LIÈGE université
Animal systematics and diversity

Ifremer

SORBONNE UNIVERSITÉ

CheReef

Dining in the deep: Unraveling energy acquisition strategies in syntopic cold-water corals

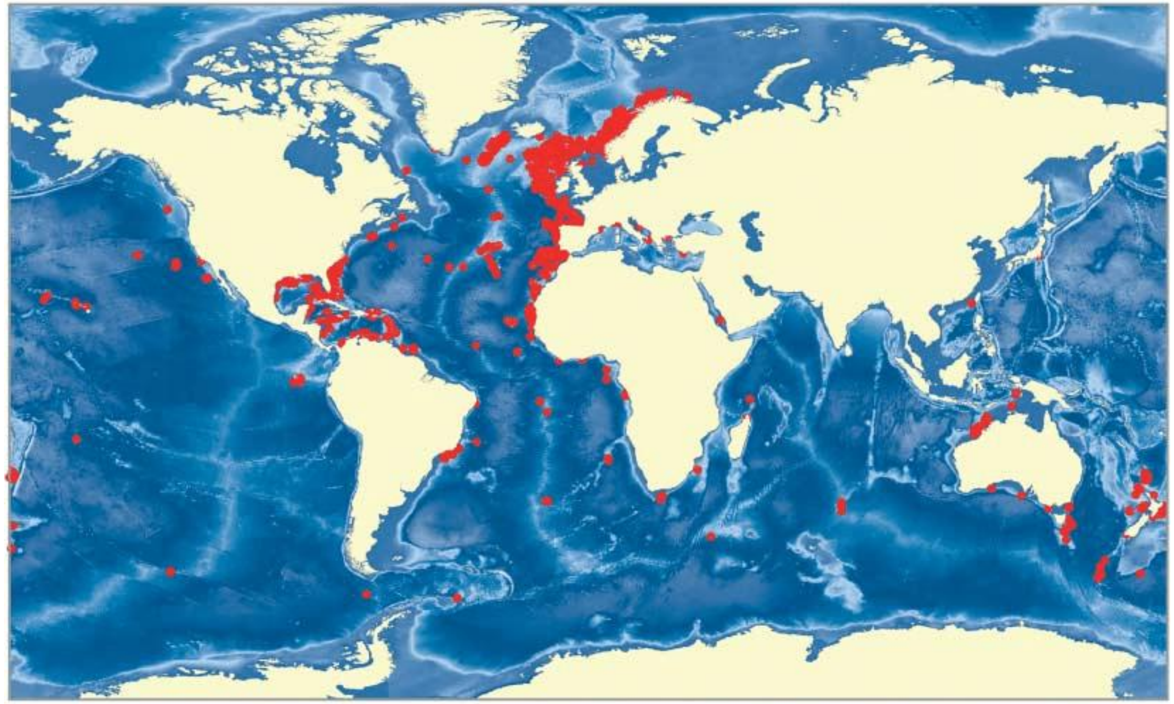
L. N. MICHEL[1], M. MATHIEU-RESUGE, L. AMAND, E.-J. ARSENAULT-PERNET, A. BOURIAT, J. BOUSQUET, S. FUCHS, C. LE GOFF, G. LEPOINT, M. MARINIER, V. MEUNIER, F. PERNET, J. ROBBE, B. SHILLITO, L. THERASSE, J. TOUROLLE, M. ZBINDEN & L. MENOT

[1]University of Liège, Belgium - Contact: loic.michel@uliege.be

Zoology 2024 – Mons, Belgium, 13/12/2024

CORALS

Cold-water corals



Roberts *et al.* 2006 Science 312: 543-547

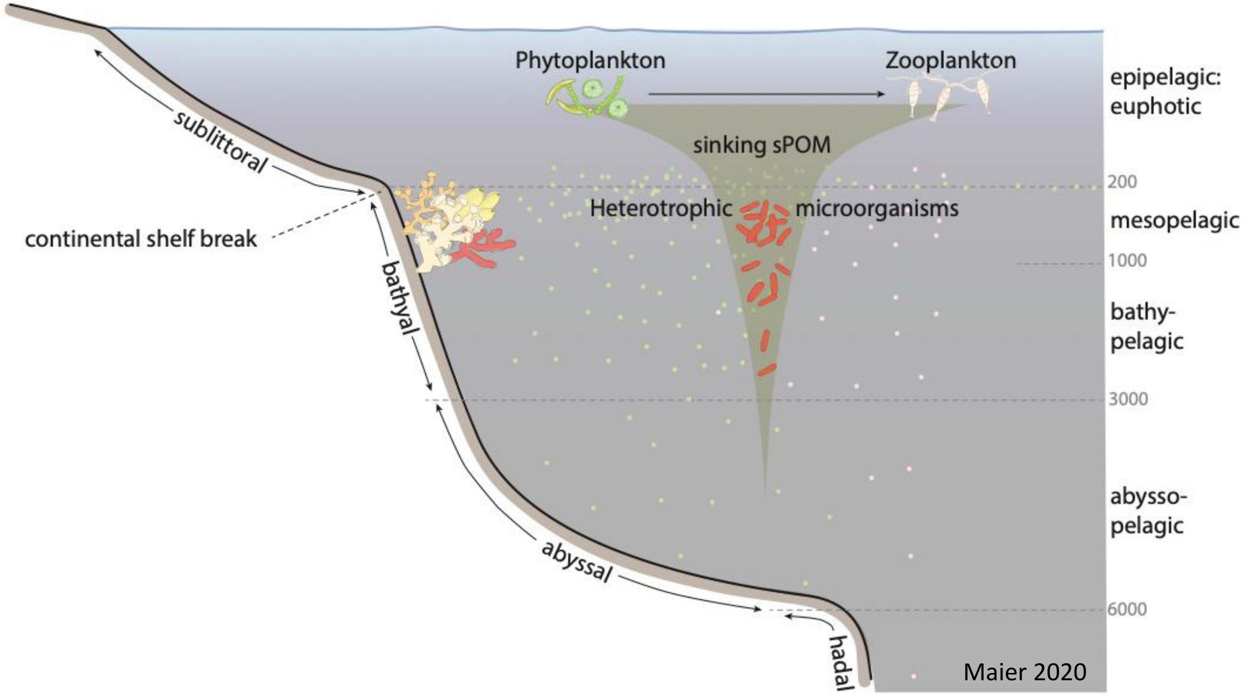
Foundation species forming reefs with wordwide distribution, most commonly at depths ranging between 200 and 2000 meters

Those reefs provide habitats and/or nursery grounds for many other species: deep-sea biodiversity hotspots

Cold-water corals

Cold-water corals mostly depend on photosynthetic organic matter produced in the euphotic zone and exported through benthic-pelagic coupling


Buhl-Mortensen *et al.* 2010 Mar. Ecol. 31: 21-50



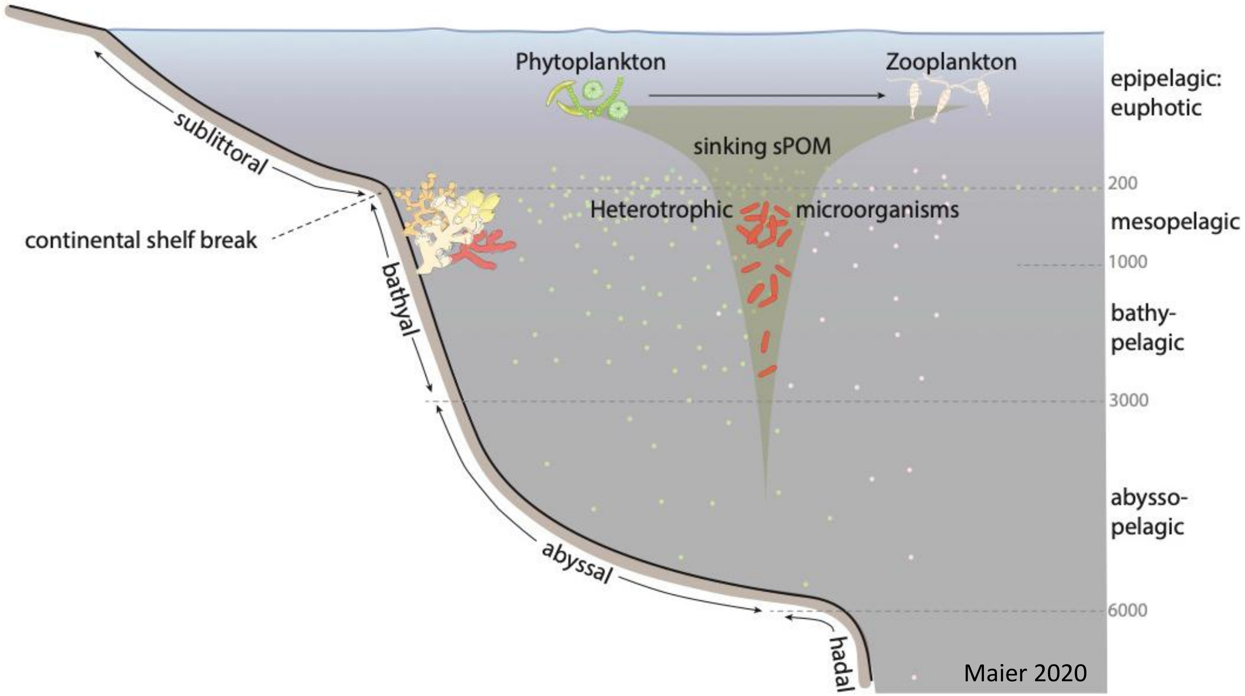
Maier 2020

Cold-water corals

Cold-water corals mostly depend on photosynthetic organic matter produced in the euphotic zone and exported through benthic-pelagic coupling

Food availability is therefore limited, and usually available through infrequent but massive resource pulses ("feast & famine" environment)

Buhl-Mortensen *et al.* 2010 Mar. Ecol. 31: 21-50



Maier 2020

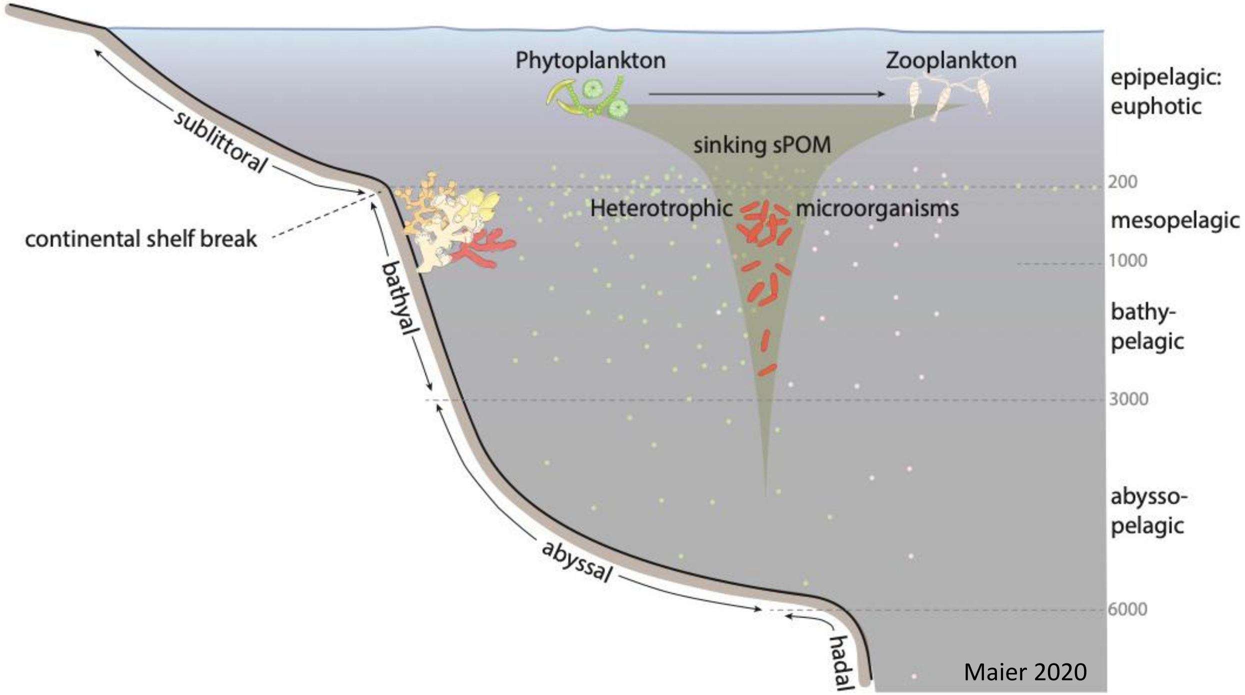
Cold-water corals

Cold-water corals mostly depend on photosynthetic organic matter produced in the euphotic zone and exported through benthic-pelagic coupling

Food availability is therefore limited, and usually available through infrequent but massive resource pulses ("feast & famine" environment)

Energy acquisition is a major challenge for CWCs, and will likely become even more so in the next few decades as global change could shift coral energy budgets (ocean acidification)

Buhl-Mortensen *et al.* 2010 Mar. Ecol. 31: 21-50



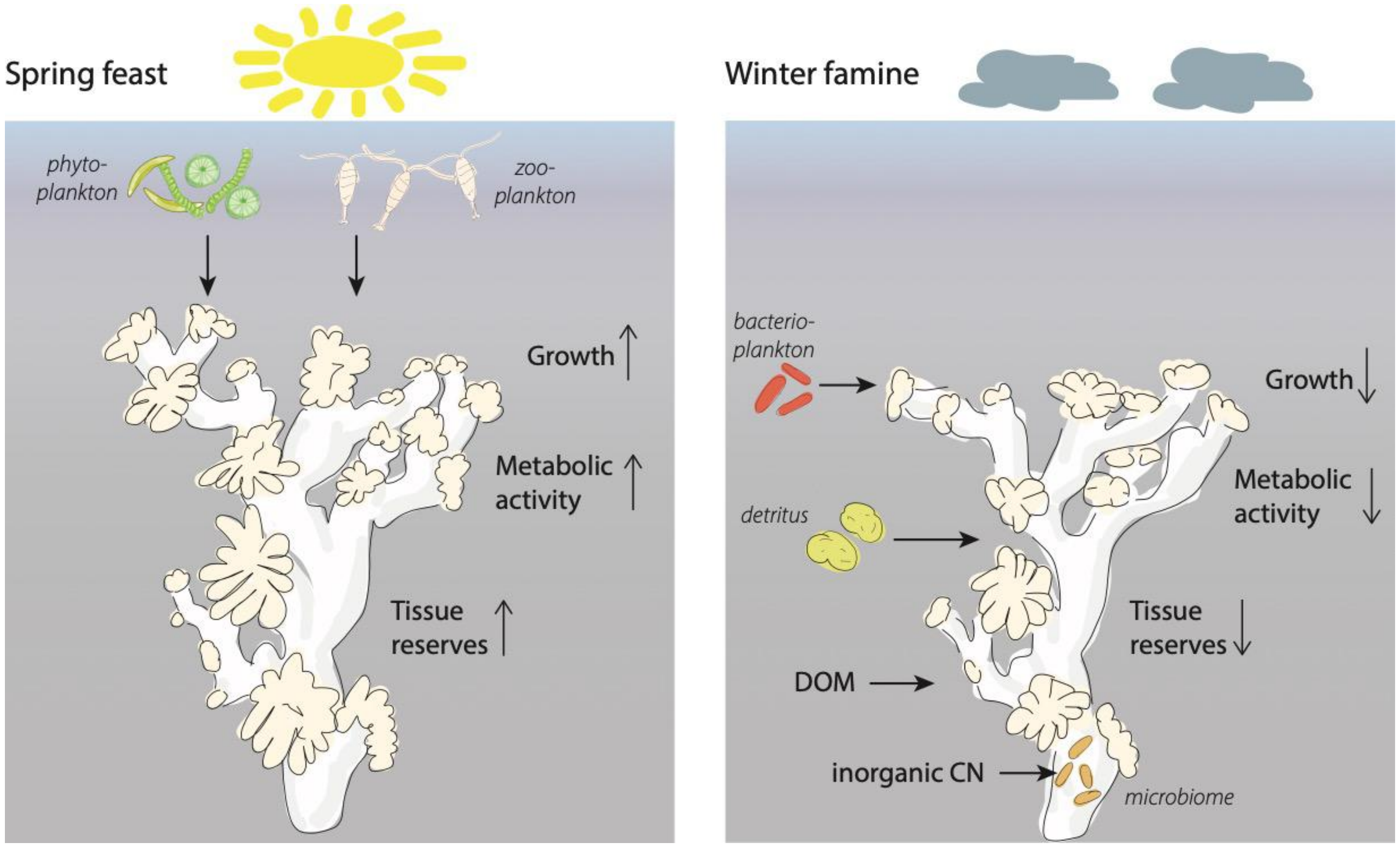
Maier 2020

Adaptations to food-poor environments

Zetsche *et al.* 2016, PLoS ONE 11(2): e0146766

Passive suspension feeders: secret mucus to enhance particle/prey trapping

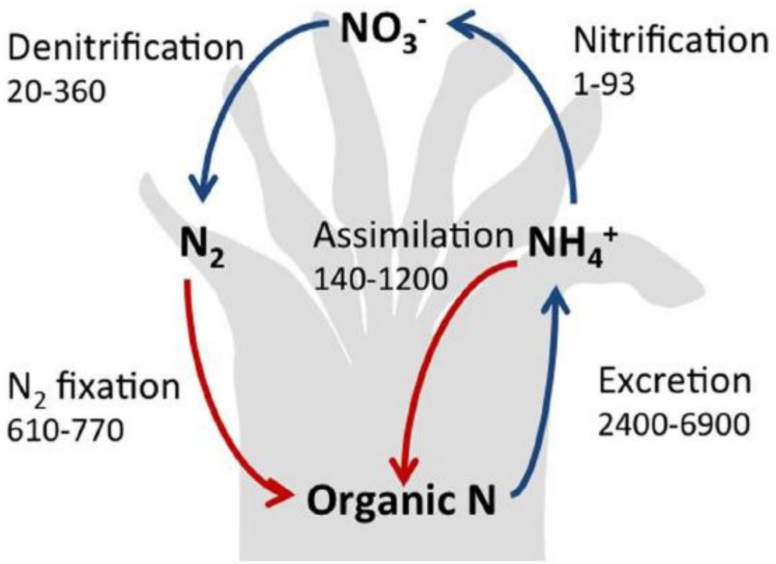
Adaptations to food-poor environments



Maier 2020

Selective suspension feeders: able to feed on multiple items (phytoplankton, zooplankton, bacterioplankton, detritus, etc.), with considerable ecological plasticity

Adaptations to food-poor environments



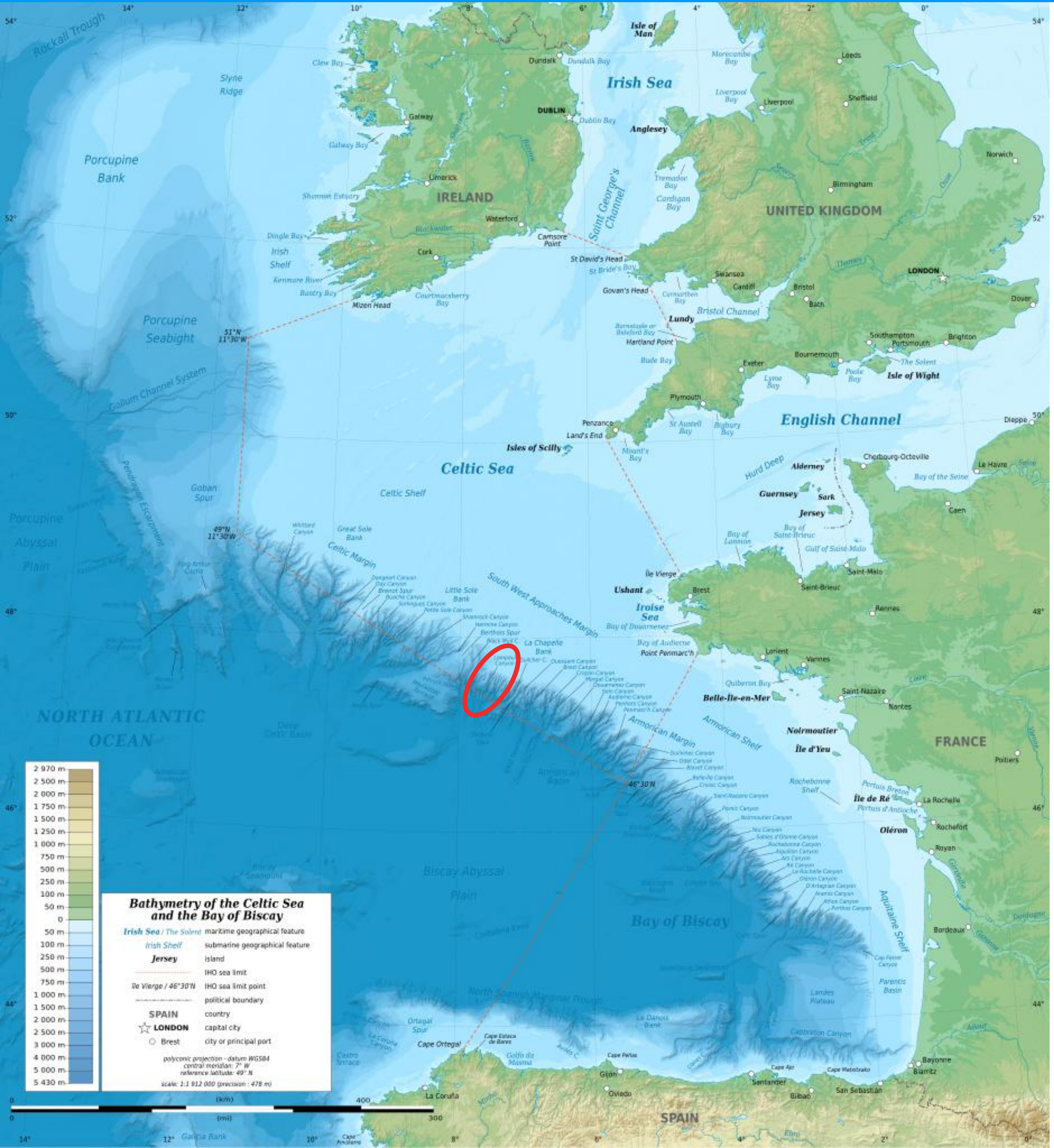
Middelburg *et al.* 2015, Sci. Rep. 5, 17962

No symbiosis with photosynthetic partners, but corals + micro-organisms colonizing them act as a holobiont

Micro-organisms : multiple metabolic activities

Desmophyllum pertusum derives nitrogen from bacterial metabolism and uses it to meet its nutritional requirements

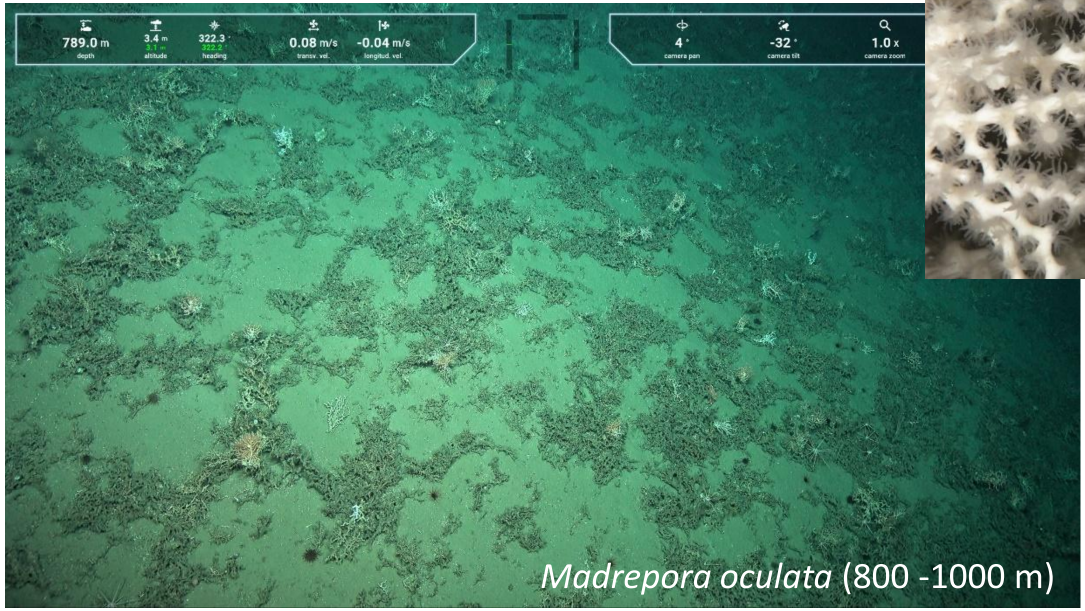
Study site: Lampaul Canyon, Bay of Biscay



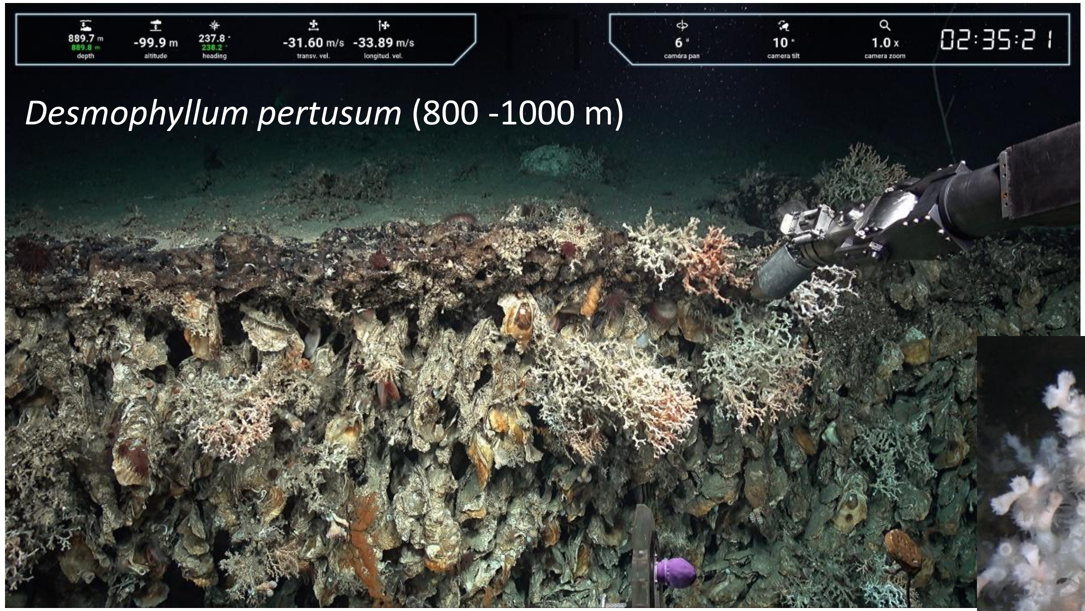
Extensive coral formations between 800 and 1600 m, built by three of the globally dominant cold-water reef building species

Image: Wikimedia Commons – Eric Gaba (Sting)

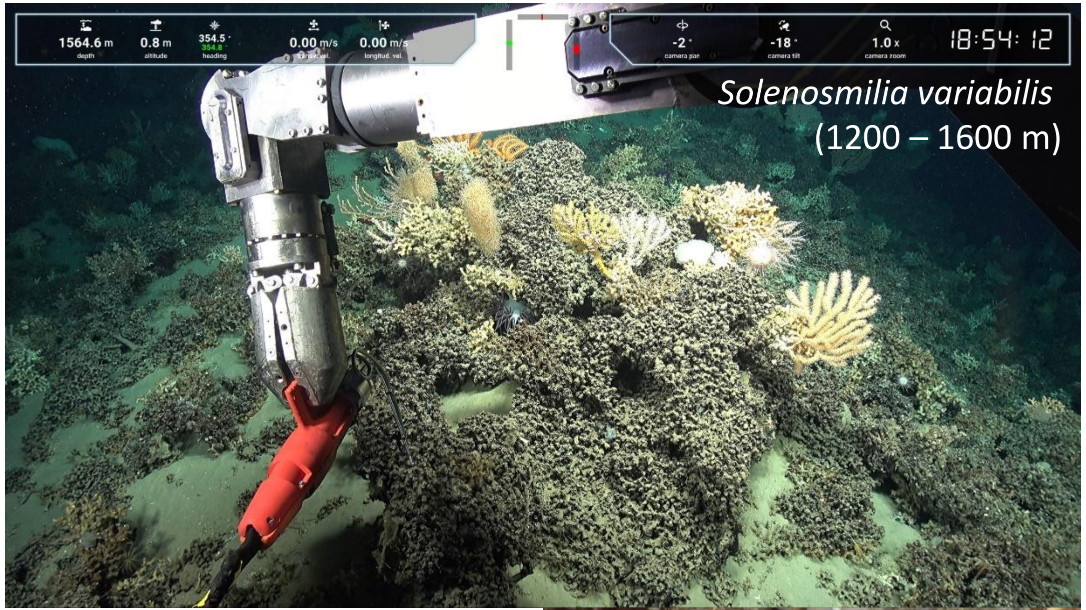
Study site: Lampaul Canyon, Bay of Biscay



Madrepora oculata (800 -1000 m)

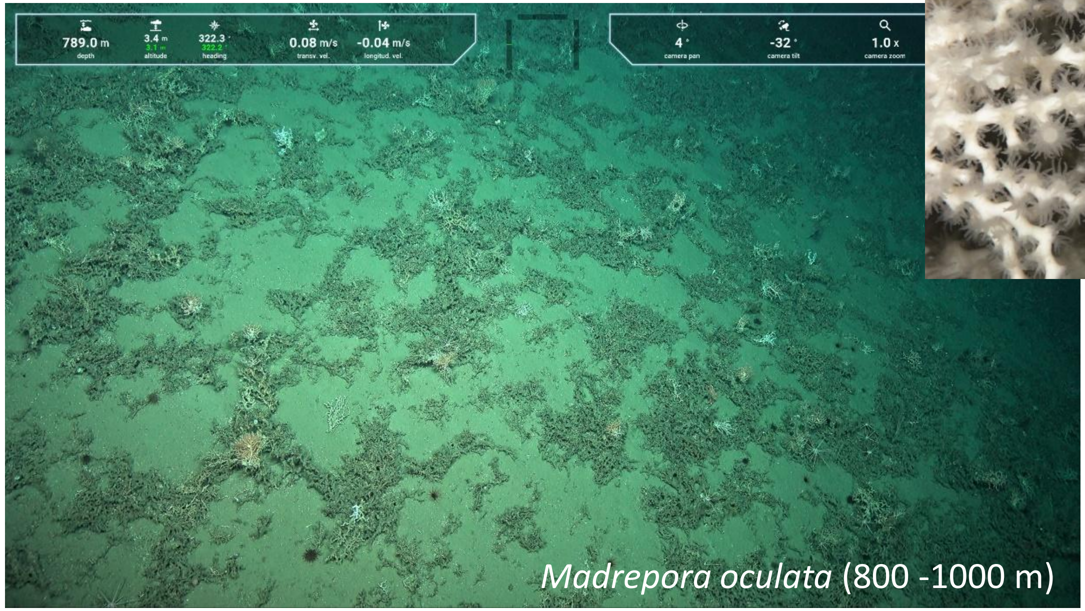


Desmophyllum pertusum (800 -1000 m)

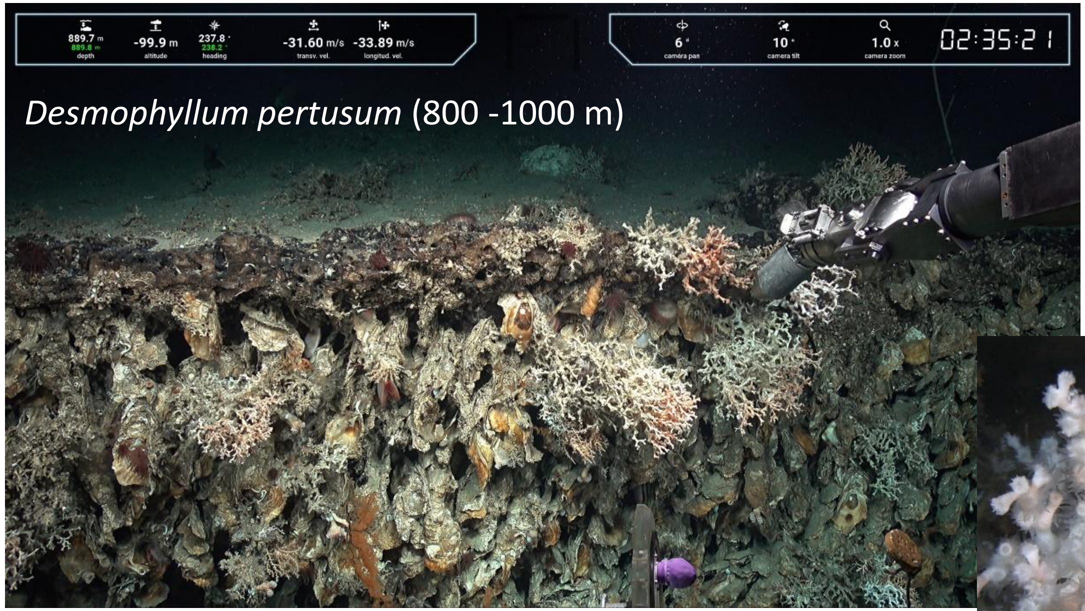


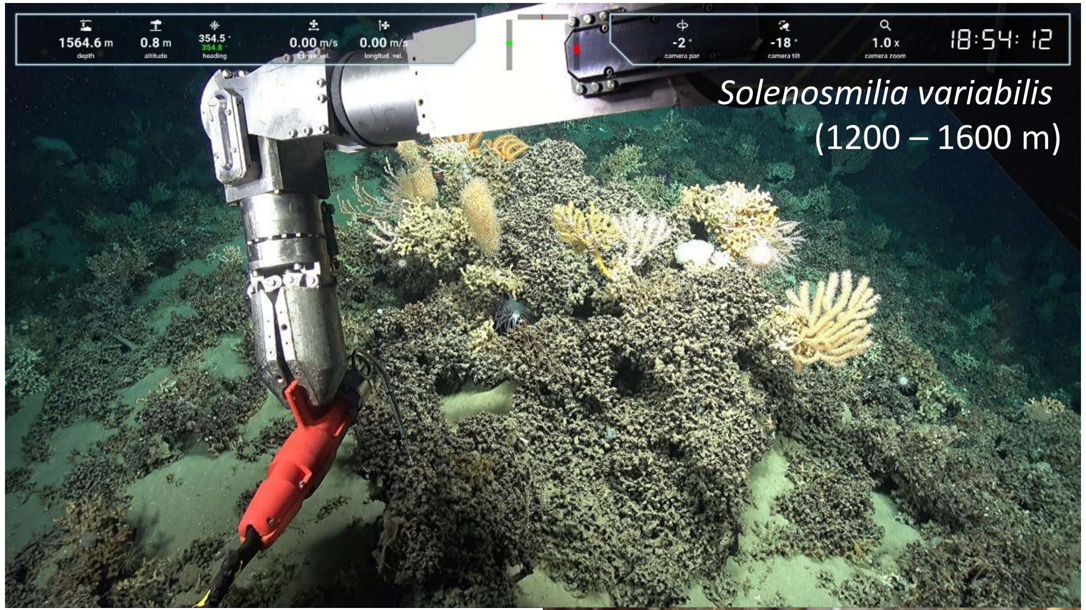
Solenosmilia variabilis (1200 – 1600 m)

Study site: Lampaul Canyon, Bay of Biscay



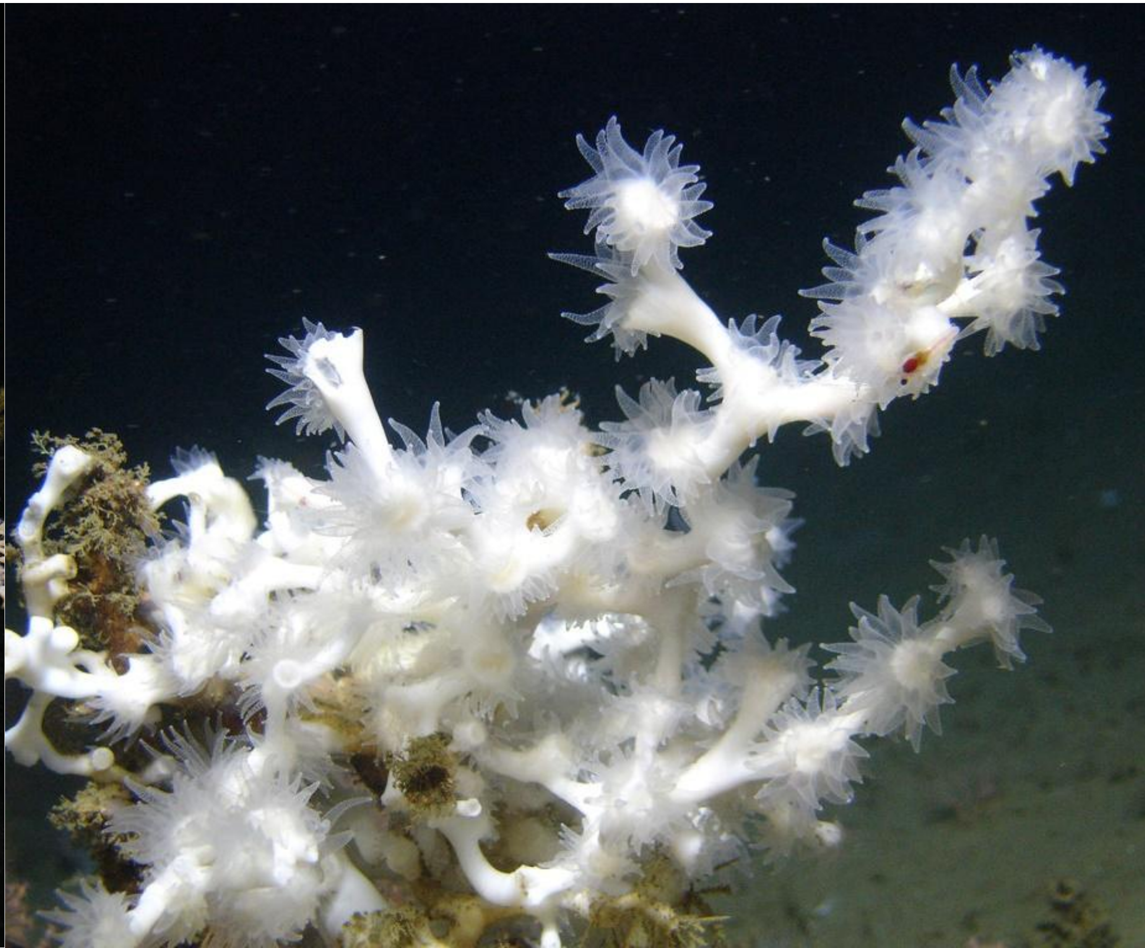
M. *oculata* and *D. pertusum* are often found in syntopy (intertwined colonies)





Objectives

Cold-water corals have multiple feeding strategies (wide fundamental niches) and show considerable trophic plasticity.

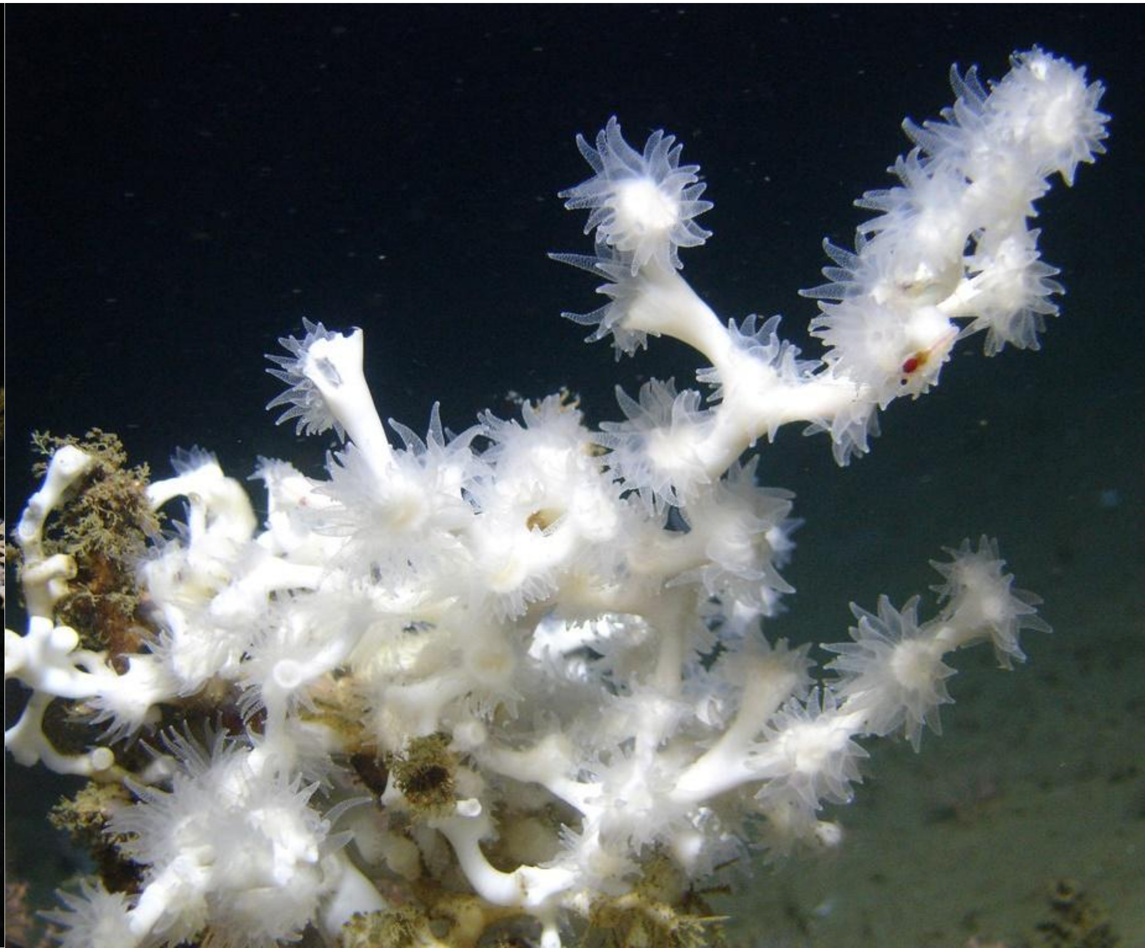


Objectives

Cold-water corals have multiple feeding strategies (wide fundamental niches) and show considerable trophic plasticity.

In the Lampaul Canyon: what is the realized trophic niche of corals? How does each species acquire energy? Do they share dietary resources with each other or with associated fauna, particularly filter and/or suspension feeders?

Maier 2020



Methods

3 cruises onboard RV Thalassa (August/September 2021, 2022 and 2023)

Sampling of coral colonies and biomass-dominant associated fauna using either HROV Ariane or ROV Victor 6000

Dissection and extraction of relevant tissues

Trophic markers measurements

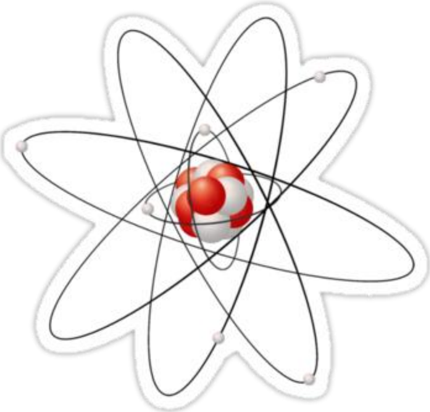
Trophic markers: You are what you eat

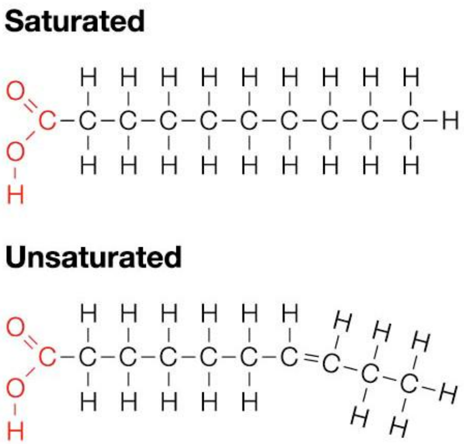
When animals digest their food, they incorporate some compounds in their own tissues in a conservative way

Animals retain in their tissues some biochemical "traces" of the food they assimilated while synthesizing this tissue: integrative trophic markers

Measuring the relative abundances of these compounds naturally present in tissues of animal consumers and in their potential food items can generate indirect info about animal diet

Here: use of stable isotope ratios of C, N and S and fatty acid composition to build proxies of trophic niches



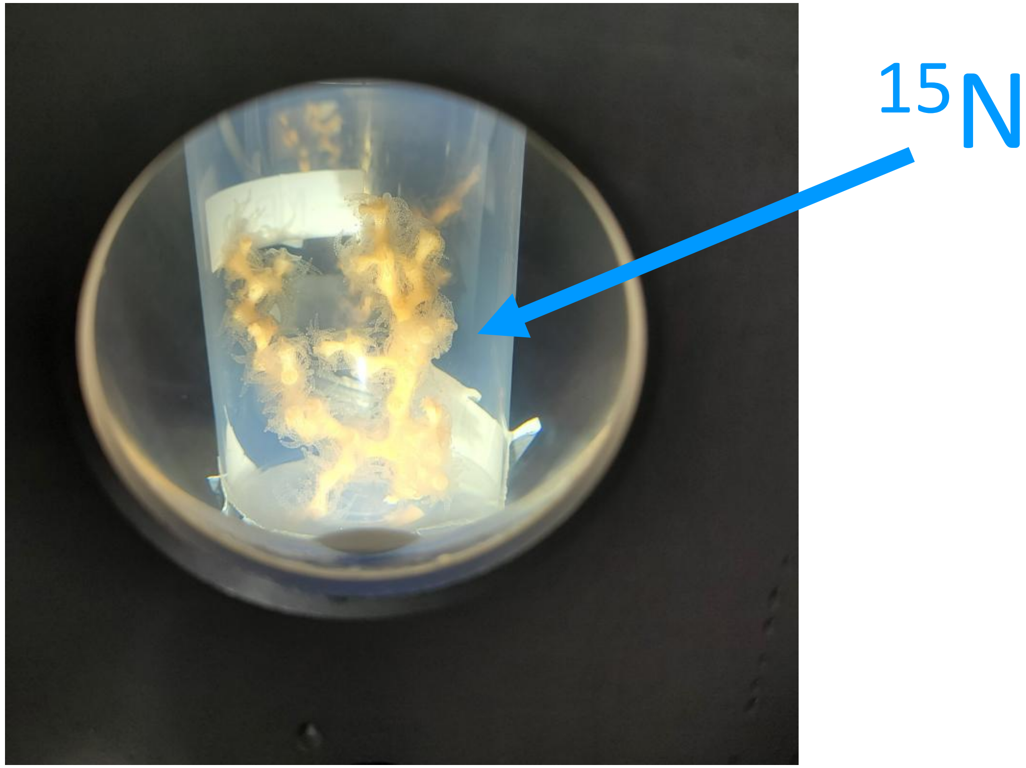


Methods

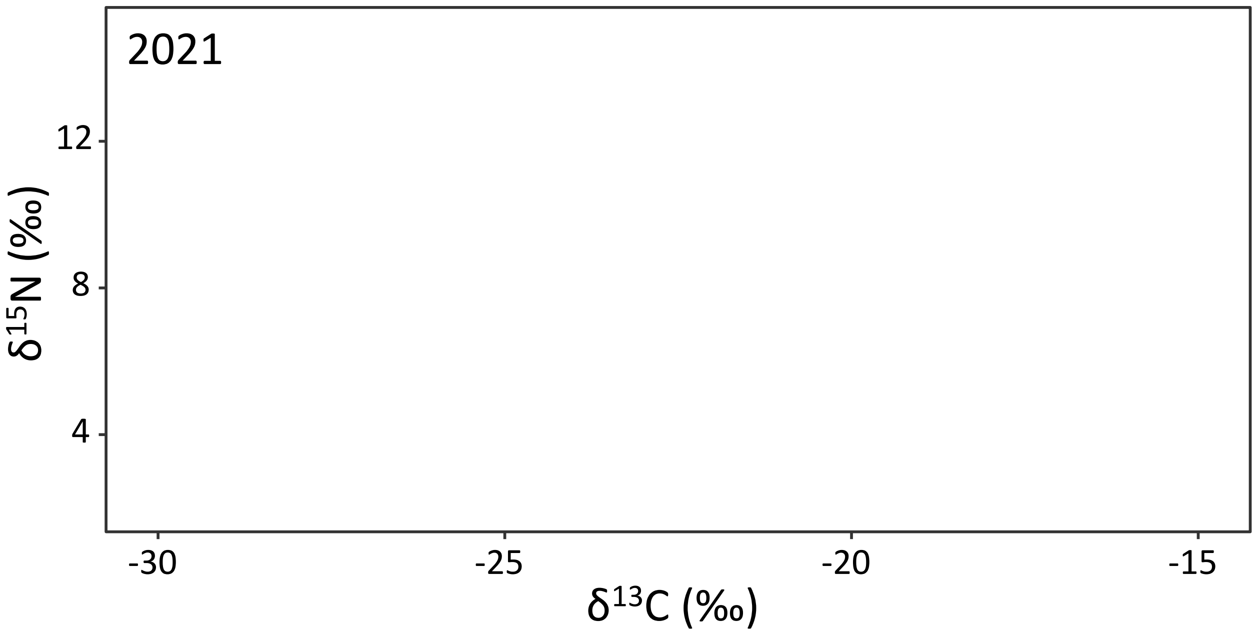
Ex situ labelling experiments onboard, during the cruises

Use of pressurized aquaria to recreate *in situ* pressure conditions

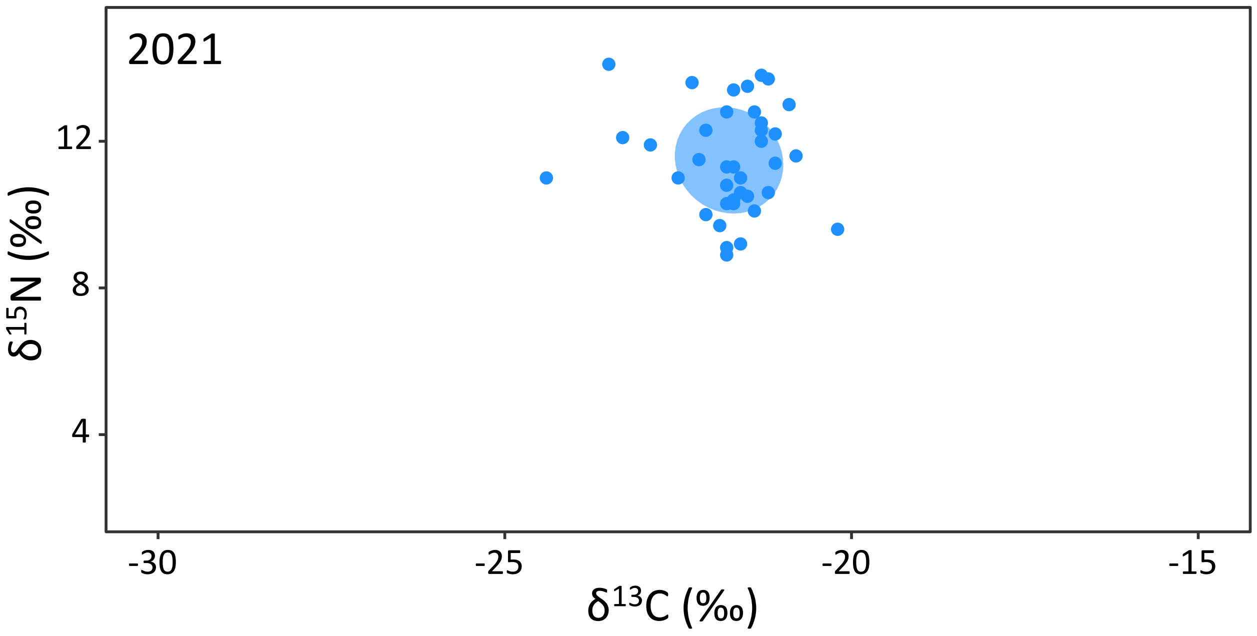
Addition of $^{15}NH_4Cl$ at environmental concentrations (3 µM), incubation for 24-72 hours, and quantification of inorganic nitrogen uptake by coral holobionts through stable isotope analysis



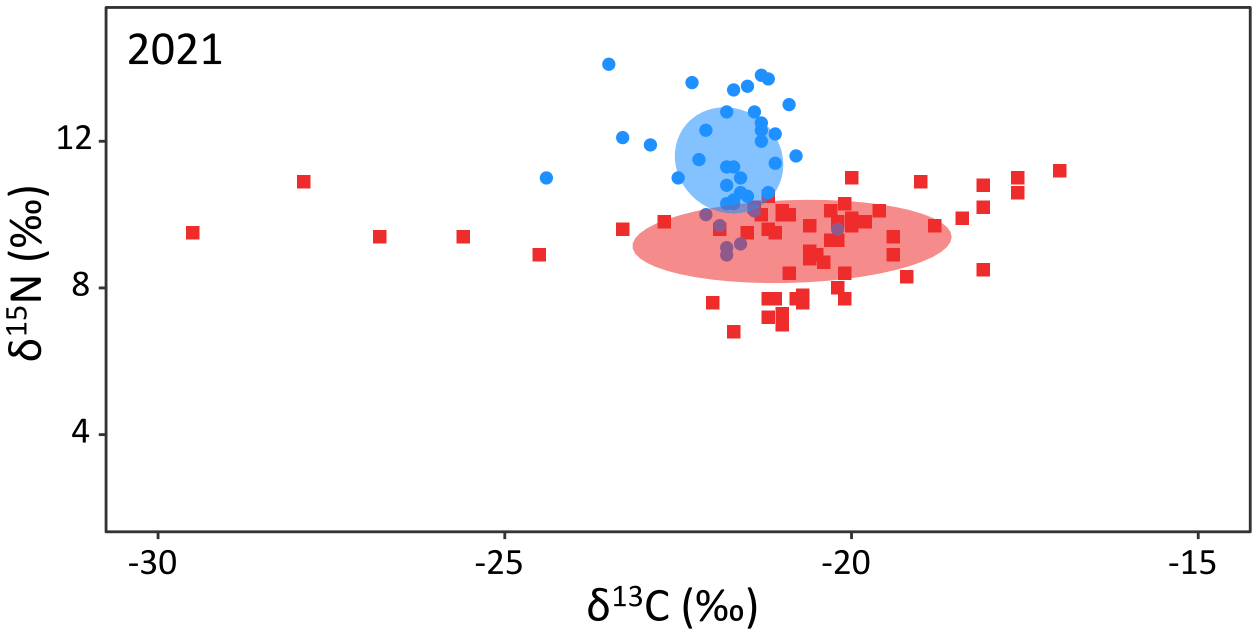
Isotopic niches of corals and associated fauna



Isotopic niches of corals and associated fauna



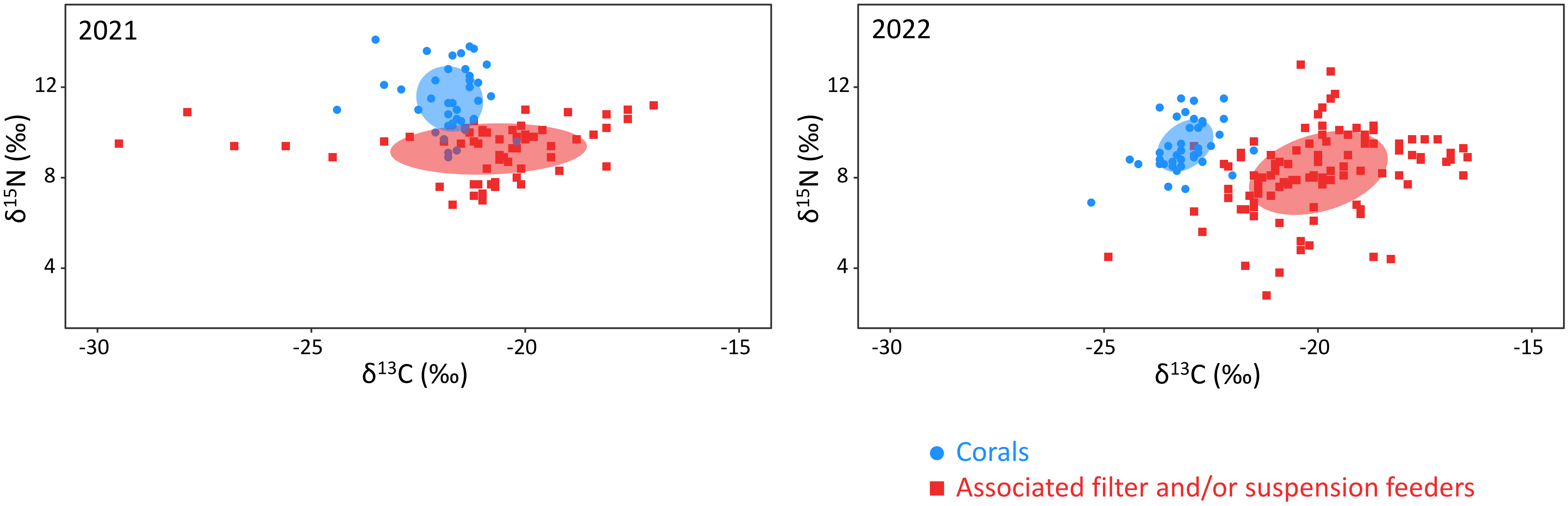
Isotopic niches of corals and associated fauna



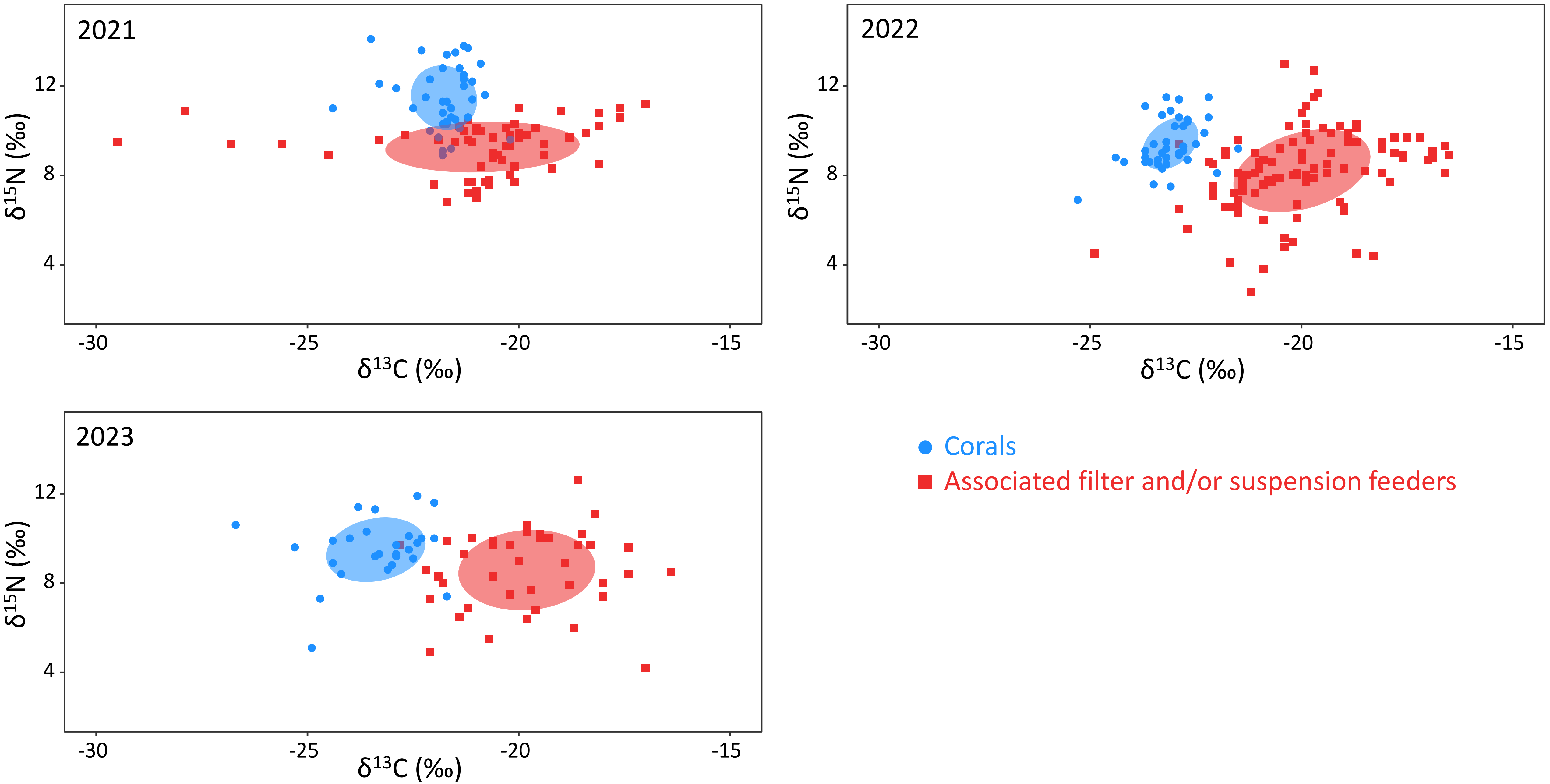
● Corals

■ Associated filter and/or suspension feeders

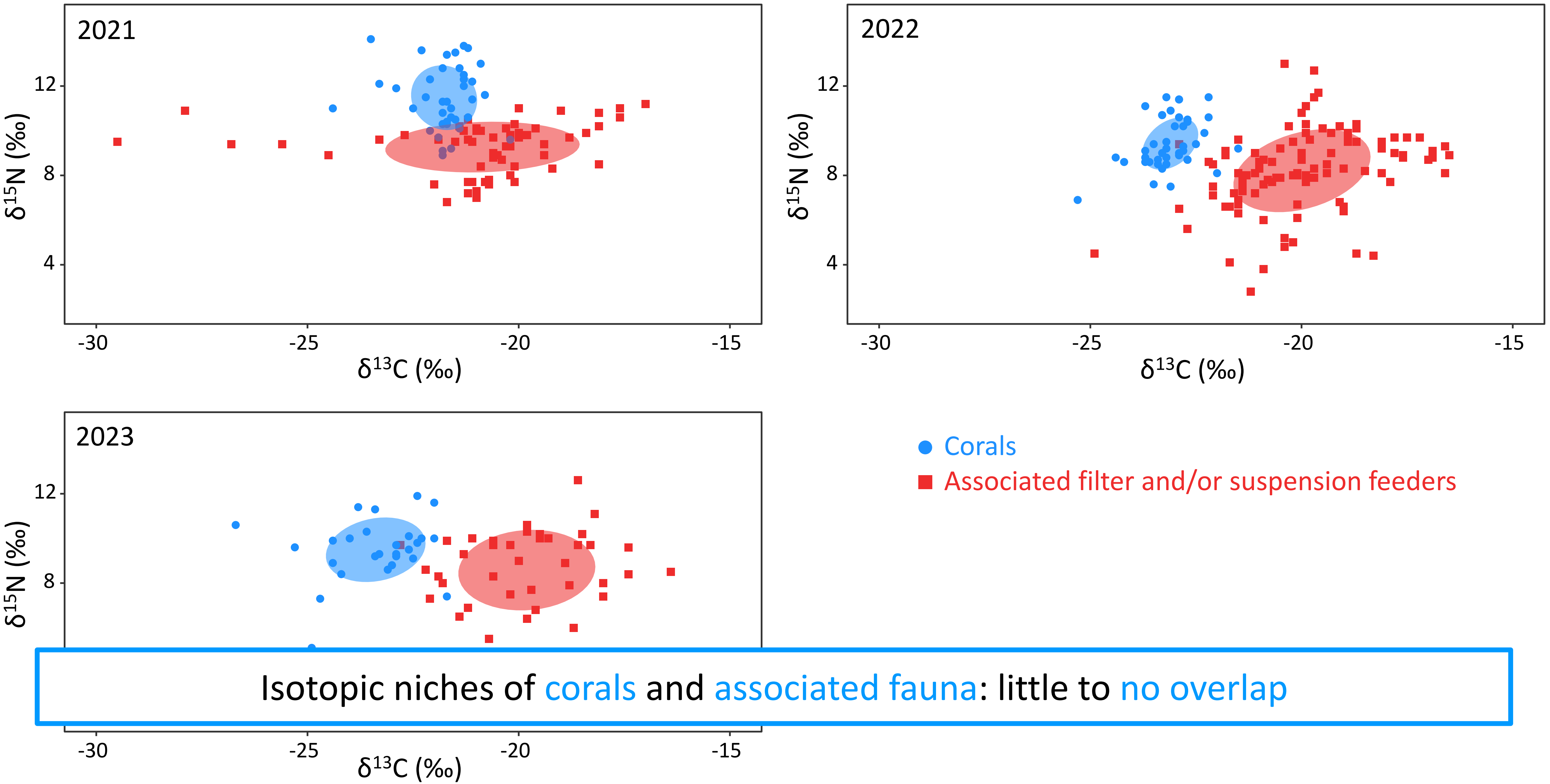
Isotopic niches of corals and associated fauna



Isotopic niches of corals and associated fauna

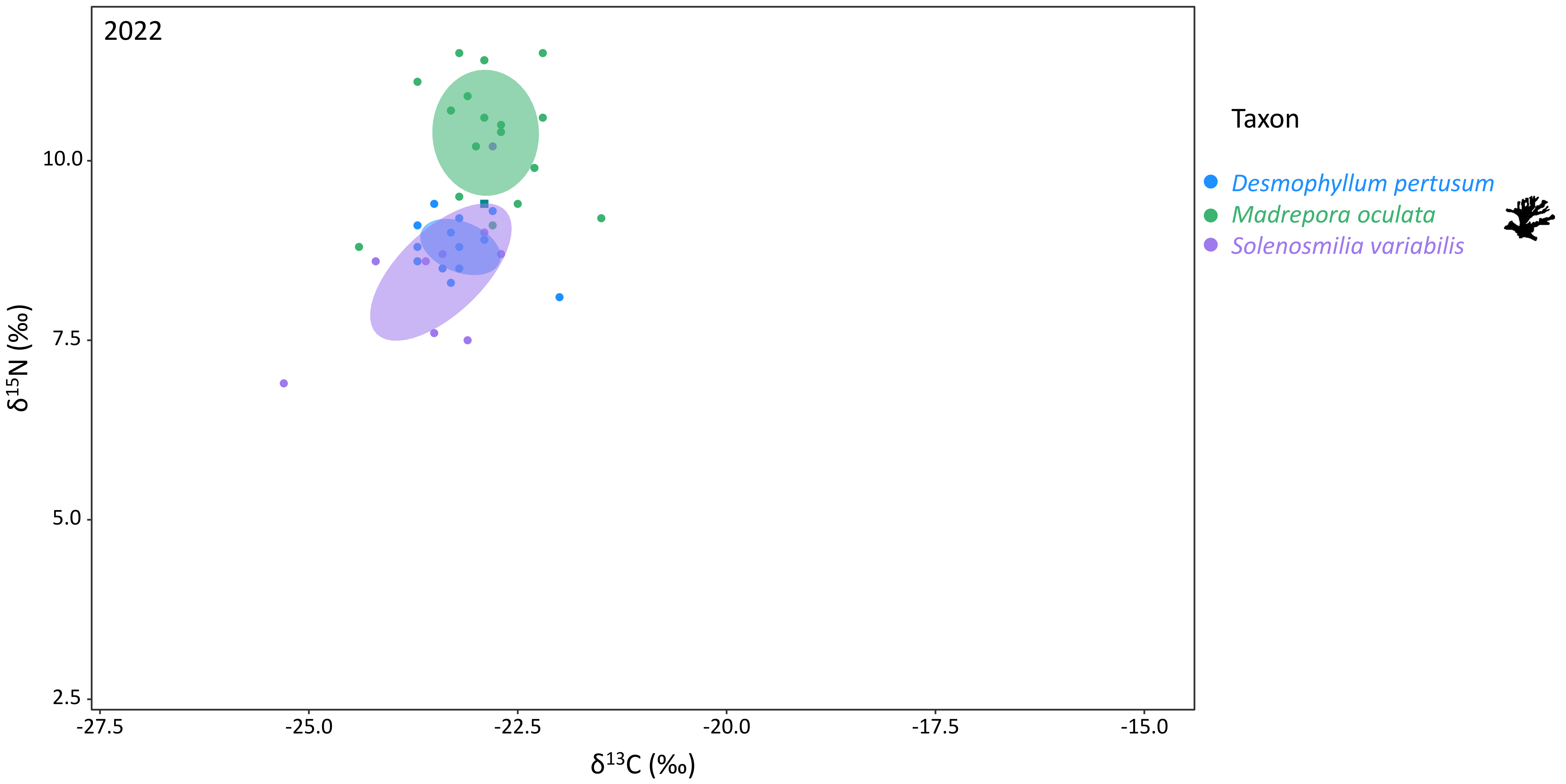


Isotopic niches of corals and associated fauna

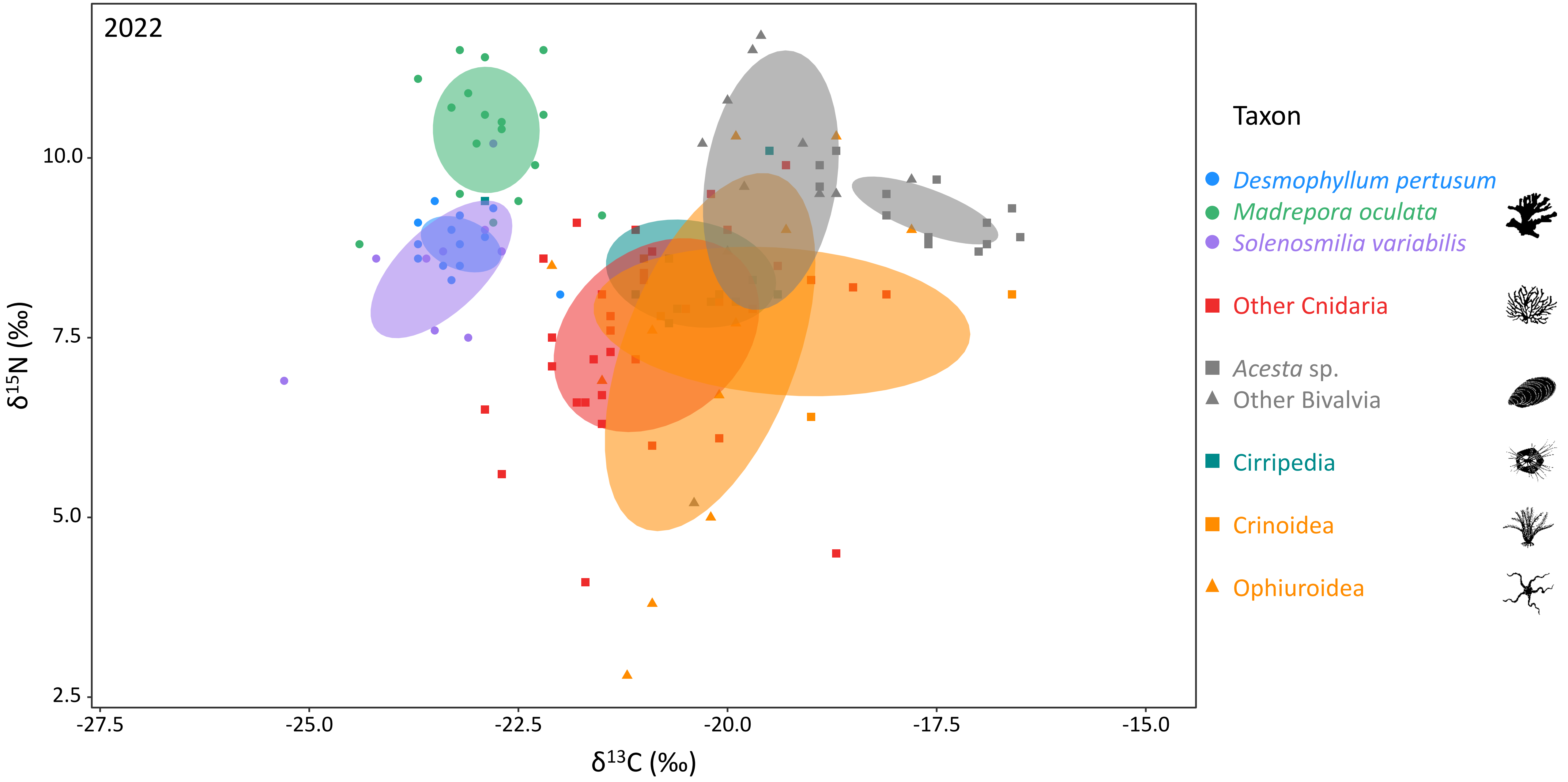


Isotopic niches of corals and associated fauna: little to no overlap

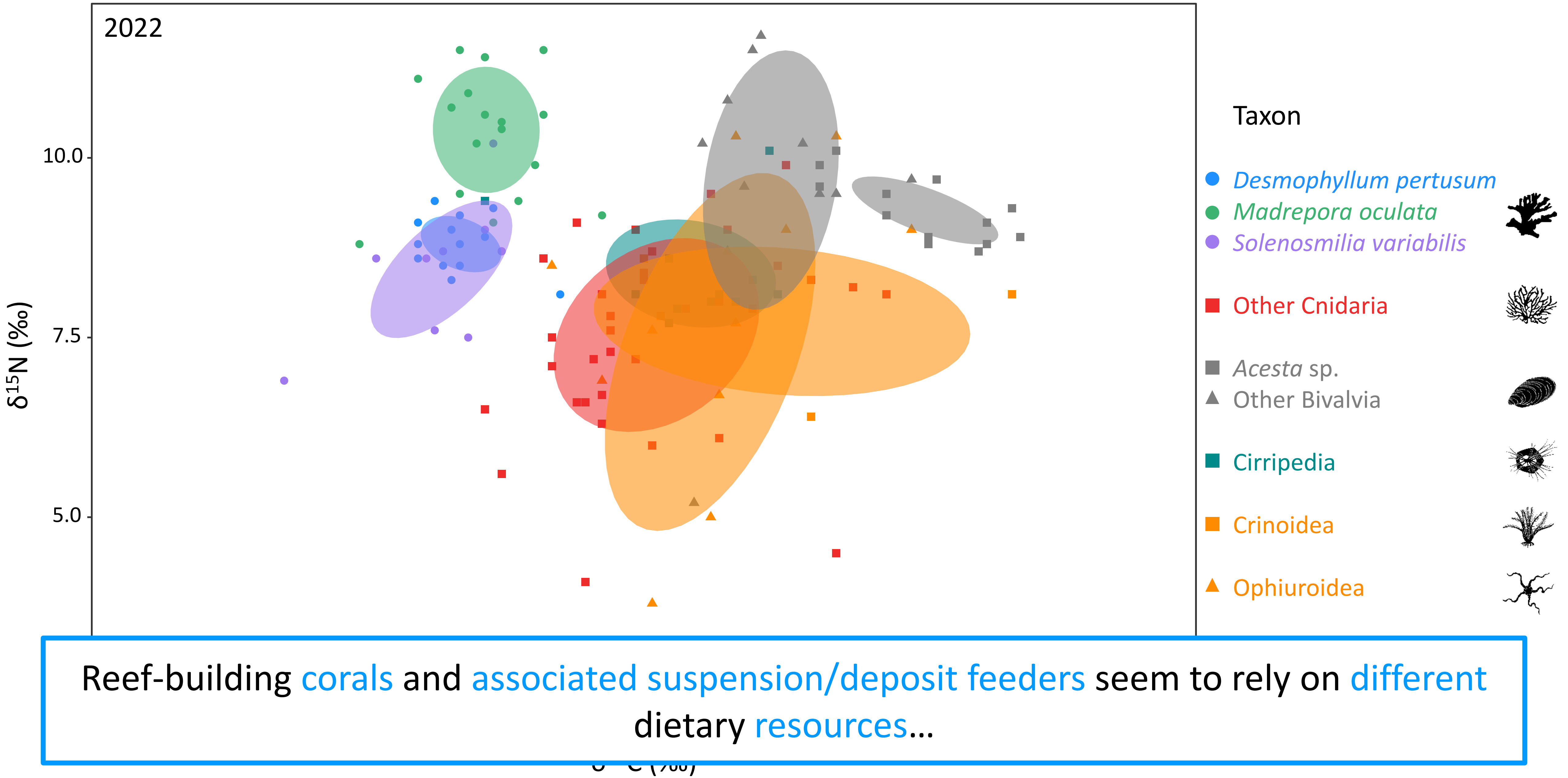
Isotopic niches of corals and associated fauna



Isotopic niches of corals and associated fauna

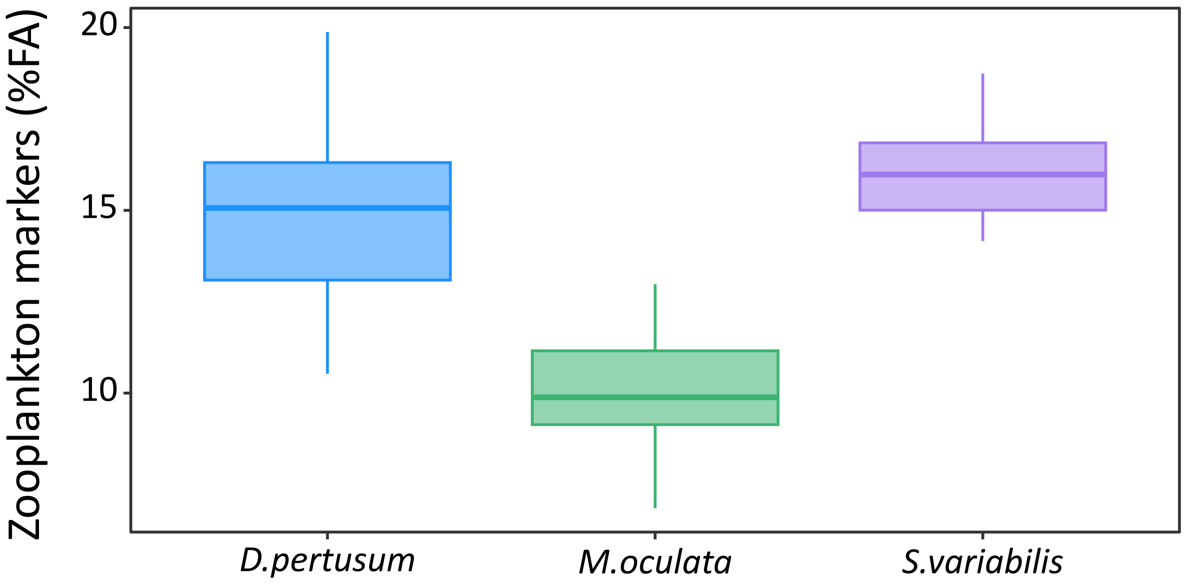


Isotopic niches of corals and associated fauna

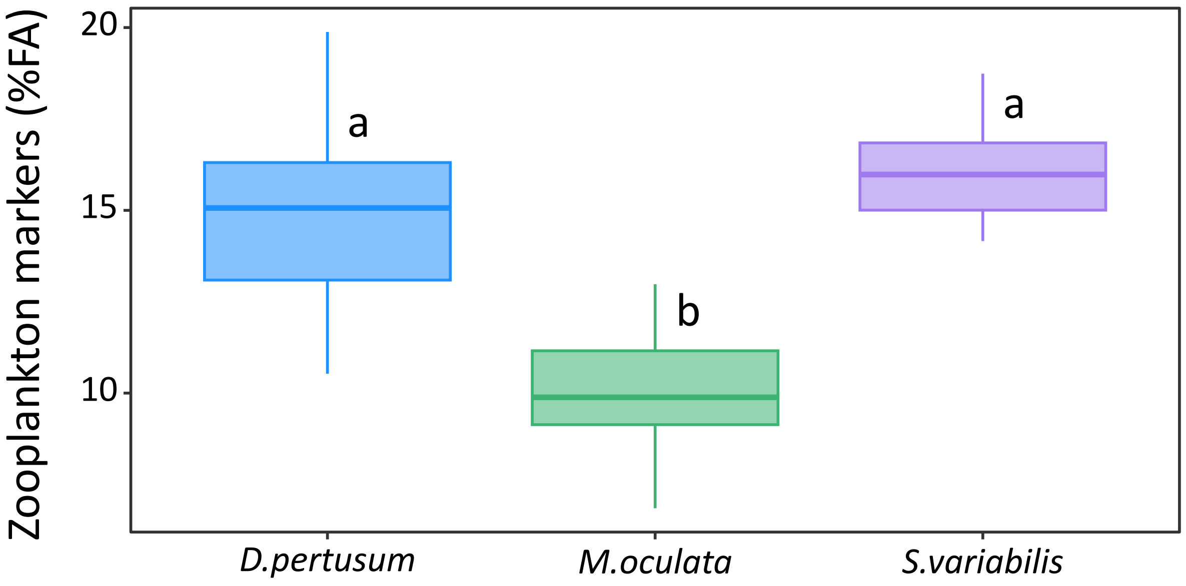


Reef-building corals and associated suspension/deposit feeders seem to rely on different dietary resources…

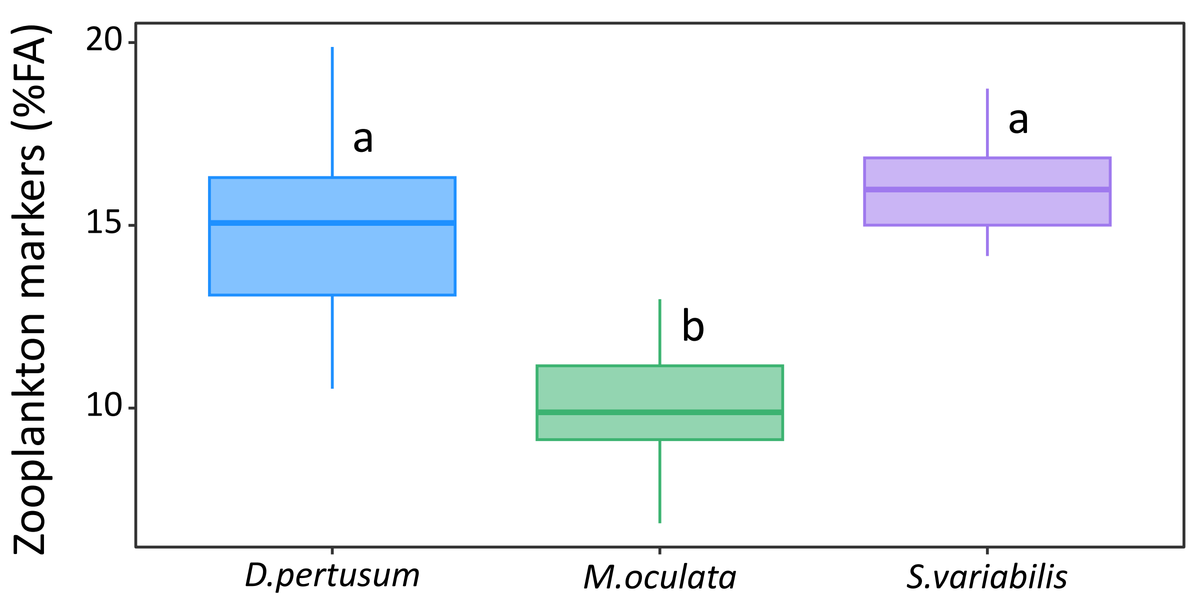
Fatty acid composition of reserve lipids

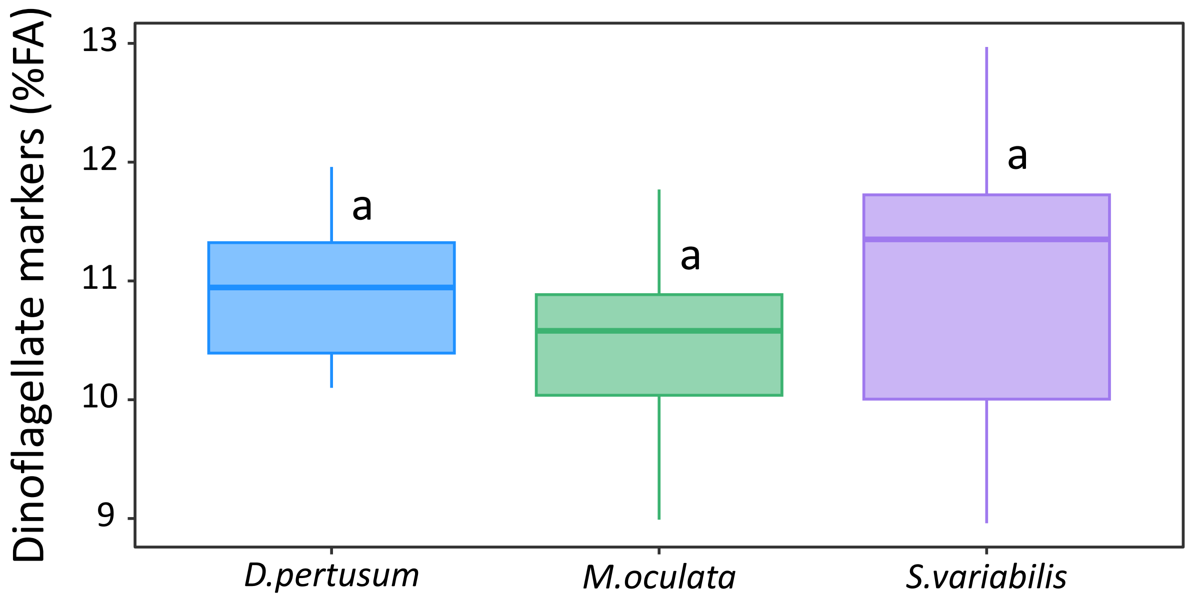


Fatty acid composition of reserve lipids

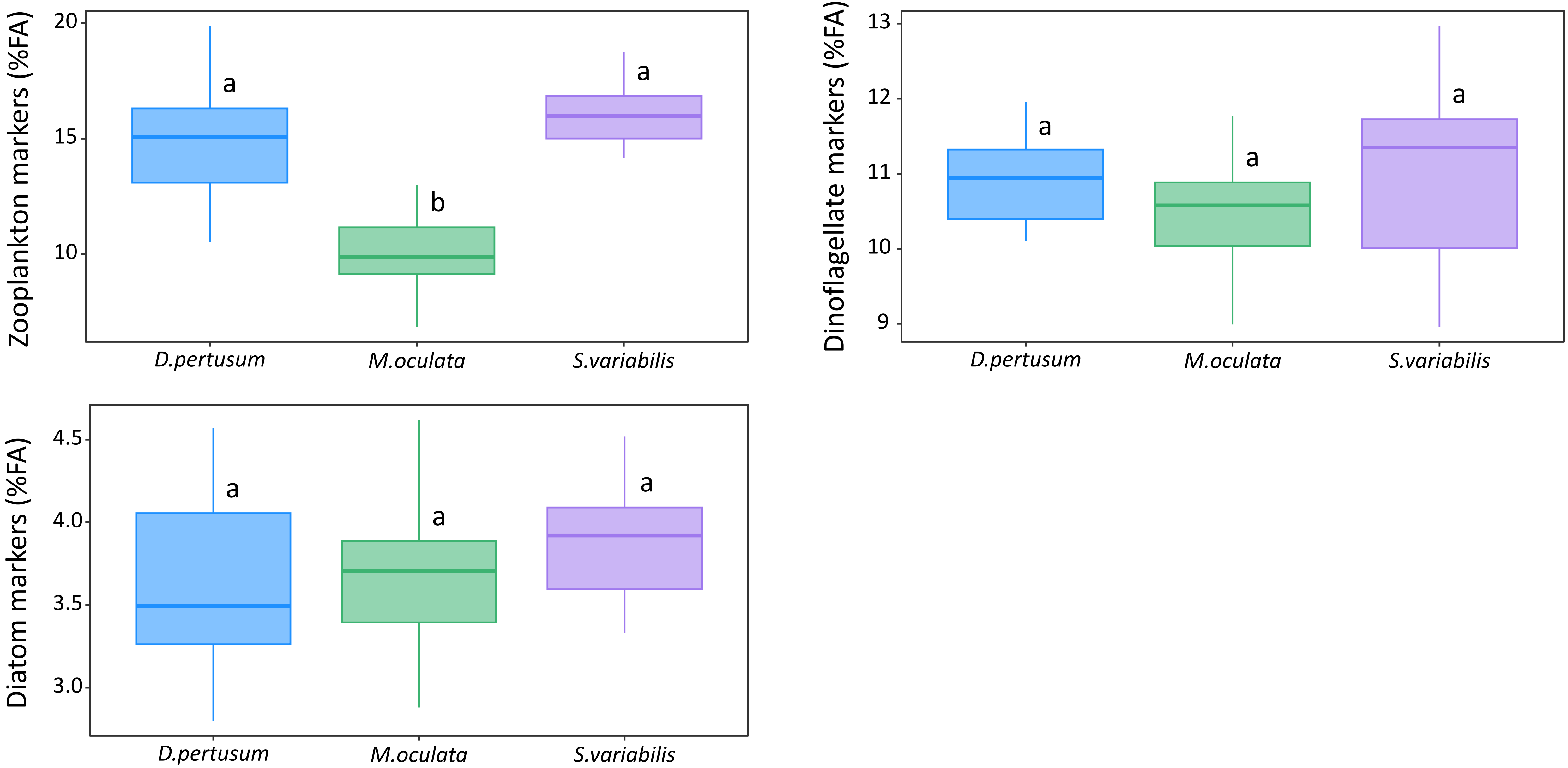


Fatty acid composition of reserve lipids

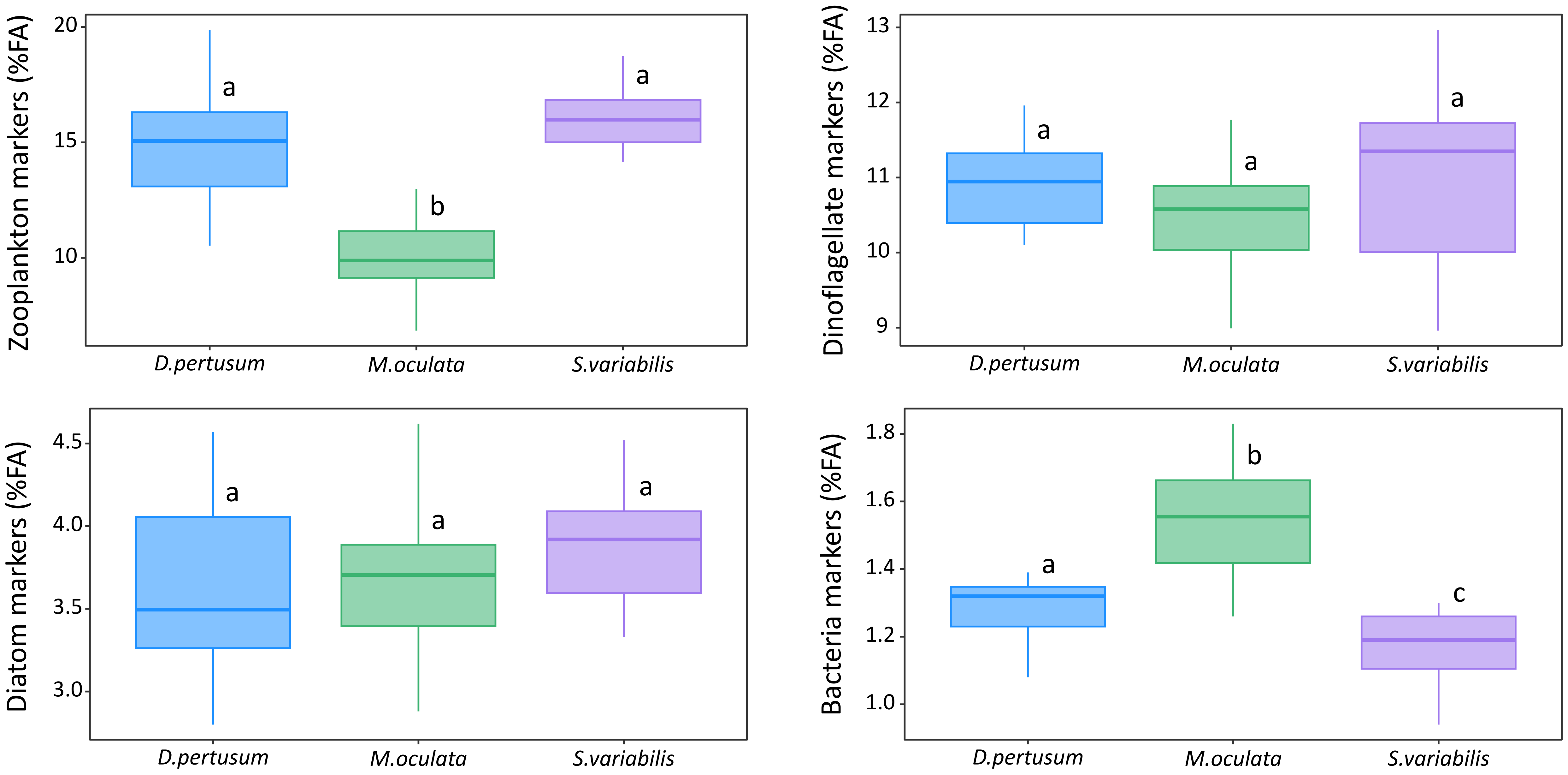




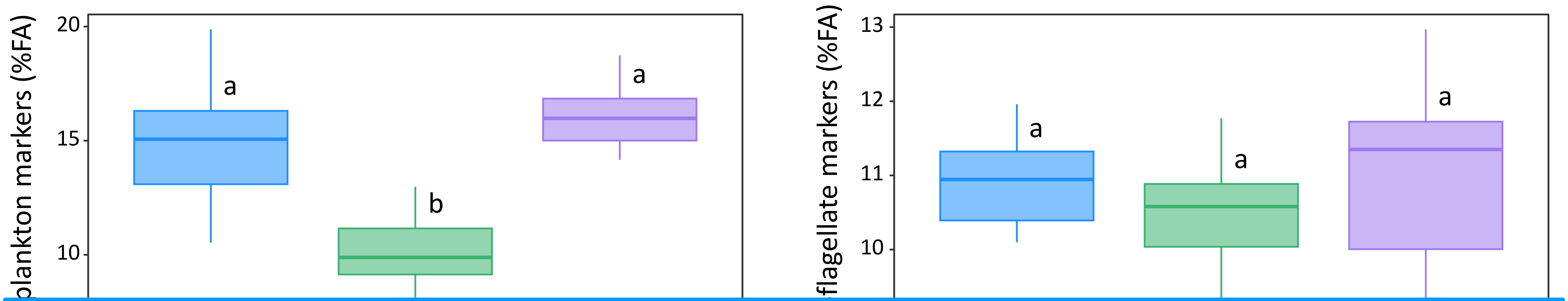
Fatty acid composition of reserve lipids



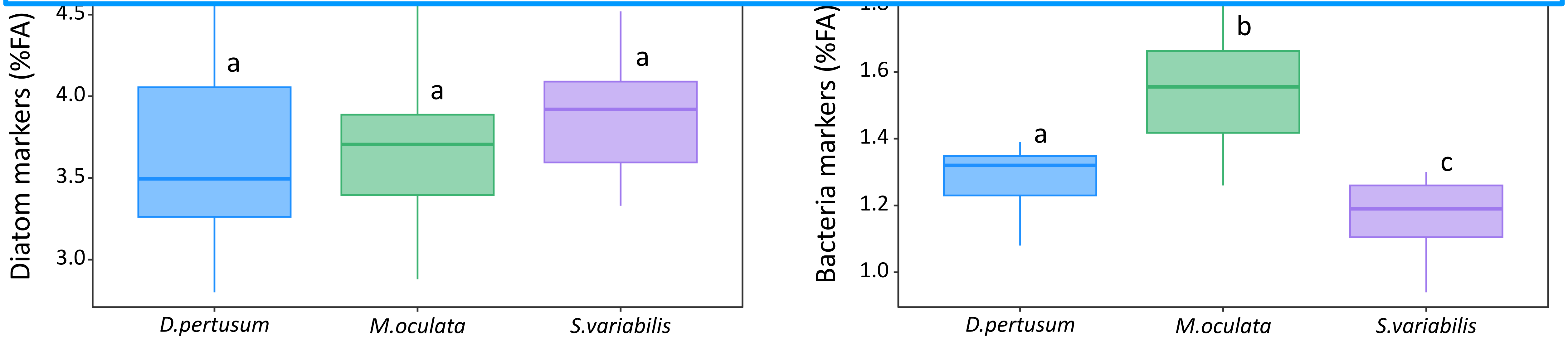
Fatty acid composition of reserve lipids



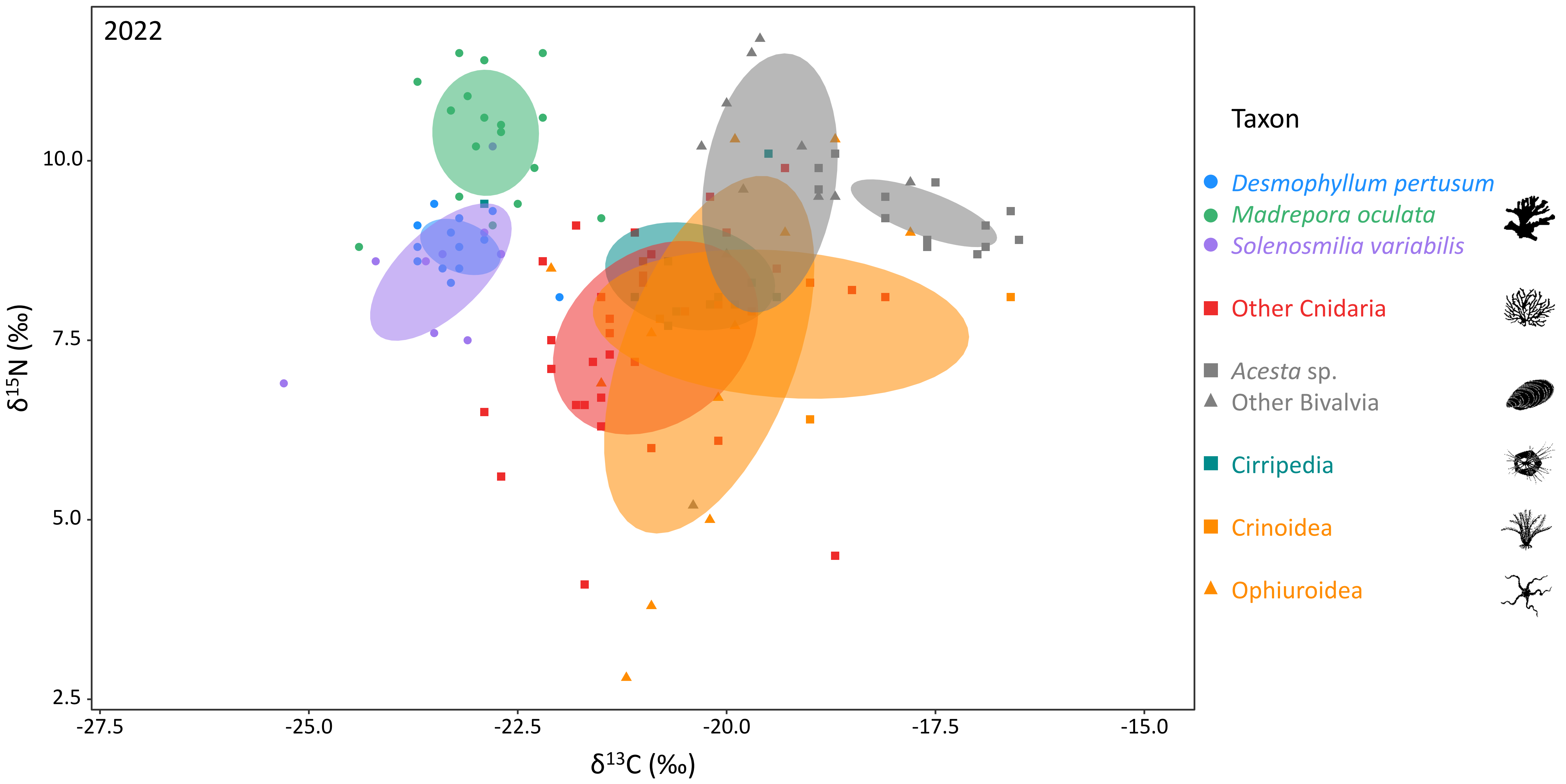
Fatty acid composition of reserve lipids



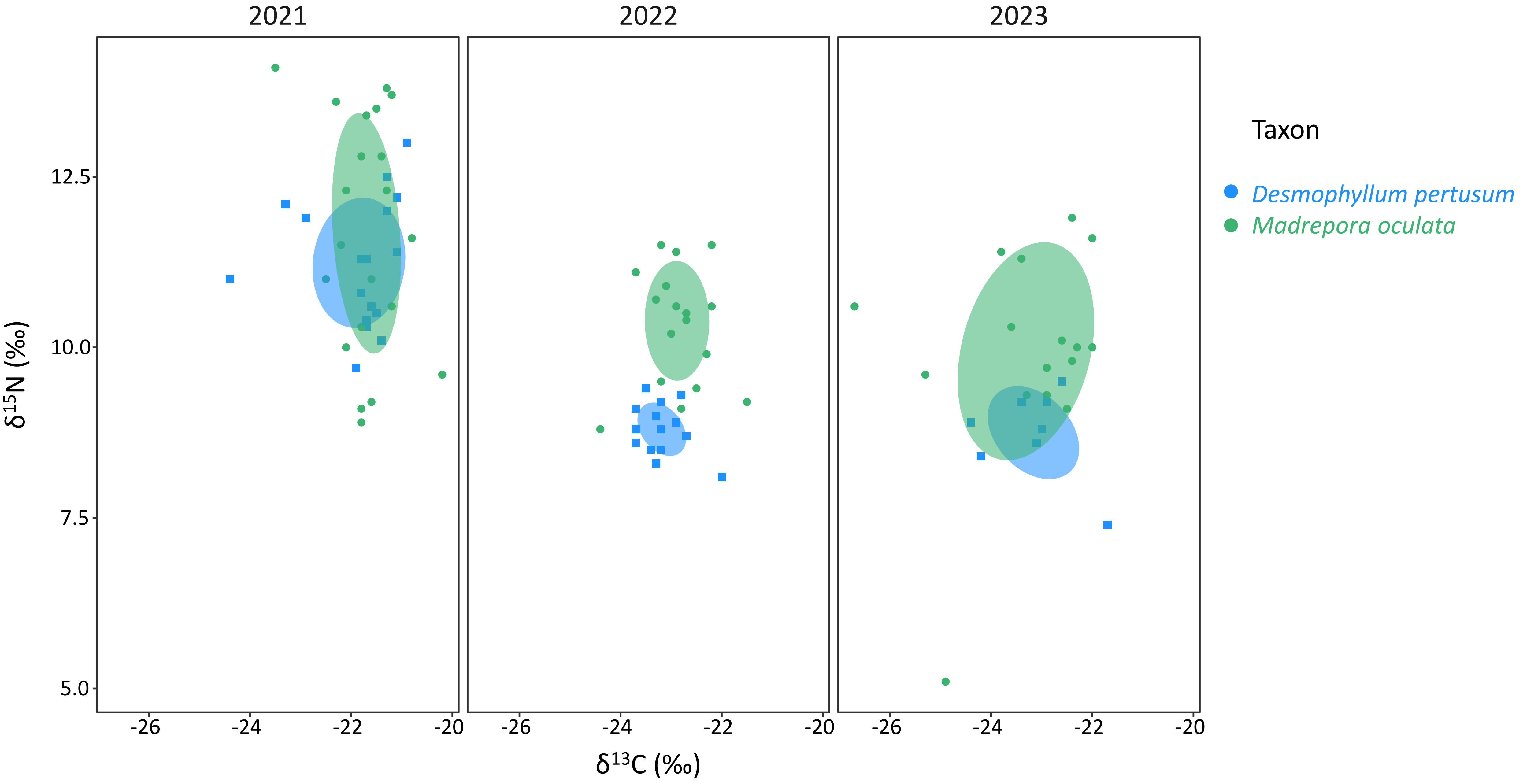
All three taxa seem to be selective plankton feeders, with species-specific differences for some resources likely increasing niche segregation



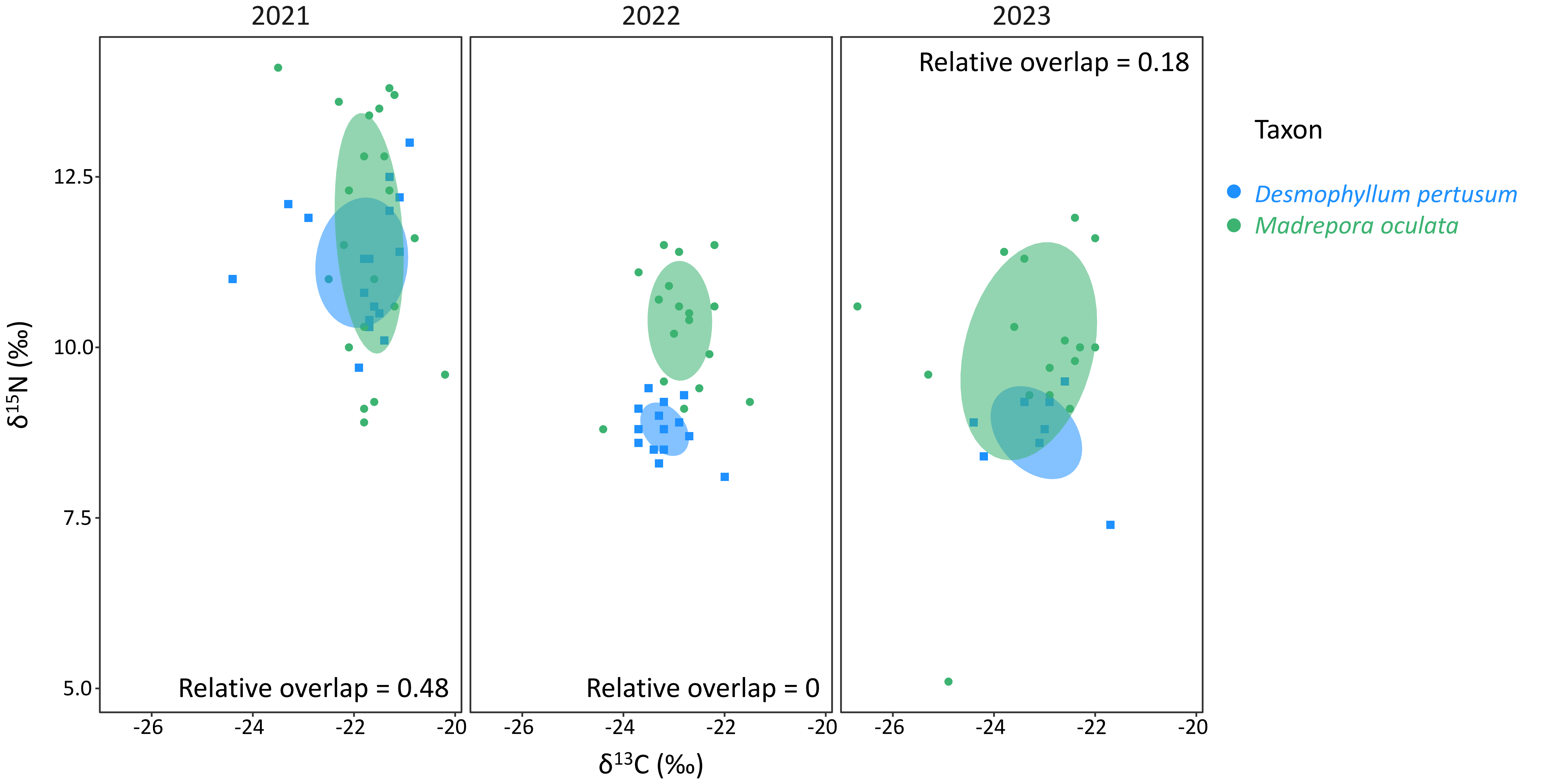
Isotopic niches of corals and associated fauna



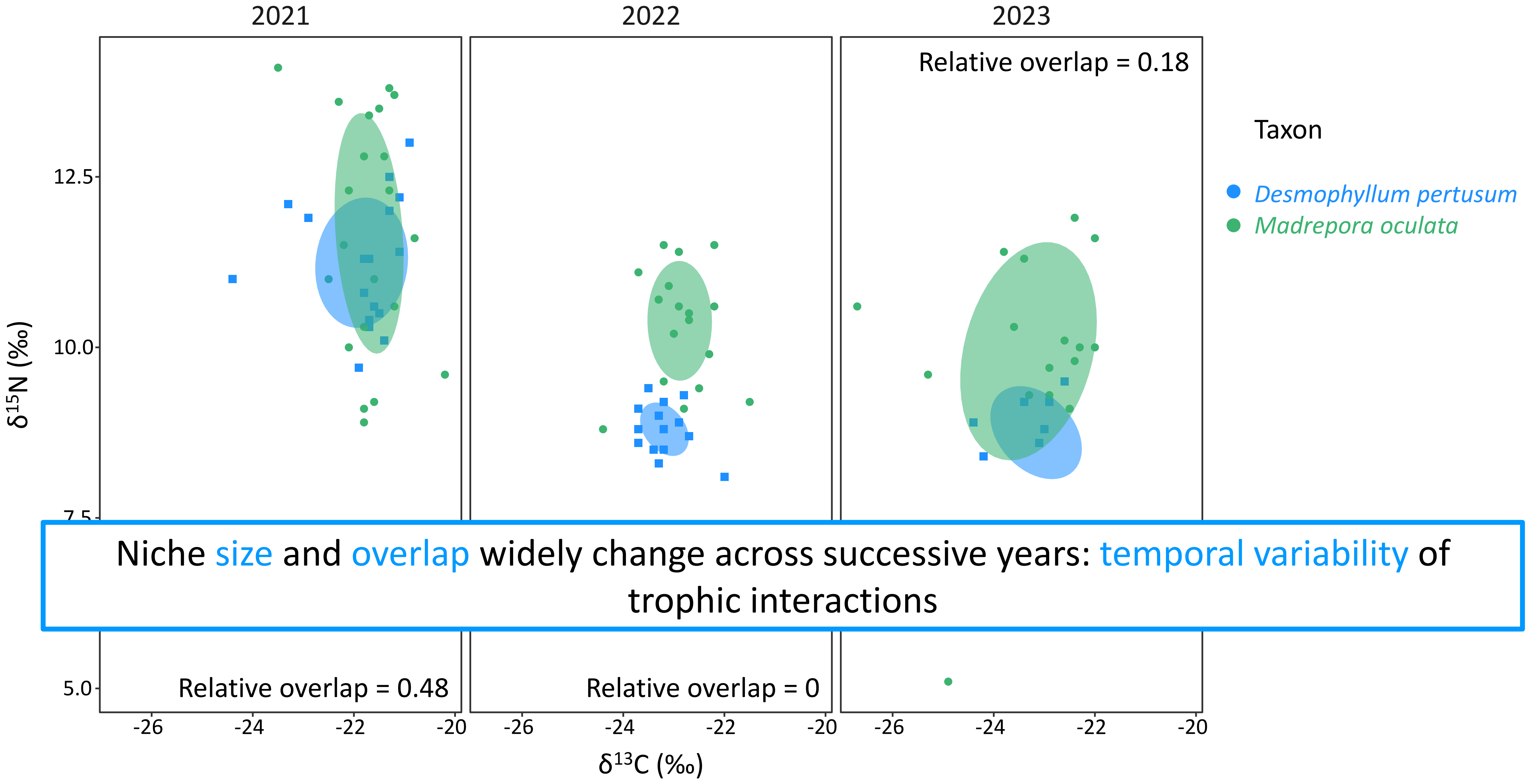
Isotopic niches – dominant syntopic corals



Isotopic niches – dominant syntopic corals

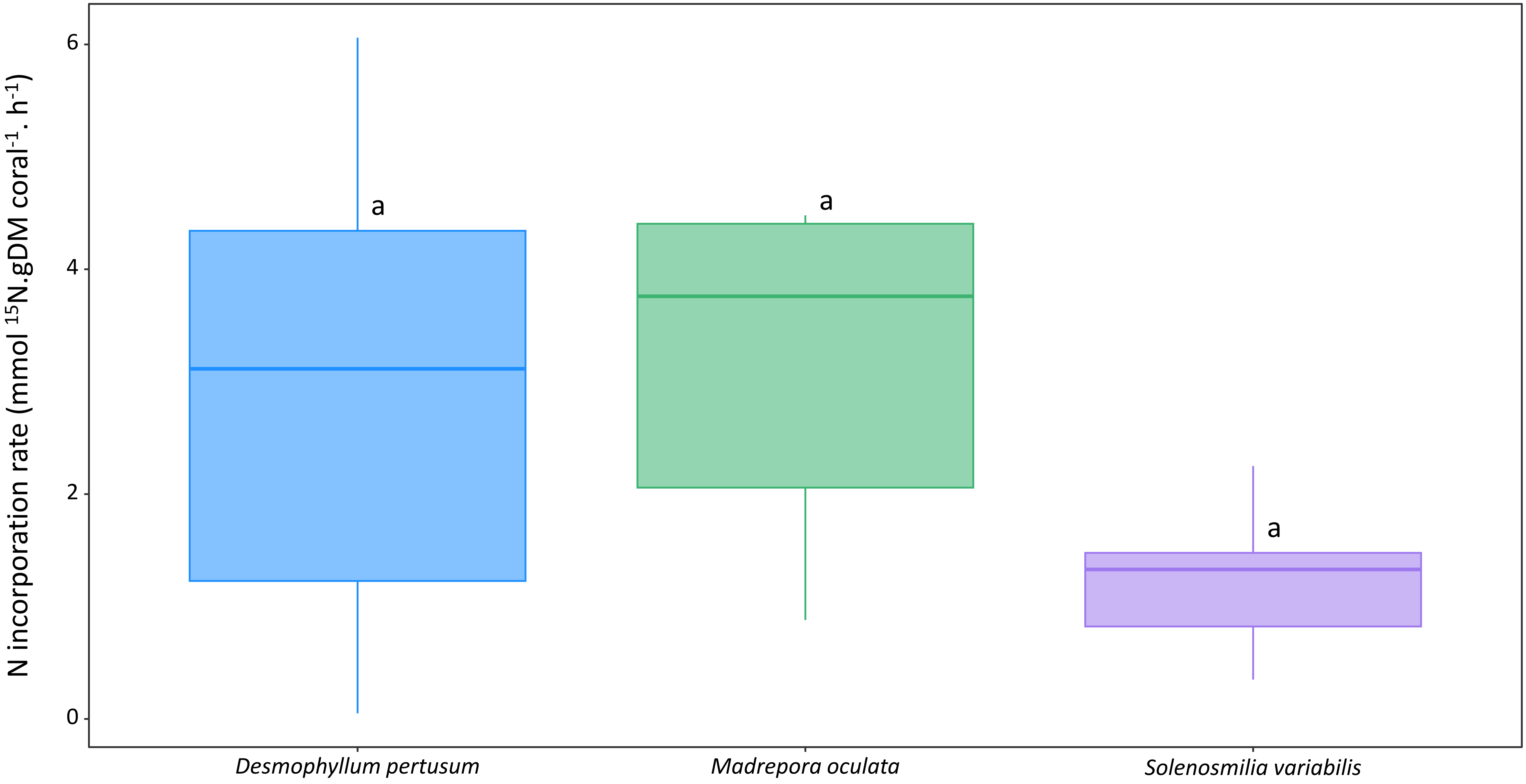


Isotopic niches – dominant syntopic corals

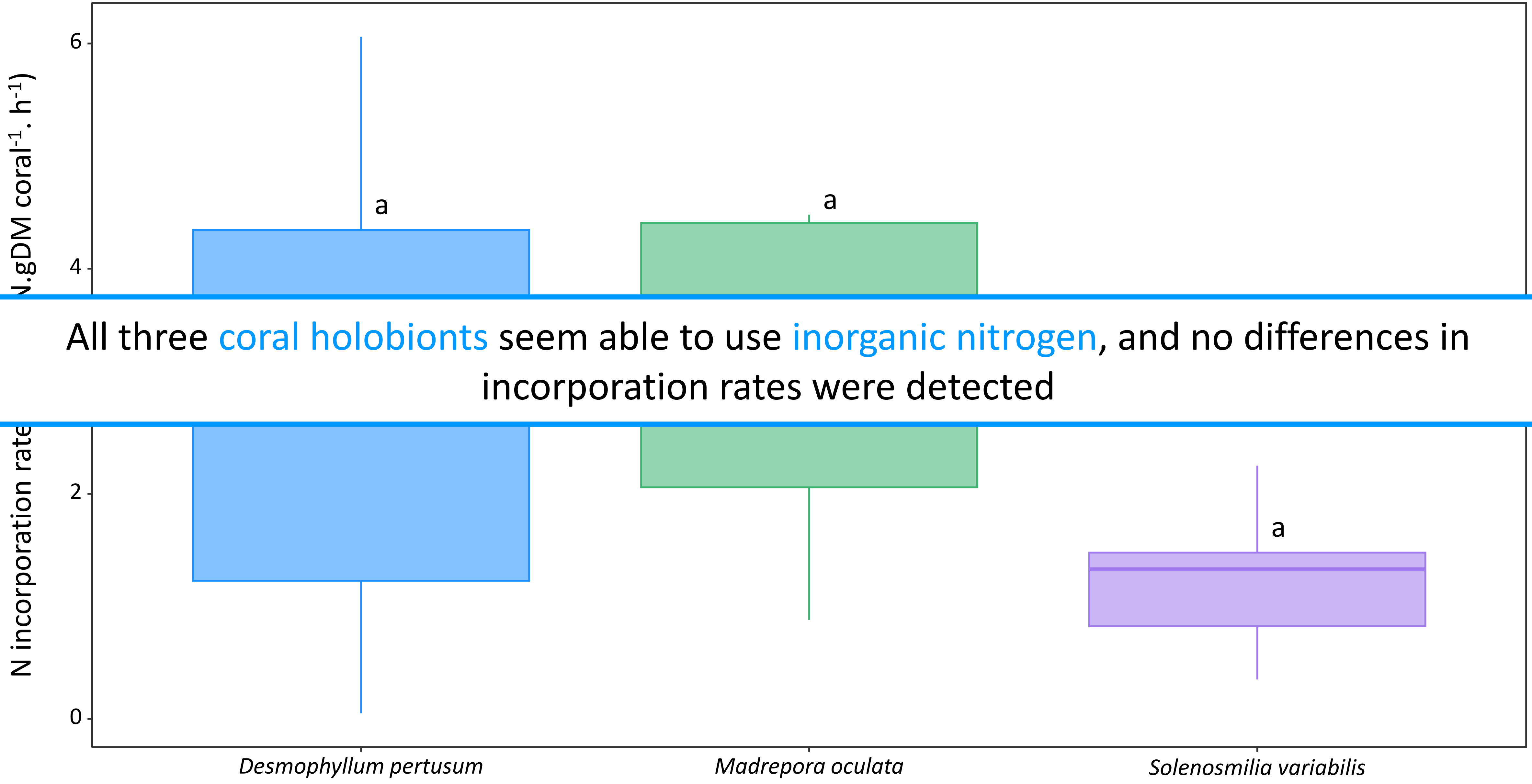


Niche size and overlap widely change across successive years: temporal variability of trophic interactions

Labelling experiments



Labelling experiments



All three coral holobionts seem able to use inorganic nitrogen, and no differences in incorporation rates were detected

Inorganic nitrogen fixation: how?

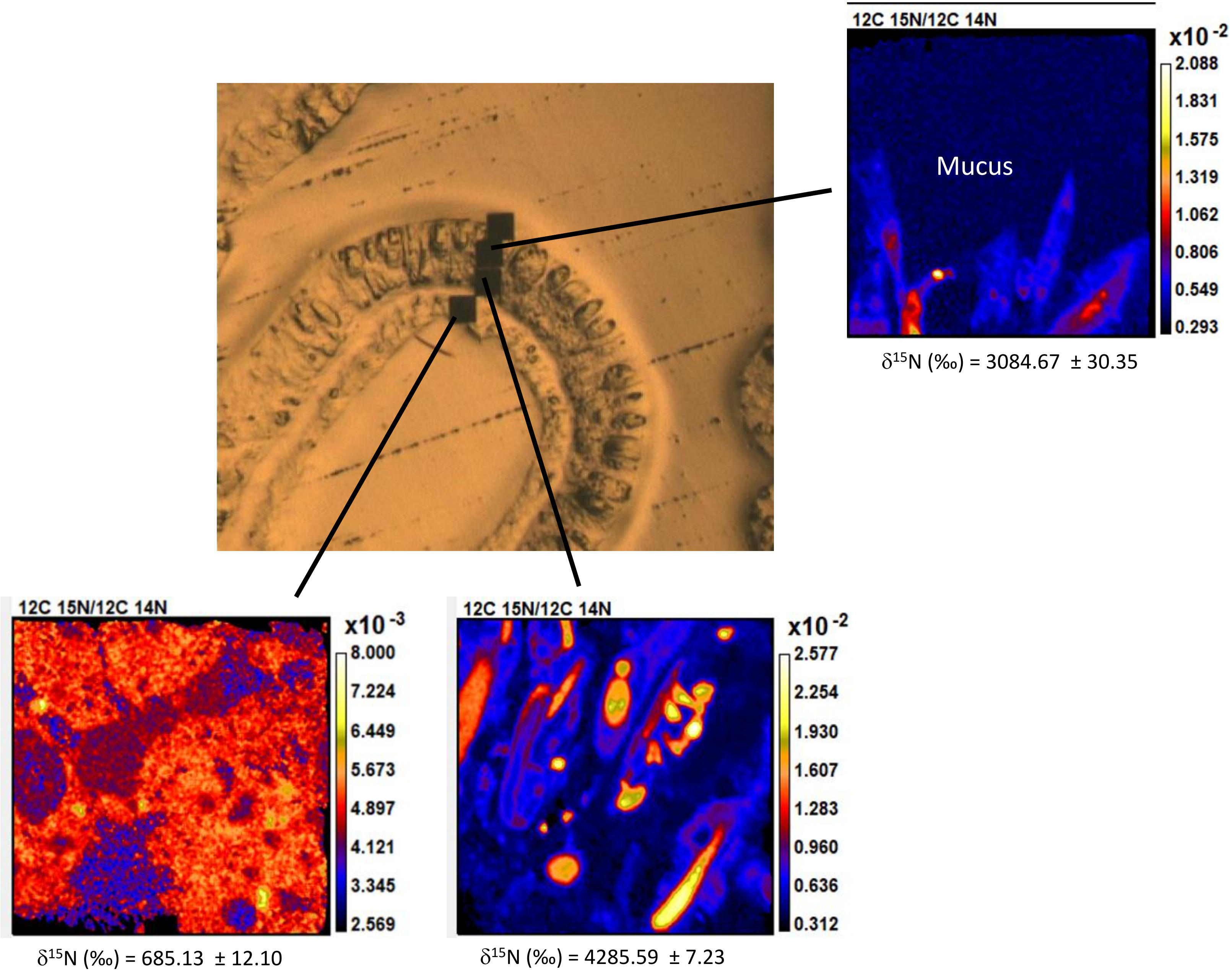
Inorganic nitrogen fixation has previously been reported in *D. pertusum*, presumably through mutualistic bacteria. However, this symbiosis is currently poorly documented.

Use of NanoSIMS to elucidate incorporation patterns

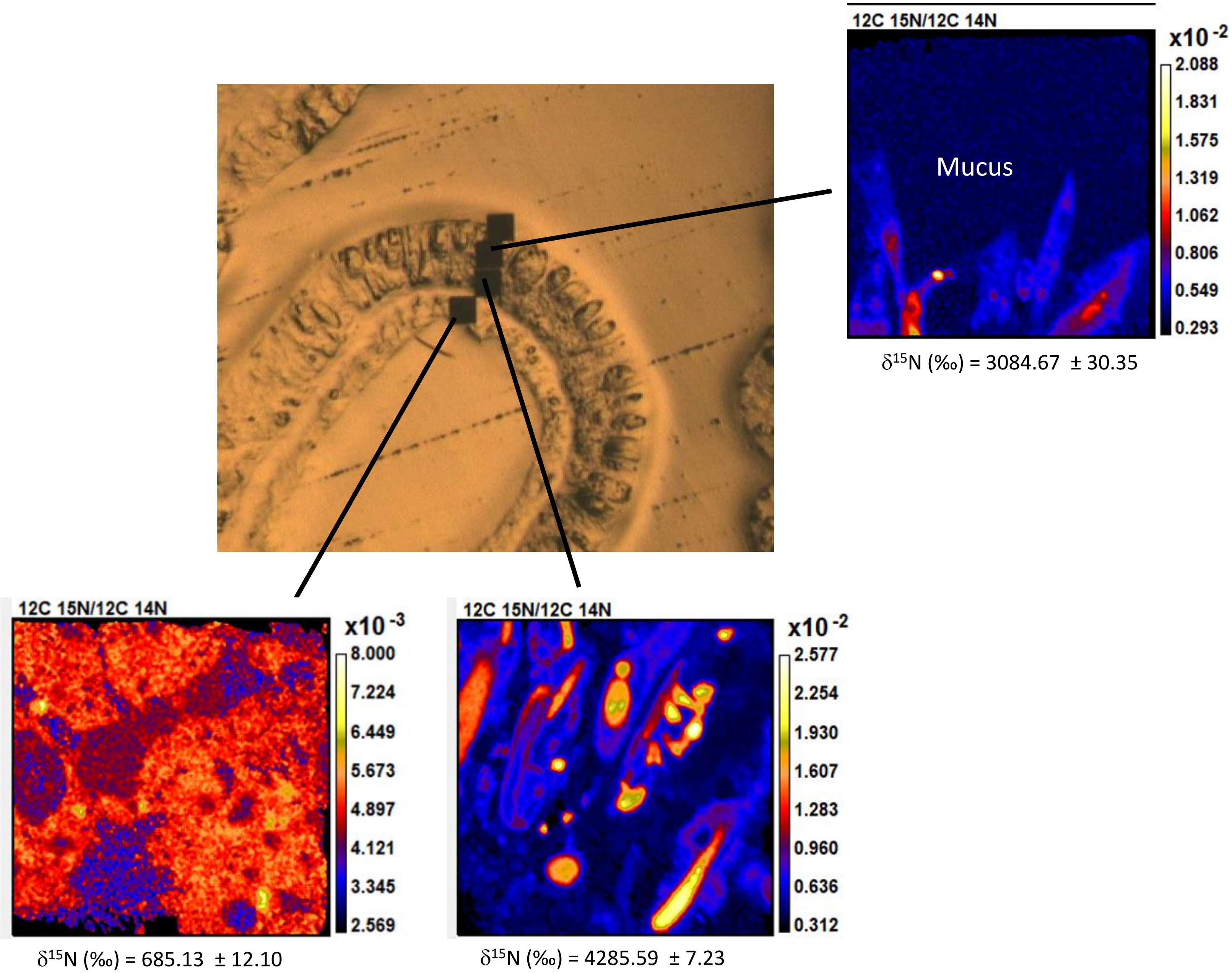
Inorganic nitrogen fixation: how?

Inorganic nitrogen fixation has previously been reported in *D. pertusum*, presumably through mutualistic bacteria. However, this symbiosis is currently poorly documented.

Use of NanoSIMS to elucidate incorporation patterns



Inorganic nitrogen fixation: how?



Inorganic nitrogen fixation has previously been reported in *D. pertusum*, presumably through mutualistic bacteria. However, this symbiosis is currently poorly documented.

Use of NanoSIMS to elucidate incorporation patterns

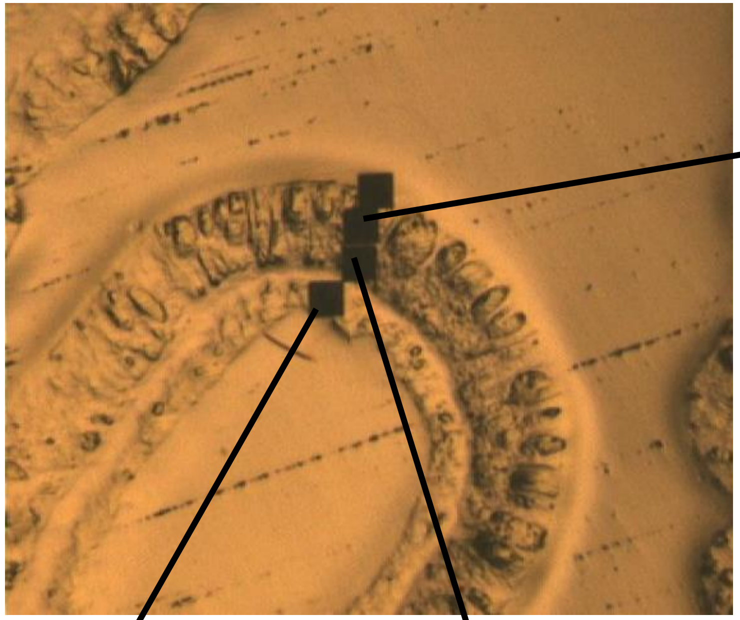
Stronger labelling in inner polyp structures (coelenteron and/or tentacle bases?)

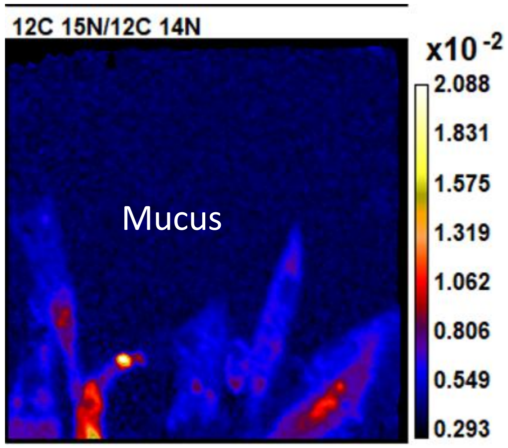
Inorganic nitrogen fixation: how?

Inorganic nitrogen fixation has previously been reported in *D. pertusum*, presumably through mutualistic bacteria. However, this symbiosis is currently poorly documented.

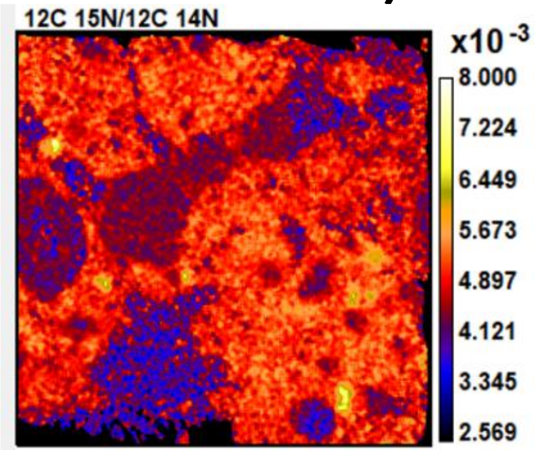
Use of NanoSIMS to elucidate incorporation patterns

Stronger labelling in inner polyp structures (coelenteron and/or tentacle bases?)

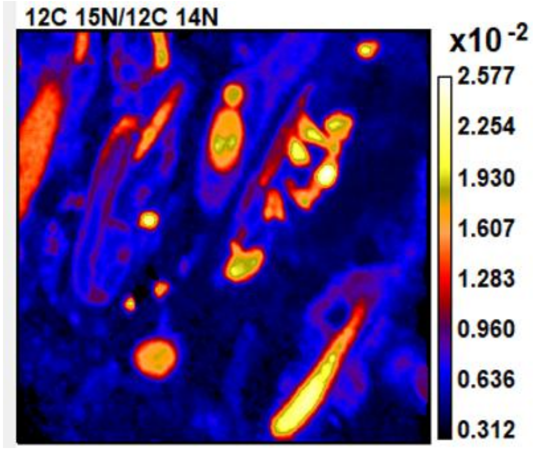




$\delta^{15}N$ (‰) = 3084.67 ± 30.35



$\delta^{15}N$ (‰) = 685.13 ± 12.10



$\delta^{15}N$ (‰) = 4285.59 ± 7.23

Inorganic nitrogen fixation: how much?

In Norwegian fjords, *D. pertusum* might derive 10 – 30 % of its nitrogen from symbiote metabolism.

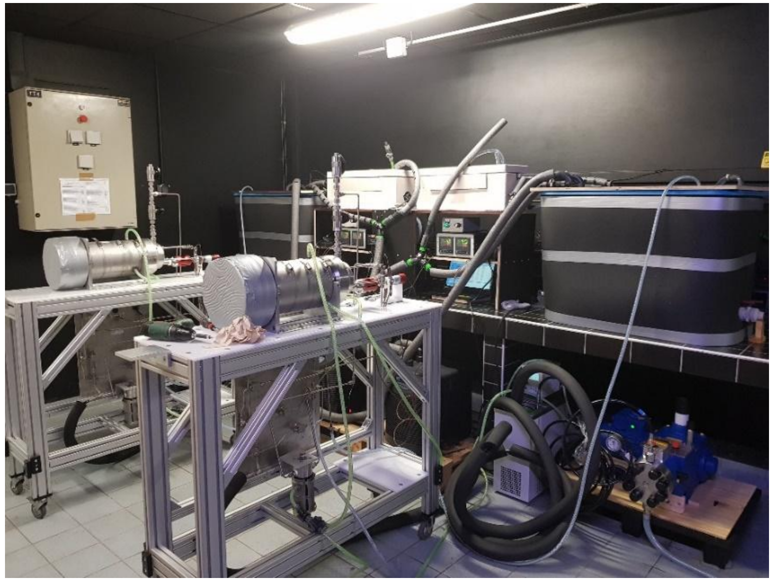
Spatial and temporal variability? Interspecific differences? Impacts of environmental changes (ocean warming and acidification)?

Inorganic nitrogen fixation: how much?

In Norwegian fjords, *D. pertusum* might derive 10 – 30 % of its nitrogen from symbiote metabolism.

Spatial and temporal variability? Interspecific differences? Impacts of environmental changes (ocean warming and acidification)?

Longer-term (9-12 months) experiments in pressurized aquaria, in partnership with Océanopolis (public aquarium, Brest, FR).



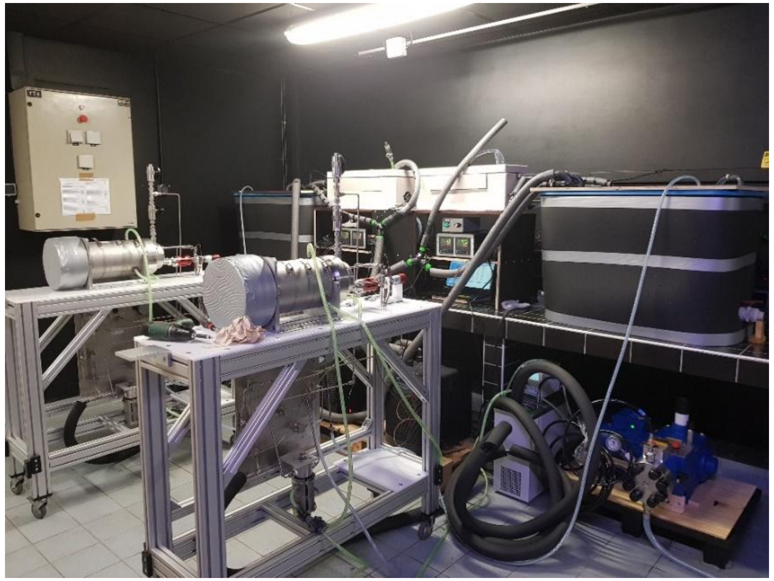
Océanopolis BREST

Inorganic nitrogen fixation: how much?

In Norwegian fjords, *D. pertusum* might derive 10 – 30 % of its nitrogen from symbiote metabolism.

Spatial and temporal variability? Interspecific differences? Impacts of environmental changes (ocean warming and acidification)?

Longer-term (9-12 months) experiments in pressurized aquaria, in partnership with Océanopolis (public aquarium, Brest, FR).

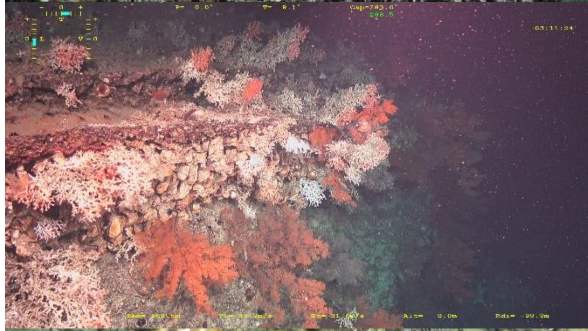


Océanopolis BREST

Take home message

- In the Lampaul canyon, all 3 reef-building coral species exhibit marked resource segregation with associated fauna.

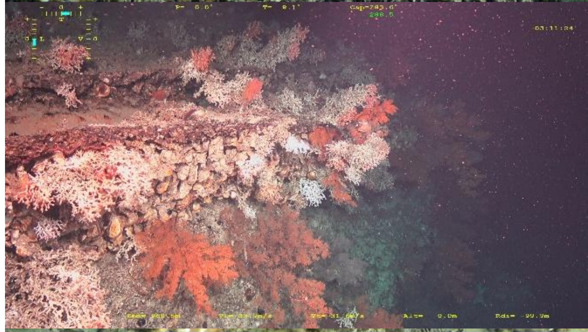





Take home message

- In the Lampaul canyon, all 3 reef-building coral species exhibit marked resource segregation with associated fauna.

- Corals are selective plankton feeders with species-specific preferences: *Desmophyllum pertusum* and *Solenosmilia variabilis* seem to favour zooplankton, while *Madrepora oculata* could have a more balanced diet comprising zooplankton, phytoplankton and bacterioplankton.

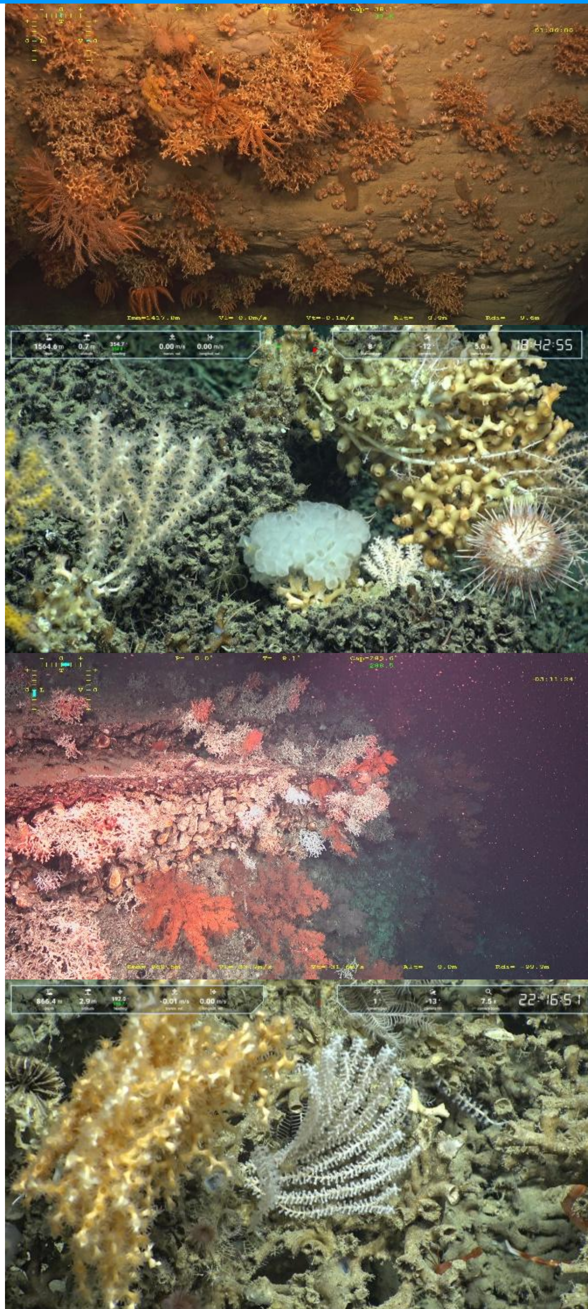


Take home message

- In the Lampaul canyon, all 3 reef-building coral species exhibit marked resource segregation with associated fauna.

- Corals are selective plankton feeders with species-specific preferences: *Desmophyllum pertusum* and *Solenosmilia variabilis* seem to favour zooplankton, while *Madrepora oculata* could have a more balanced diet comprising zooplankton, phytoplankton and bacterioplankton.

- The 3 species are able to supplement their dietary nutriment intake through inorganic nitrogen fixation. The relative importance of this mechanism for coral nitrogen budget is currently unclear.



Take home message

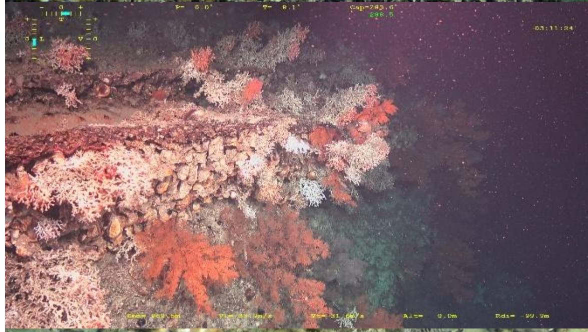
- In the Lampaul canyon, all 3 reef-building coral species exhibit marked resource segregation with associated fauna.

- Corals are selective plankton feeders with species-specific preferences: *Desmophyllum pertusum* and *Solenosmilia variabilis* seem to favour zooplankton, while *Madrepora oculata* could have a more balanced diet comprising zooplankton, phytoplankton and bacterioplankton.

- The 3 species are able to supplement their dietary nutriment intake through inorganic nitrogen fixation. The relative importance of this mechanism for coral nitrogen budget is currently unclear.

- Joint use of stable isotopes and fatty acids suggest that although foraging strategies might differ, coral niches might partly overlap. Marked differences between successive sampling years hint towards highly dynamic trophic interactions.






Acknowledgements & funding

Many friends and colleagues involved in this project

CheReef (Characterization and Ecology of Cold-Water Coral Reefs) - French Oceanographic Fleet

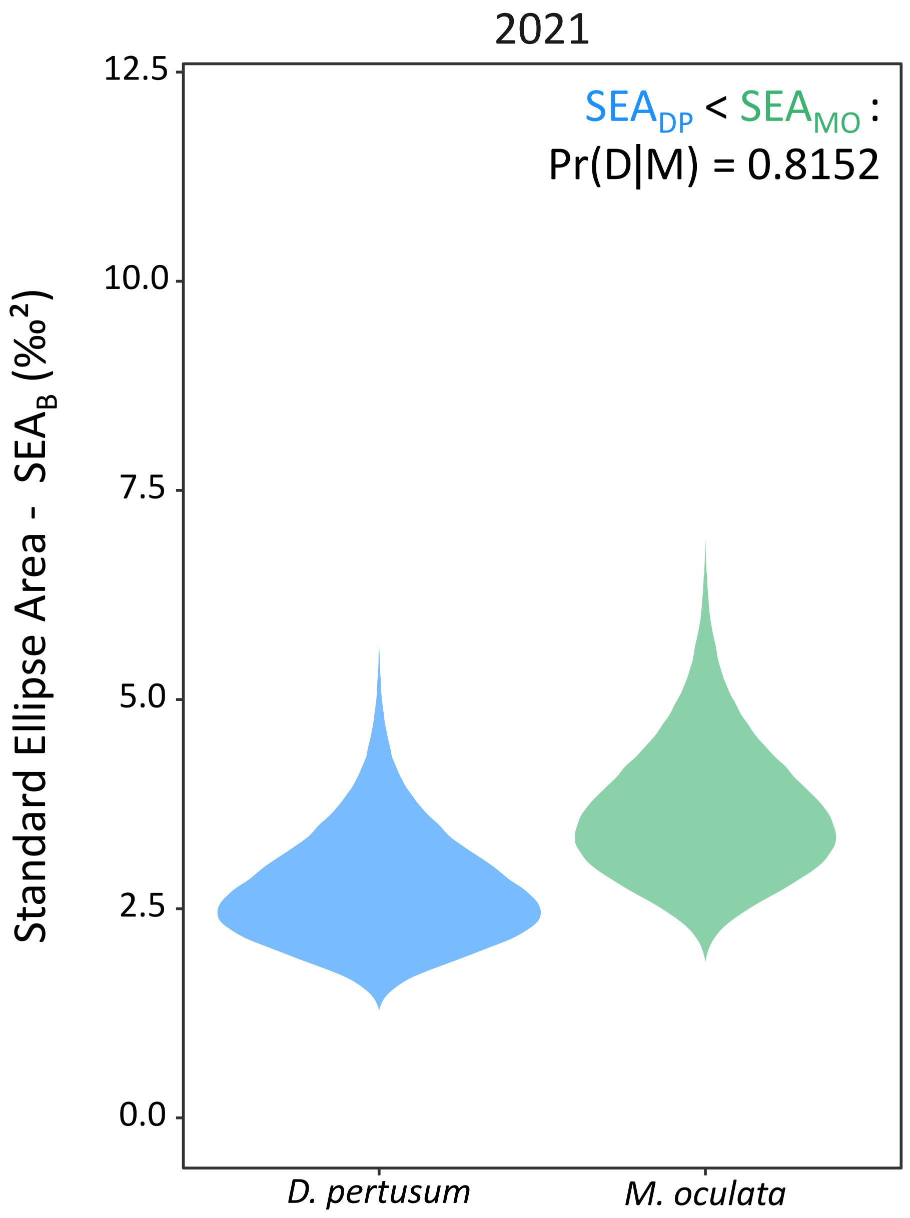
ARDECO (Assessing Resilience of Deep-Water Corals to global change) - ANR (French National Research Agency)

Funded by the Horizon 2020 Framework Programme of the European Union

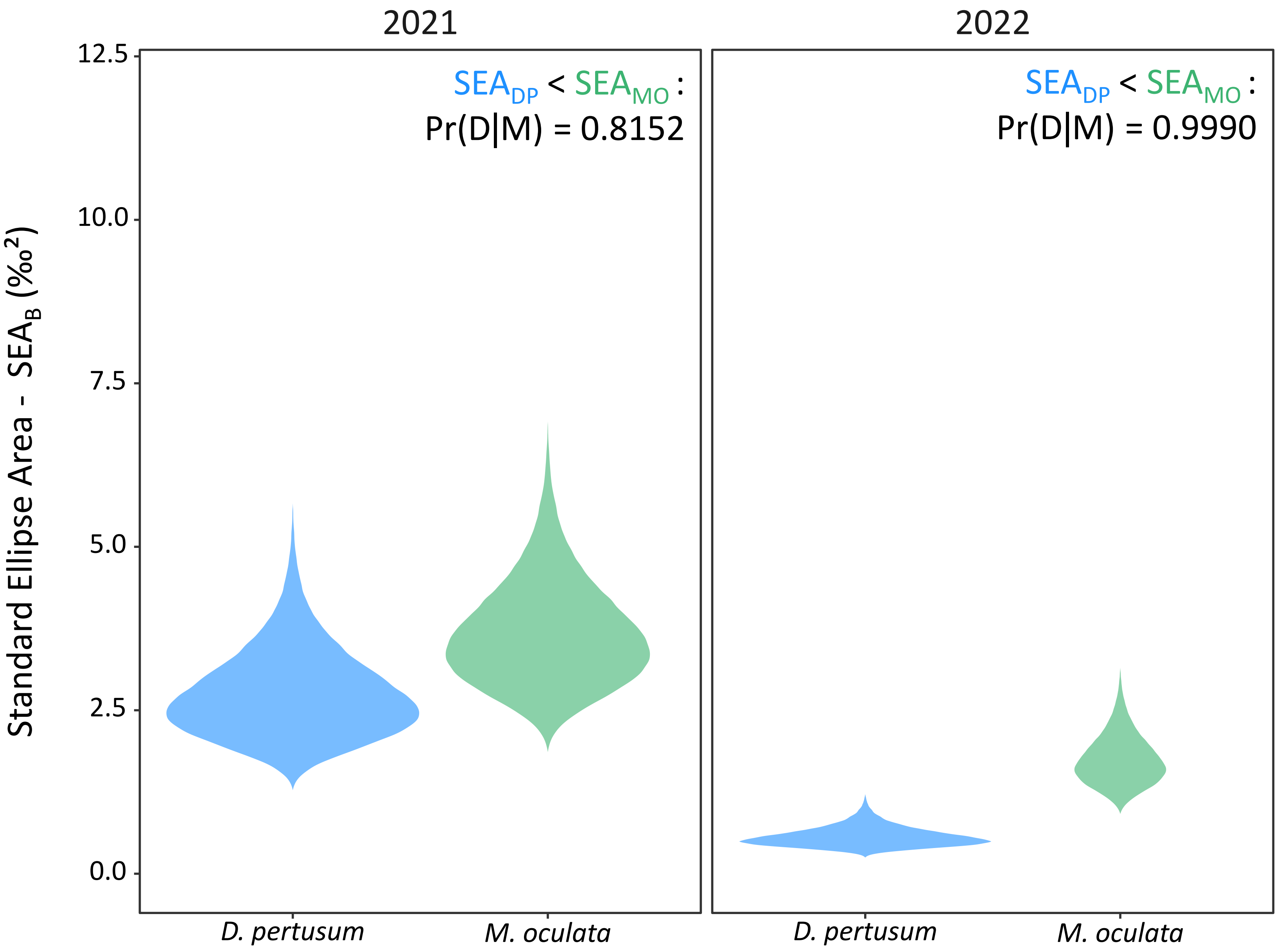
iAtlantic (Integrated Assessment of Atlantic Marine Ecosystems in Space and Time) – European Union


Maier 2020
Thanks for your attention

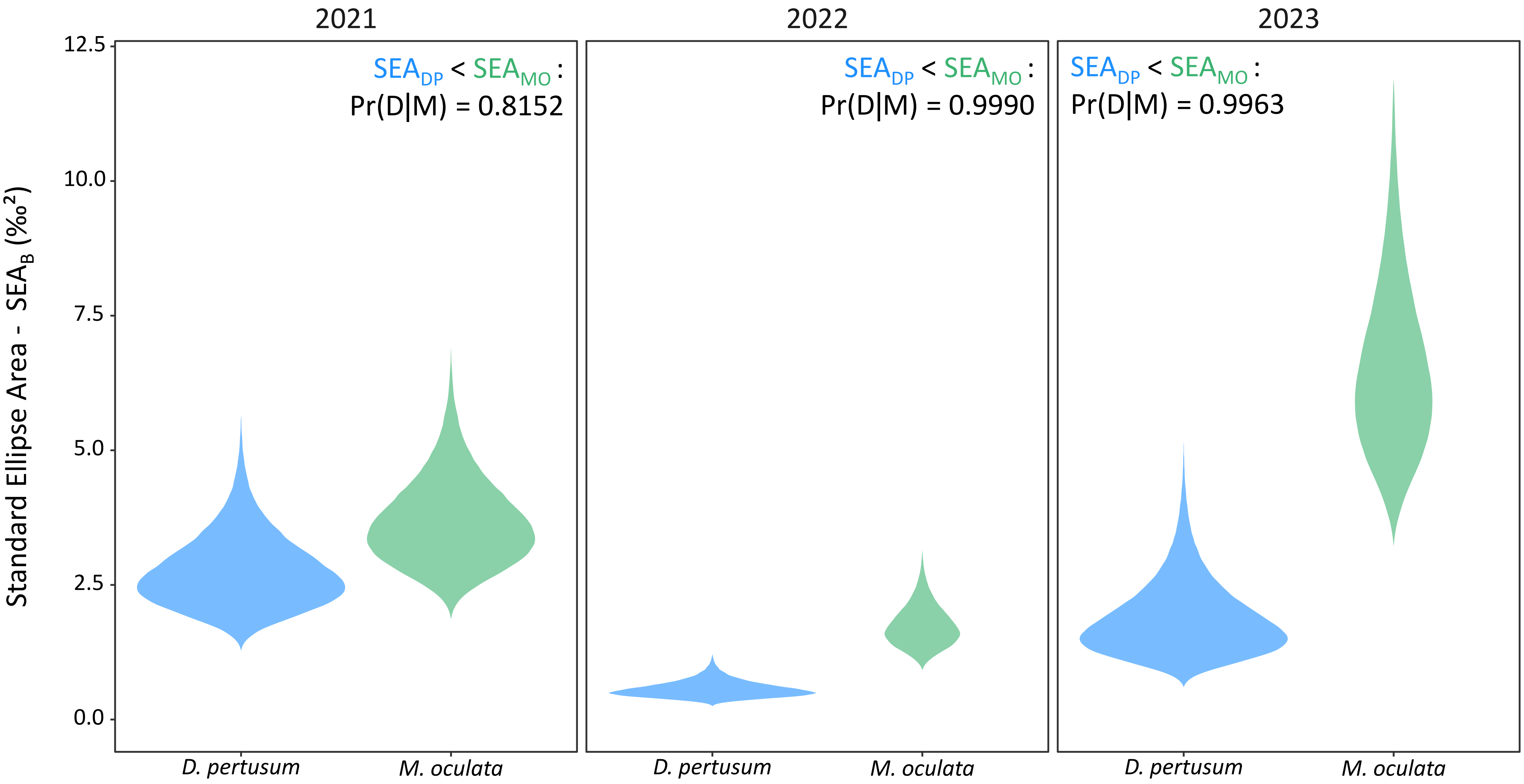
Isotopic niches – dominant syntopic corals



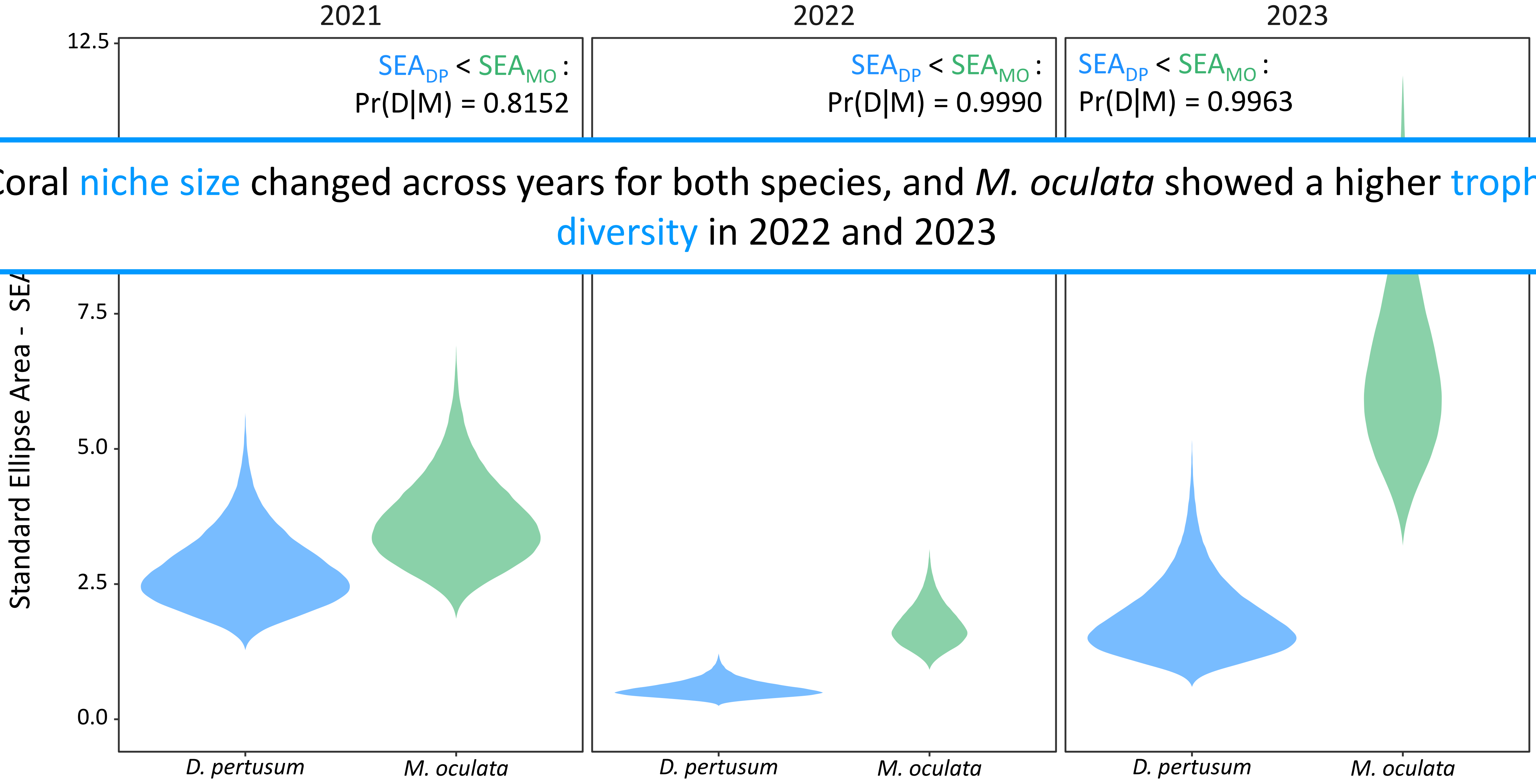
Isotopic niches – dominant syntopic corals



Isotopic niches – dominant syntopic corals

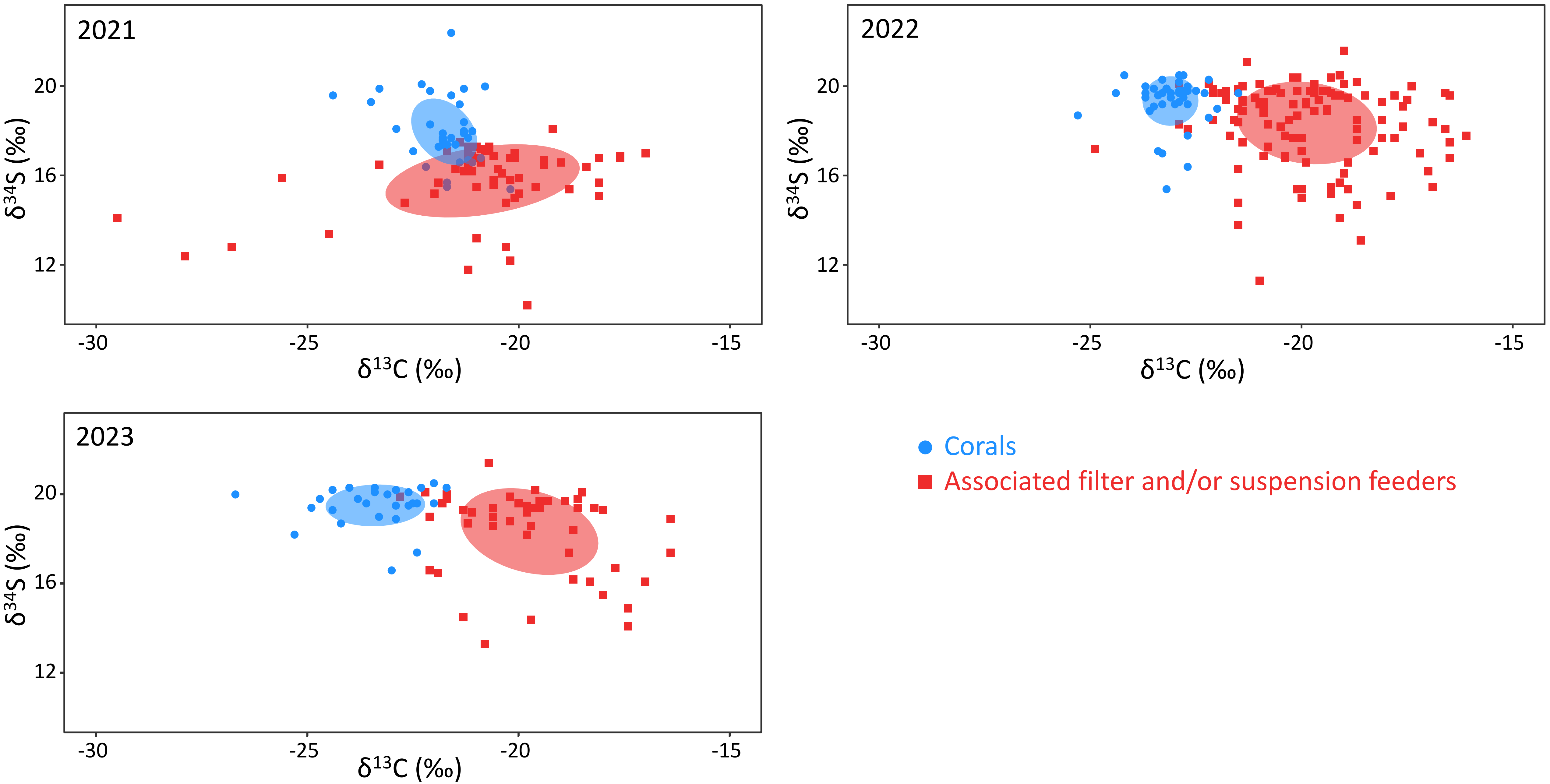


Isotopic niches – dominant syntopic corals



Coral niche size changed across years for both species, and *M. oculata* showed a higher trophic diversity in 2022 and 2023

Trophic niches of corals and associated fauna



Fatty acid composition of reserve lipids

Zooplankton trophic markers: Σ 20:1(n-9), 20:1(n-11), 22:1(n-11)

Dinoflagellate trophic markers: Σ 22:6(n-3), 18:4(n-3)

Diatom trophic markers: Σ 16:1(n-7), 16:2(n-4), 16:4(n-1)

Bacteria trophic markers: Σ 15:0, iso15:0, 17:0, iso17:0

Fatty acid composition of reserve lipids