarrow \delta^{34}S$

"You are what you eat, plus a few per mil"



Carbon 12
6 protons
6 neutrons



Carbon 13
6 protons
7 neutrons

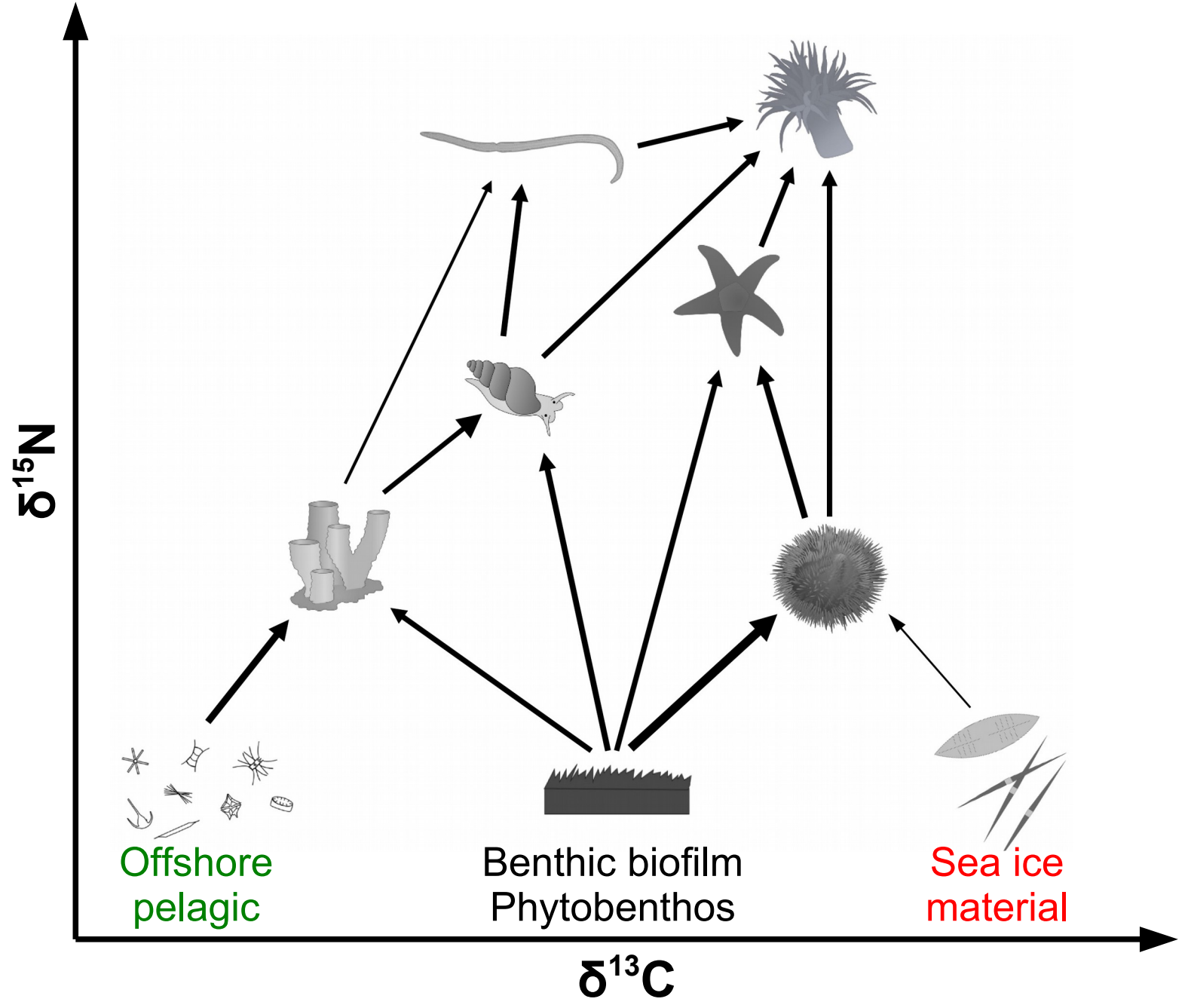
Prey

^{13}C ^{12}C
^{13}C ^{12}C ^{13}C
^{12}C ^{13}C ^{12}C

Predator

^{13}C ^{12}C
^{13}C ^{13}C ^{13}C
^{12}C ^{13}C ^{12}C

Stable isotopes in trophic ecology



^{15}N ^{14}N

^{15}N ^{15}N ^{15}N

^{14}N ^{15}N ^{15}N

Predator or degraded substrate

Trophic enrichment or bacterial degradation

^{15}N ^{14}N

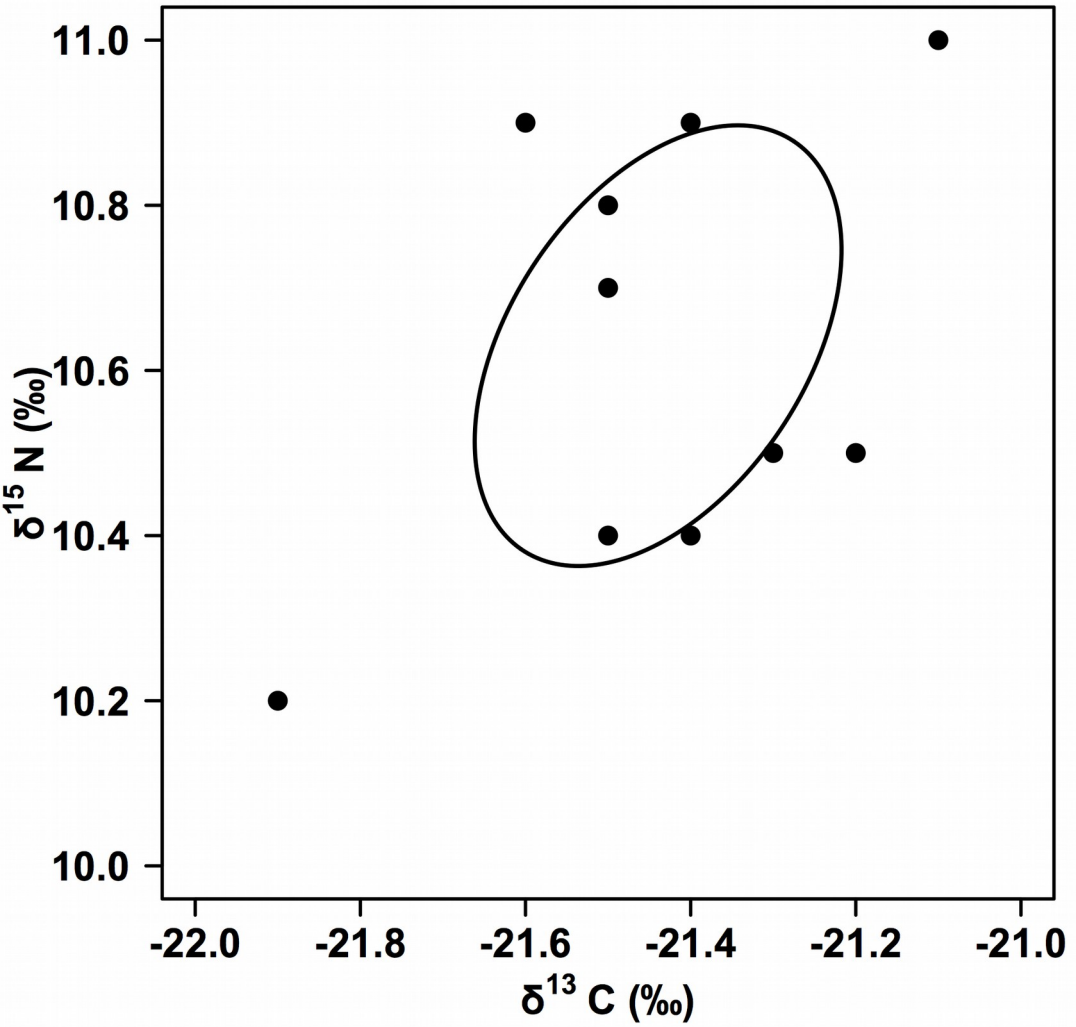
^{15}N ^{14}N ^{15}N

^{14}N ^{15}N ^{14}N

Prey or "fresh" substrate

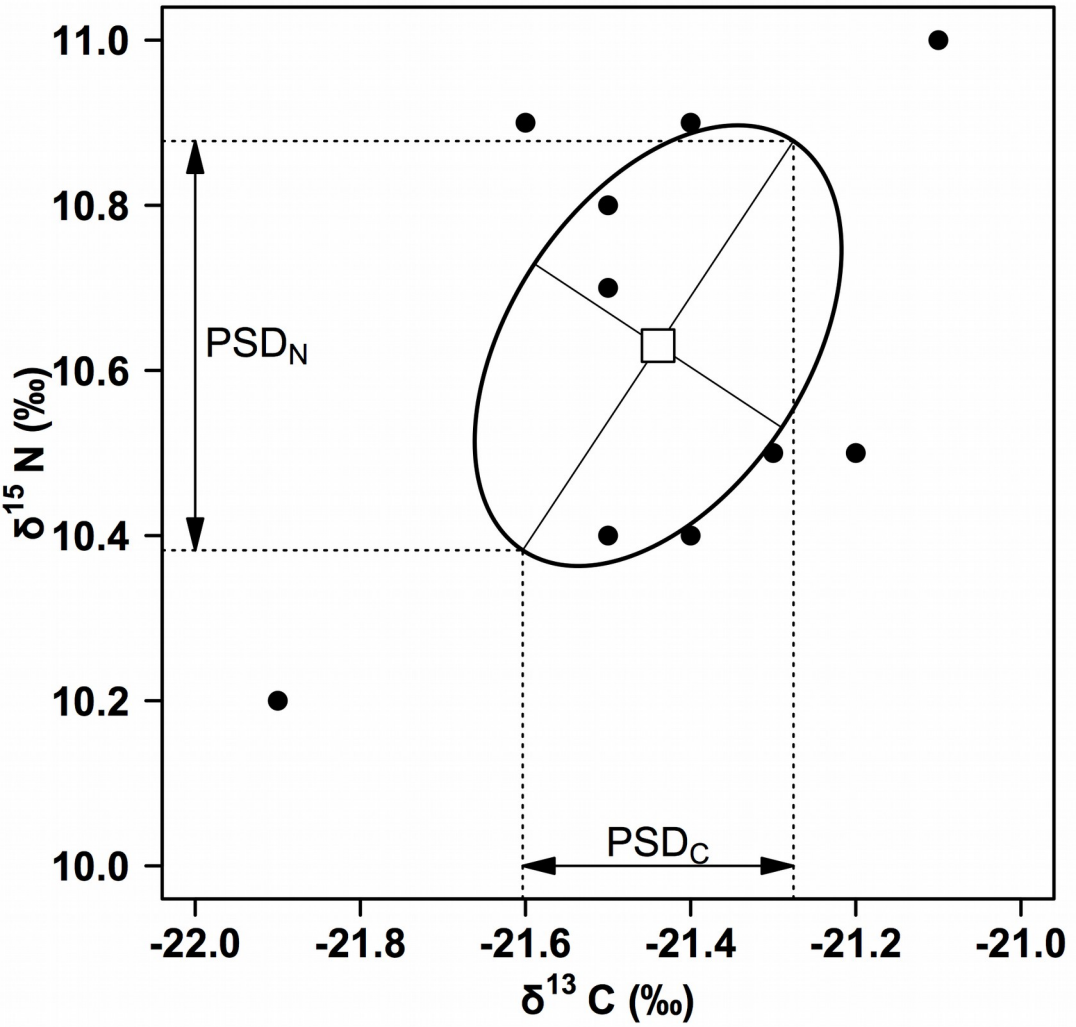
Michel et al. 2017

Stable isotopes: standard ellipse metrics



- Standard Ellipse Area (SEA)

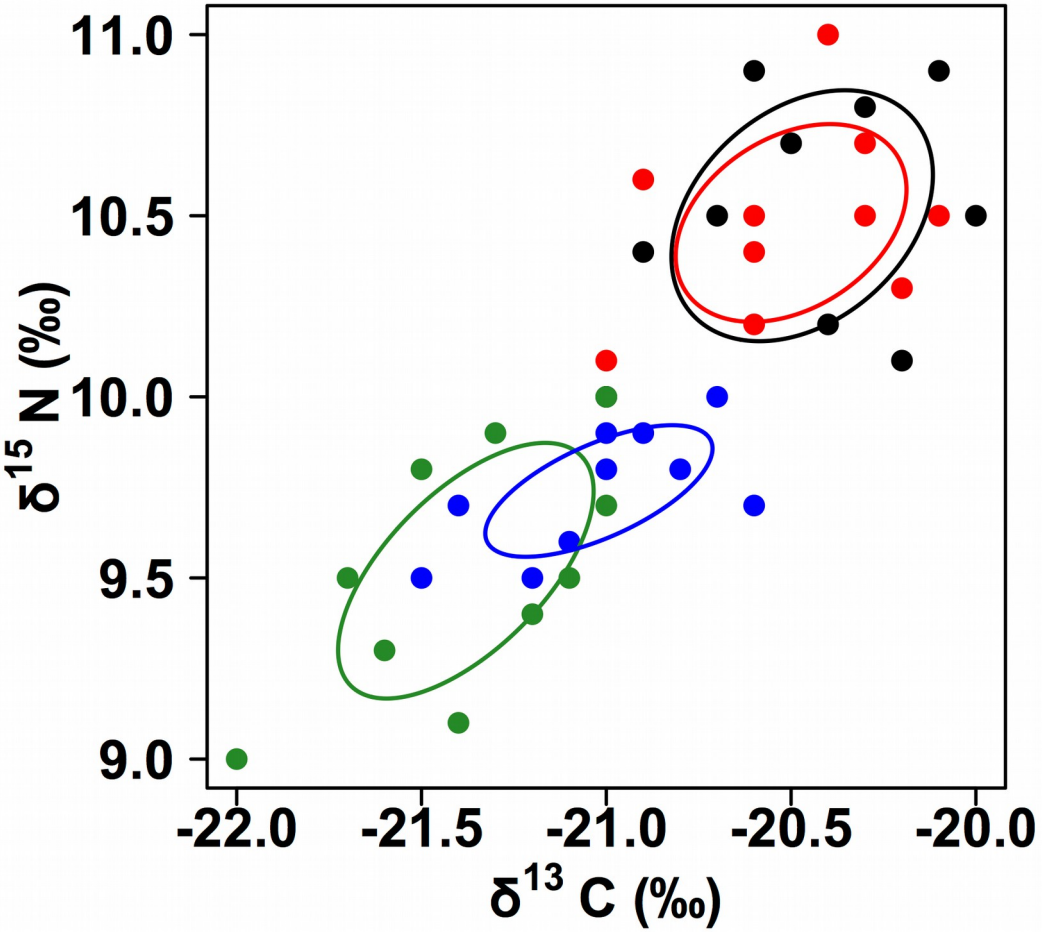
Stable isotopes: standard ellipse metrics

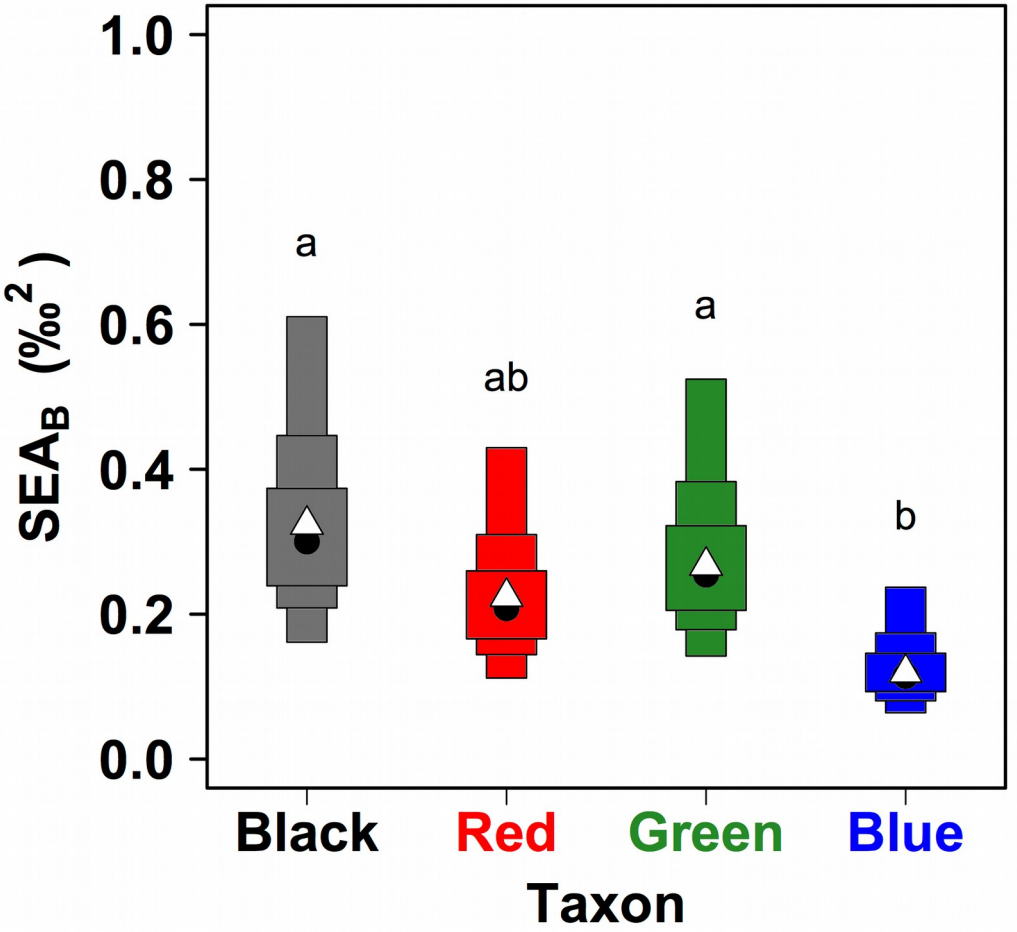


- Standard Ellipse Area (SEA)
- Pseudo-Standard Deviation (PSD)

Stable isotopes: standard ellipse metrics

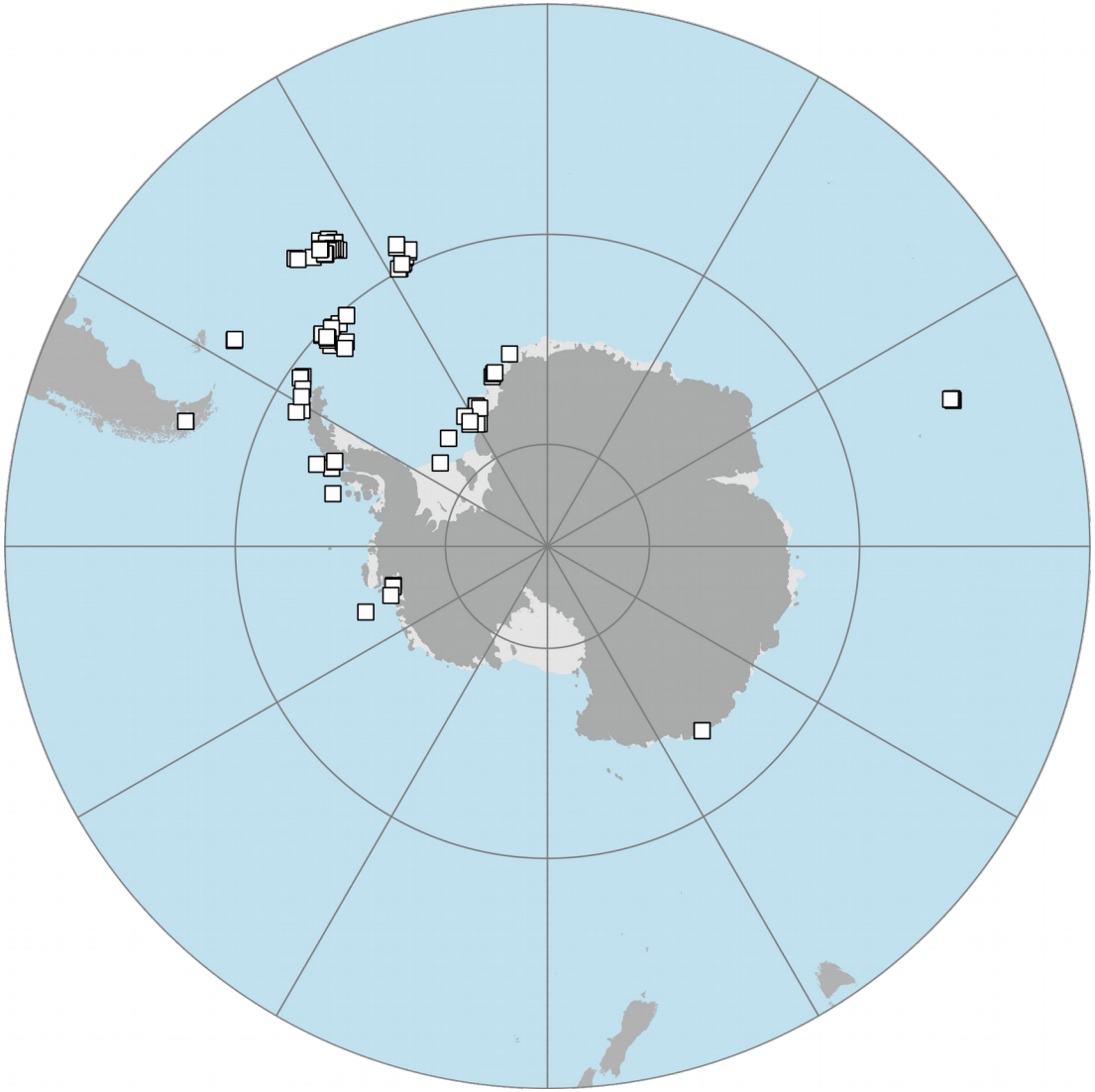
- Bayesian estimation of isotopic metrics → comparison of metric values
- Isotopic overlap: high niche overlap between black and red taxa; intermediate niche overlap for blue and green taxa; niche partitioning of black and red taxa from blue and green taxa





Sampling

- ☐ Frozen and dried samples



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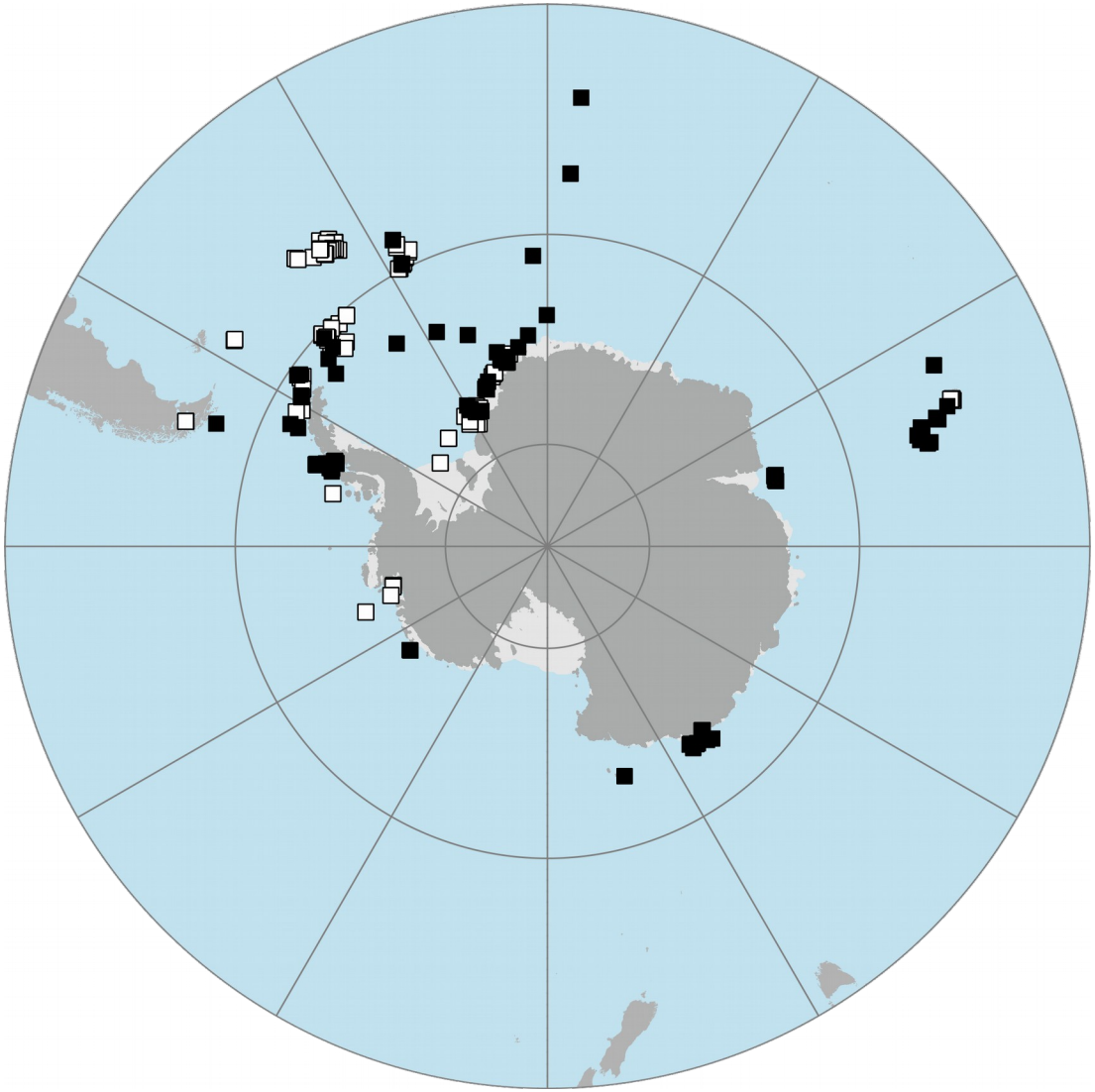
- ☐ Frozen and dried samples

  ■ Preserved samples



RESEARCH ARTICLE

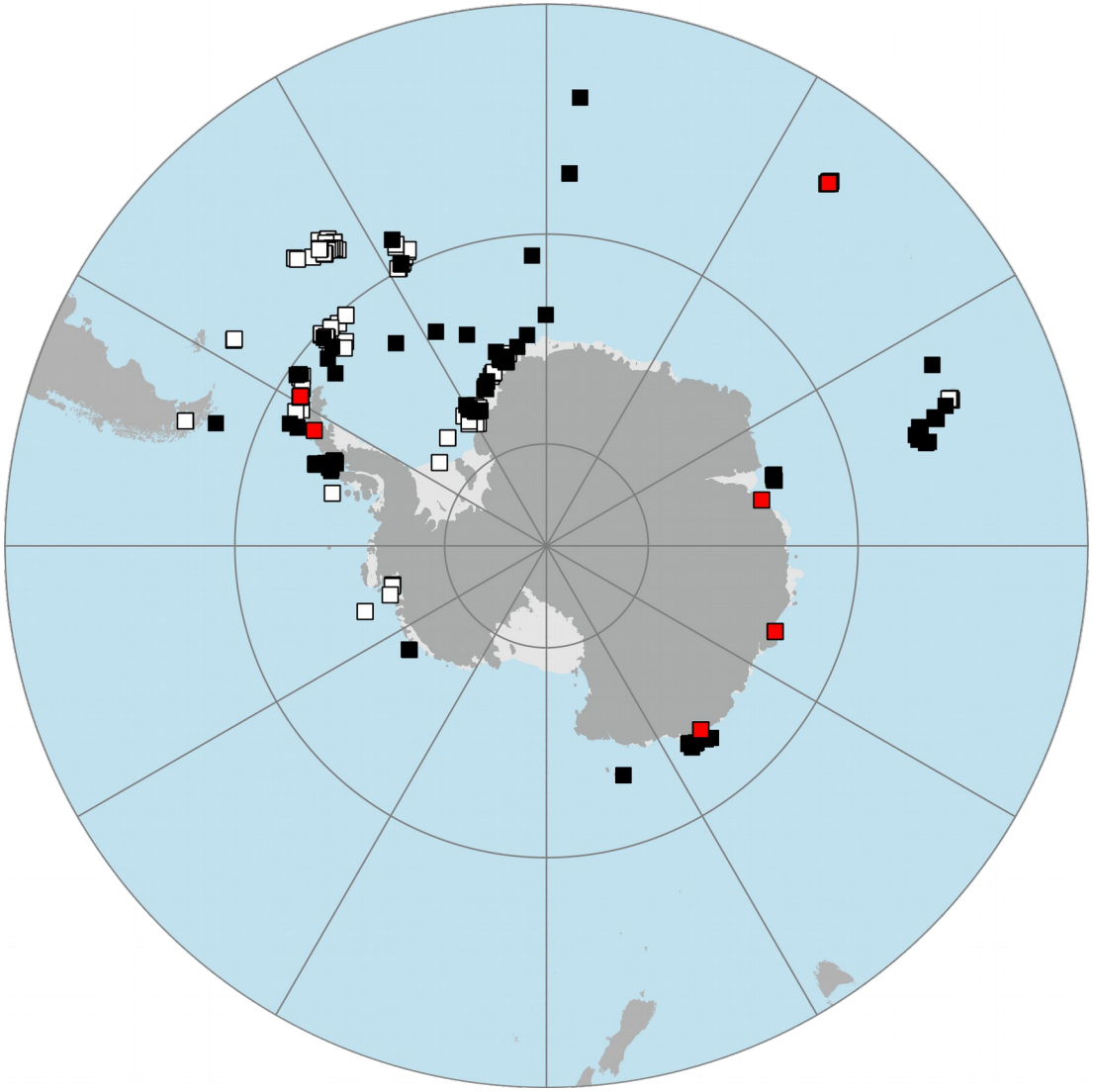
WILEY Rapid Communications in Mass Spectrometry

Effects of preservation methodology on stable isotope compositions of sea stars

Baptiste Le Bourg[1] | Gilles Lepoint[1] | Loïc N. Michel[1,2]

Sampling

- ☐ Frozen and dried samples
- ■ Preserved samples
- ■ Shared datasets



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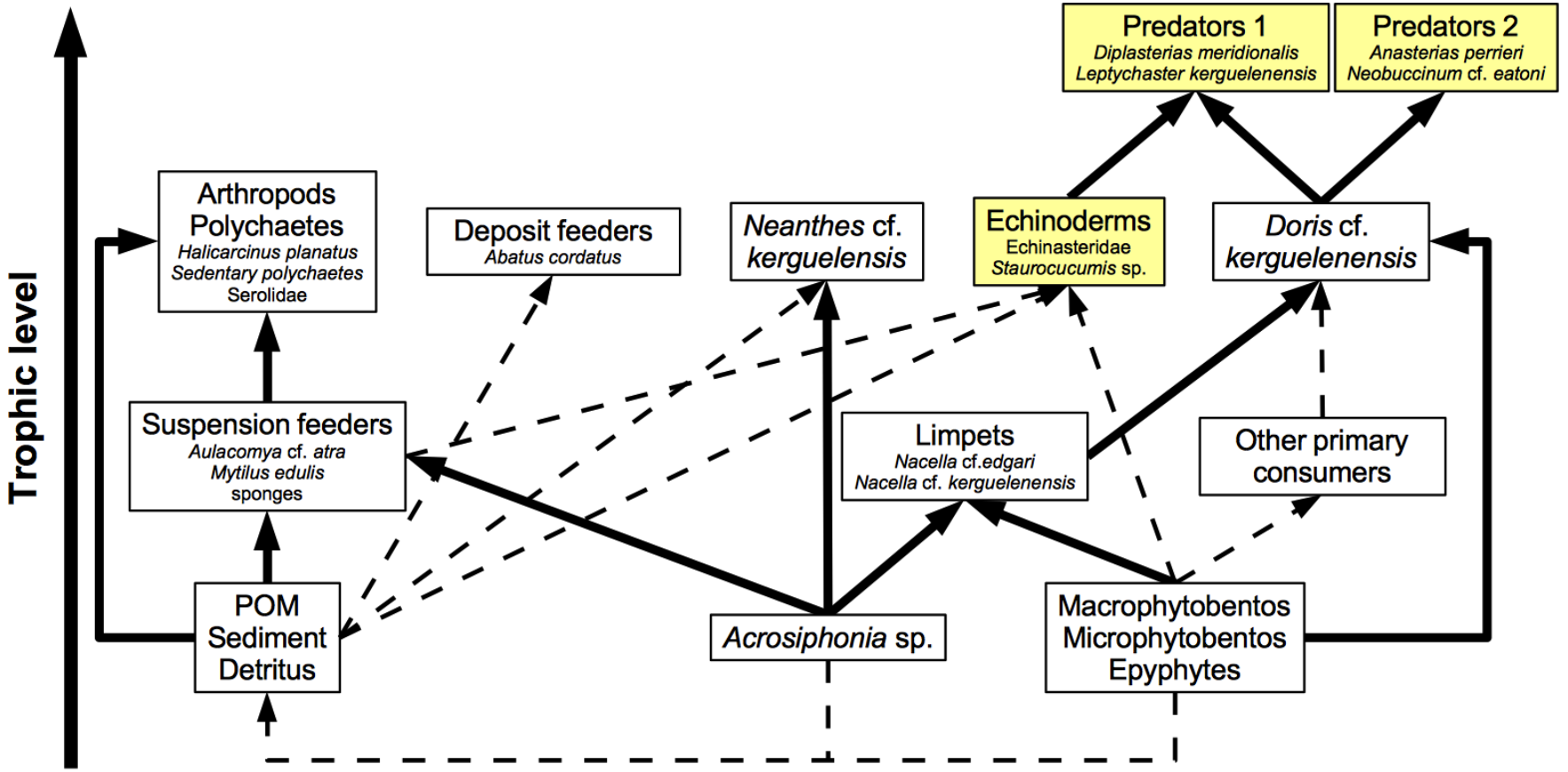
Thesis outline

- What is the trophic role of sea stars in Subantarctic kelp forests?



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- How do terrestrial glaciers impact the trophic ecology of sea stars?

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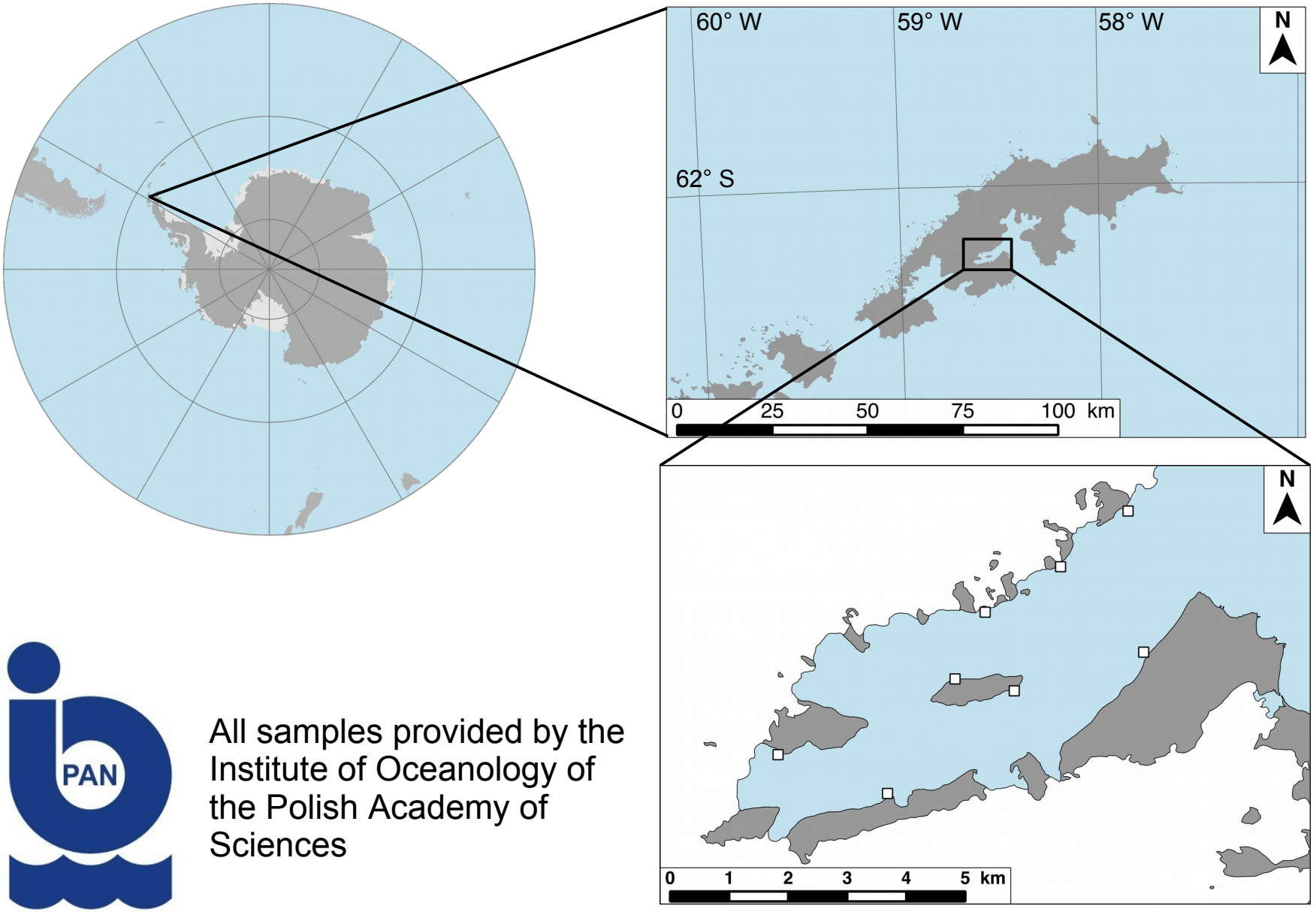
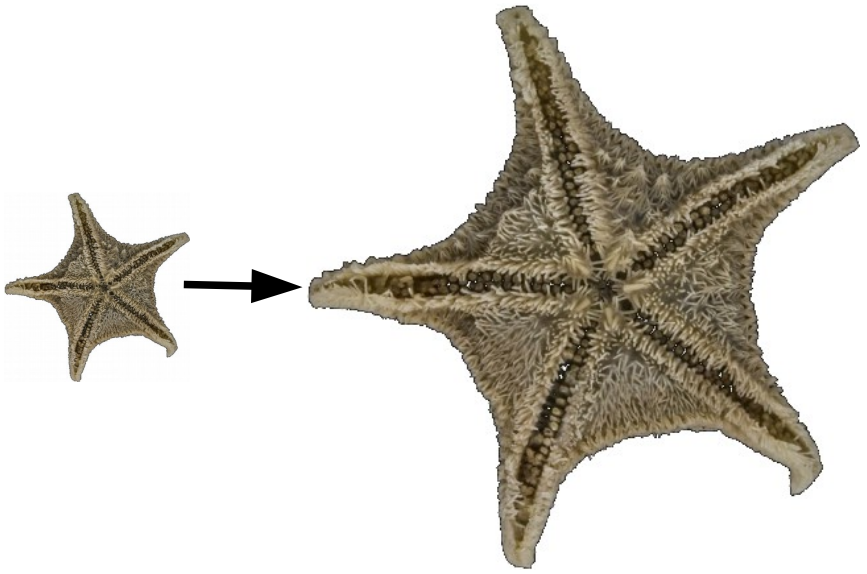
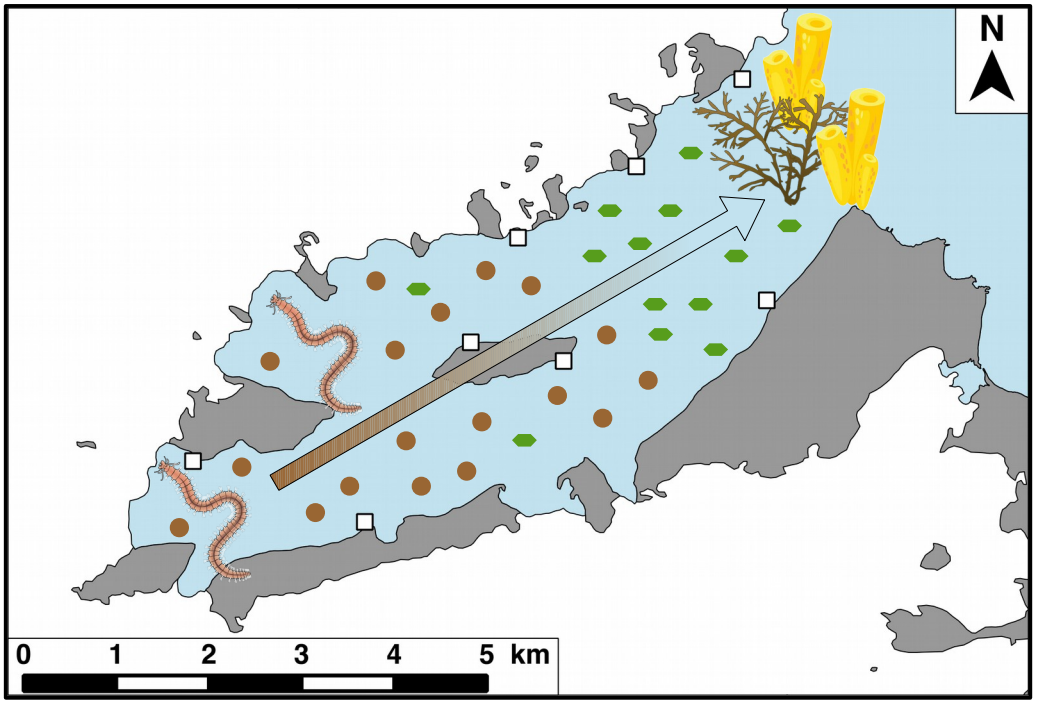


All samples provided by the Institute of Oceanology of the Polish Academy of Sciences

→ Does the trophic ecology of sea stars change during growth?

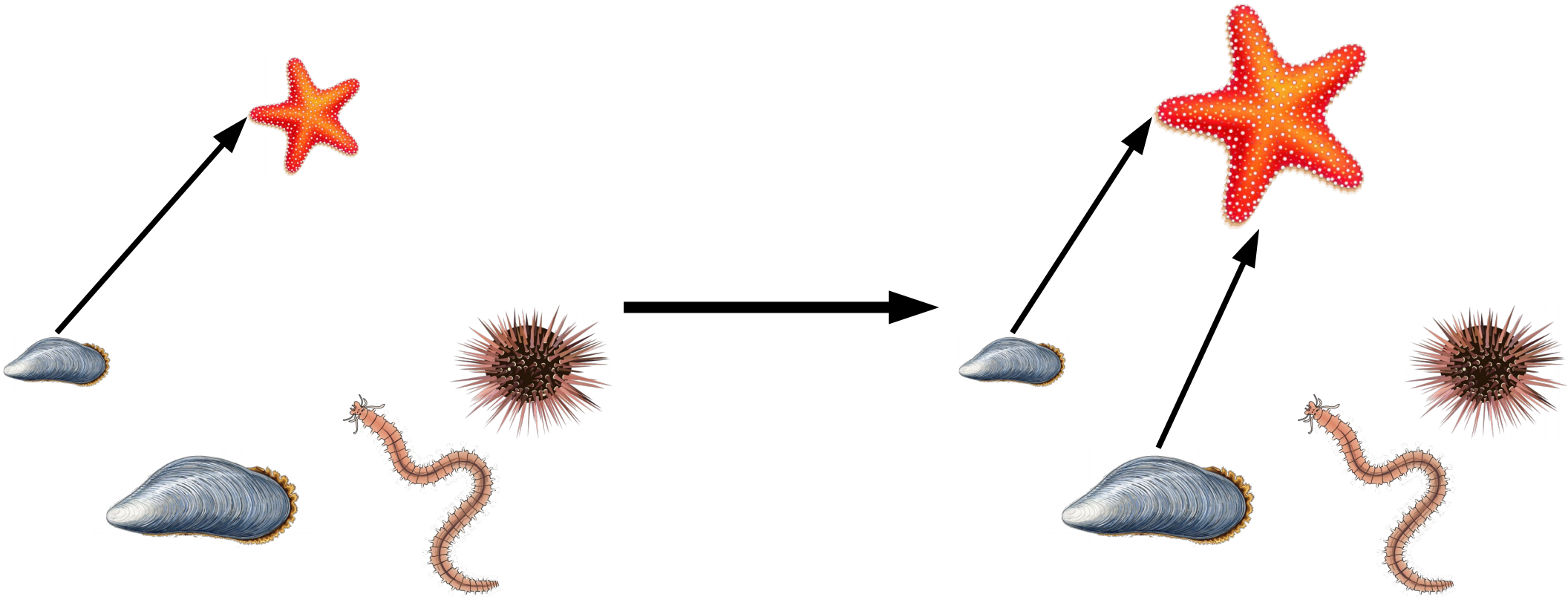
→ How do terrestrial glaciers impact the trophic ecology of sea stars?





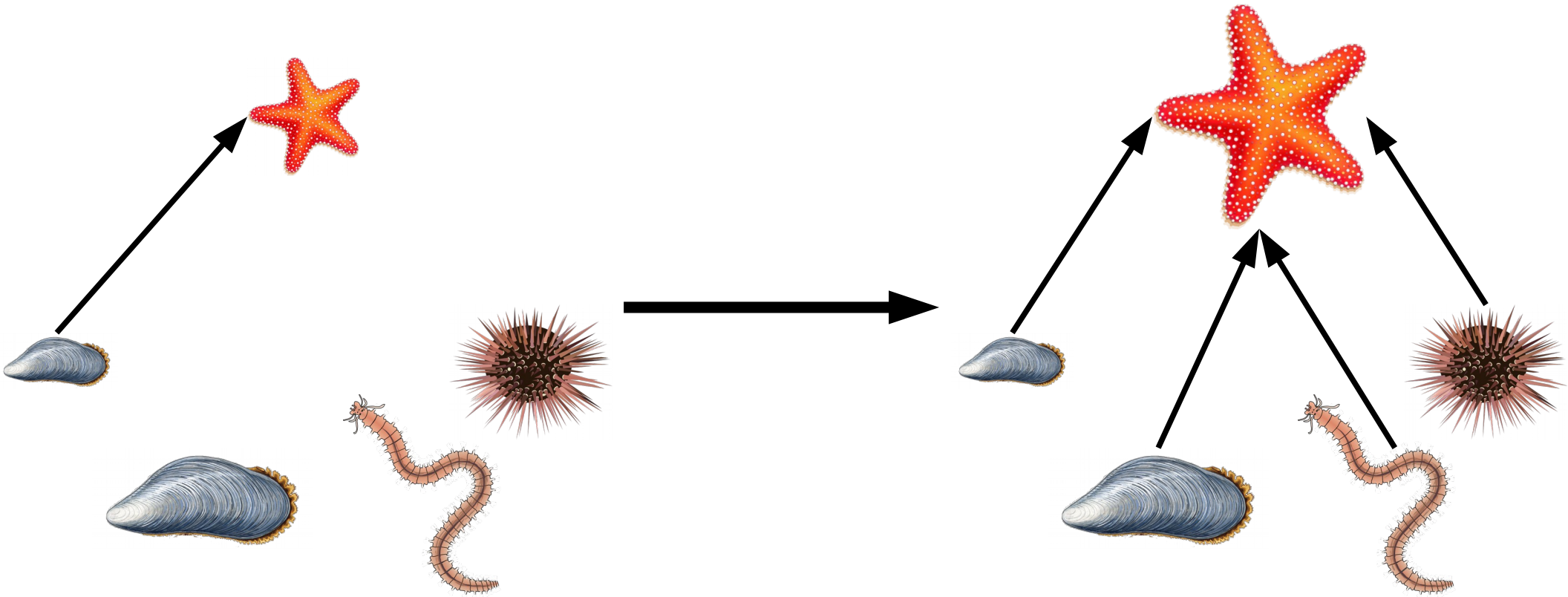
Ontogenetic variations of trophic ecology

- Change of prey size



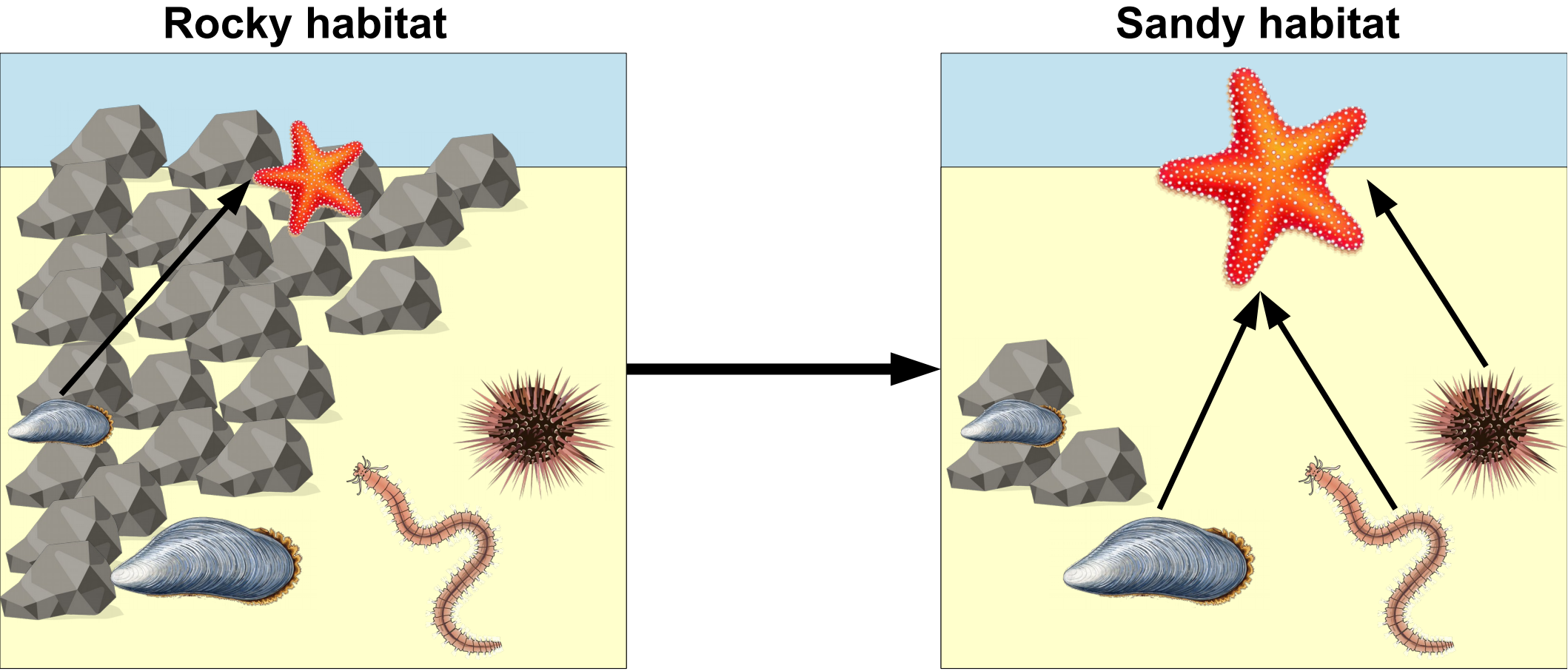
Ontogenetic variations of trophic ecology

- Change of prey size
- Change of prey category



Ontogenetic variations of trophic ecology

- Change of prey size
- Change of prey category
- Change of habitat

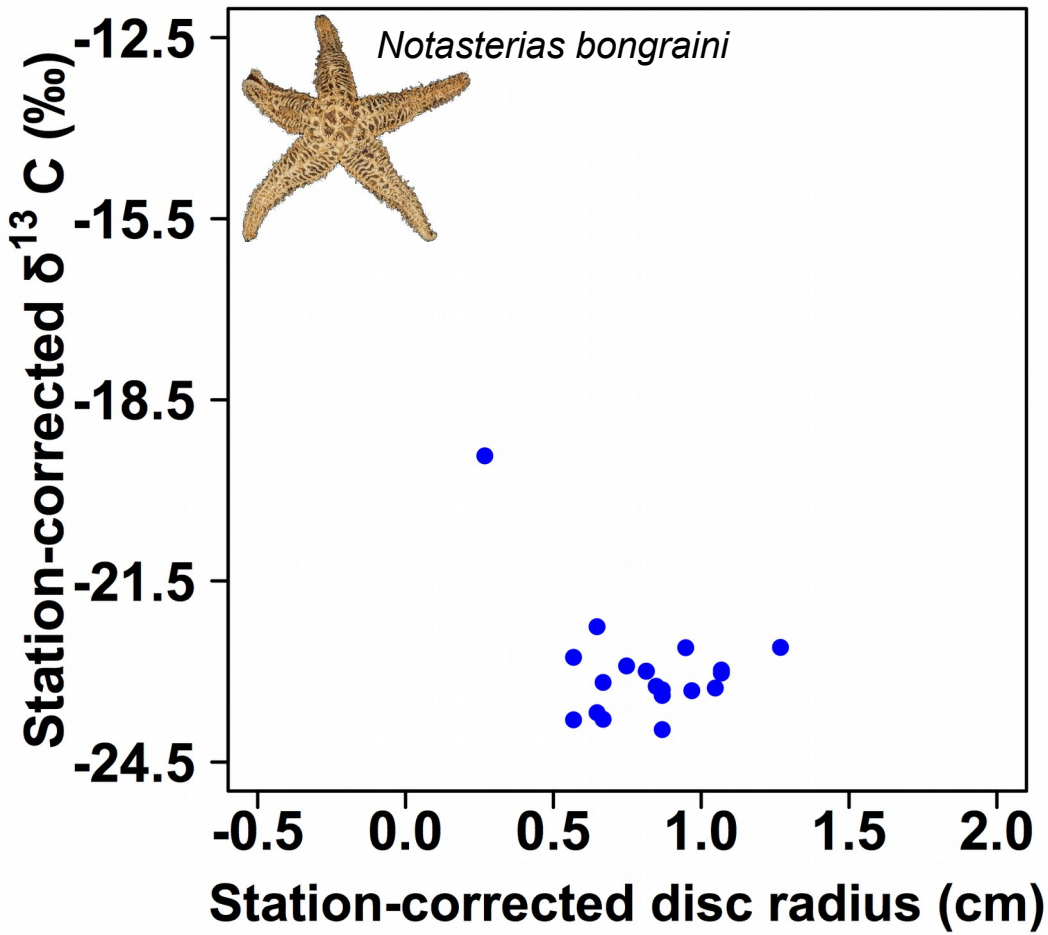


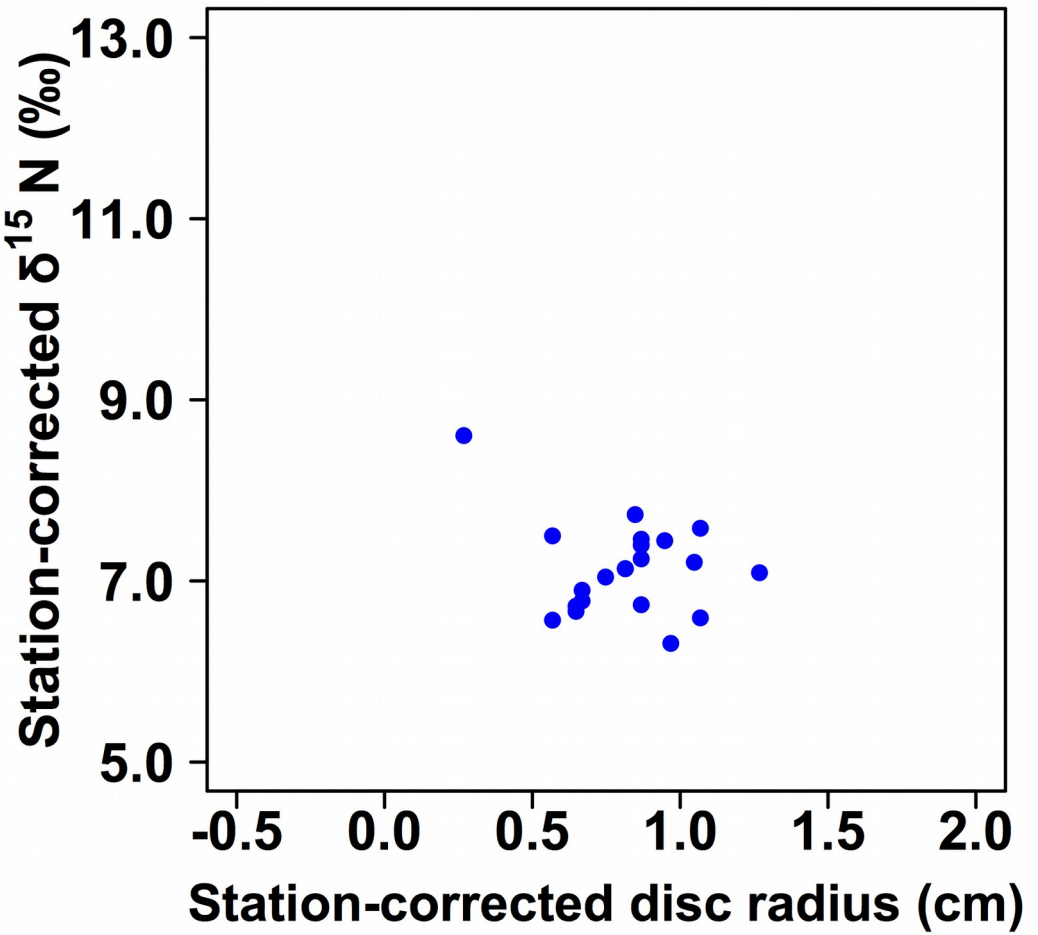
Ontogenetic variations of trophic ecology

- Relationship of disc radius with $\delta^{13}C$ and $\delta^{15}N$ values for each species

Ontogenetic variations of trophic ecology

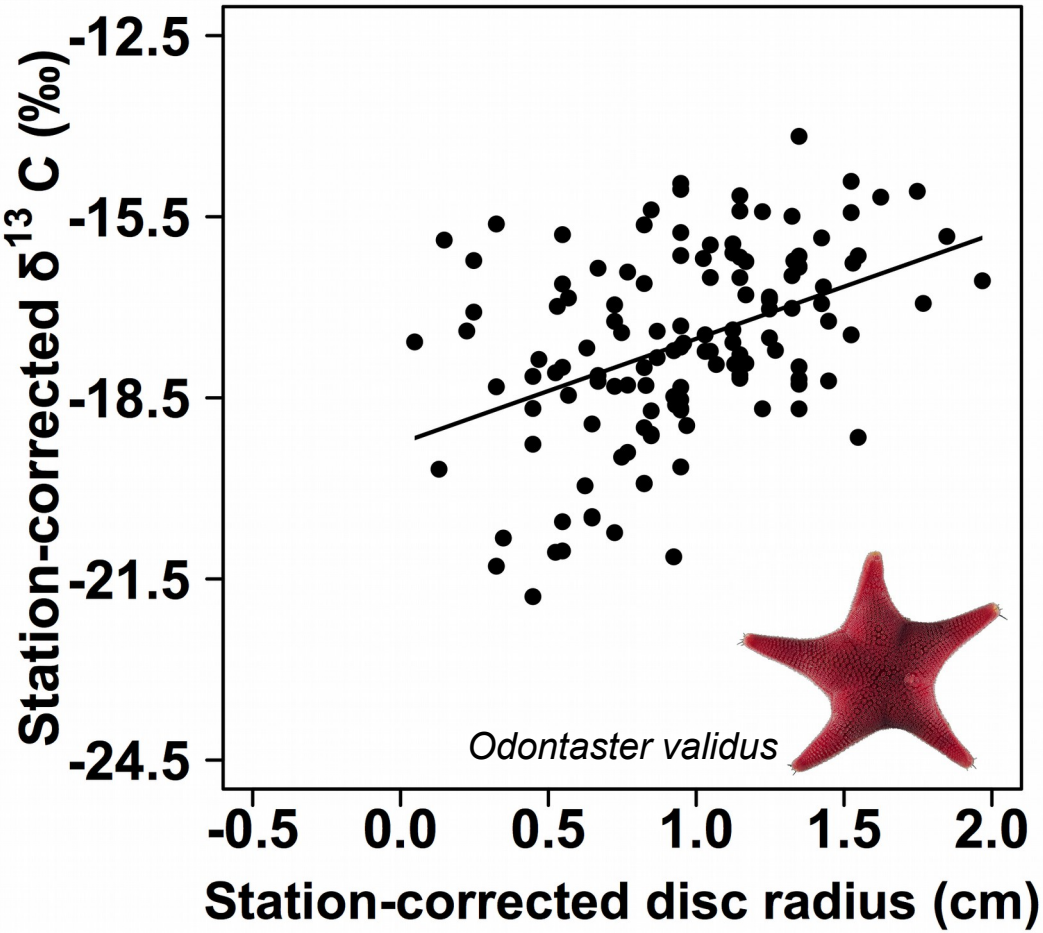
- No impact of disc radius on $\delta^{13}C$ and/or $\delta^{15}N$ values in several species (*Bathybiaster loripes*, *Notasterias bongraini*, *Perknaster sladeni*)

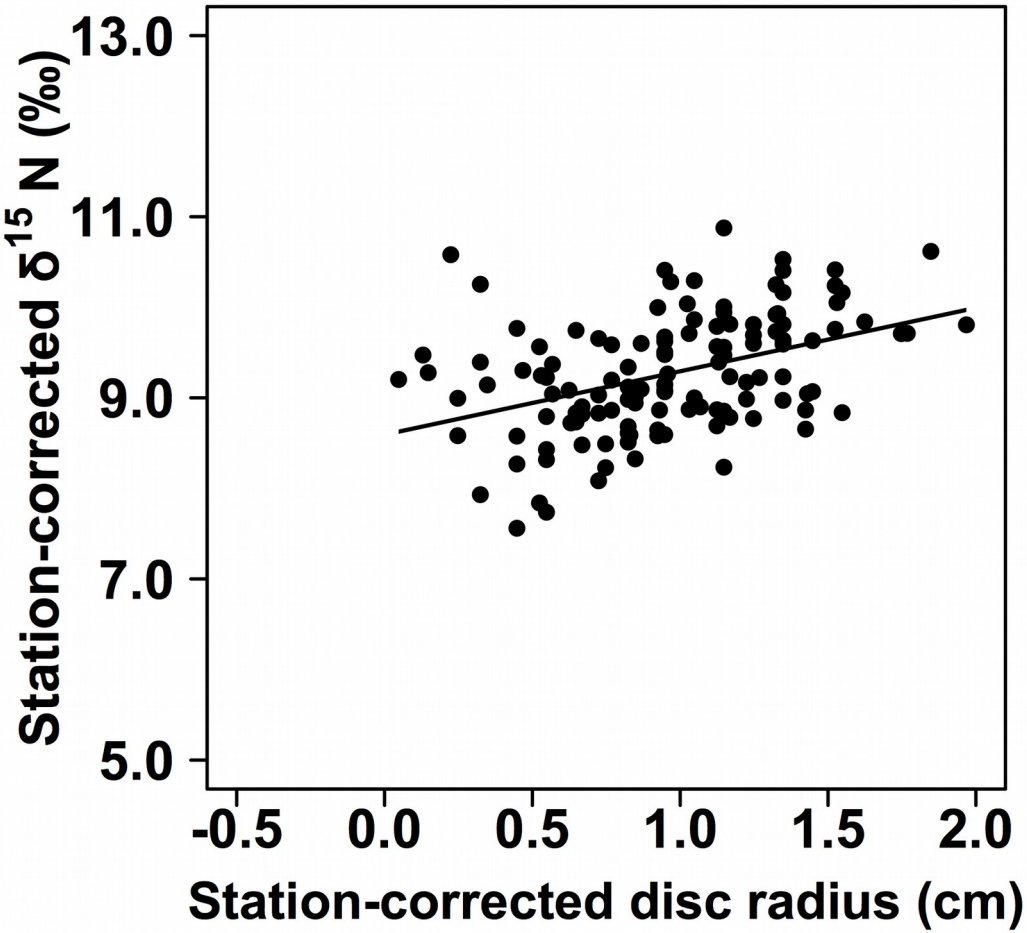




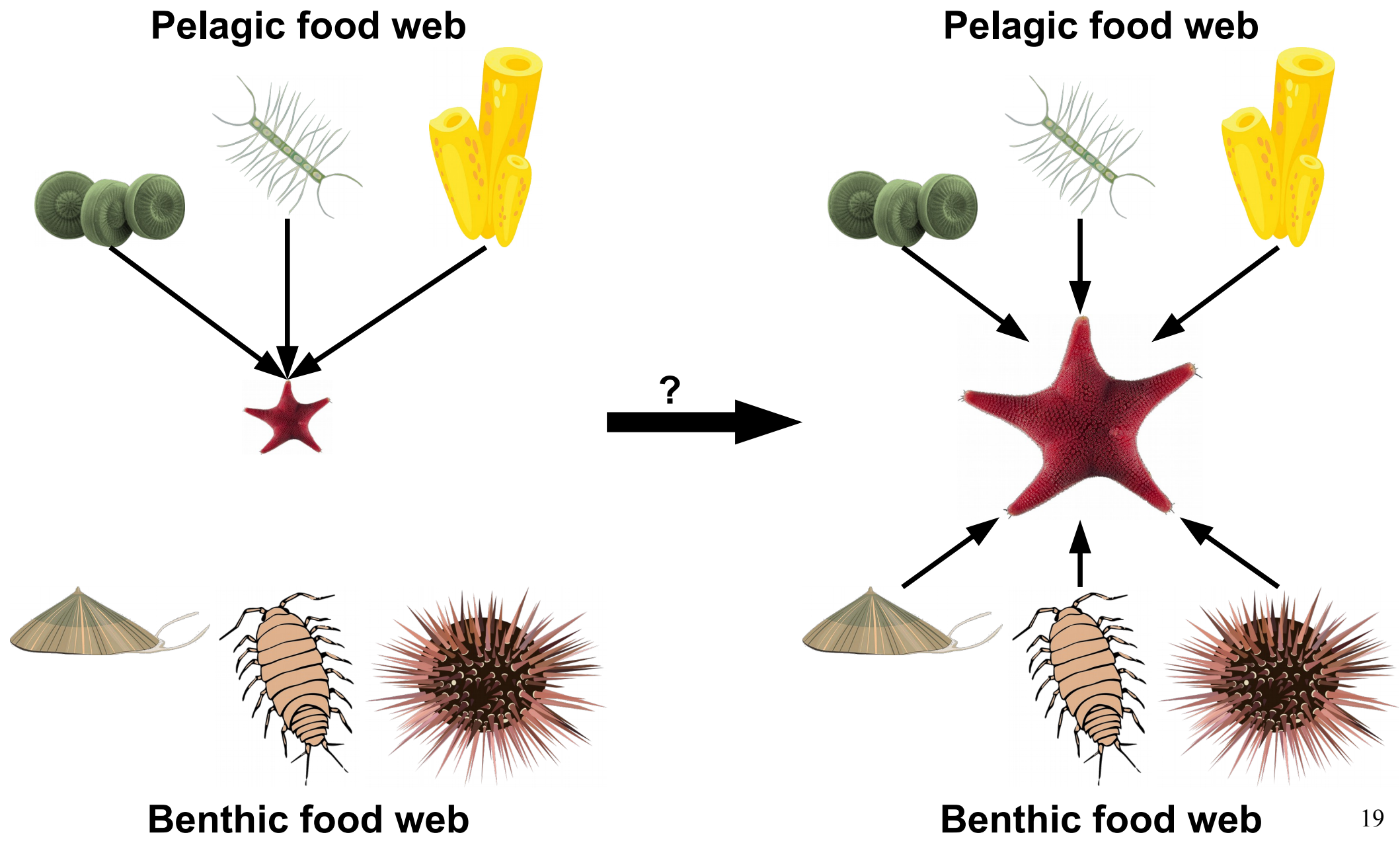
Ontogenetic variations of trophic ecology

- Impact of disc radius on $\delta^{13}C$ and/or $\delta^{15}N$ values in several species (*Bathybiaster loripes*, *Diplasterias brandti*, *Odontaster validus*, *Perknaster sladeni*)





Ontogenetic variations of trophic ecology



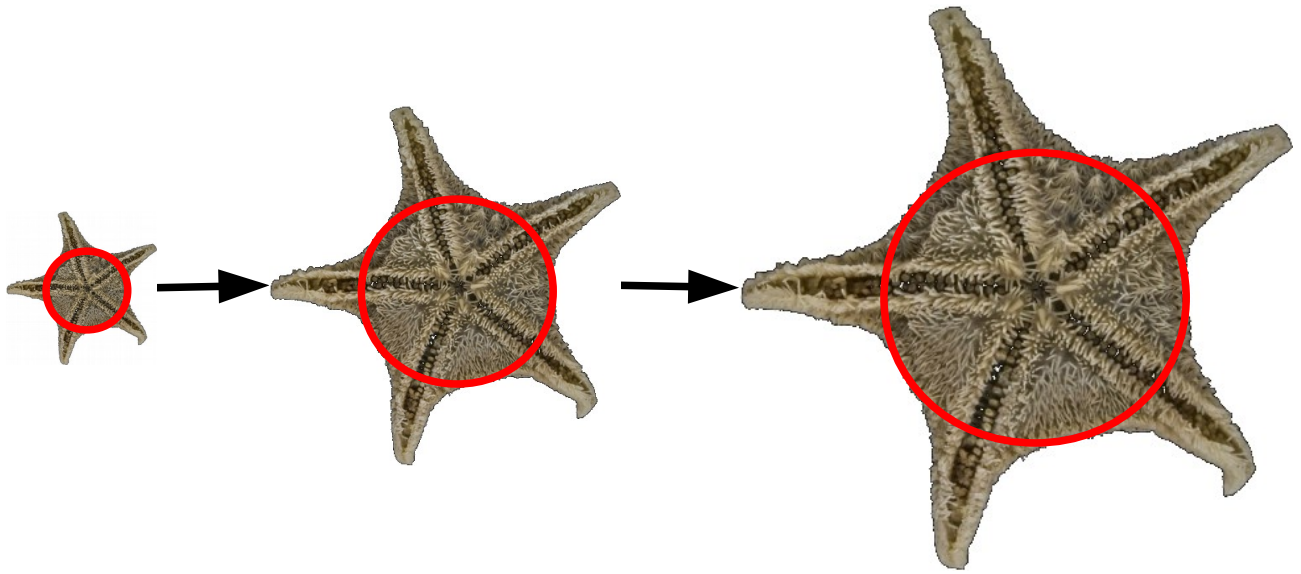
Ontogenetic variations of trophic ecology

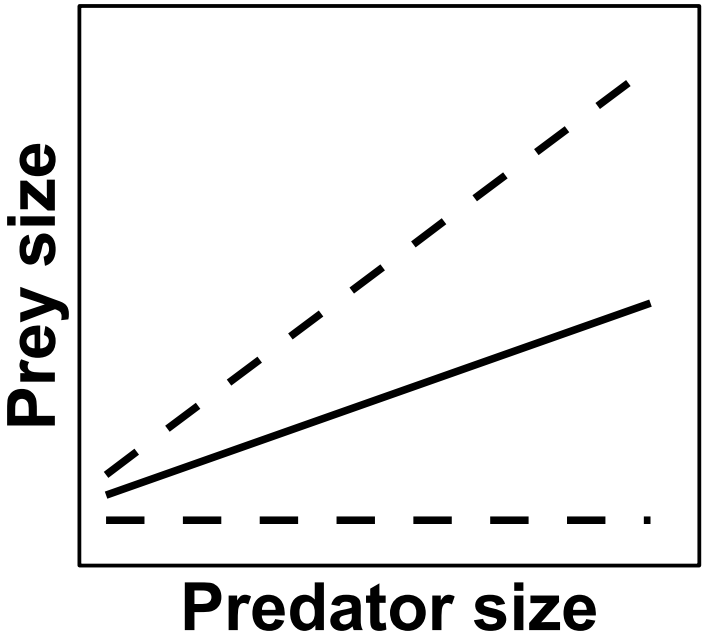
- Impacts of the disc radius on $\delta^{13}C$ and $\delta^{15}N$ values.
- Increasing disc radius:

  → Extension of cardiac stomach over a larger surface

  → Larger and more diverse prey → Higher trophic plasticity

  → Increasing mean trophic level in some species
- Impact of the disc radius depending on the species



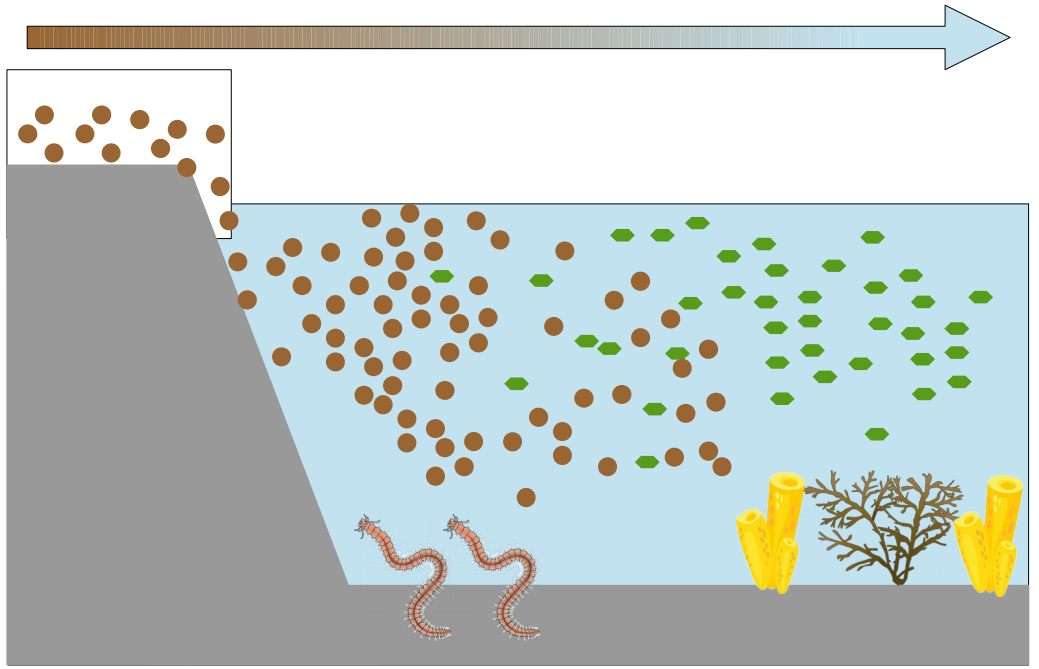


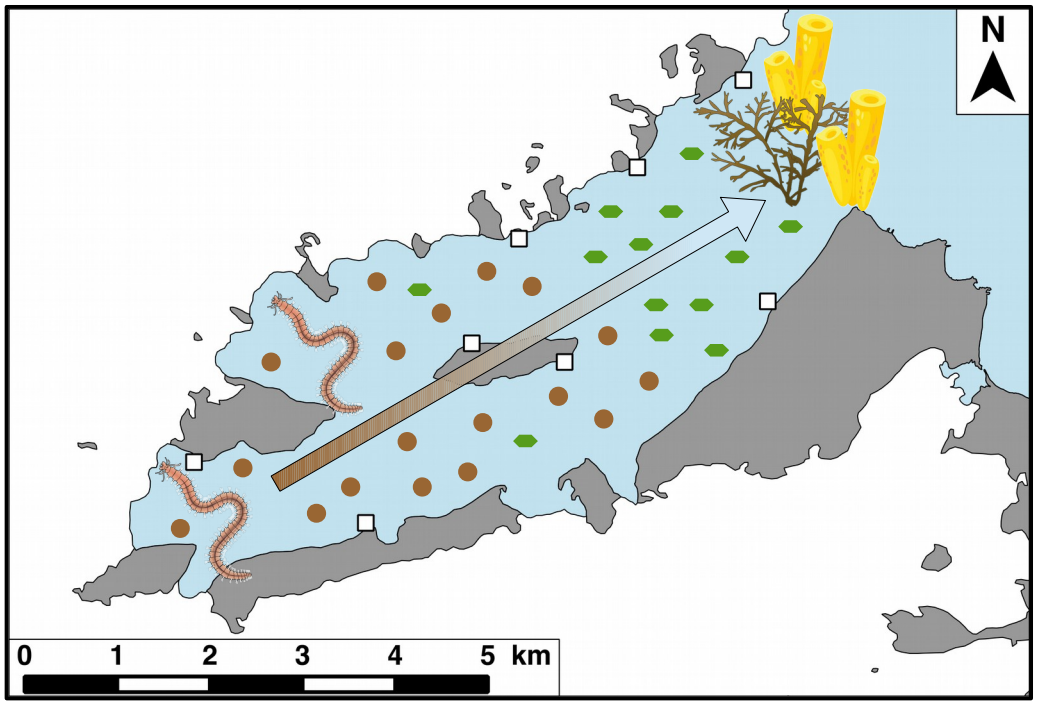
Impact of glaciers on trophic ecology

- Glacier melting → terrestrial inputs → turbidity
- Impacts on community structure

  → impact on trophic ecology and diversity?

+	Turbidity	–
–	Primary production	+
–	Diversity	+
–	Abundance	+
–	Suspension feeders	+



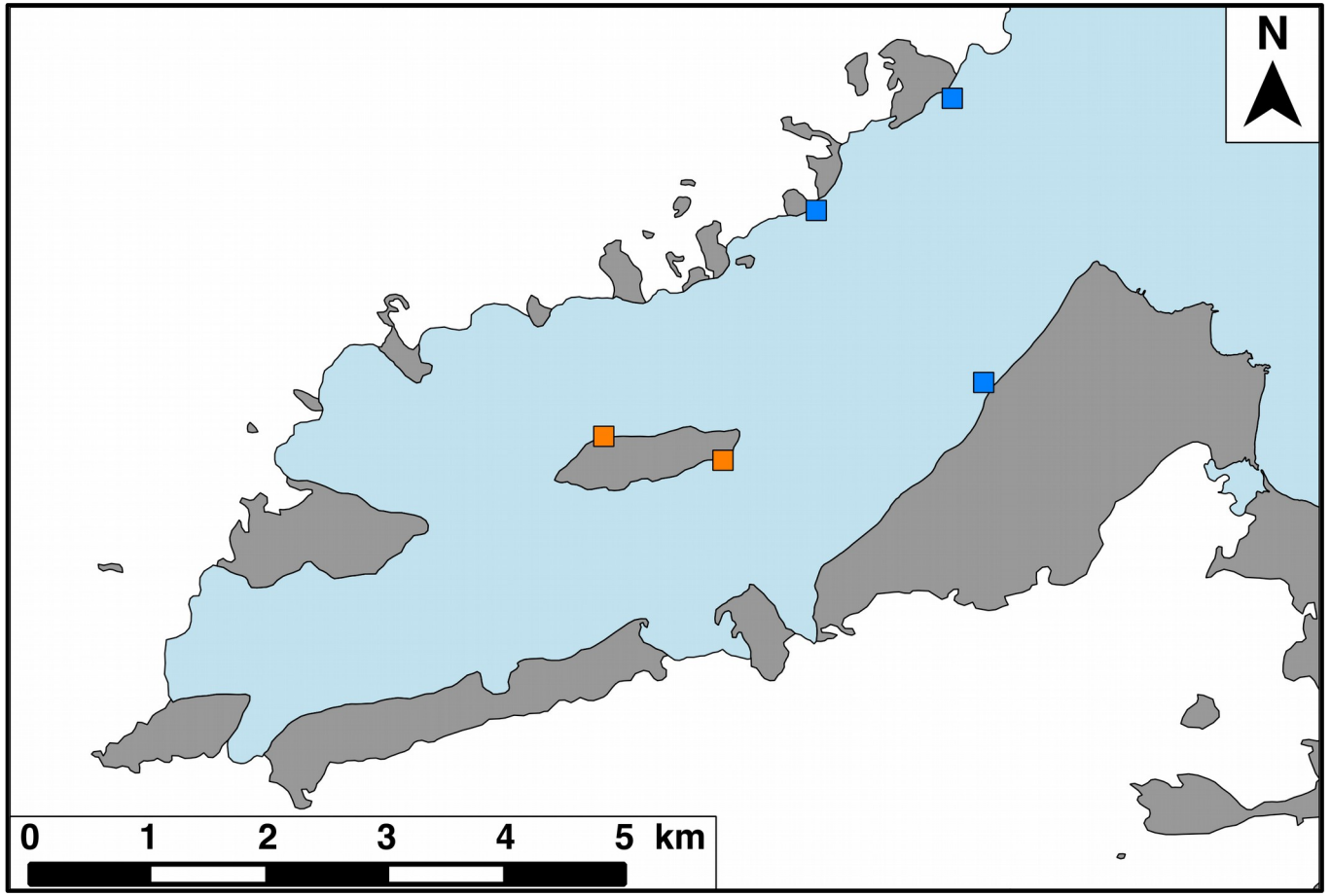


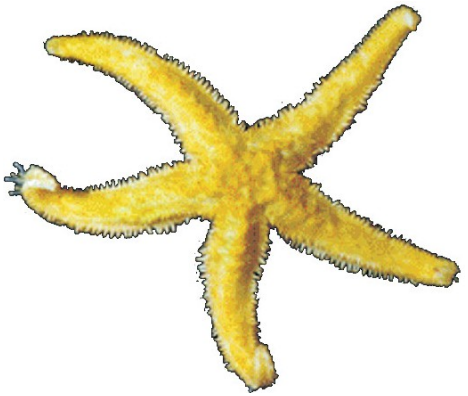
Impact of glaciers on trophic ecology

- *Diplasterias brandti* and *Odontaster validus* together in 5 stations from outer and inner Ezcura inlet

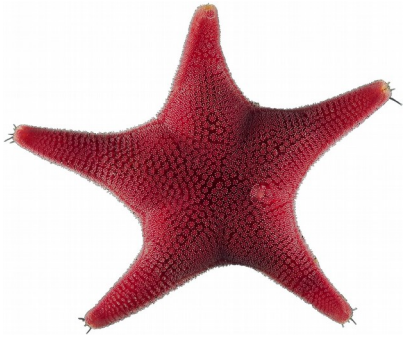
  → Interaction between species and station

  → Isotopic niche size (SEA) and overlap by station





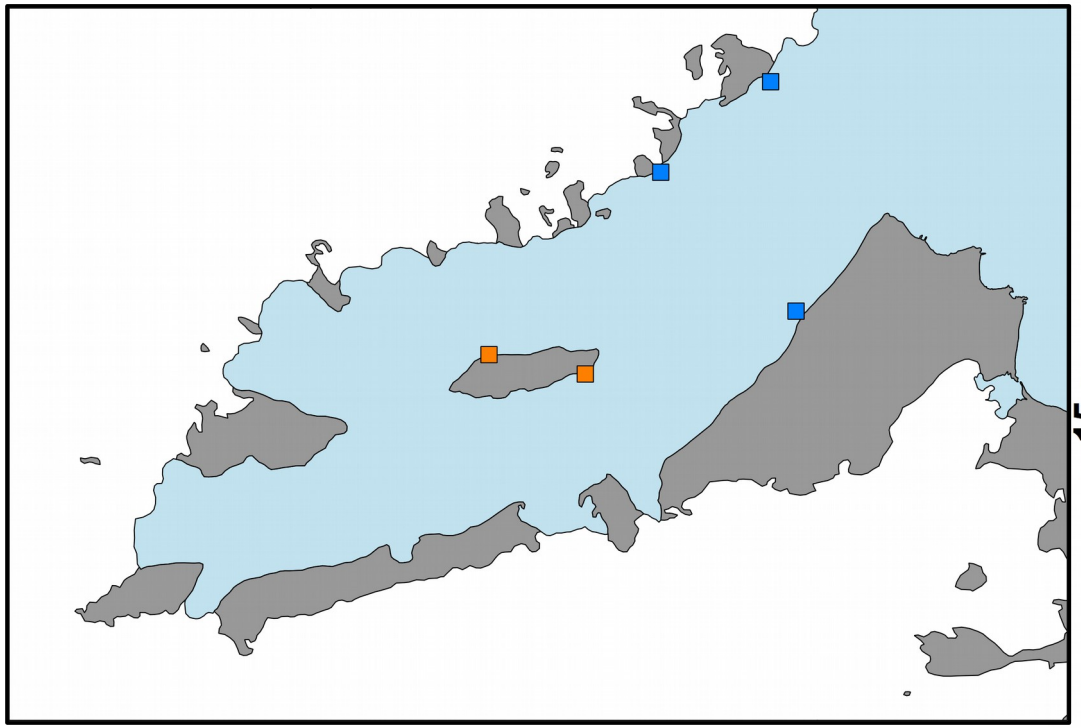
Diplasterias brandti

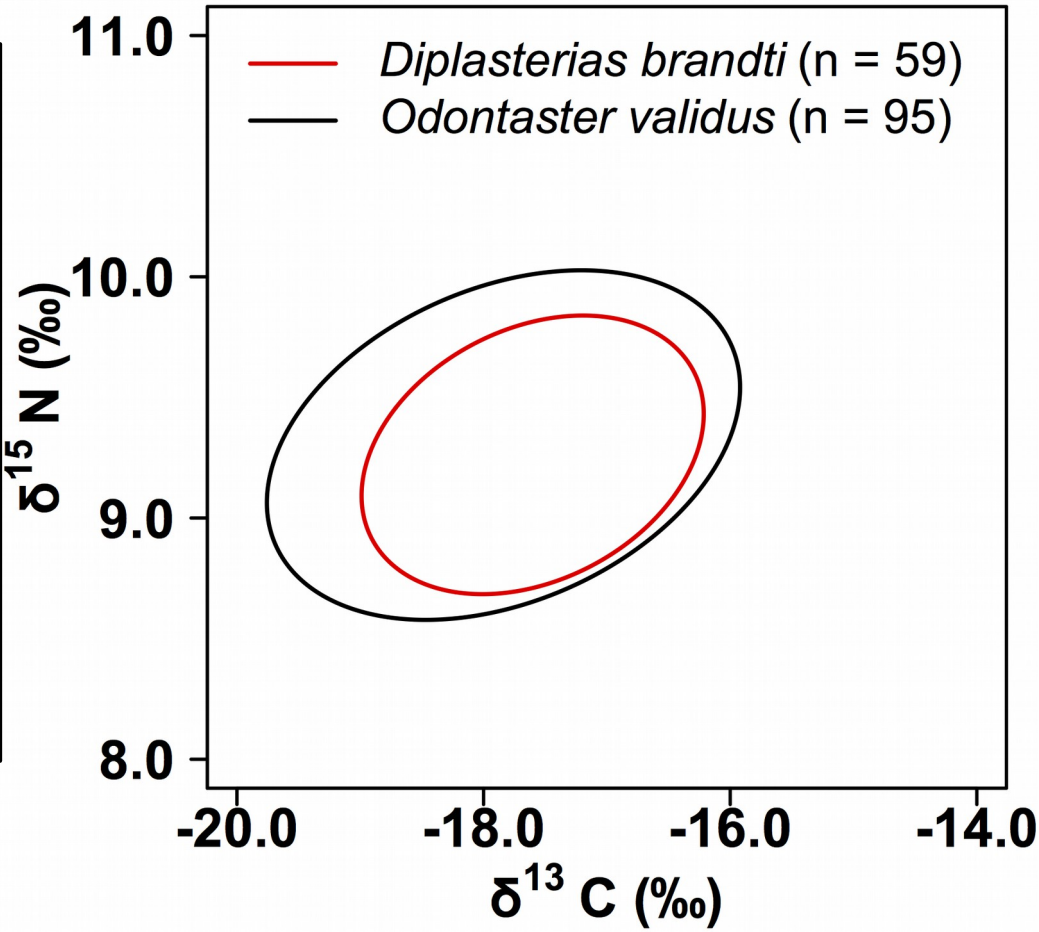


Odontaster validus

Impact of glaciers on trophic ecology

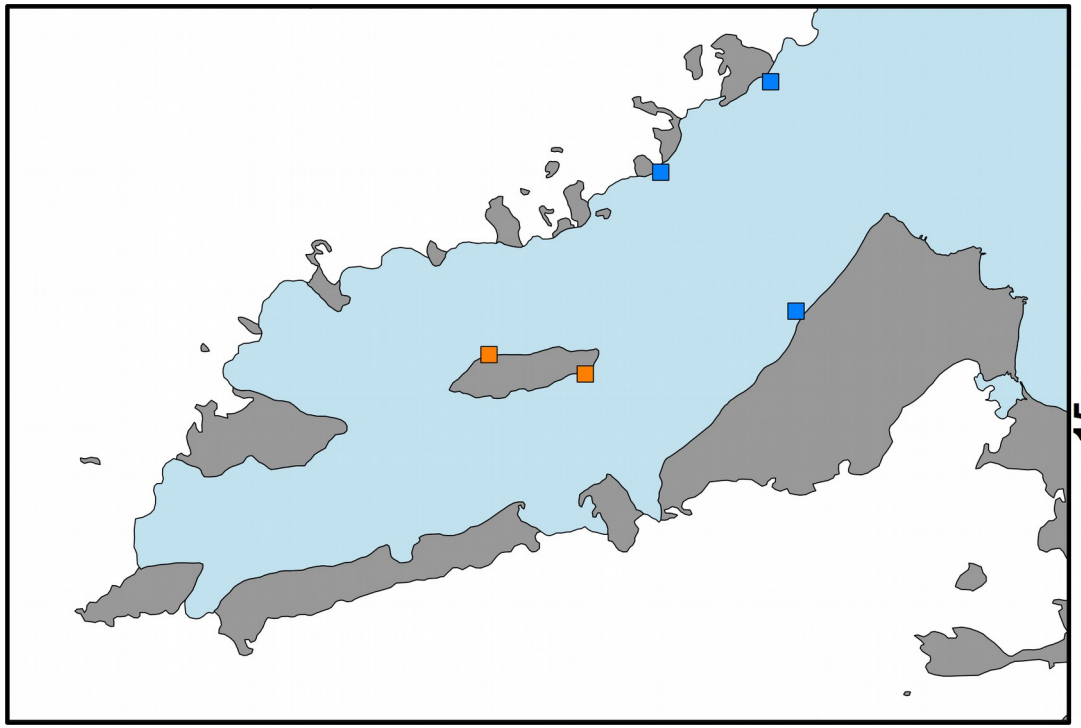
- Outer Ezcurra Inlet:
  → Similar stable isotopes values
  → Isotopic overlap
  → large isotopic niche for *Odontaster validus*

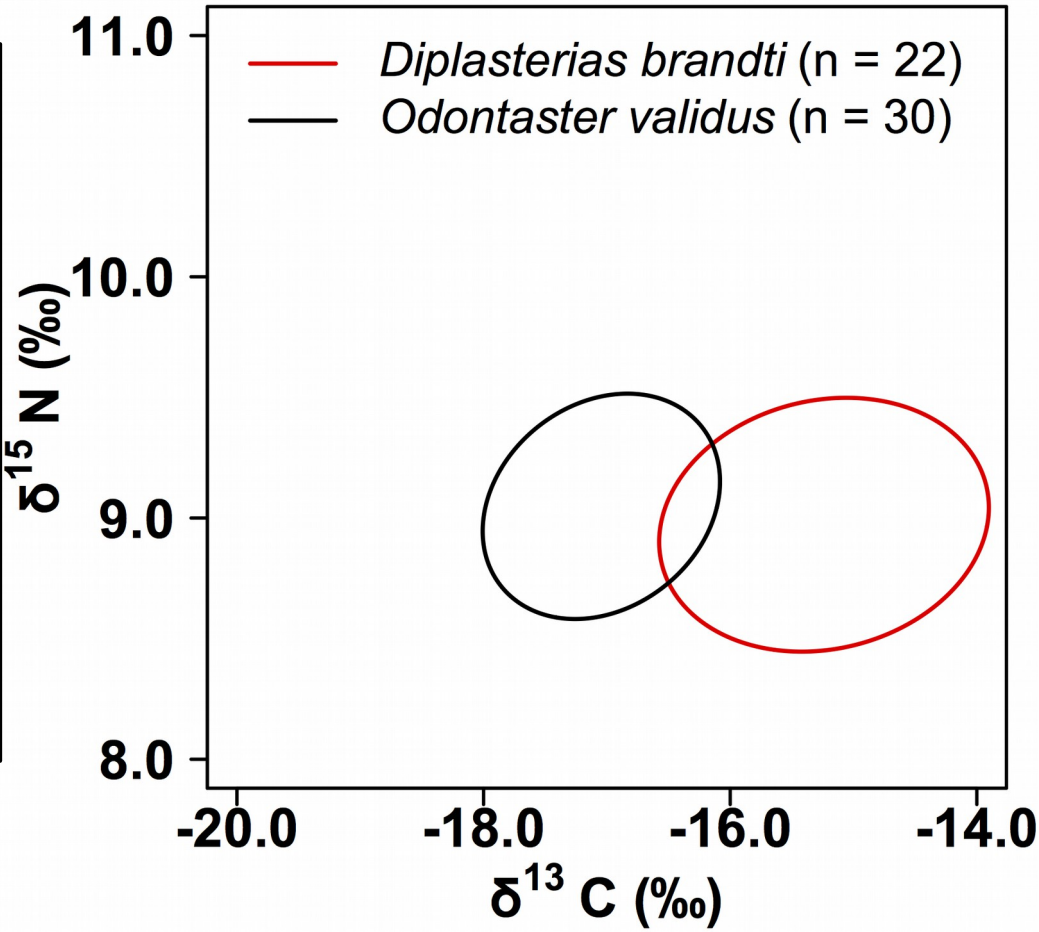




Impact of glaciers on trophic ecology

- Inner Ezcurra Inlet:
  → Different $\delta^{13}C$ values
  → Isotopic overlap
  → Decreasing isotopic niche size for *Odontaster validus*





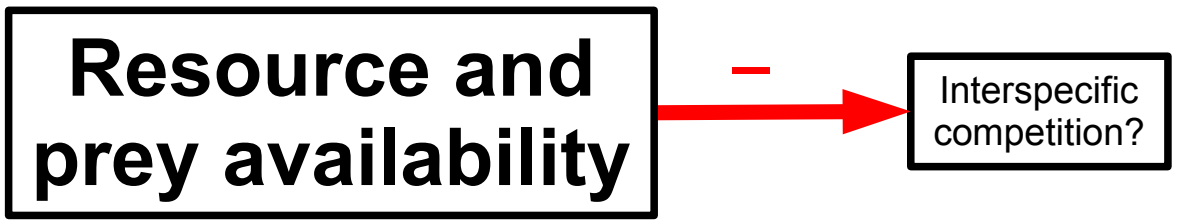
Impact of glaciers on trophic ecology

- Use of the same ressources and prey in the outer Ezcurra Inlet thanks to high resource availability

Resource and prey availability

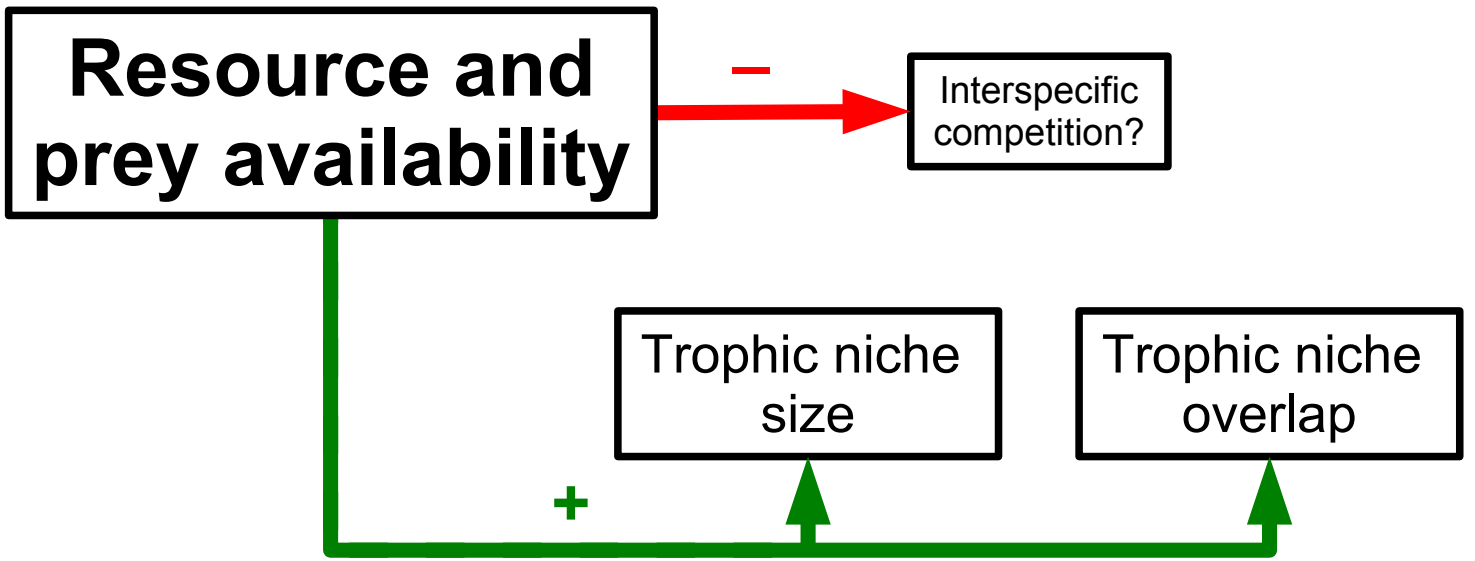
Impact of glaciers on trophic ecology

- Use of the same ressources and prey in the outer Ezcurra Inlet thanks to high resource availability



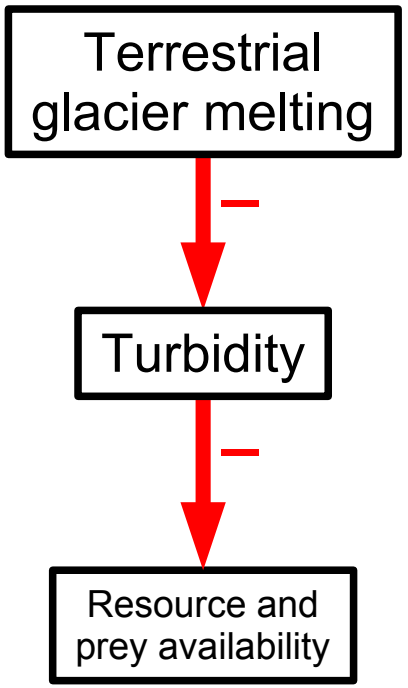
Impact of glaciers on trophic ecology

- Use of the same ressources and prey in the outer Ezcurra Inlet thanks to high resource availability



Impact of glaciers on trophic ecology

- High turbidity resulting from glacier melting in the inner Ezcurra Inlet reduces resource availability and promotes trophic niche constriction and segregation



Impact of glaciers on trophic ecology

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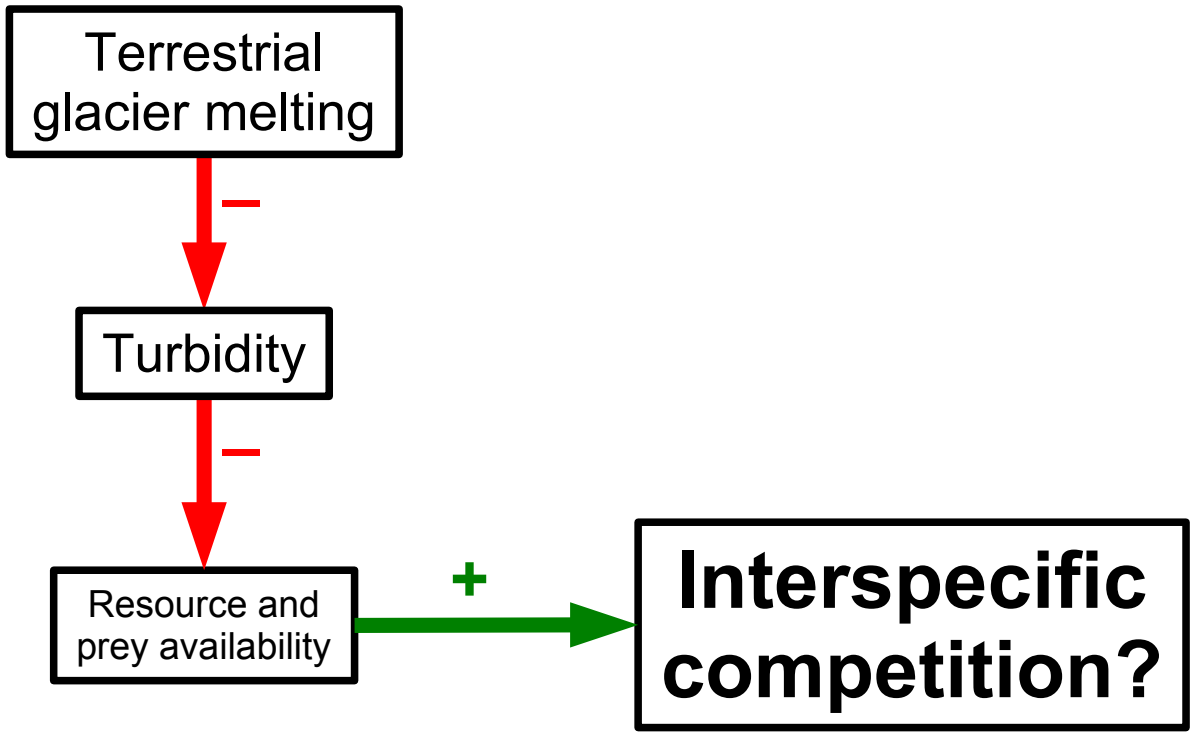

Impact of glaciers on trophic ecology

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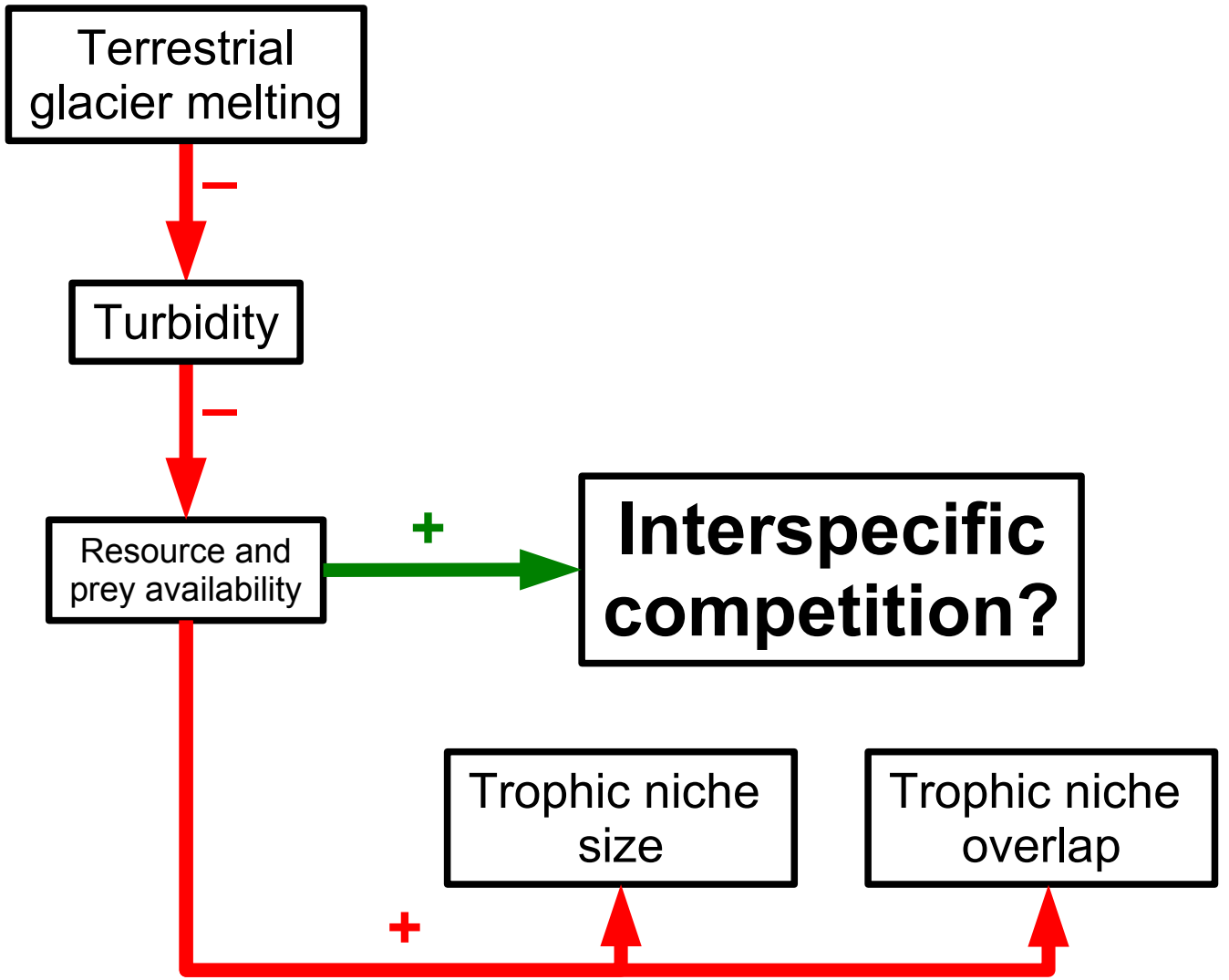
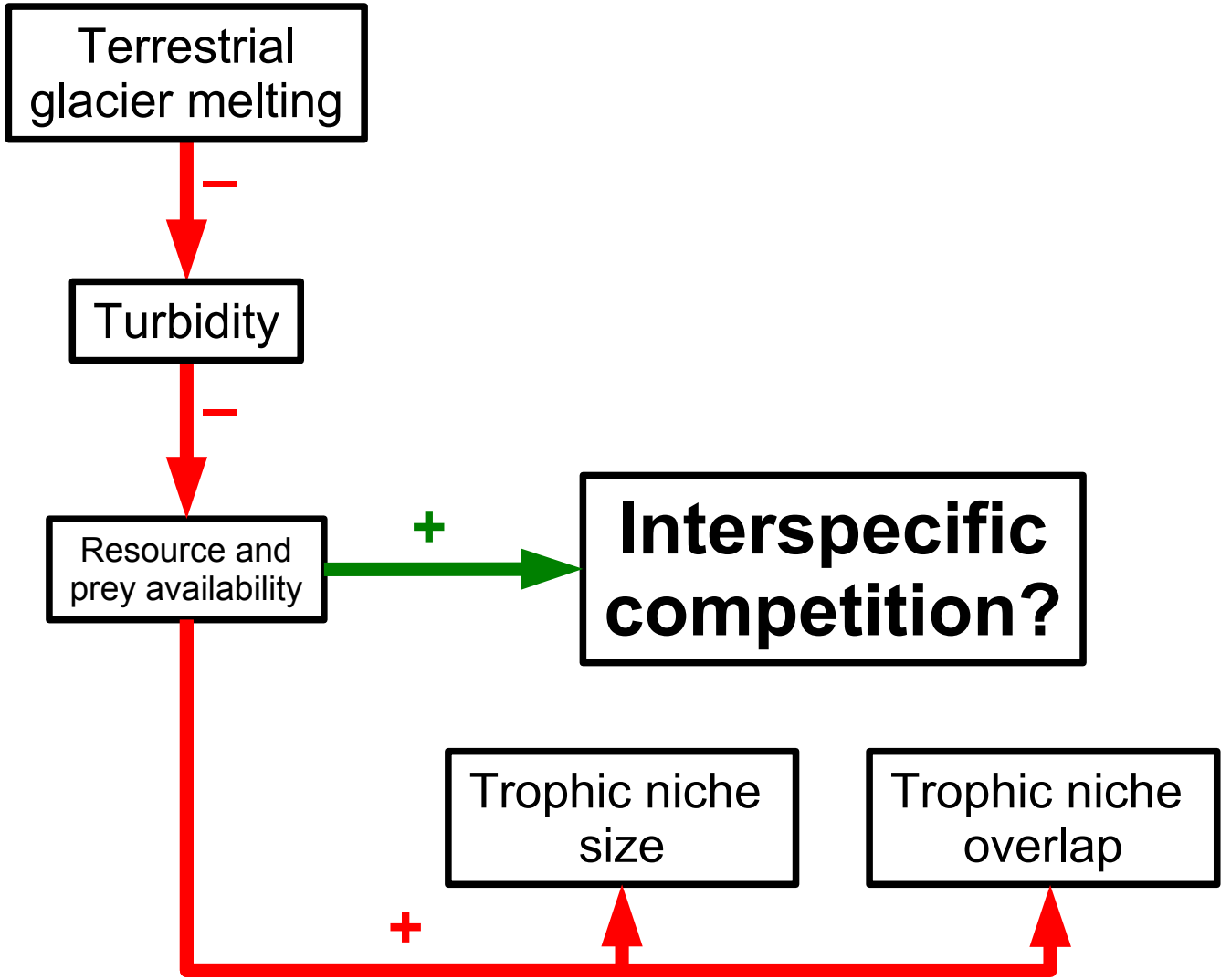


Impact of glaciers on trophic ecology

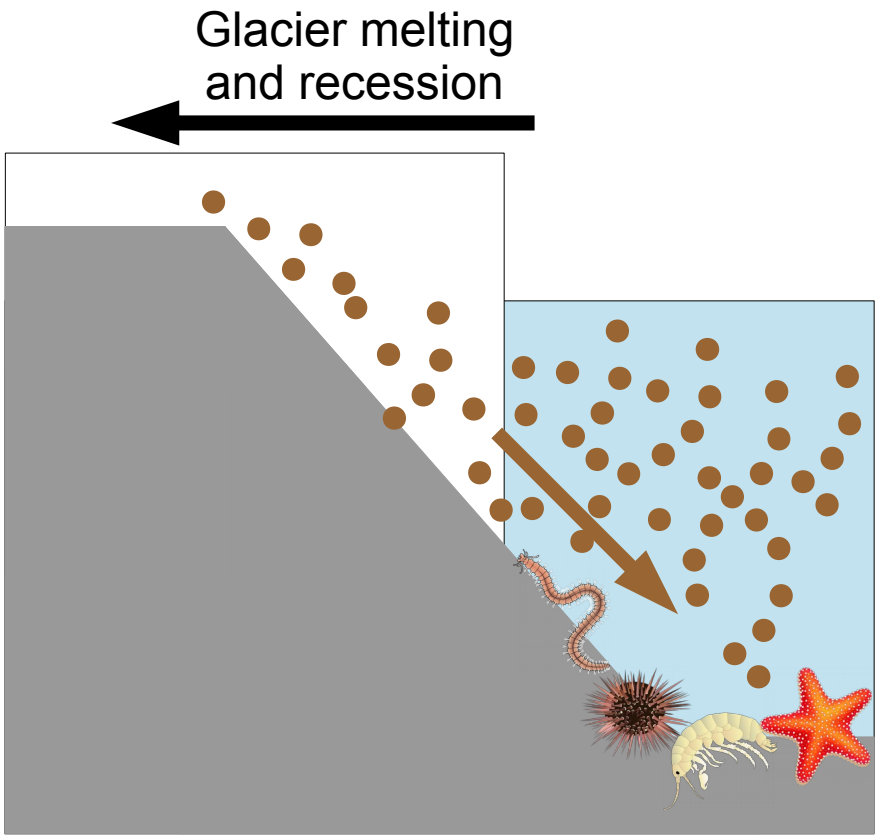
Hypothesis summary: Glacier melting and subsequent turbidity impact primary production and thus ressource availability, and then the trophic ecology of sea stars



Impact of glaciers on trophic ecology

- Climate change:

  → Short term: increasing glacier melting → Increasing turbidity



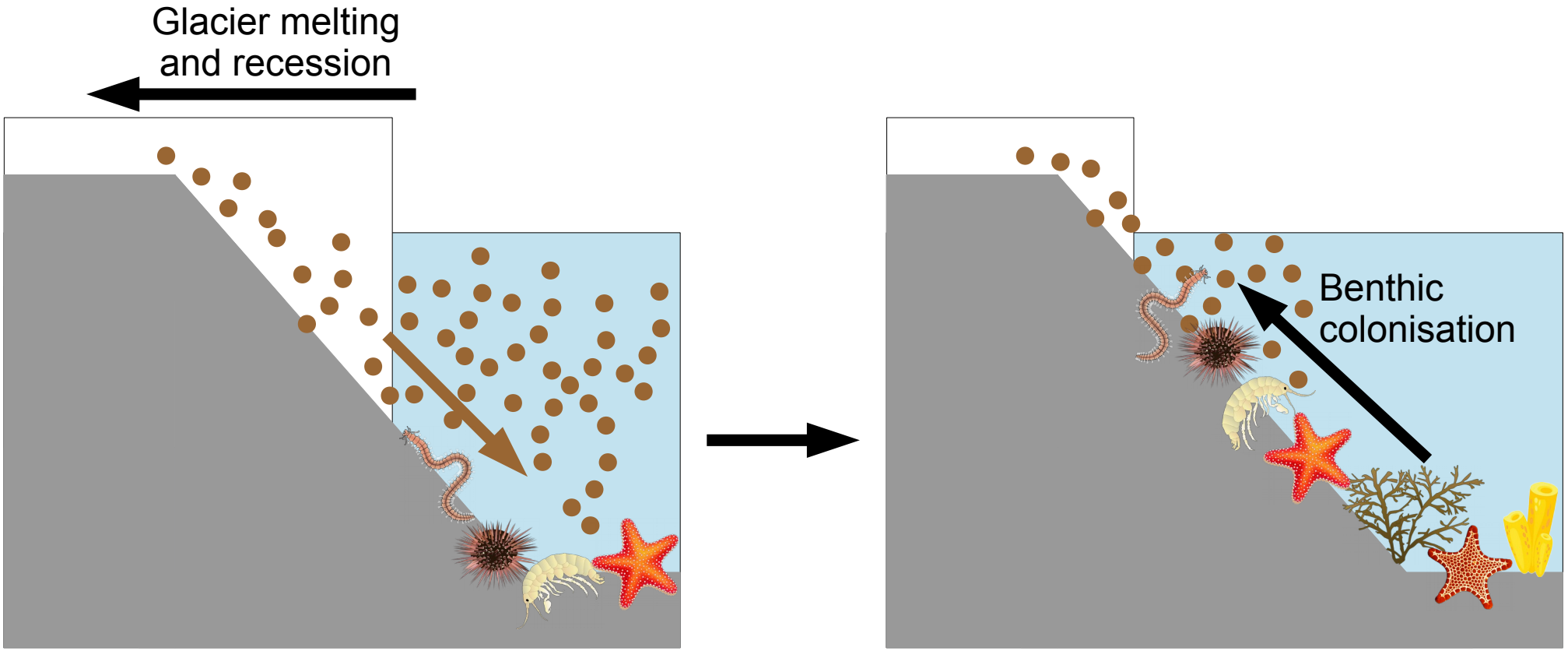
Impact of glaciers on trophic ecology

- Climate change:

  → Short term: increasing glacier melting → Increasing turbidity

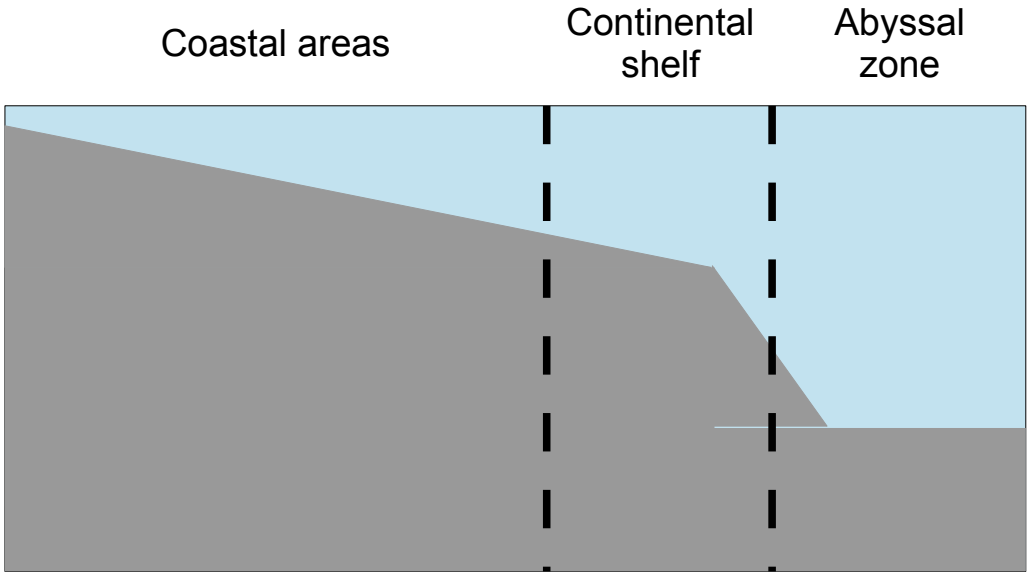
  → Long term: glacier recession → reduced turbidity

  → new areas for benthic colonisation



→ Does the trophic ecology of sea stars change with depth?

→ How does sea ice impact the trophic ecology of sea stars?

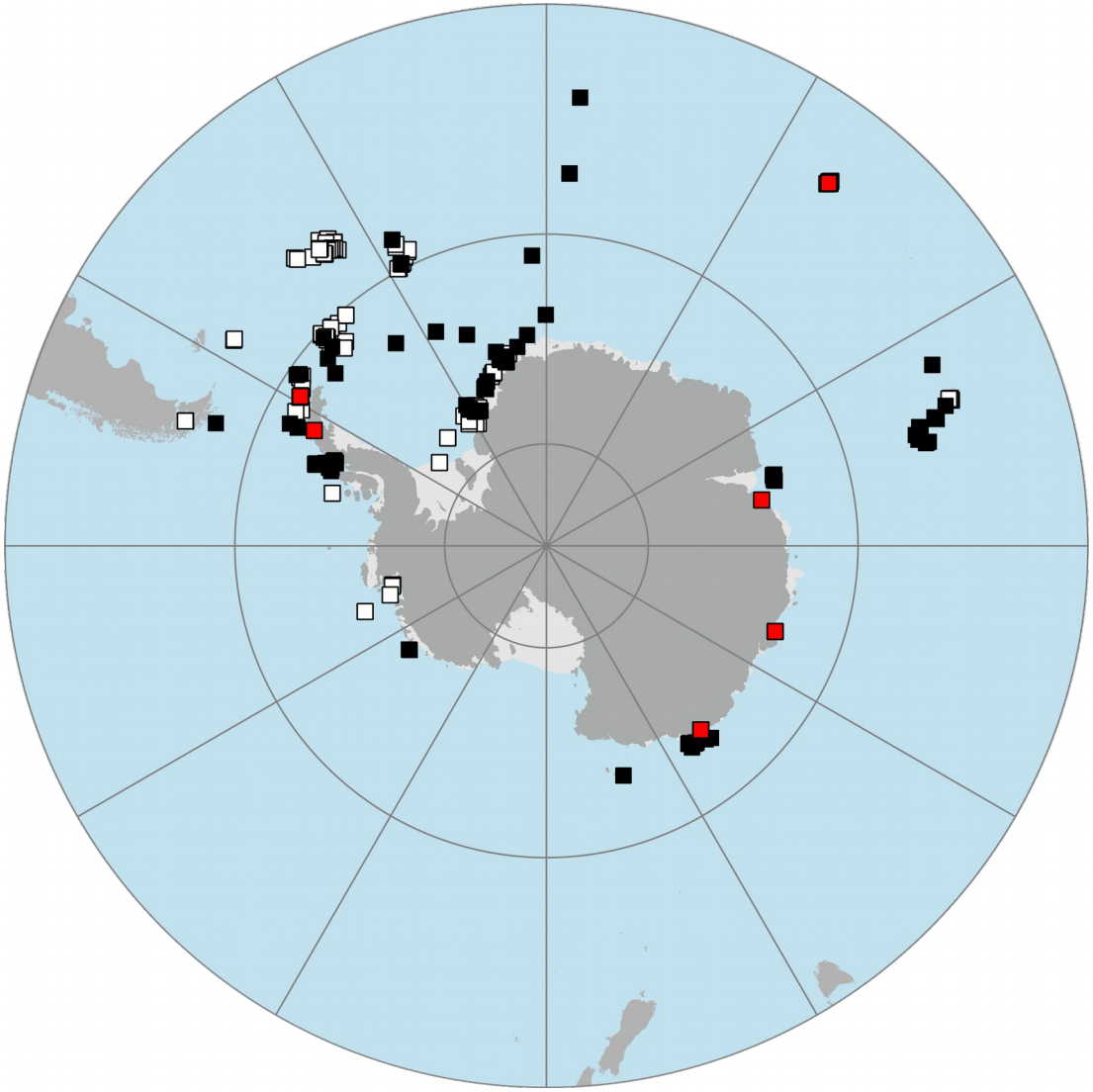


Methods

- □ Frozen and dried samples

  ■ Preserved samples

  ■ Shared datasets



- Global sampling (n = 2658)

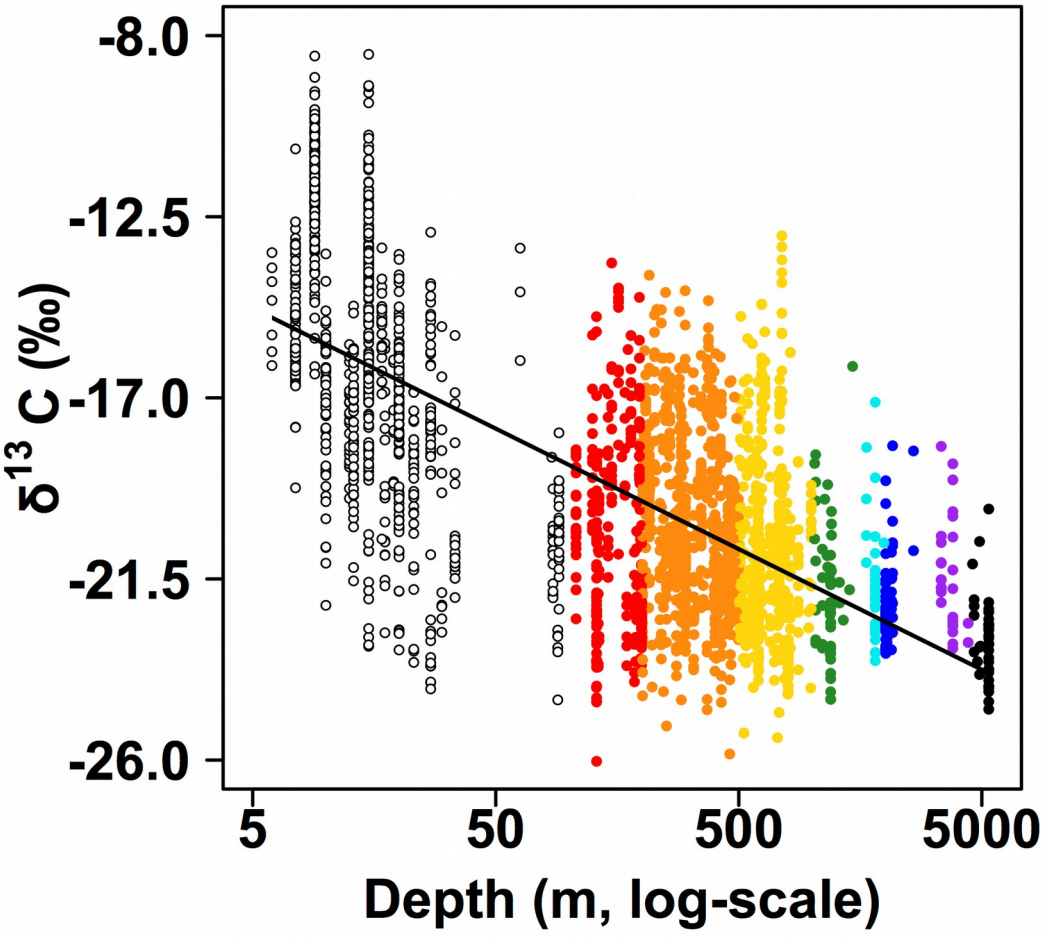
- Identification of sea star taxa
  → trophic group

- Environmental parameters:
  - Depth (6-5338 m)
  - Sea ice concentration (0-90 %)
  - Duration of year with > 85% sea ice (0-89 %)

Depth

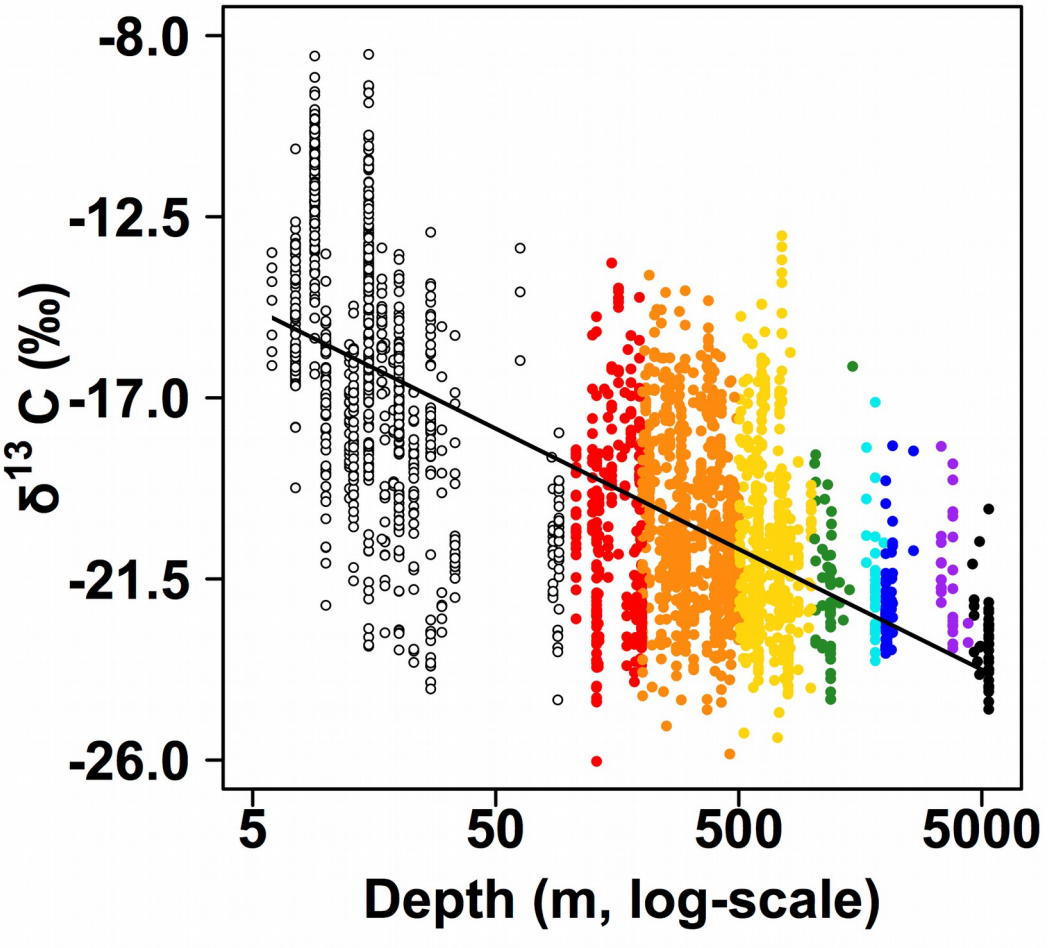
- Decrease of $\delta^{13}C$ values with depth

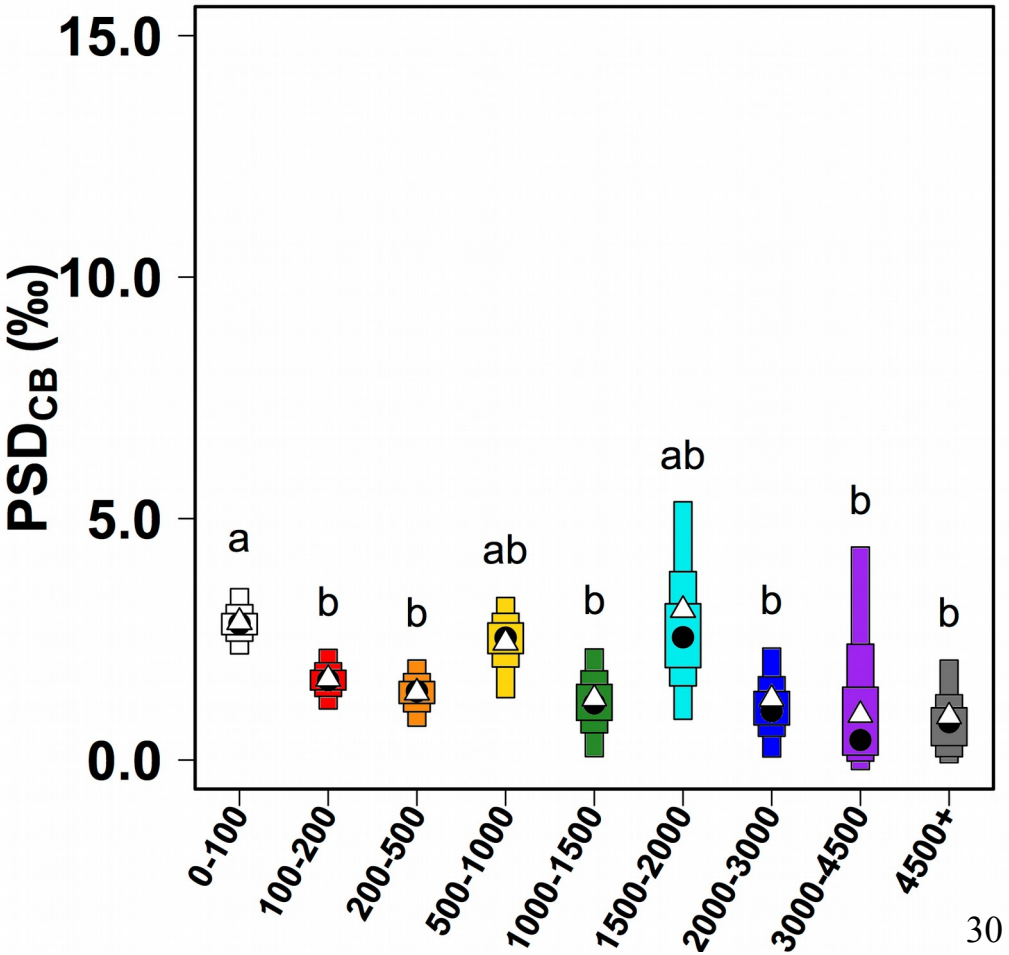
  → Higher reliance on pelagic resources for deeper sea stars?



Depth

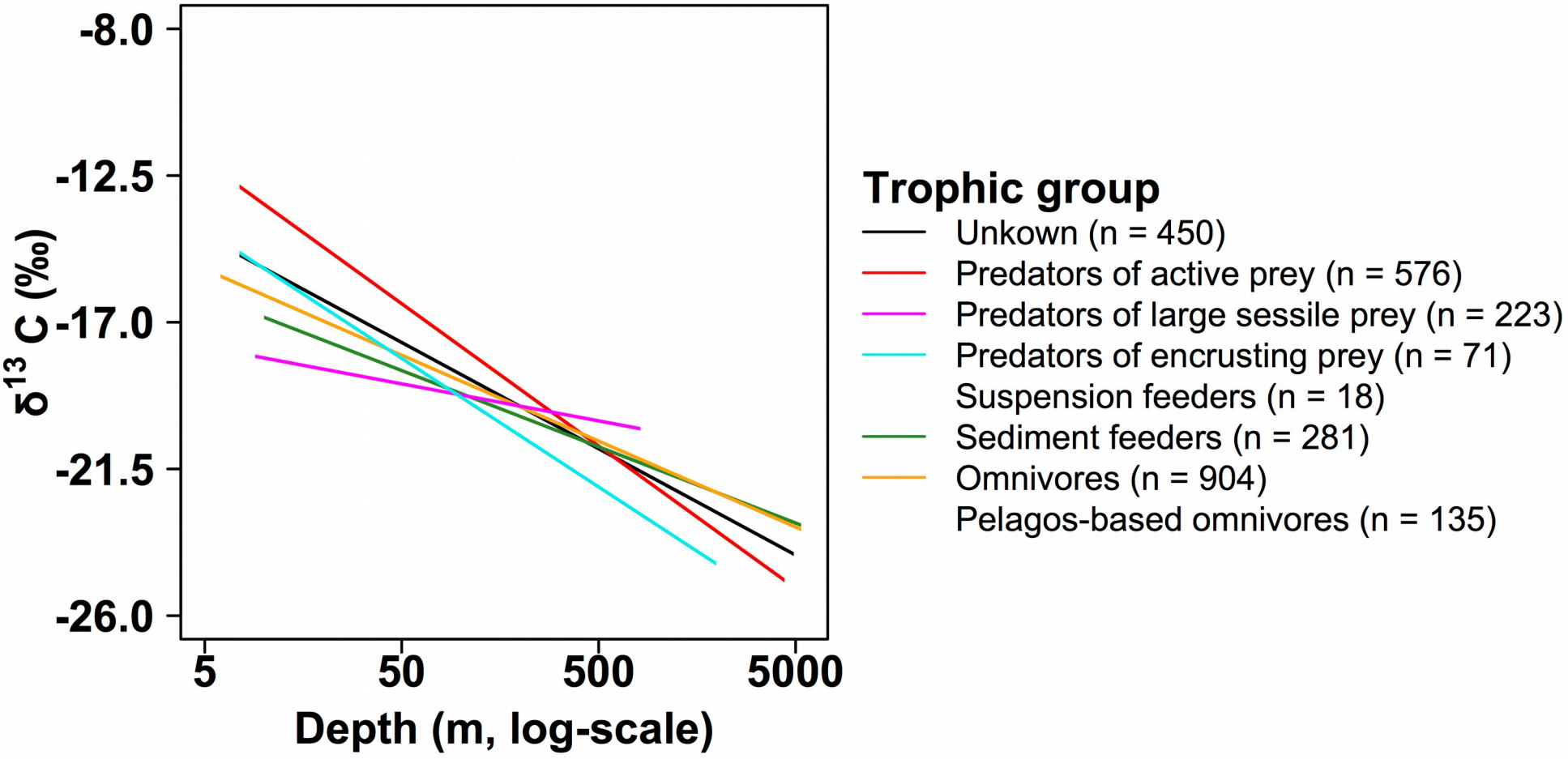
- Decrease of $\delta^{13}C$ values with depth
  → Higher reliance on pelagic resources for deeper sea stars?
- More variable $\delta^{13}C$ values between taxa in coastal sea stars





Depth

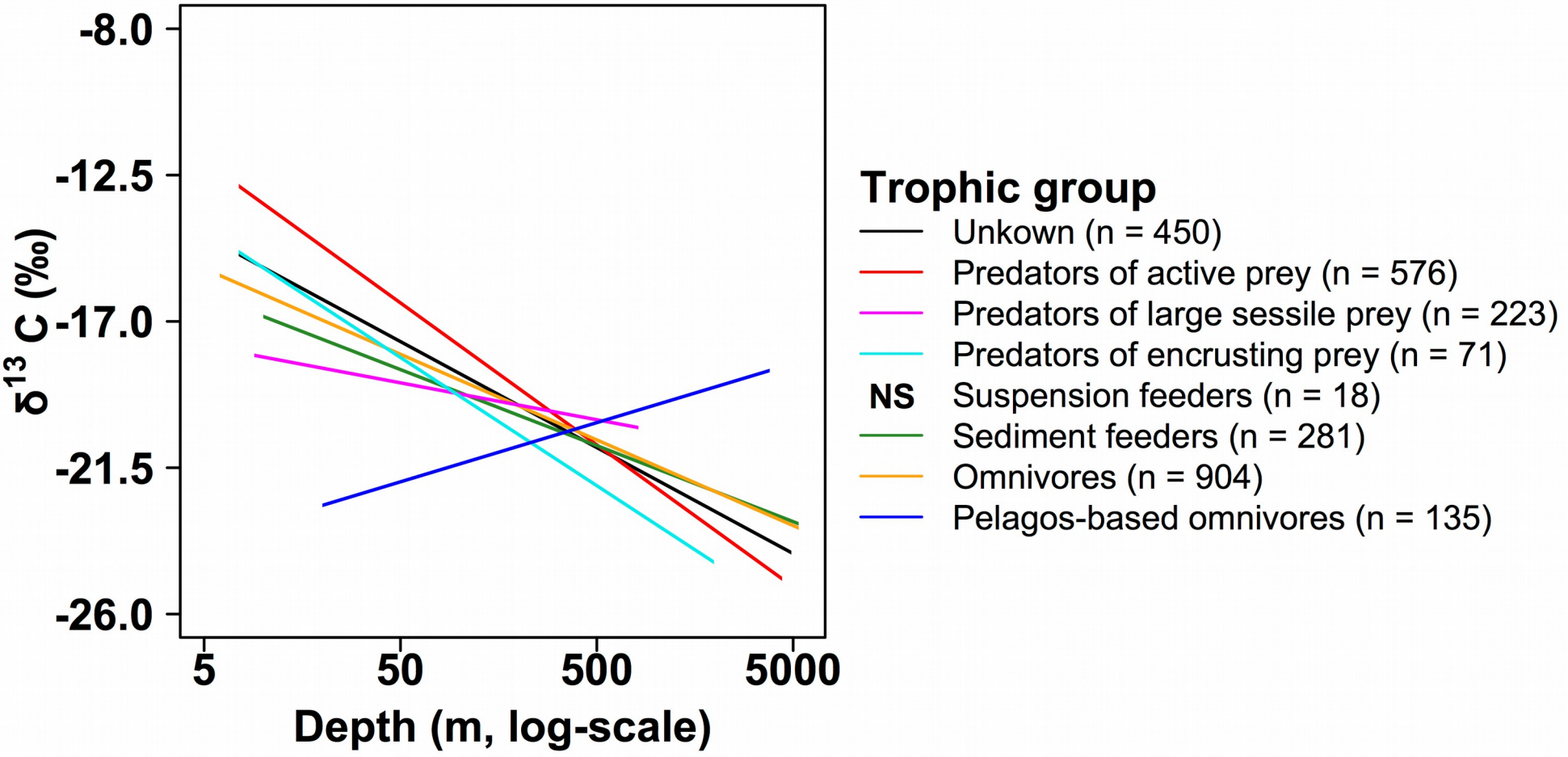
- Decrease of $\delta^{13}C$ values with depth for most trophic groups



Depth

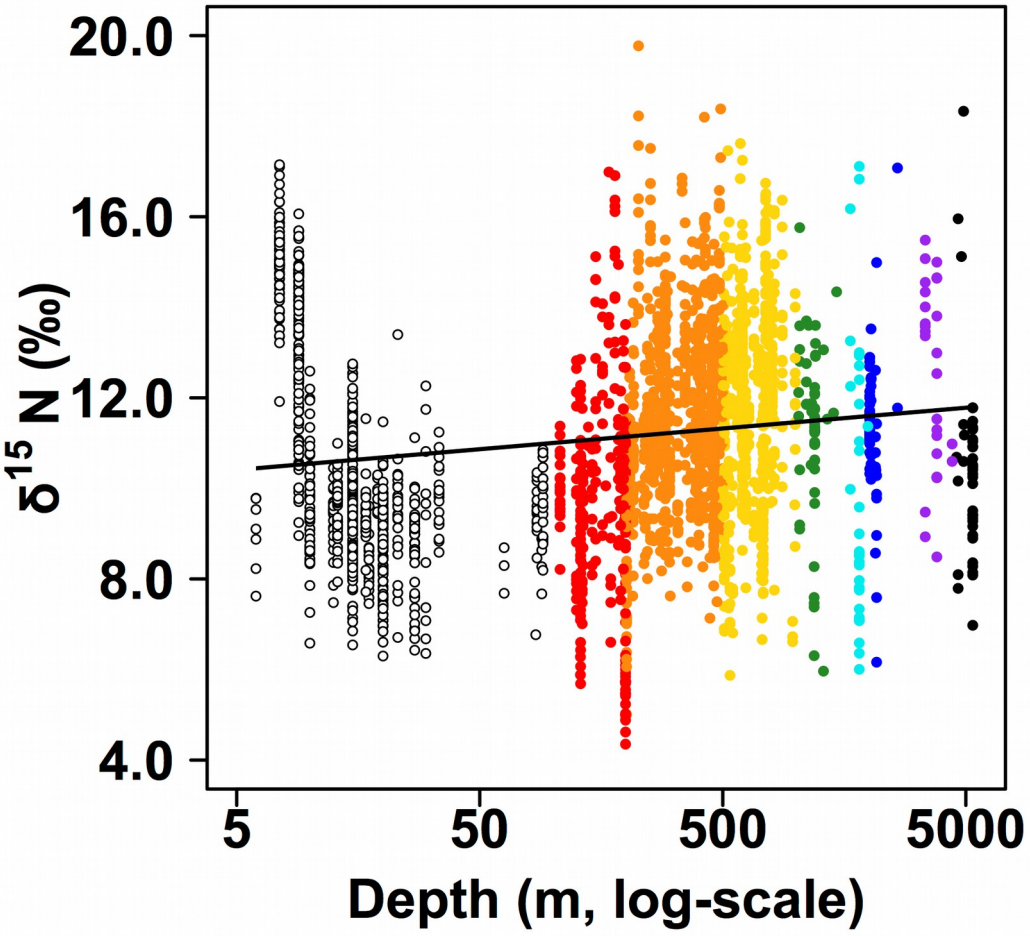
- Decrease of $\delta^{13}C$ values with depth for most trophic groups

  → Specialisation on pelagic resources even in coastal pelagos-based omnivores?



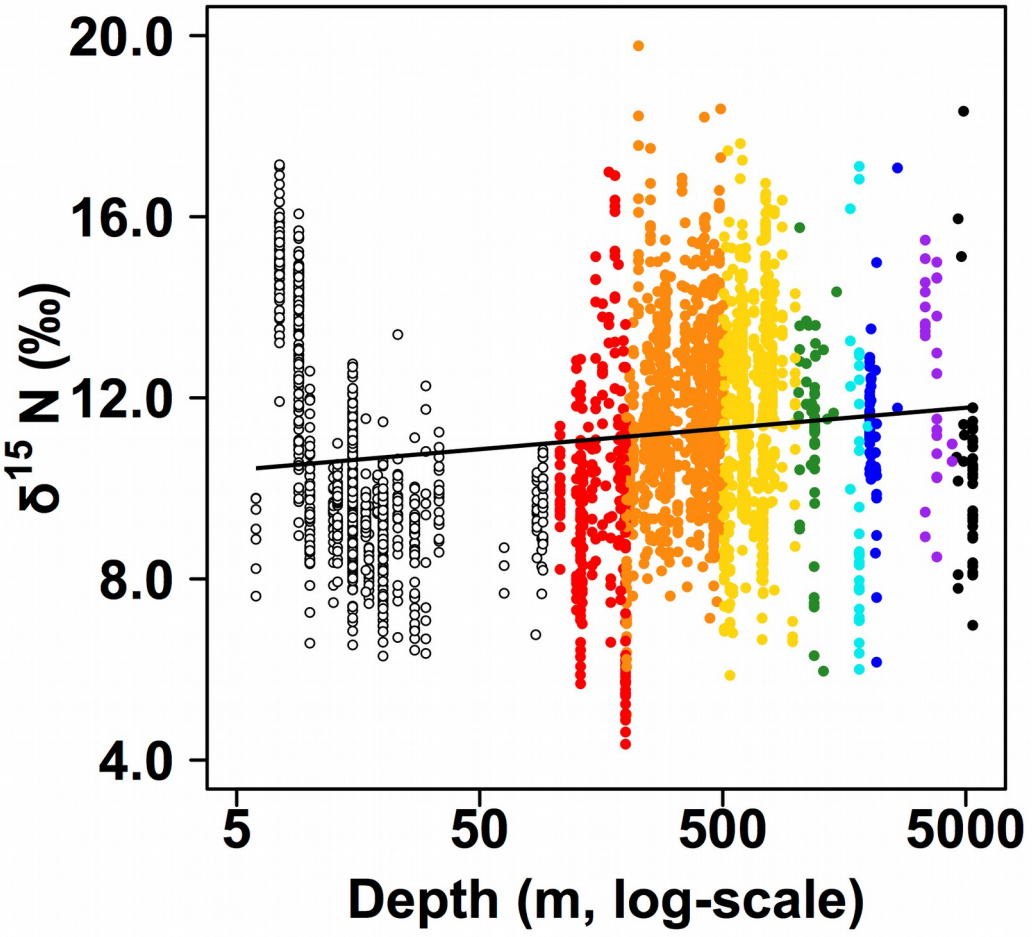
Depth

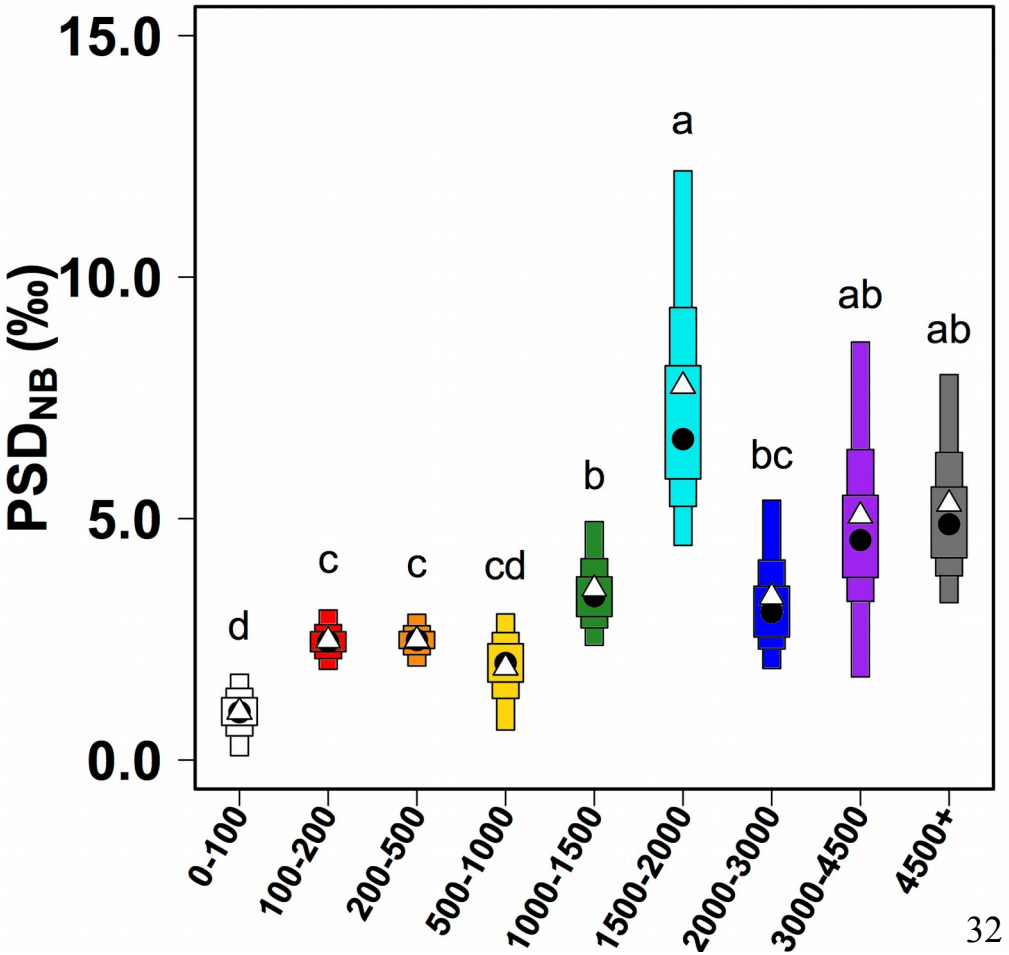
- No change of $\delta^{15}N$ values with depth



Depth

- No change of $\delta^{15}N$ values with depth
- Increasing variability of $\delta^{15}N$ values between taxa with depth

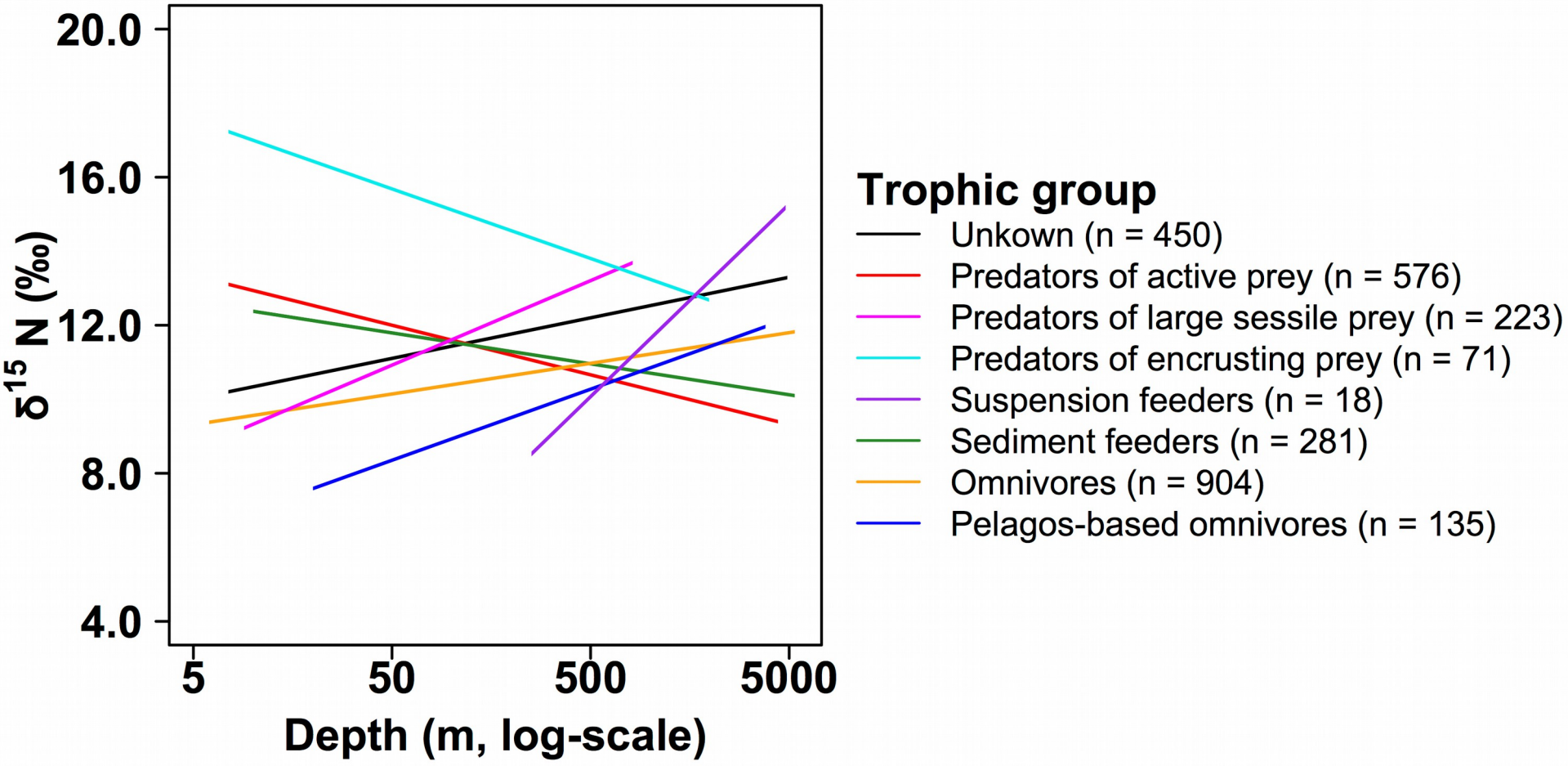




Depth

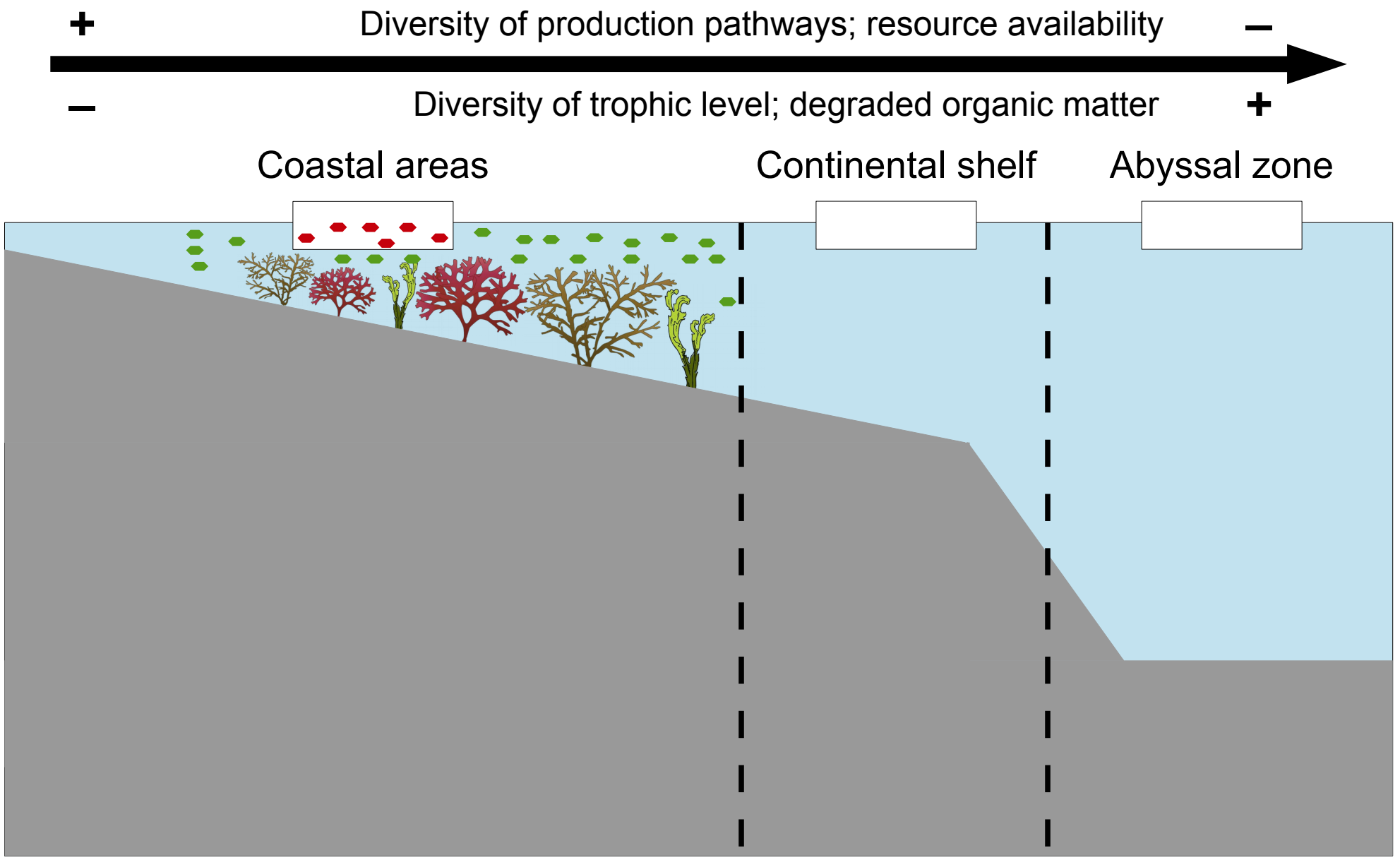
- Change of $\delta^{15}N$ values with depth depending on trophic group:

  → Increase of $\delta^{15}N$ values with depth for 3 trophic groups depending on resuspended organic matter and omnivores



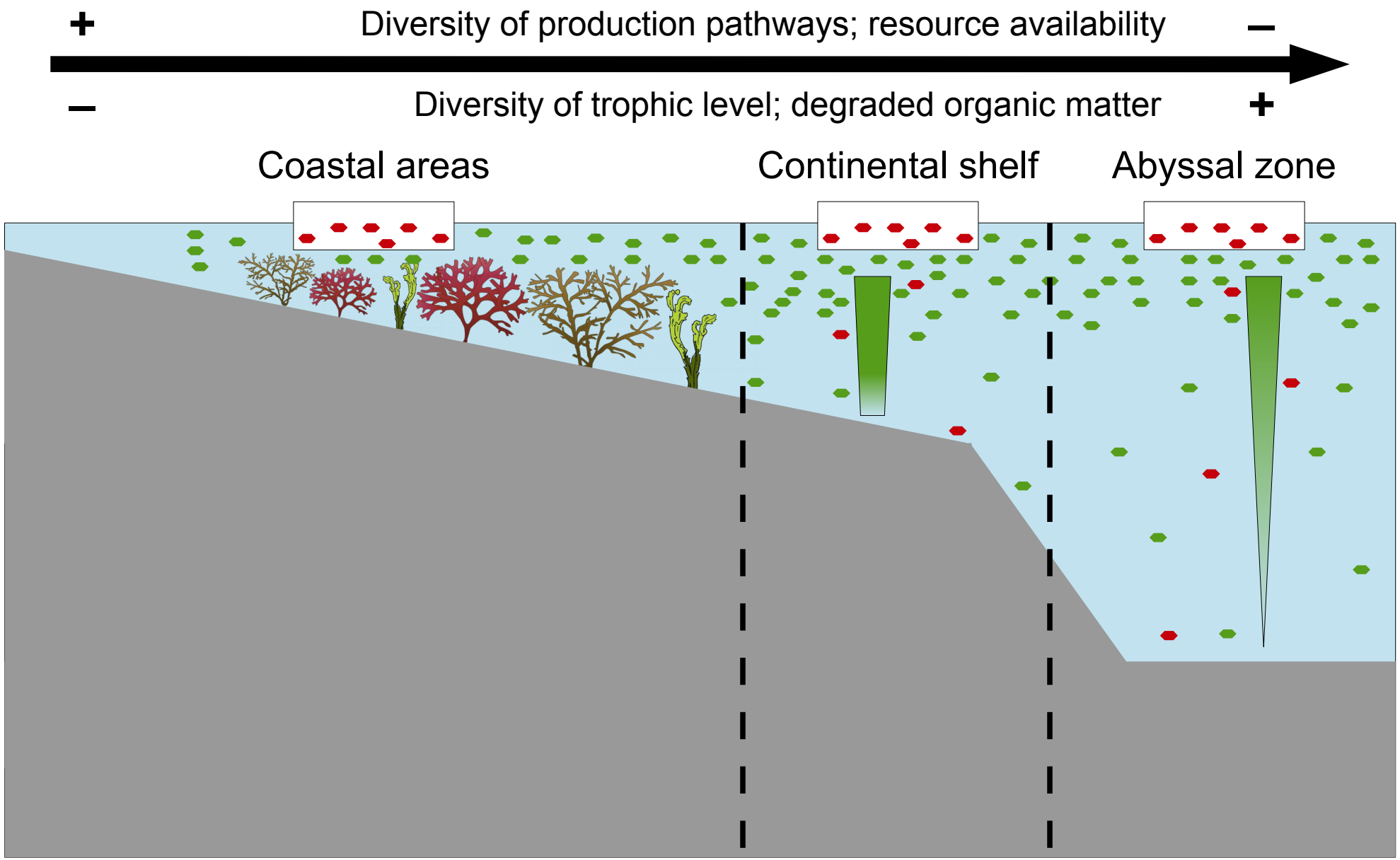
Depth

- Impact on primary production and its availability



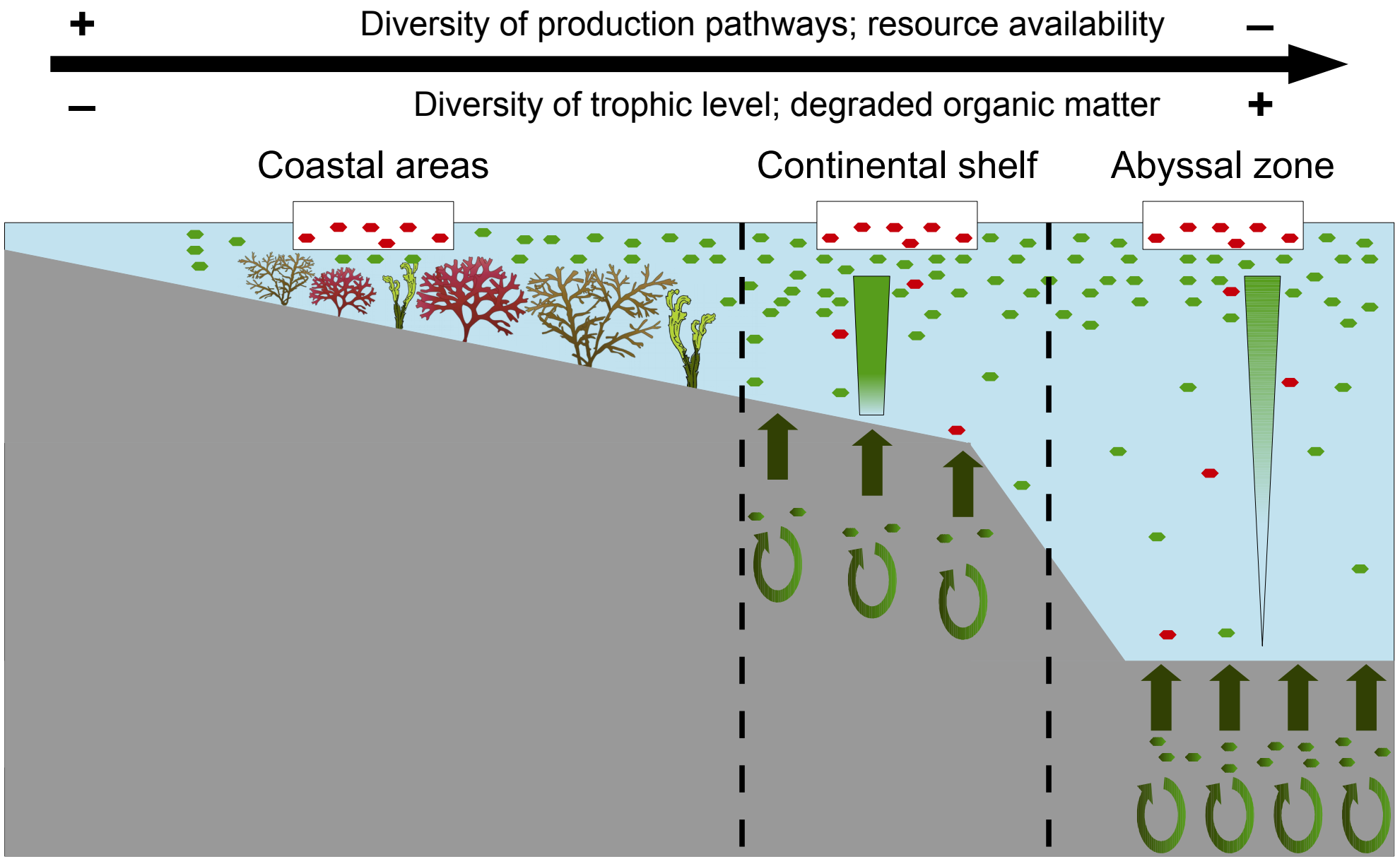
Depth

- Impact on primary production and its availability



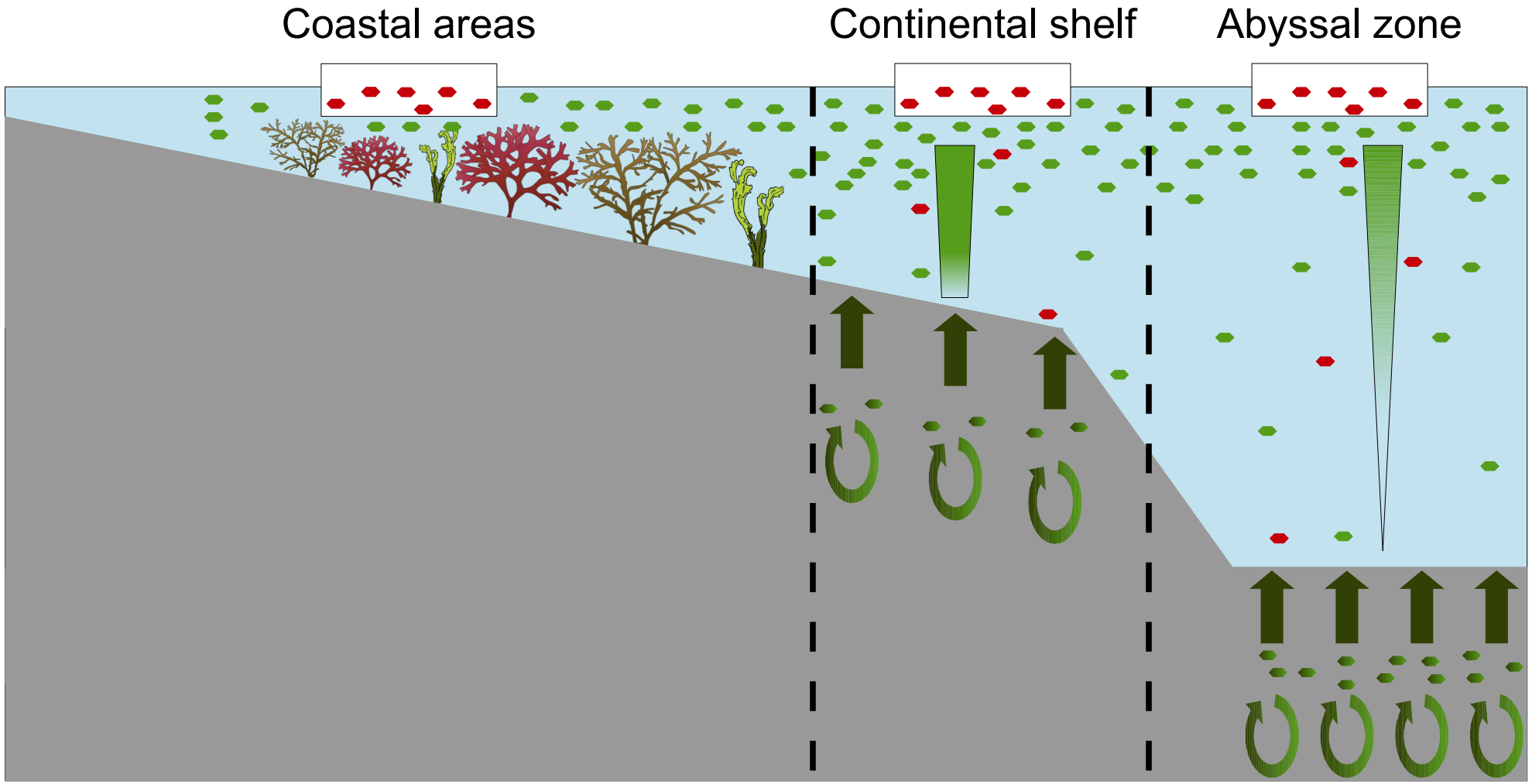
Depth

- Impact on primary production and its availability



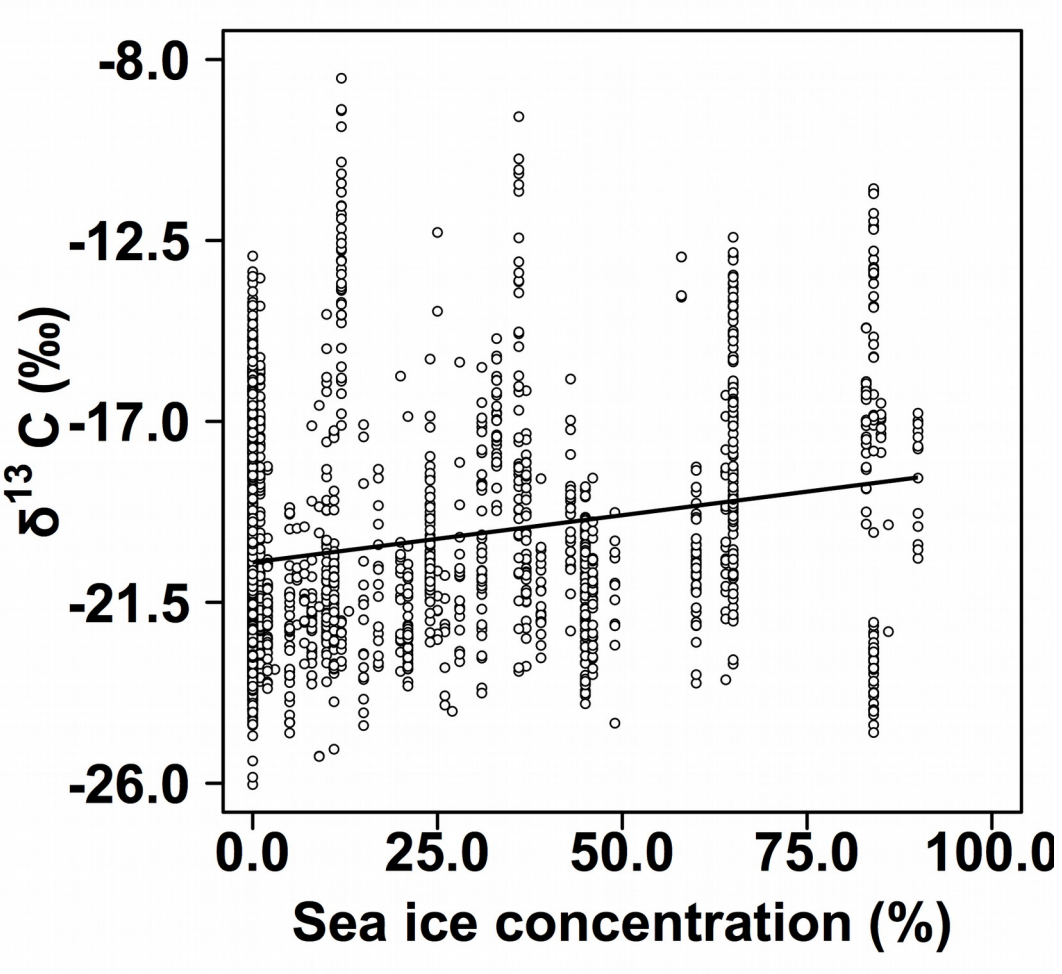
Depth

Hypothesis summary: The impacts of depth on primary production characteristics influence the resource availability and thus the trophic ecology of sea stars.



Sea ice

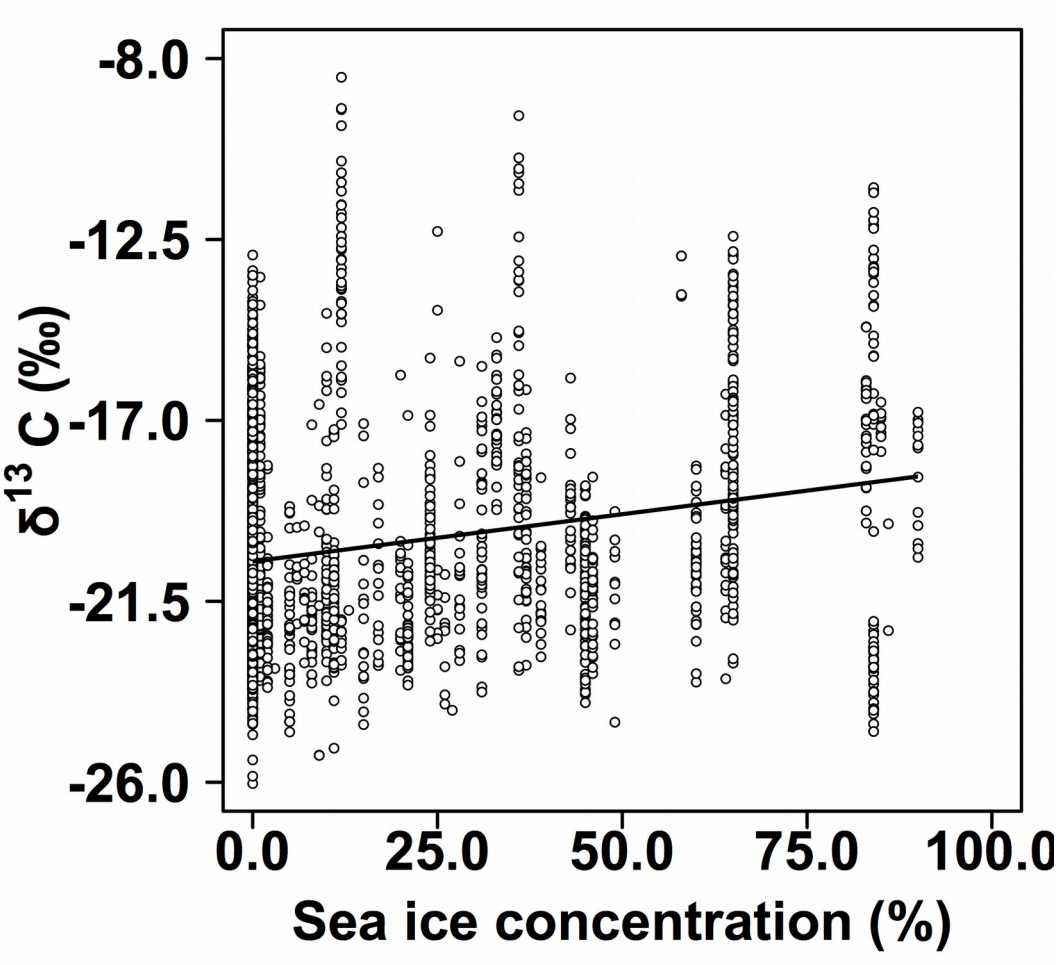
- Increasing $\delta^{13}C$ values with sea ice concentration
- High $\delta^{13}C$ values at high sea ice concentration

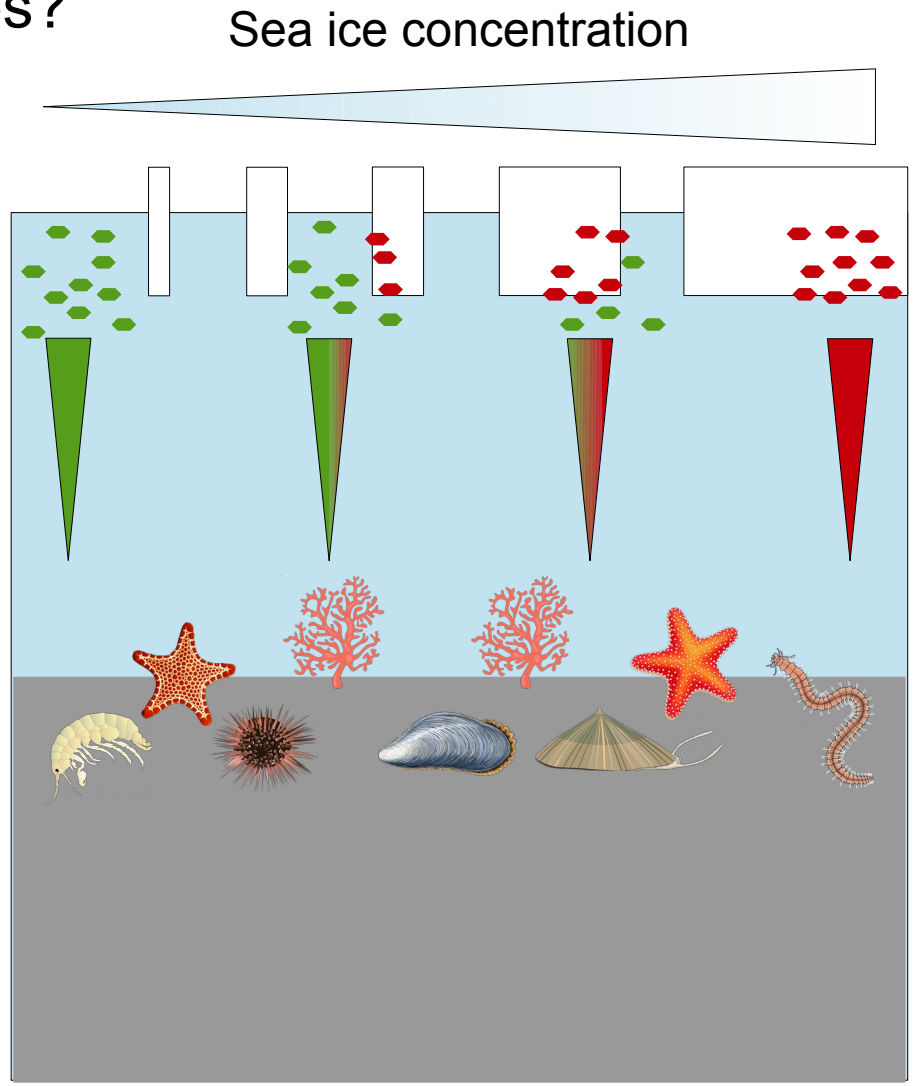


Sea ice

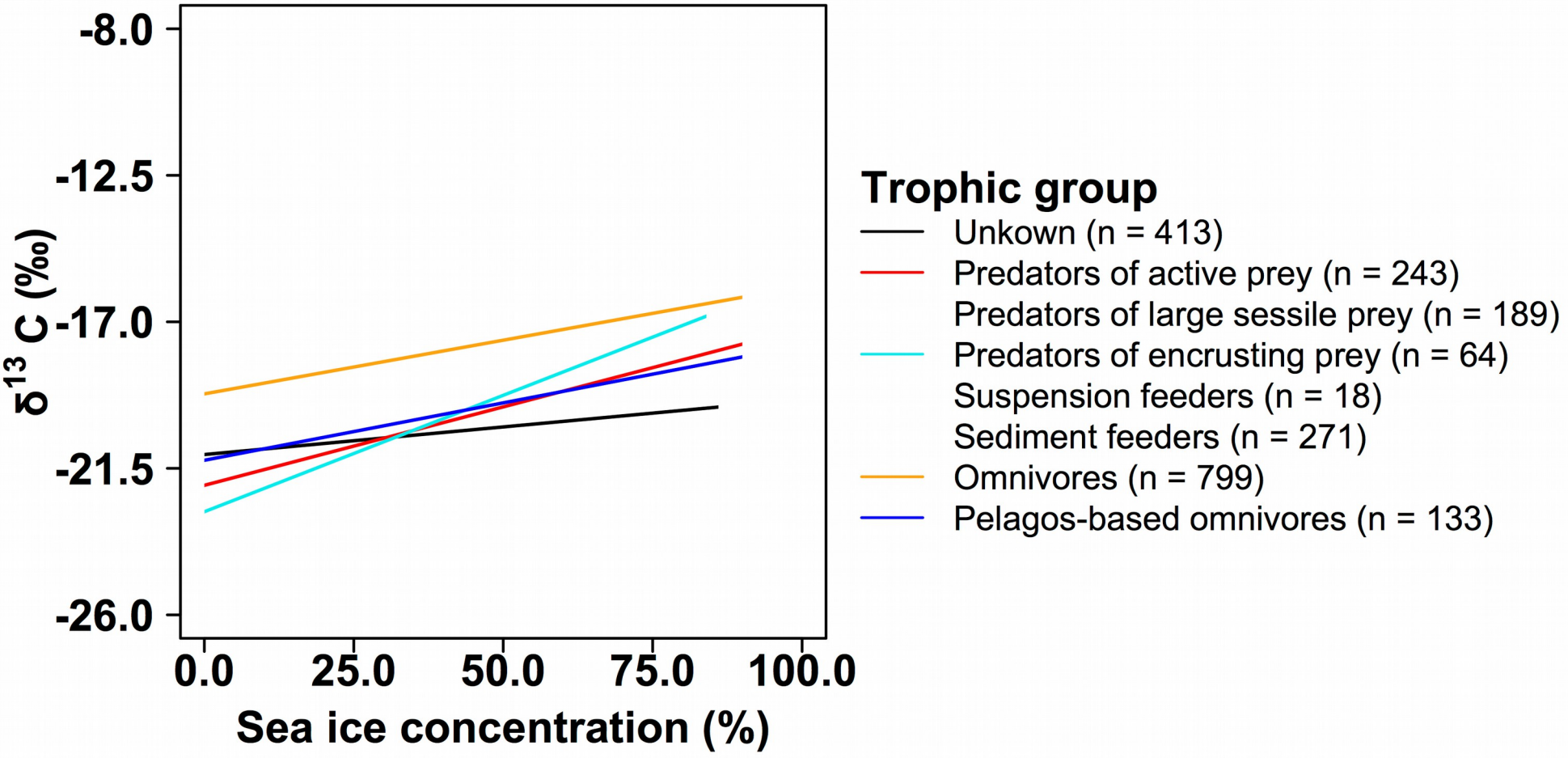
- Increasing $\delta^{13}C$ values with sea ice concentration
- High $\delta^{13}C$ values at high sea ice concentration

  → Reliance on sympagic communities?





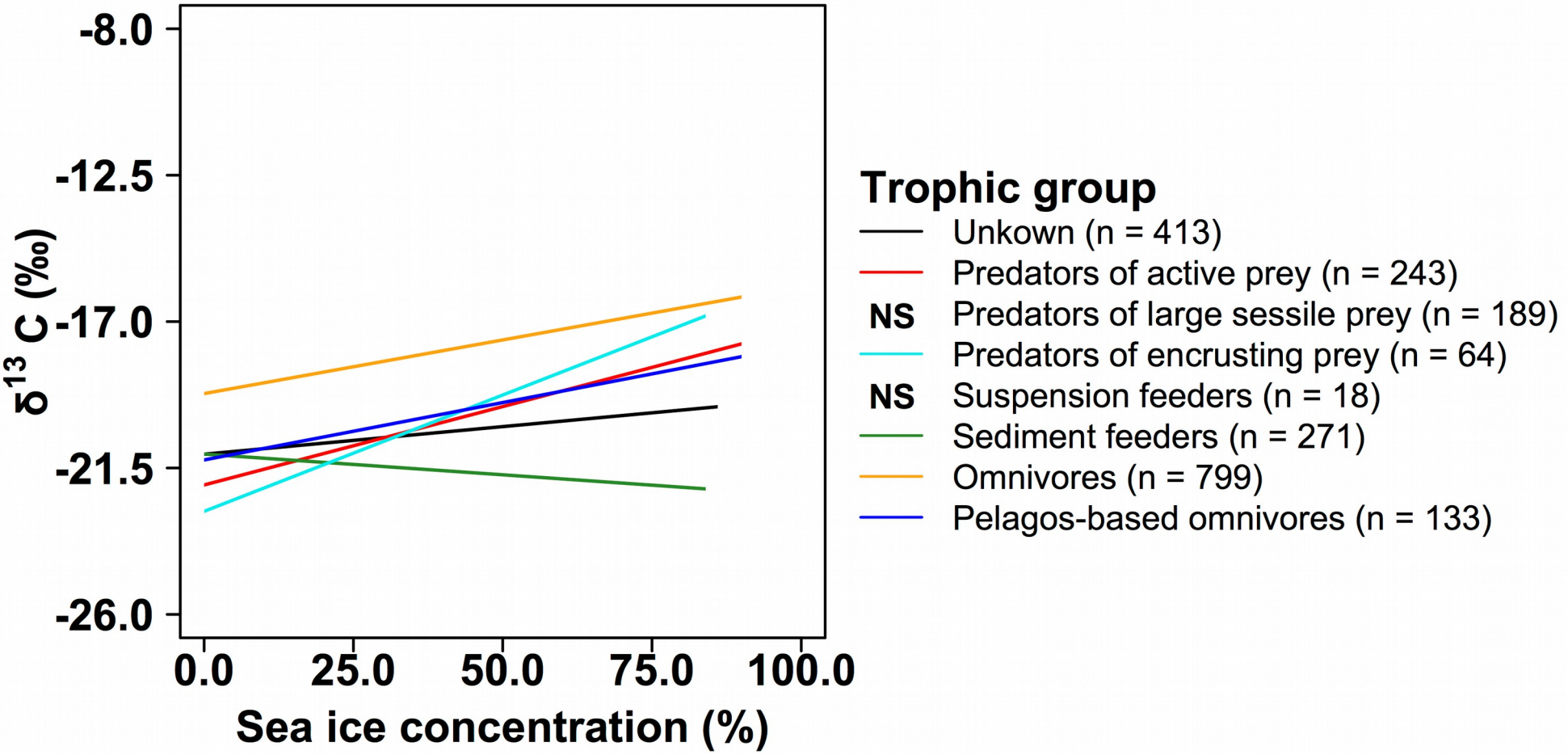
Sea ice


-8.0
-12.5
-17.0
-21.5
-26.0
δ13 C (‰)
0.0
25.0
50.0
75.0
100.0
Sea ice concentration (%)
Trophic group
Unkown (n = 413)
Predators of active prey (n = 243)
Predators of large sessile prey (n = 189)
Predators of encrusting prey (n = 64)
Suspension feeders (n = 18)
Sediment feeders (n = 271)
Omnivores (n = 799)
Pelagos-based omnivores (n = 133)

Sea ice

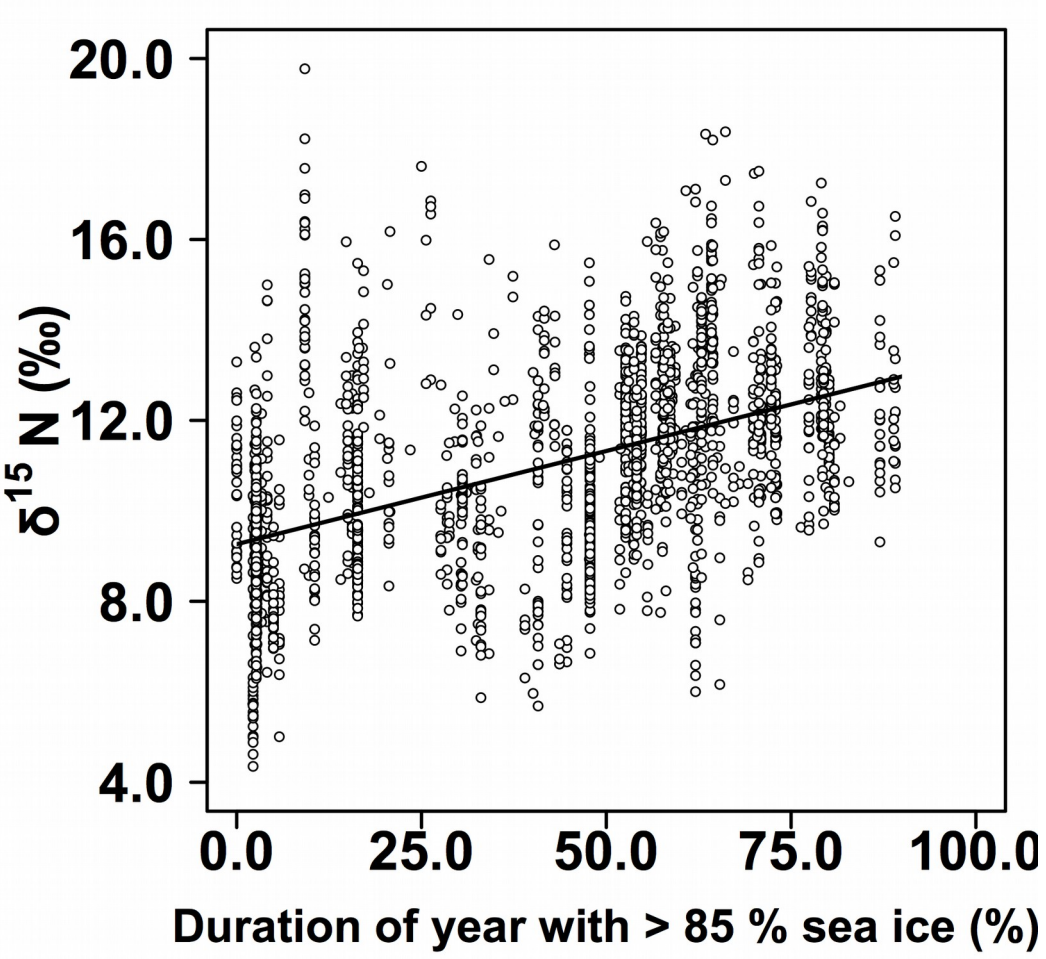
- No increasing $\delta^{13}C$ values with sea ice concentration for predators of sessile prey and sediment feeders (low sea ice concentration range for suspension feeders)

  → Reliance on other sources than sympagic communities?



Sea ice

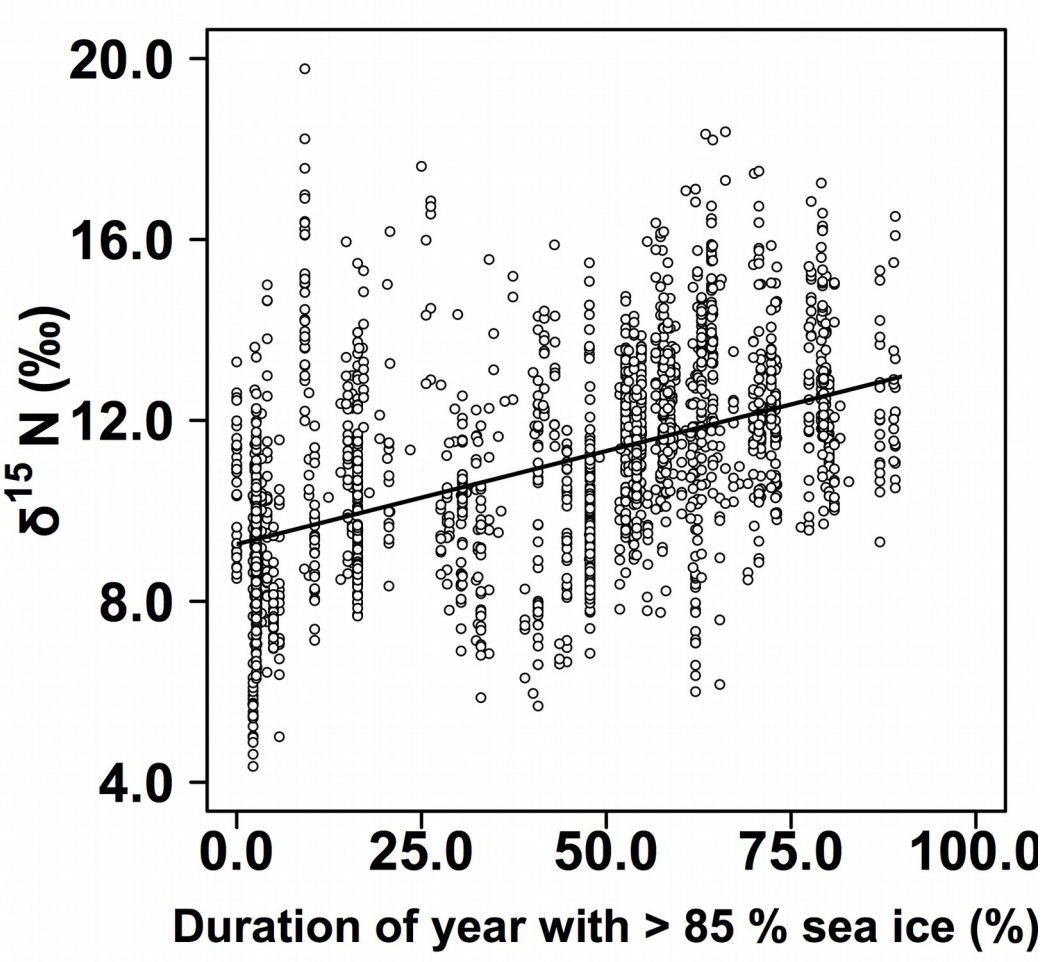
- Increasing $\delta^{15}N$ values with sea ice season duration

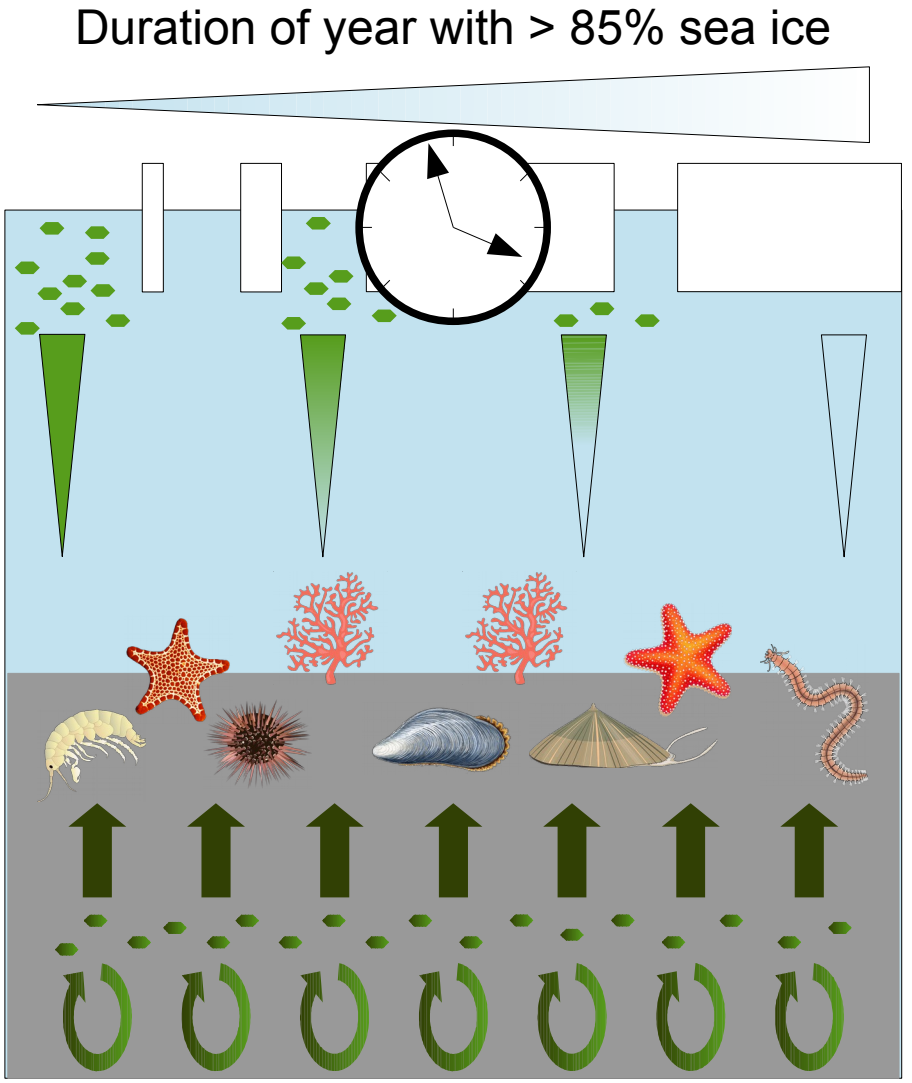


Sea ice

- Increasing $\delta^{15}N$ values with sea ice season duration

  → Reliance on degraded phytodetritus?

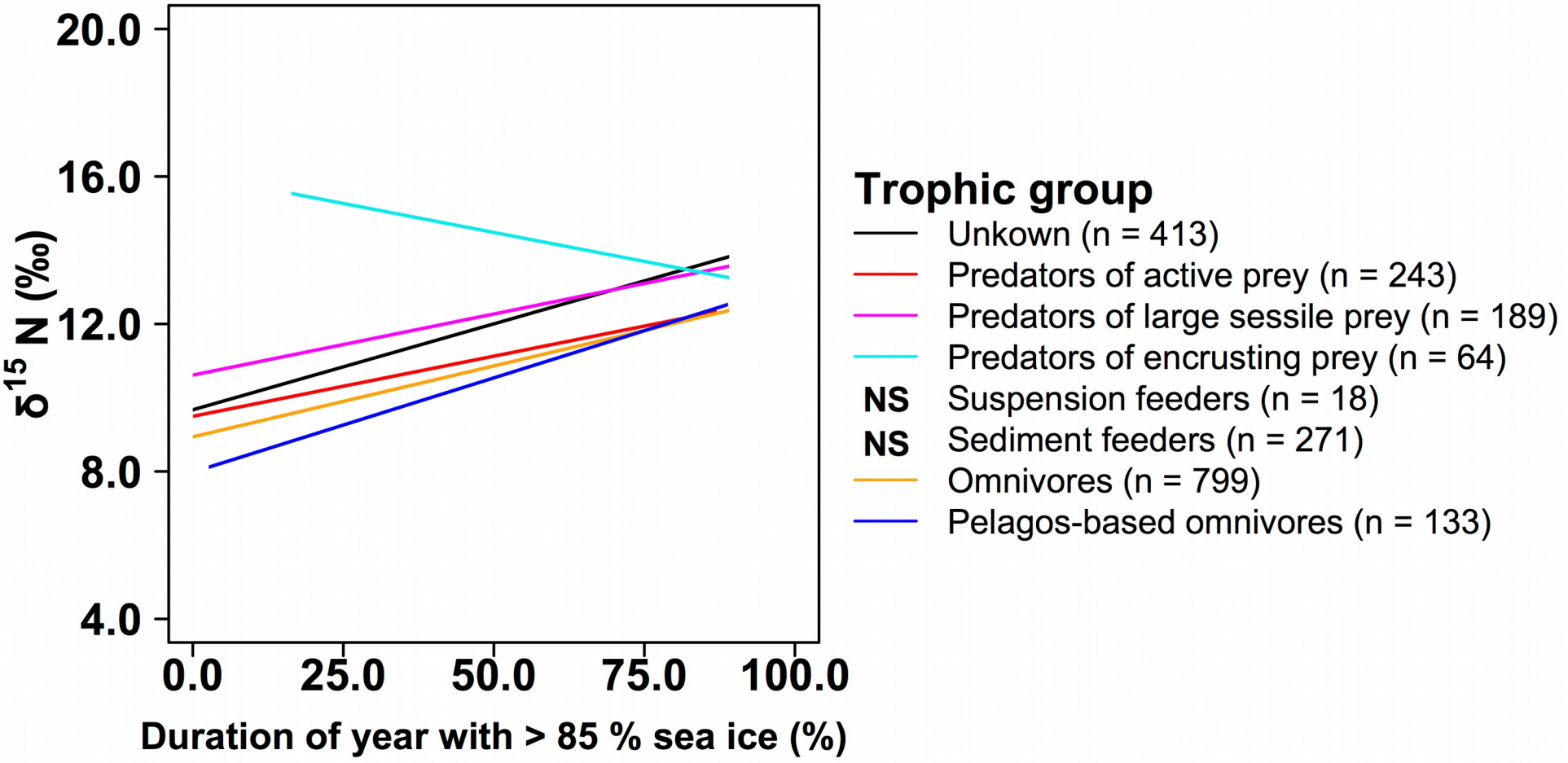




Sea ice

- No increasing $\delta^{15}N$ values with sea ice season duration for predators of encrusting prey, suspension feeders and sediment feeders

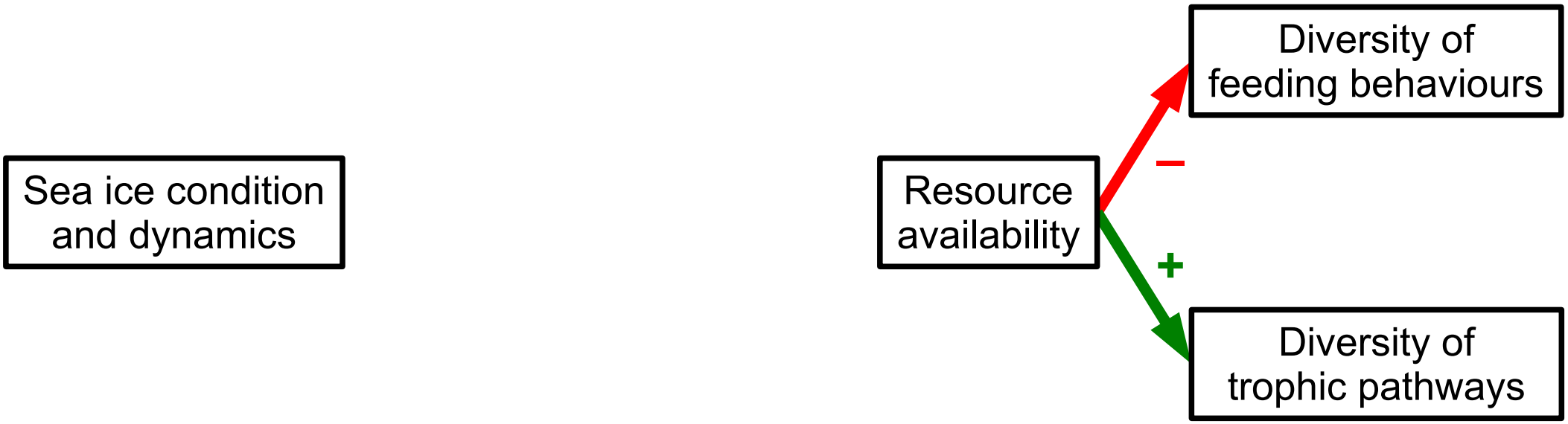
  → Reliance on non-degraded materials?



Sea ice

- No consistant impact of sea ice on trophic diversity

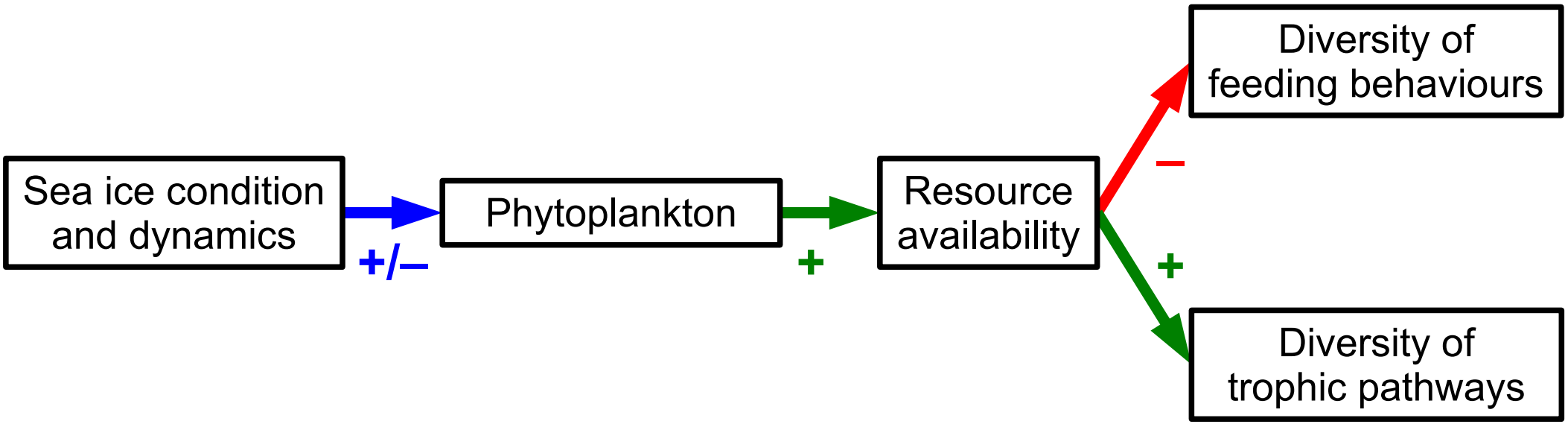
  → Multiple impacts of sea ice on resource availability



Sea ice

- No consistant impact of sea ice on trophic diversity

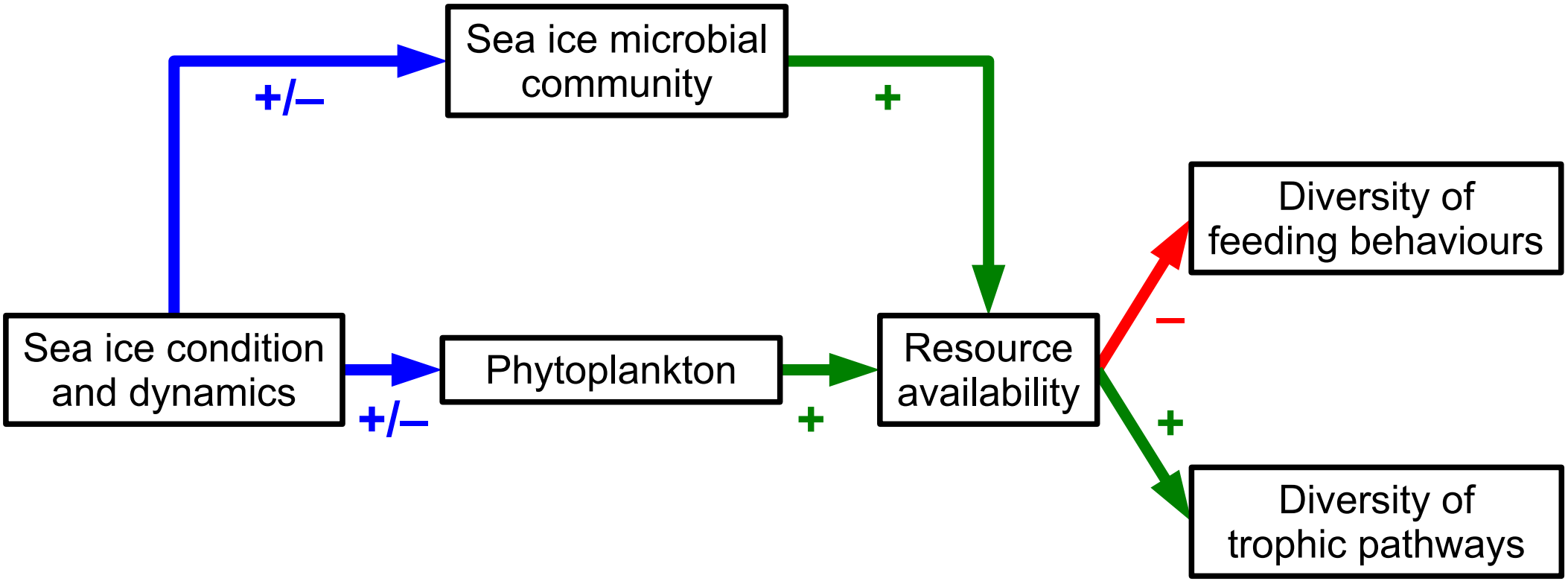
  → Multiple impacts of sea ice on resource availability



Sea ice

- No consistant impact of sea ice on trophic diversity

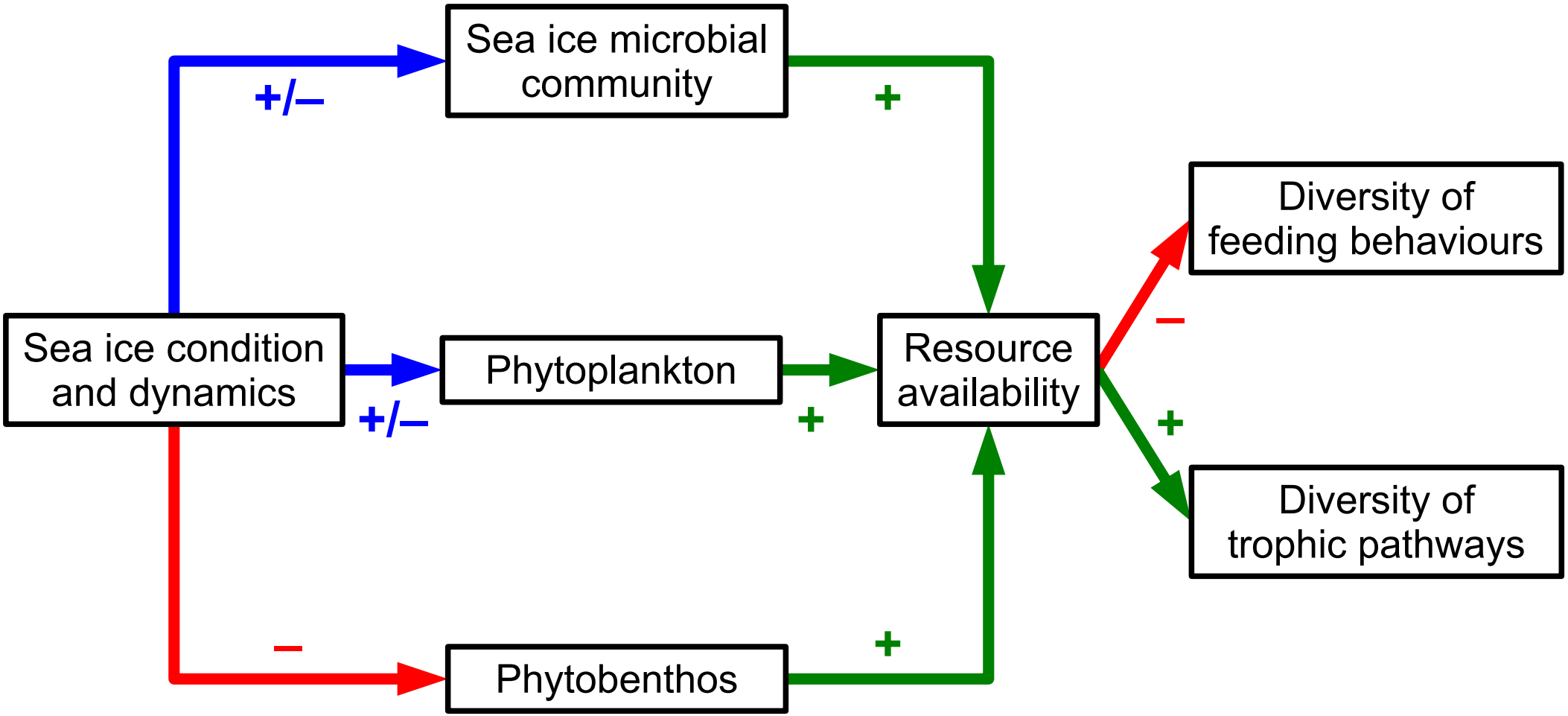
  → Multiple impacts of sea ice on resource availability



Sea ice

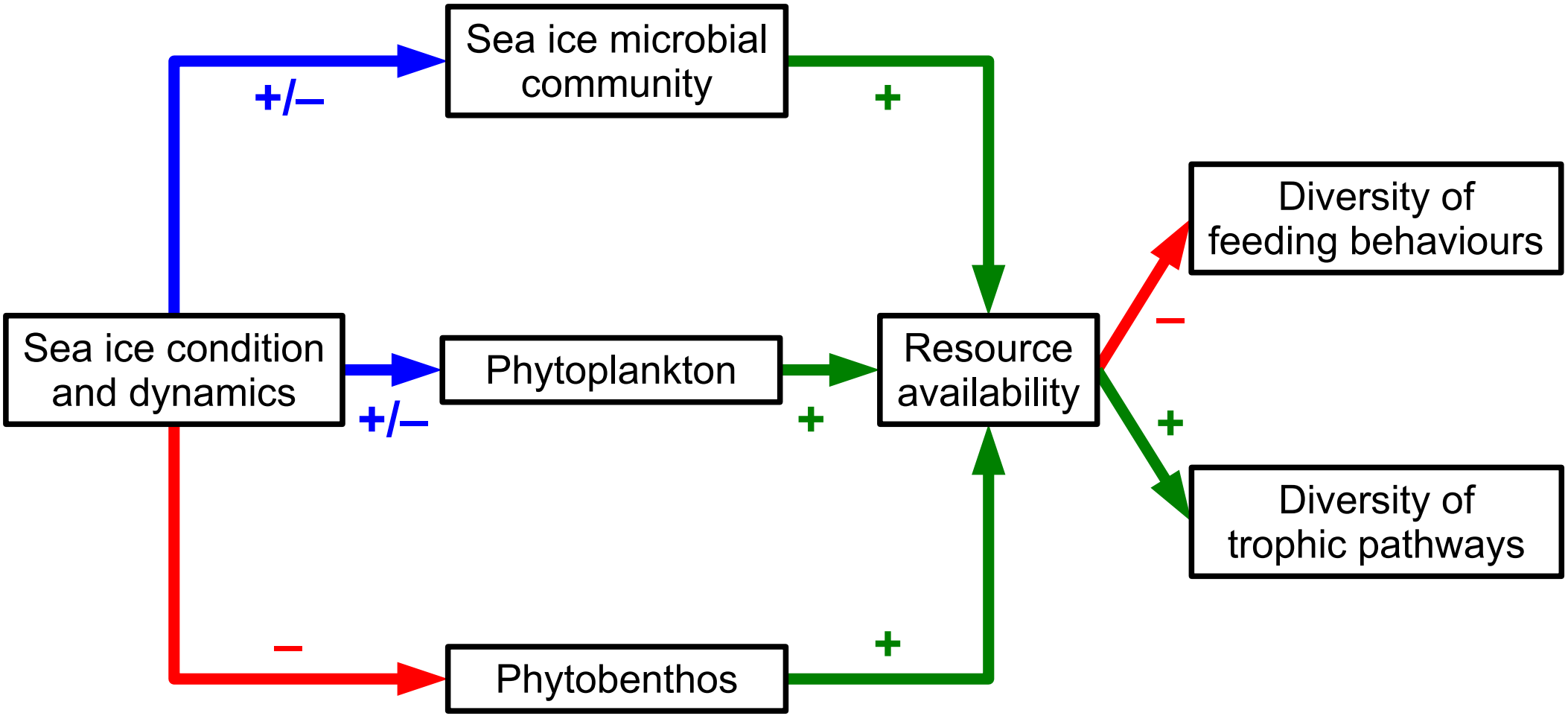
- No consistant impact of sea ice on trophic diversity

  → Multiple impacts of sea ice on resource availability



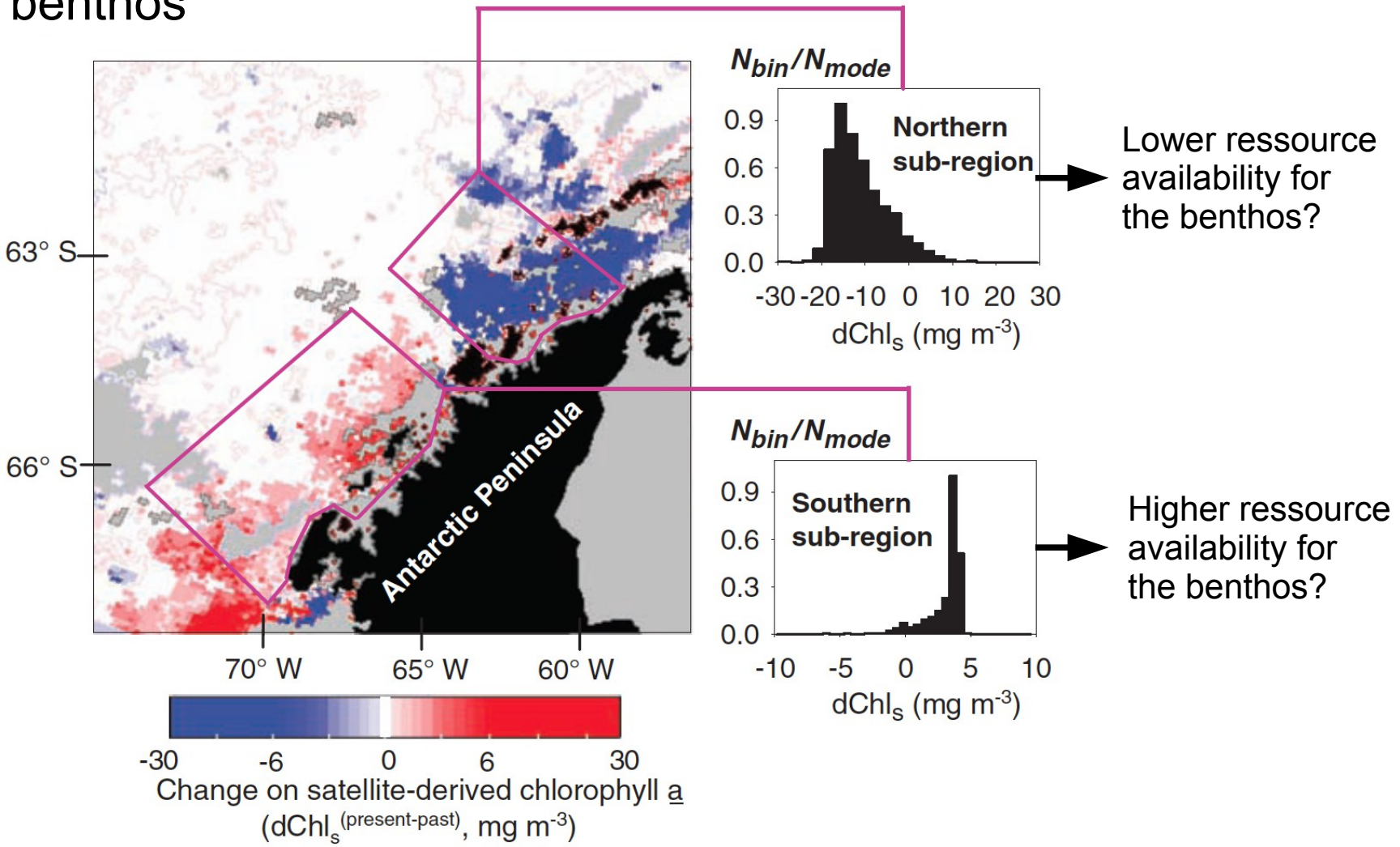
Sea ice

Hypothesis summary: Different impacts of sea ice on primary production and thus on resource availability and thus the trophic ecology of sea stars.



Sea ice

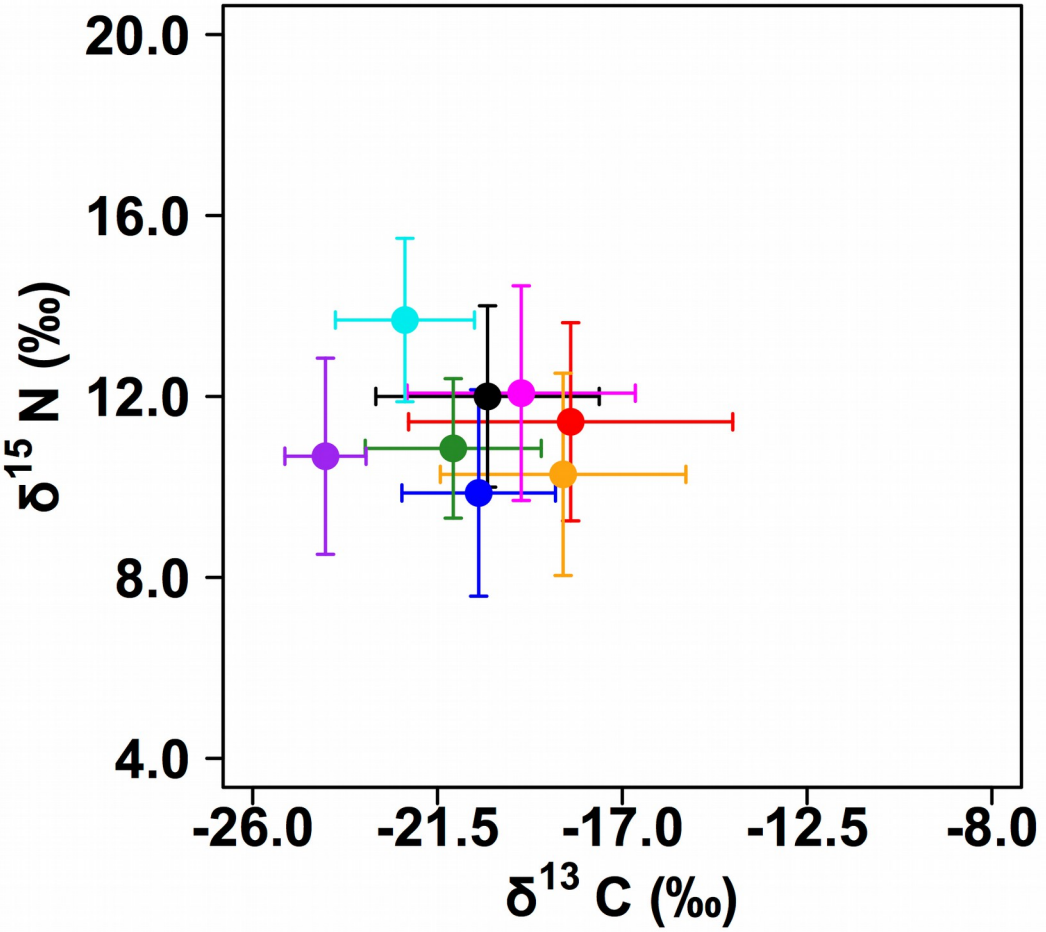
- Multiple impacts of sea ice on resource availability
  → Different effects of change in sea ice cover on primary production
  → Changes in the importance of surface production transfer to the benthos

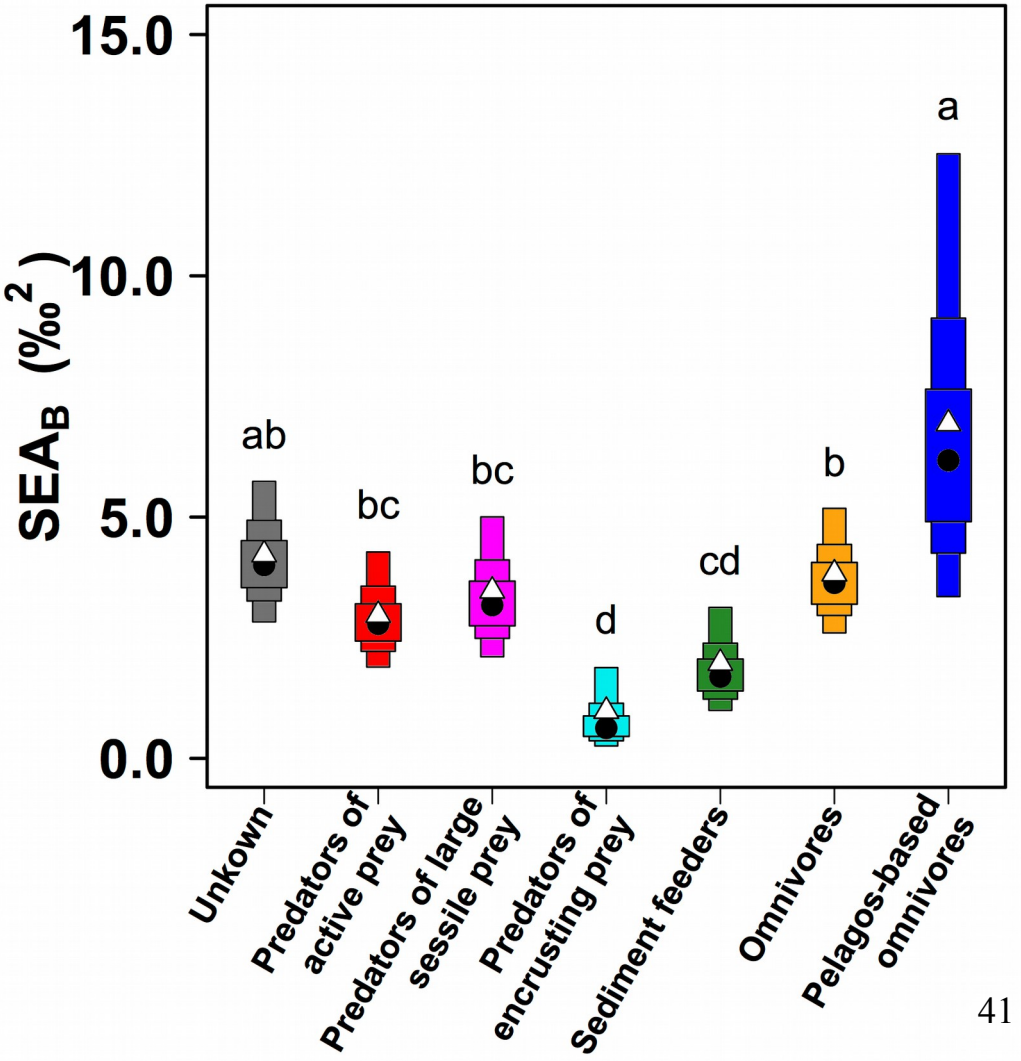


Montes-Hugo et al., 2009

Differences between trophic groups

- Differences of feeding behaviours between trophic groups
- Differences of feeding behaviours between taxa within trophic groups

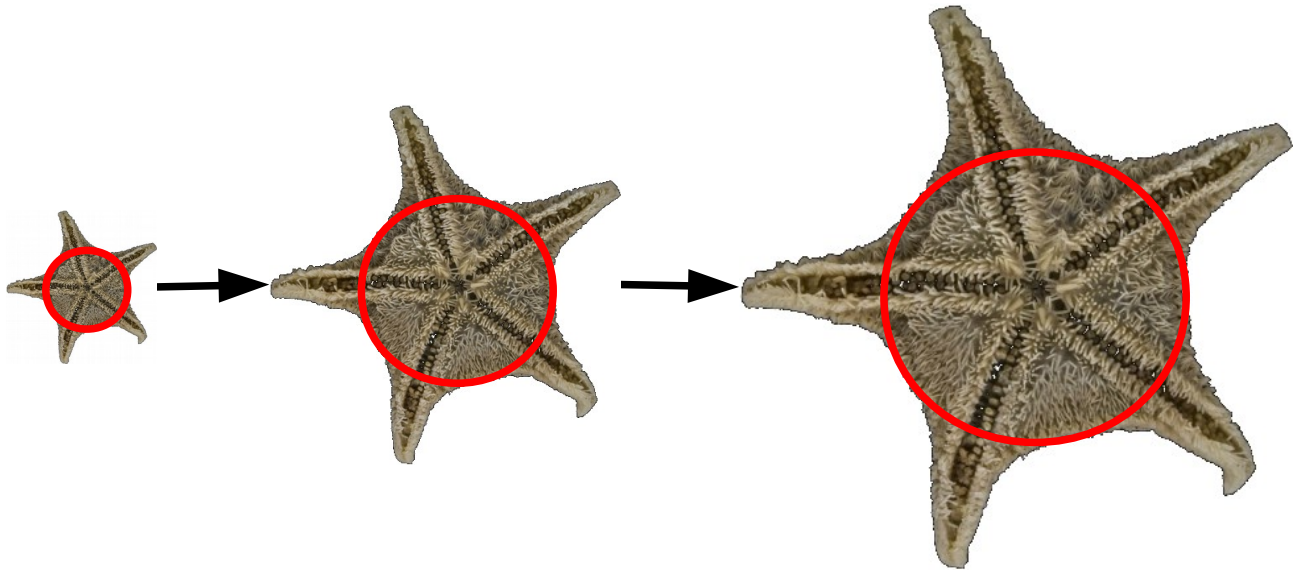


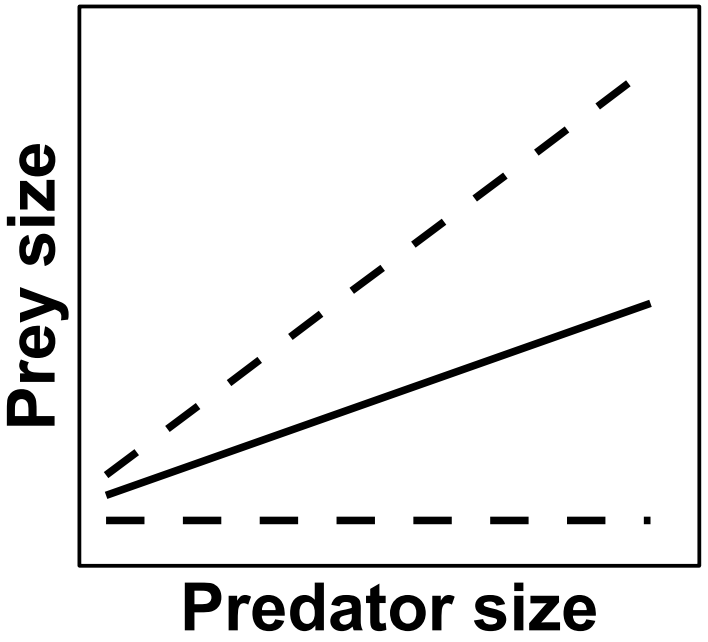


Summary and conclusions

- Ontogenetic changes of size

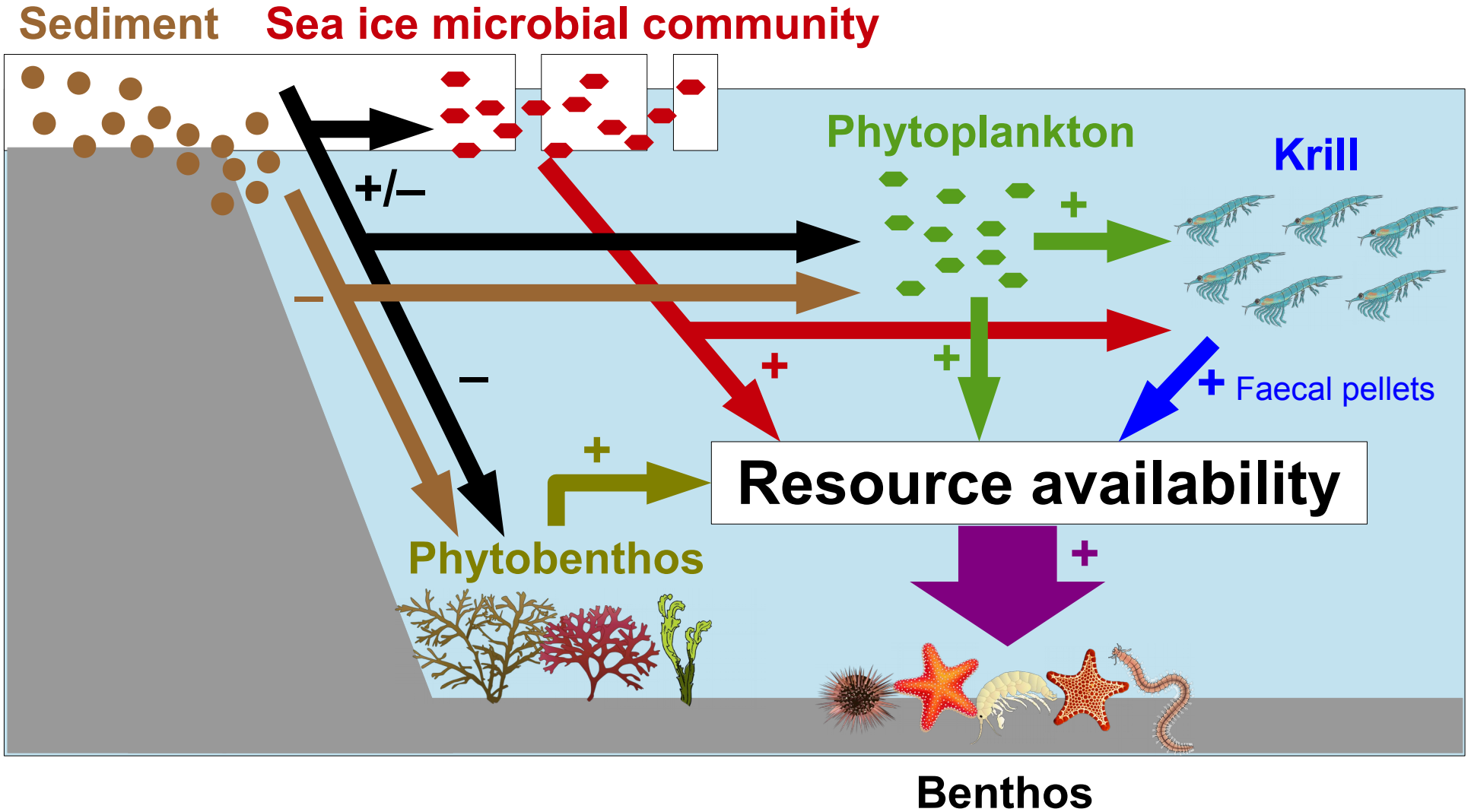
  → Changes in ingested prey size and/or category
- Importance of ontogenetic changes of trophic ecology depending on species and/or trophic groups





Summary and conclusions

- Impacts of environmental parameters on resource availability
  → Impacts on competition risks? → Impacts on trophic diversity
- Different impacts of environmental parameters on trophic groups



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