Trophic plasticity in Antarctic echinoderms: an adaptive trait with implications at ecosystem-wide scale?

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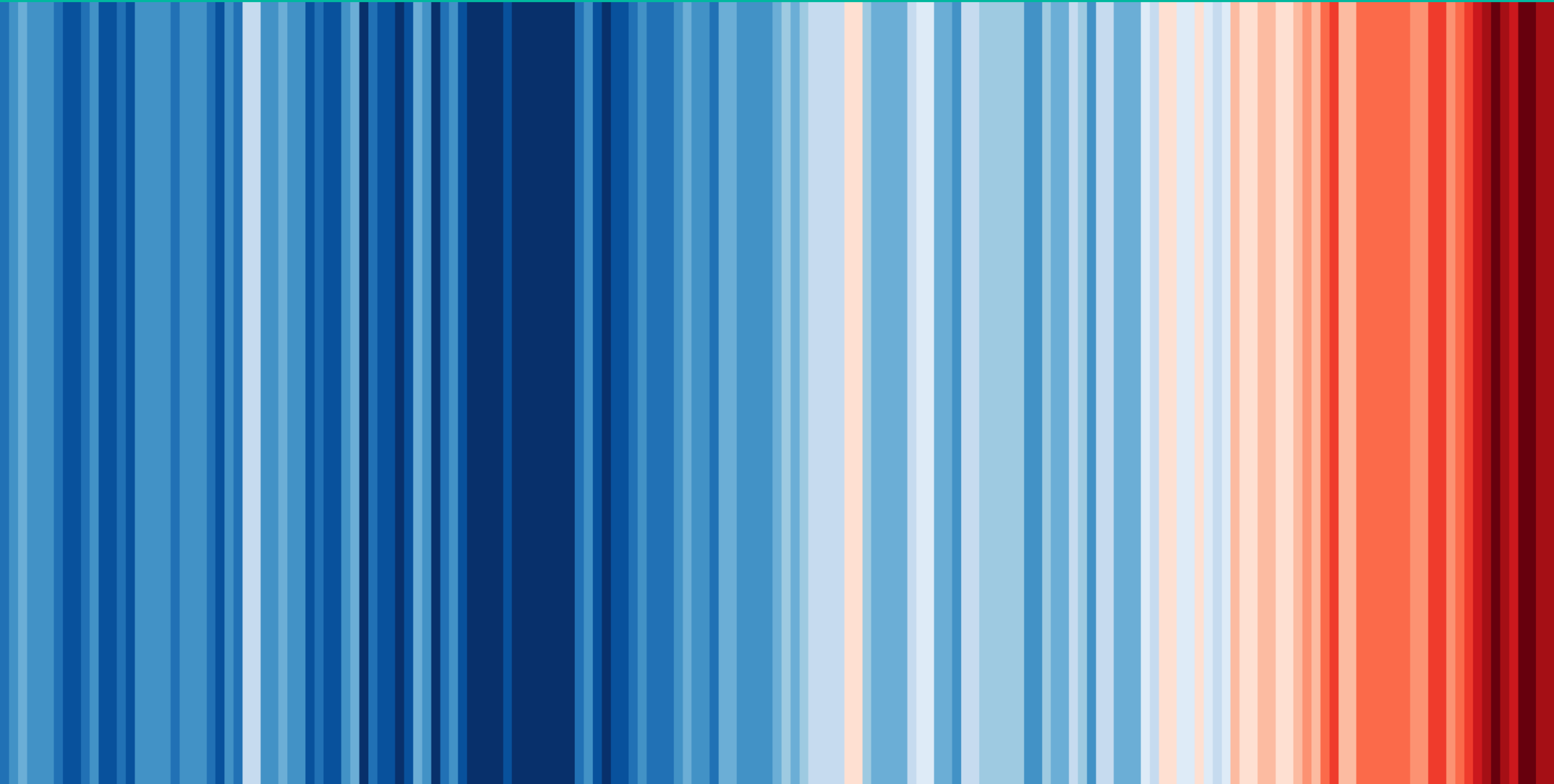
Workshop on Species Interactions in the Southern Ocean – UGent – 30-31/05/2023

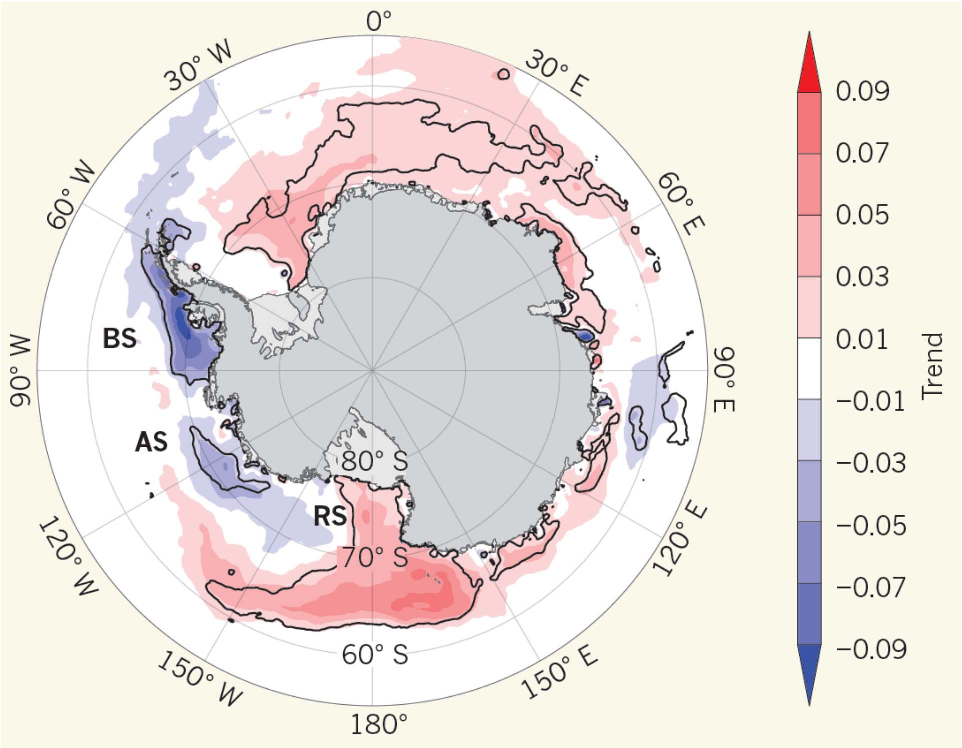
Contact: loic.michel@uliege.be

Environmental change



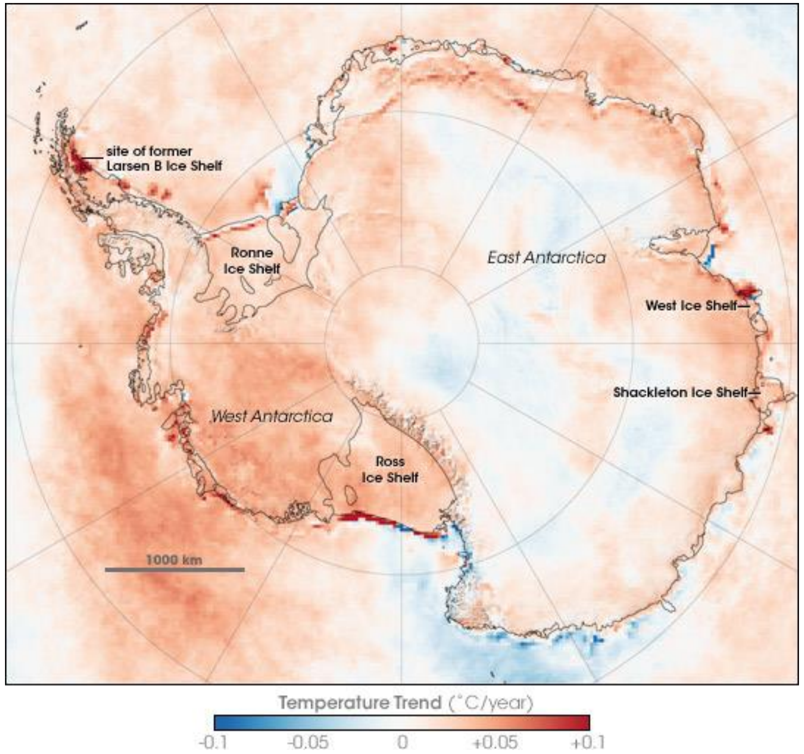
Environmental change

Global change has strong, unprecedently fast and contrasted impacts on Southern Ocean ecosystems, resulting in steep environmental gradients



Changes in sea ice concentration

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

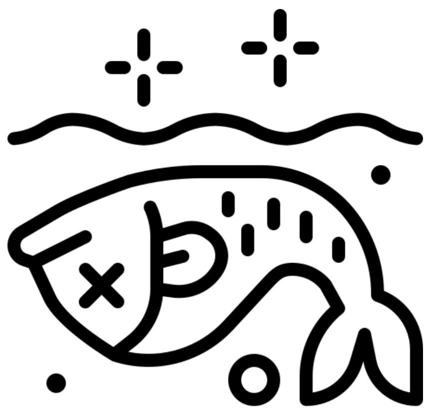


Changes in temperature

NASA Earth Observatory (Data 1981-2007).

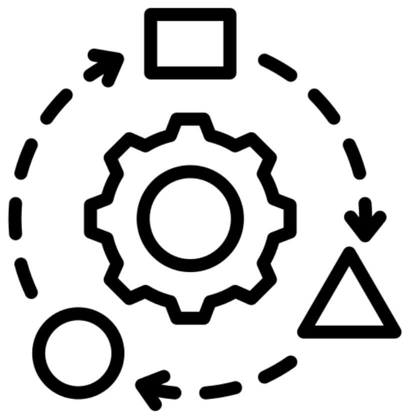
Environmental change

When facing environmental changes incompatible with their ecological requirements, species can…



Suffer negative consequences

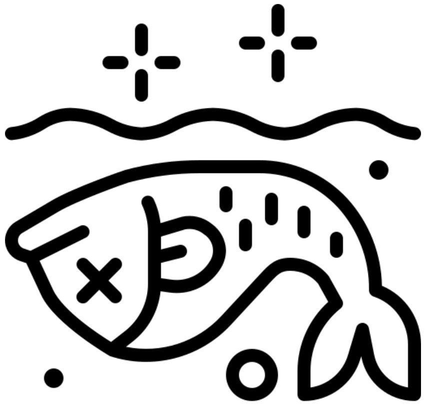
Migrate



Adapt

Environmental change

When facing environmental changes incompatible with their ecological requirements, species can…



Suffer negative consequences

Migrate

Adapt

At shorter than evolutionary timescales, ecological plasticity in general, and trophic plasticity in particular, could be important adaptive mechanisms

Trophic plasticity

Trophic plasticity: the ability of a species to display different feeding habits according to varying environmental conditions

Trophic plasticity

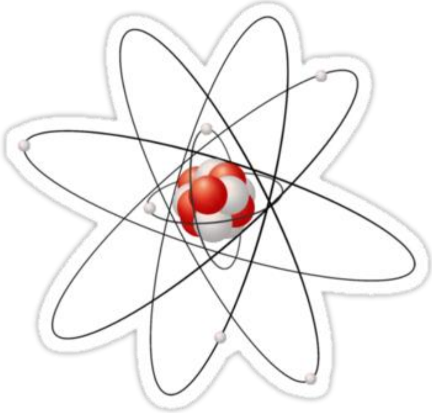
Trophic plasticity: the ability of a species to display different feeding habits according to varying environmental conditions

What is the extent of trophic plasticity among Antarctic zoobenthos? What does it imply for ecosystem functioning?

Use of integrative trophic markers

Trophic markers: stable isotopes

Stable isotope ratios in animals can be used as trophic markers (indirect info on animal diet): "You are what you eat"

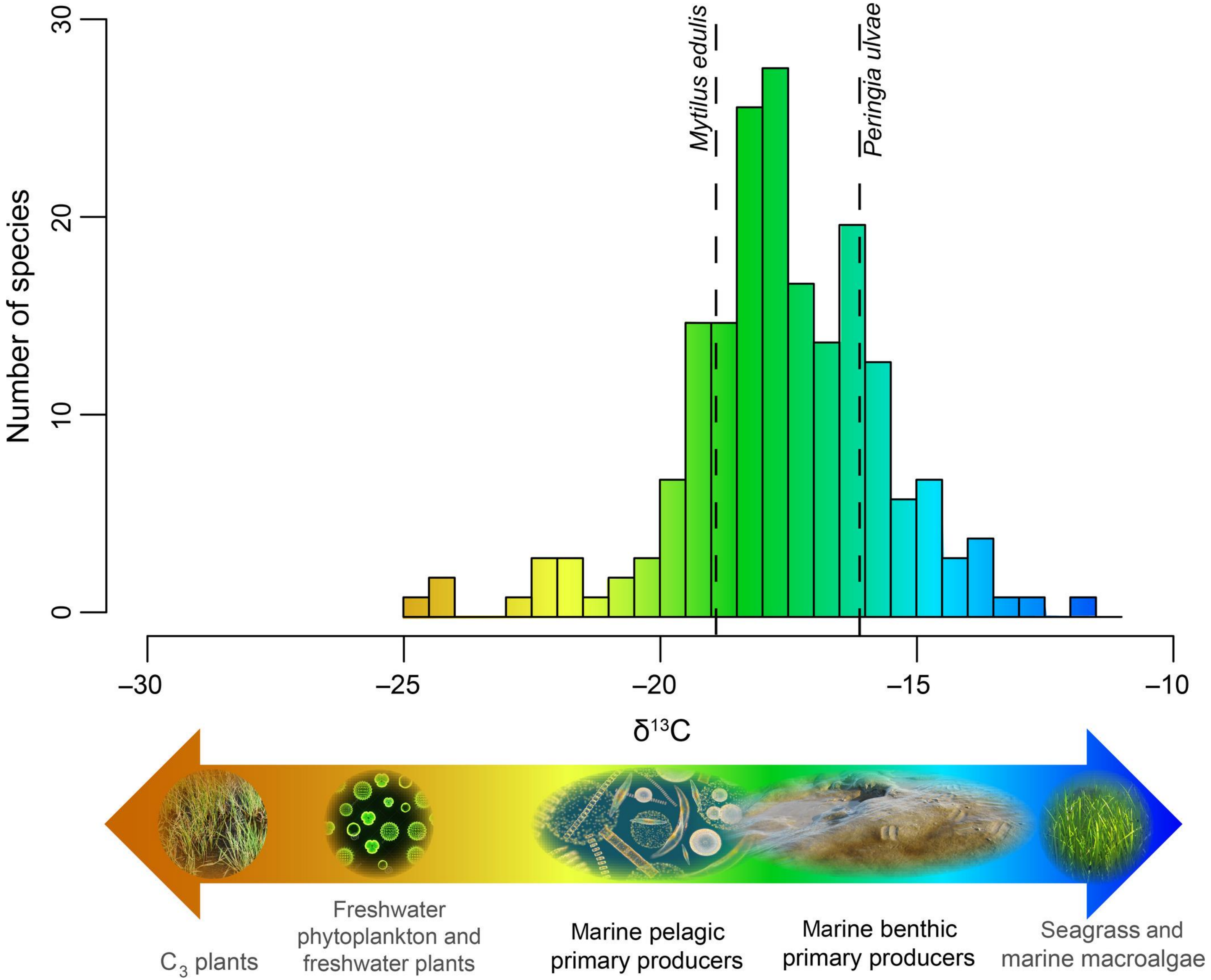


Mixing law: stable isotope composition of an animal is a proportional mix of its food sources' isotopic compositions

↓

By measuring the isotopic composition of an animal and those of its food sources, it is possible to estimate the contribution of each food source to the animal's diet

Carbon stable isotopes



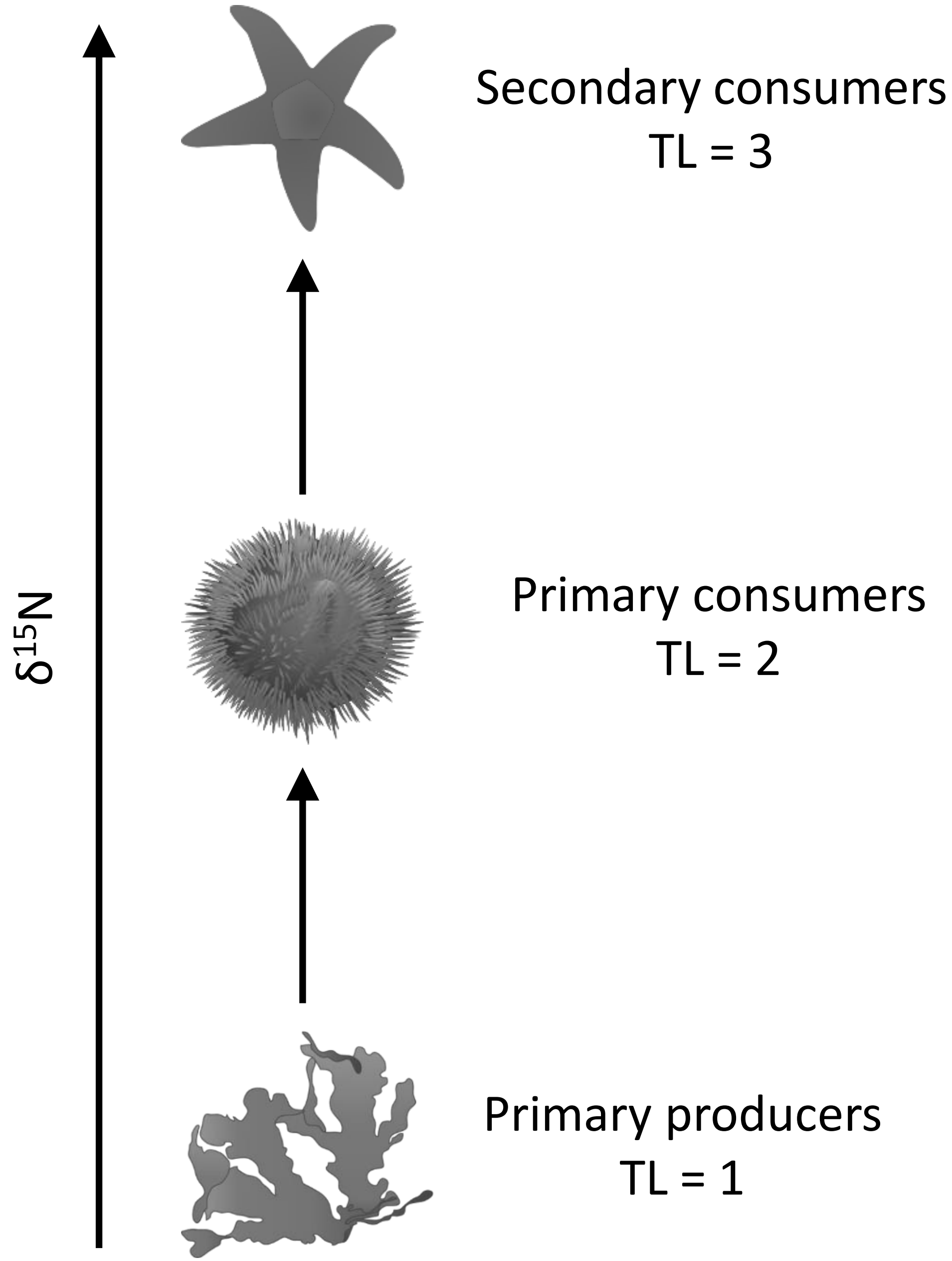
$\delta^{13}C$ of marine producers is variable

This $\delta^{13}C$ is mostly conserved throughout the food web

$\delta^{13}C$ can be used to identify producers supporting animal populations in marine ecosystems

Christianen *et al.* 2017 Ecology 98: 1498-1512

Nitrogen stable isotopes

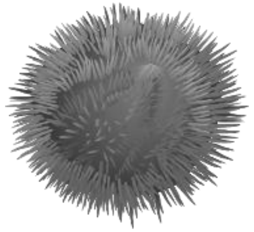


The heavy nitrogen stable isotope (^{15}N) follows a predictable stepwise enrichment pattern with increasing trophic level

Nitrogen stable isotopes

$\delta^{15}N$

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

↓

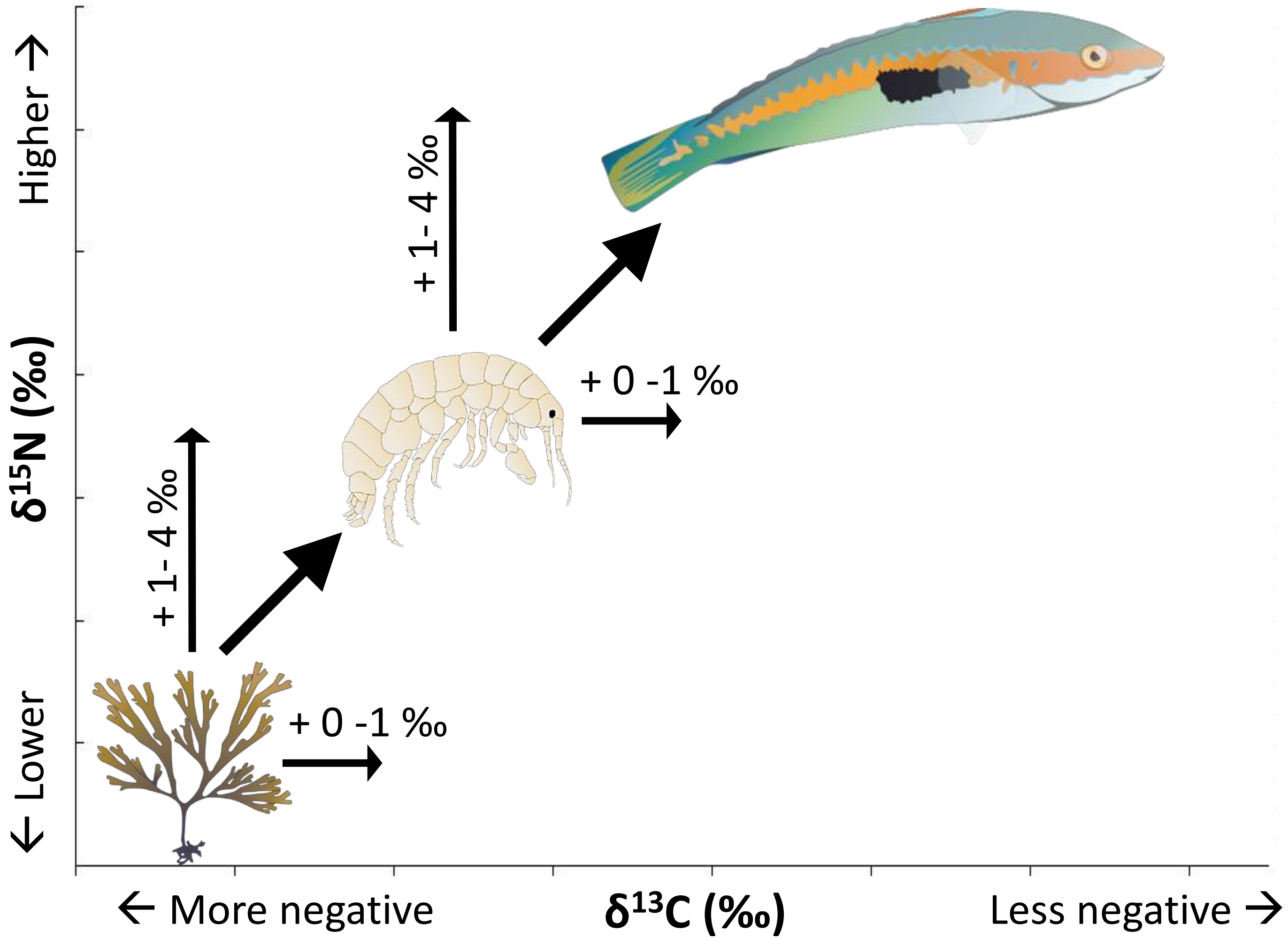
Measurement of stable isotope composition of consumers and baseline items (primary producers)

↓

Infer trophic level of animals through calculation or use of a model

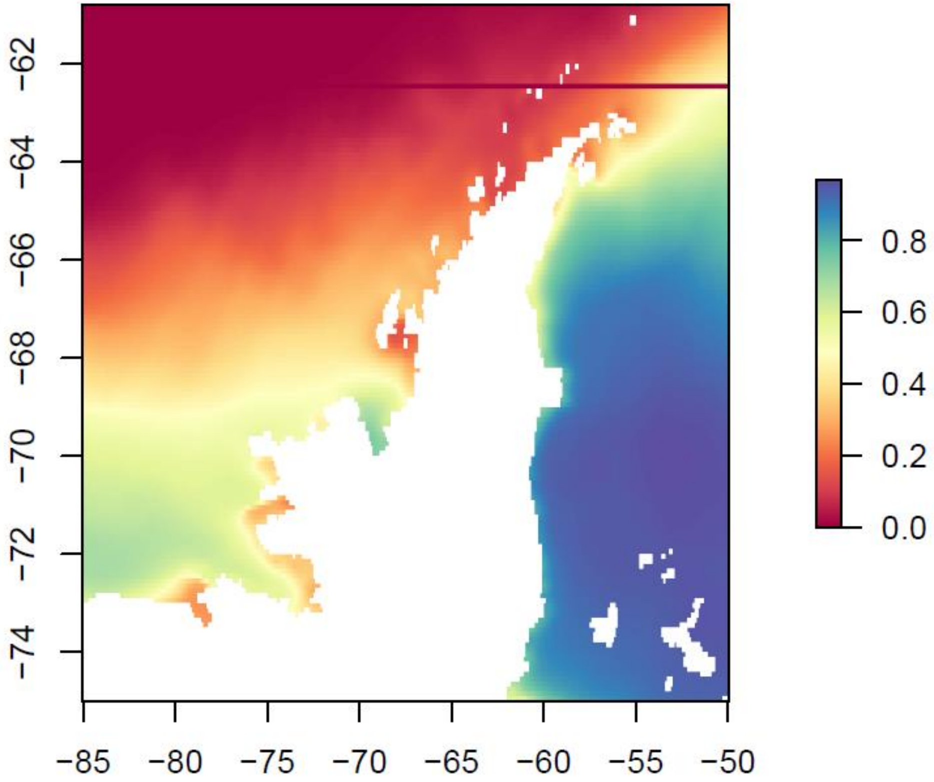
Stable isotope ratios: biplots

Typical food web representation using an isotopic biplot



Trophic plasticity: Echinoids

West Antarctic Peninsula: Strong local, latitudinal and east-west environmental gradients in water temperature, sea ice cover, glacier influence, etc.



Mean sea ice concentraction fraction along the WAP (1957-2017)

Data from Guillaumot *et al.* 2018 (doi:10.26179/5b8f30e30d4f3)

Michel *et al.* 2016 Polar Biol. 39: 913-23

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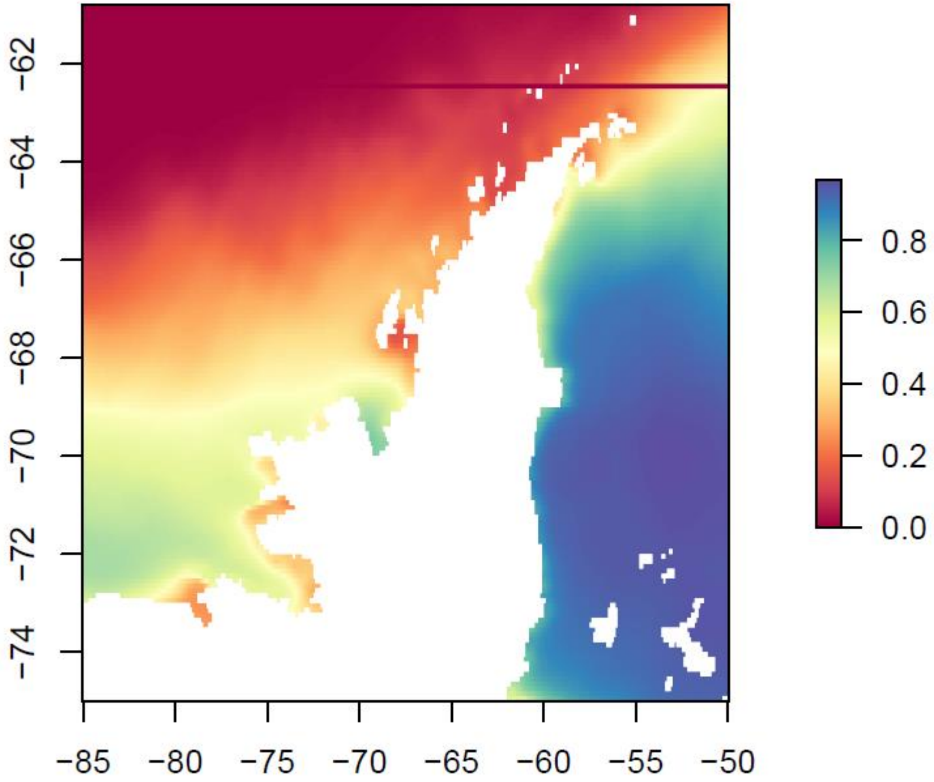

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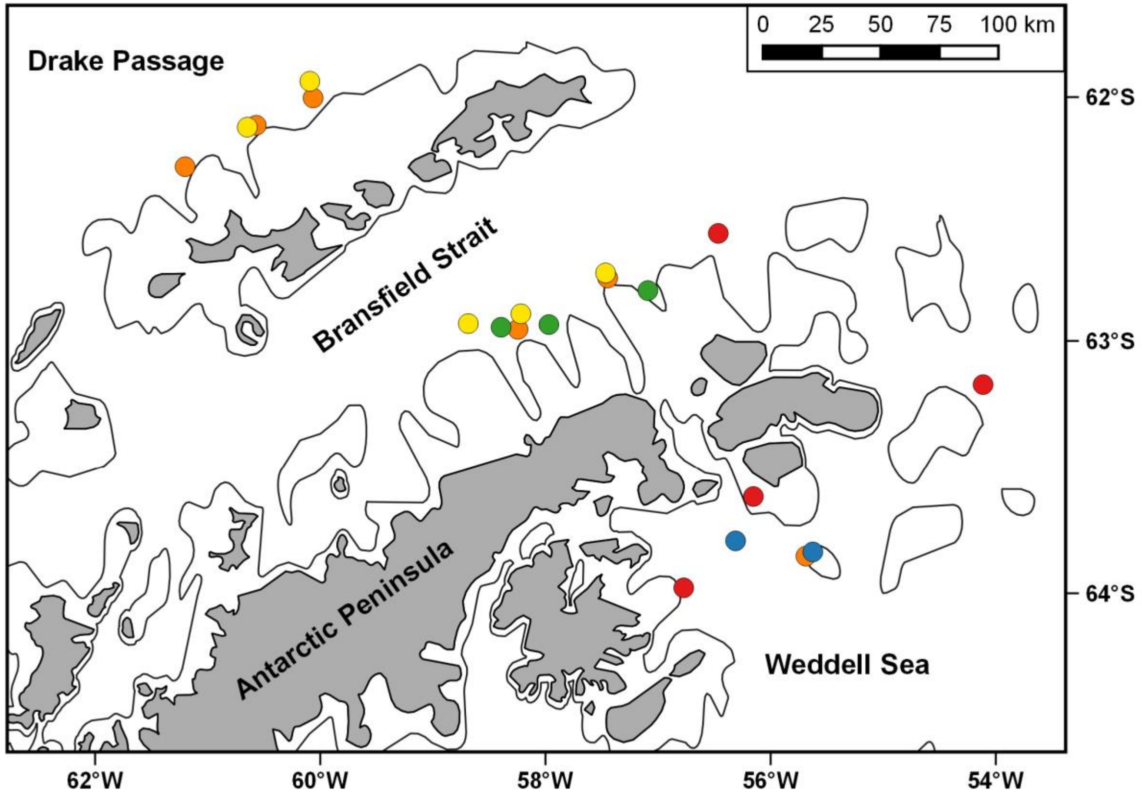
RV Polarstern PS81 (ANTXXIX/3) expedition



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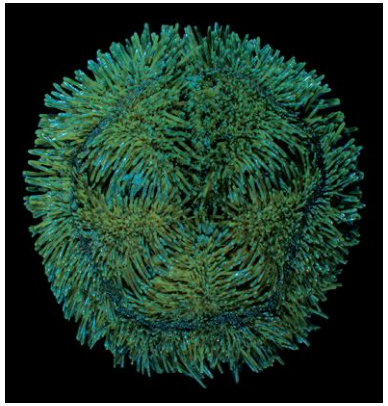
Trophic plasticity: Echinoids

Schizasteridae: Surface / subsurface deposit feeders

Amphipneustes similis
Amphipneustes rostratus
Brachyternaster chesheri
Abatus cavernosus



Flores et al. 2021 Rev. Biol. Trop. 69(S1), 14-34

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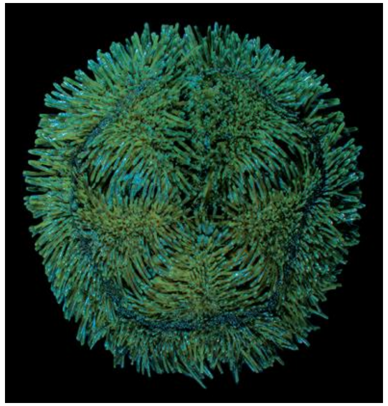

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Echinidae: Omnivores

Sterechinus antarcticus
Sterechinus neumayeri

Trophic plasticity: Echinoids

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Amphipneustes similis
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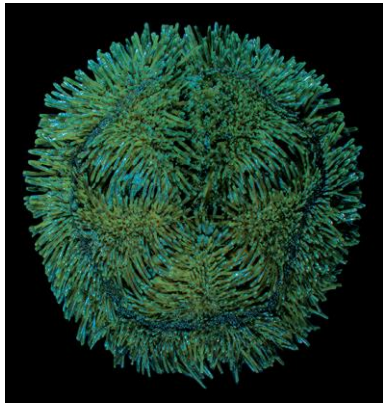


Flores et al. 2021 Rev. Biol. Trop. 69(S1), 14-34

Echinidae: Omnivores

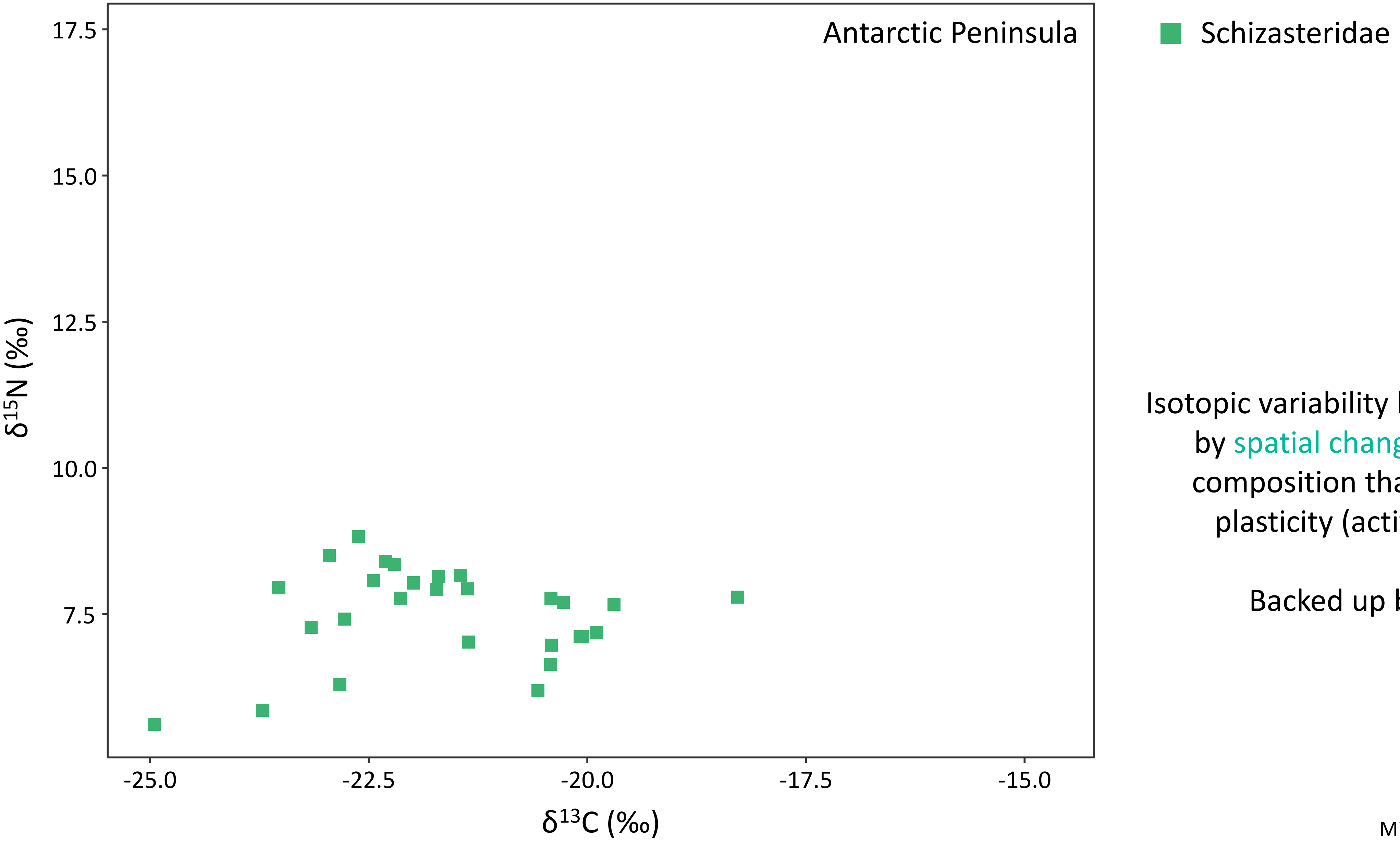
Sterechinus antarcticus
Sterechinus neumayeri

Cidaridae: Omnivores but preference for animal prey

Ctenocidaris gigantea
Aporocidaris eltaniana
Notocidaris gaussiensis
Notocidaris mortenseni

Schultz 2011 ISBN 3-9809868-4-5

Trophic plasticity: Echinoids

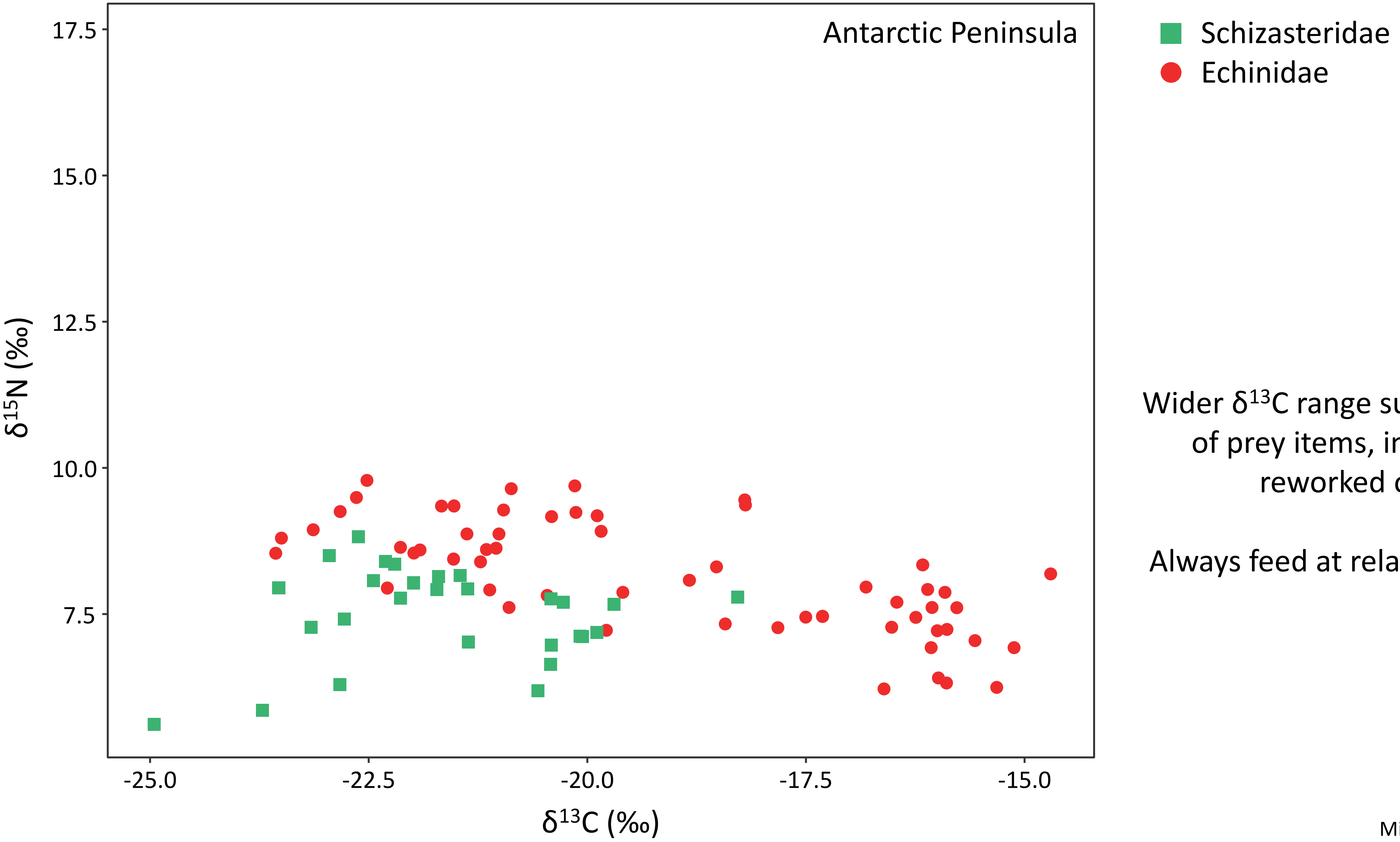


Isotopic variability likely more driven than by spatial changes in exported OM composition than by actual trophic plasticity (active prey selection)

Backed up by gut contents

Michel *et al.* 2016 Polar Biol. 39: 913-23

Trophic plasticity: Echinoids

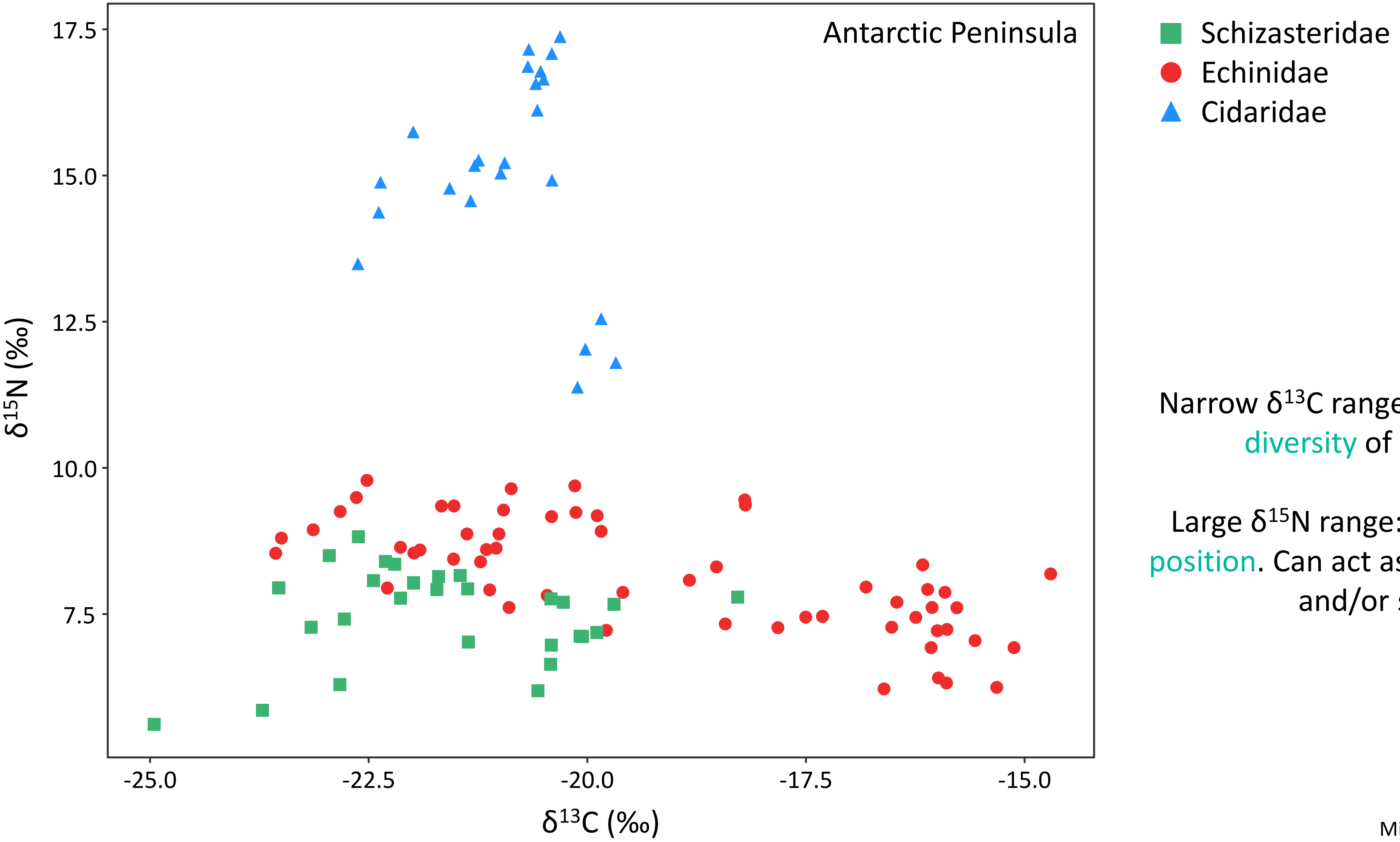


Wider $\delta^{13}C$ range suggests active selection of prey items, including microbially reworked organic matter

Always feed at relatively low trophic level

Michel *et al.* 2016 Polar Biol. 39: 913-23

Trophic plasticity: Echinoids

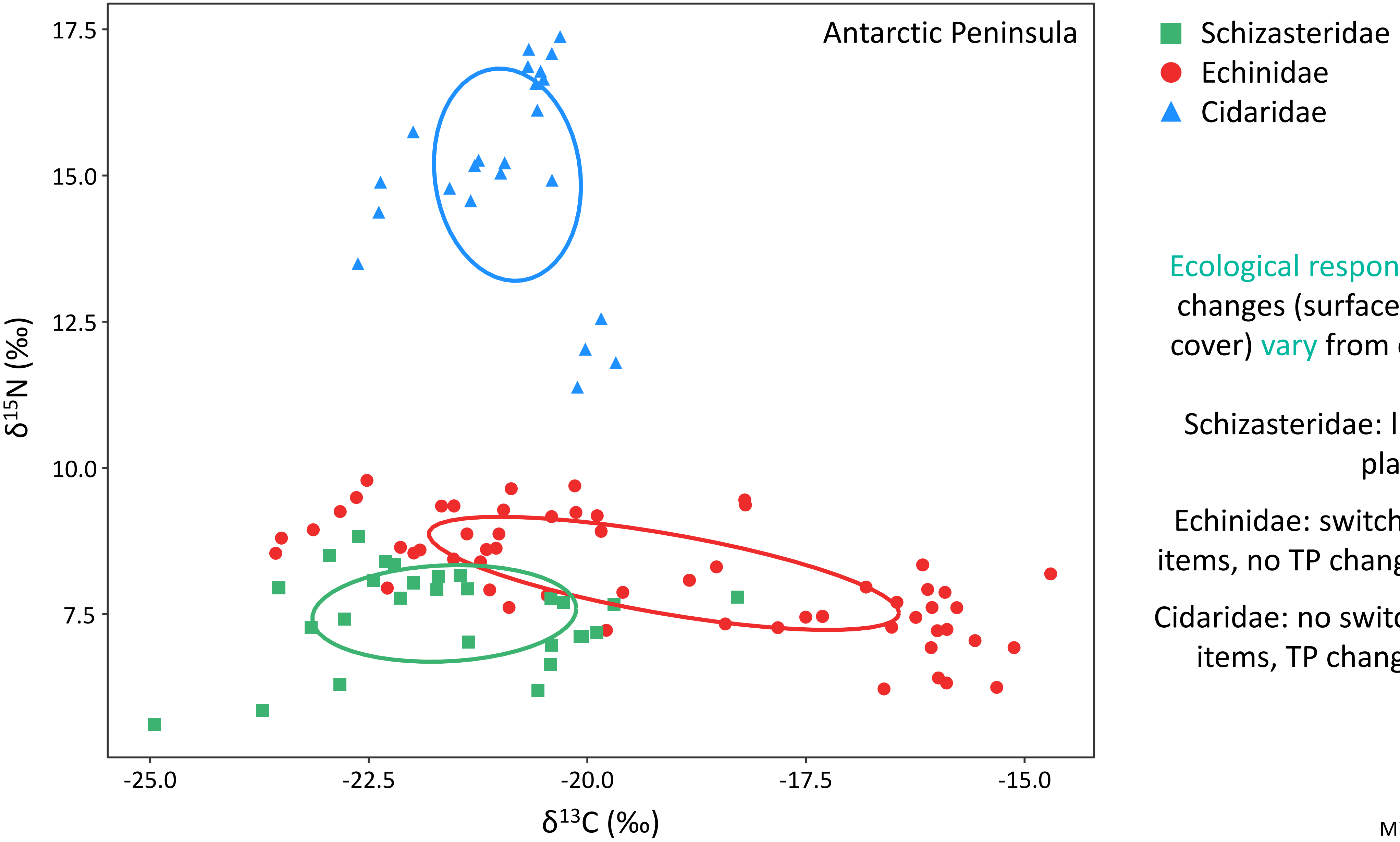


Narrow $\delta^{13}C$ range: depend on a limited diversity of basal resources

Large $\delta^{15}N$ range: variability of trophic position. Can act as omnivores, predators and/or scavengers.

Michel *et al.* 2016 Polar Biol. 39: 913-23

Trophic plasticity: Echinoids



Ecological responses to environmental changes (surface productivity, sea ice cover) vary from one taxon to another

Schizasteridae: limited changes (low plasticity)

Echinidae: switch between basal food items, no TP changes (horizontal ellipse)

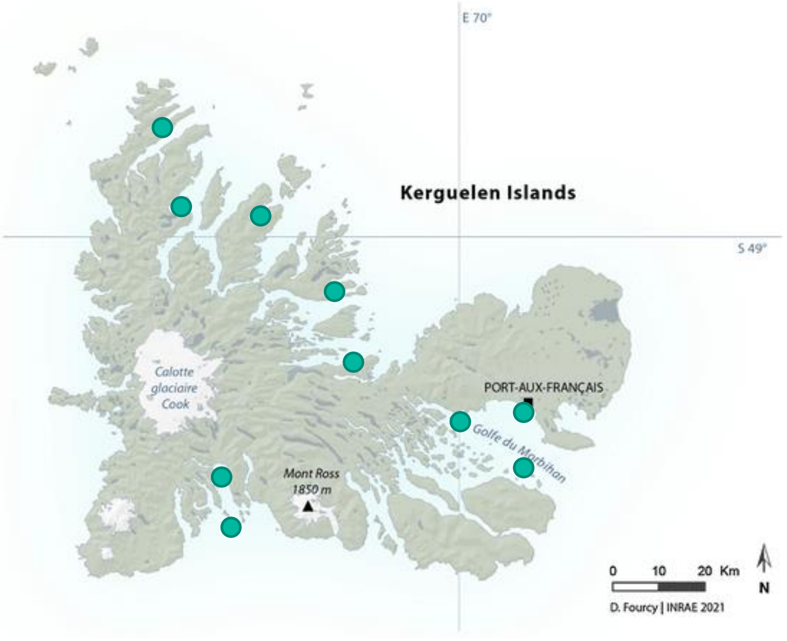
Cidaridae: no switch between basal food items, TP changes (vertical ellipse)

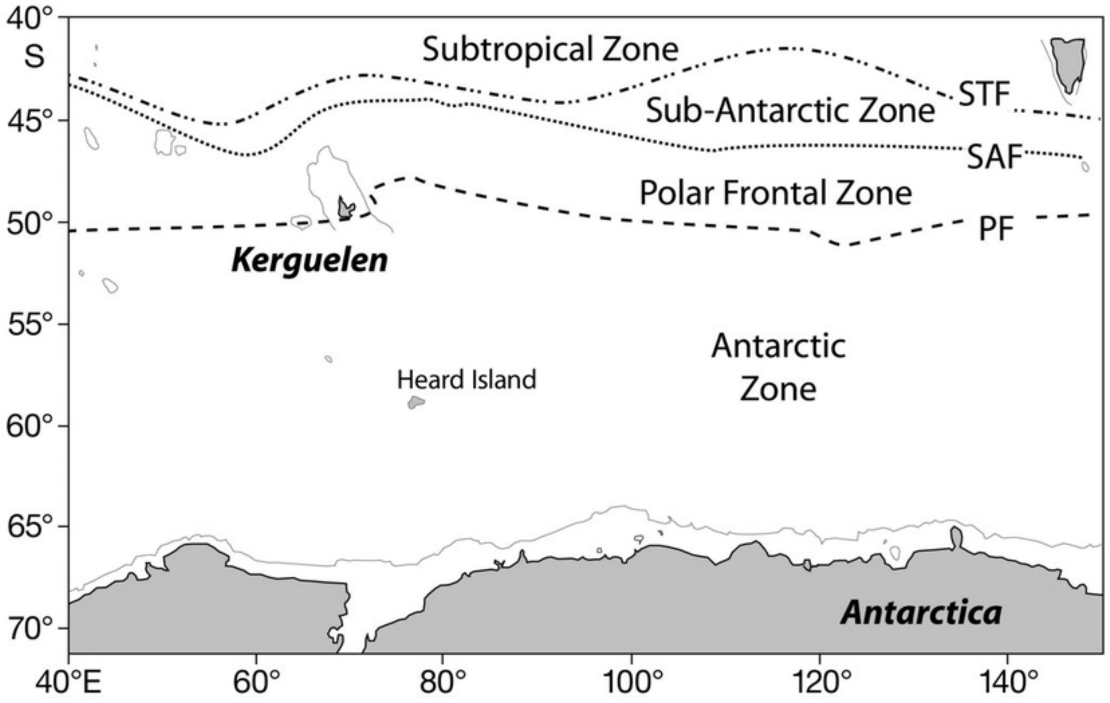
Michel *et al.* 2016 Polar Biol. 39: 913-23

Trophic plasticity: Echinoids

Subantarctic Kerguelen Islands (49-50° S)

Strong regional (close to the Polar Front) and local (fjords and bays with contrasted conditions) environmental gradients



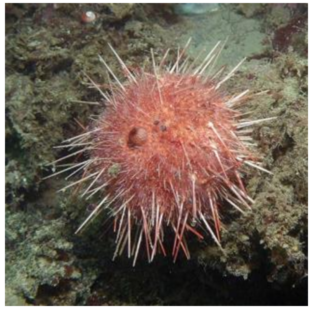


Martin *et al.* 2011 Mar Ecol Prog Ser 439:295-305

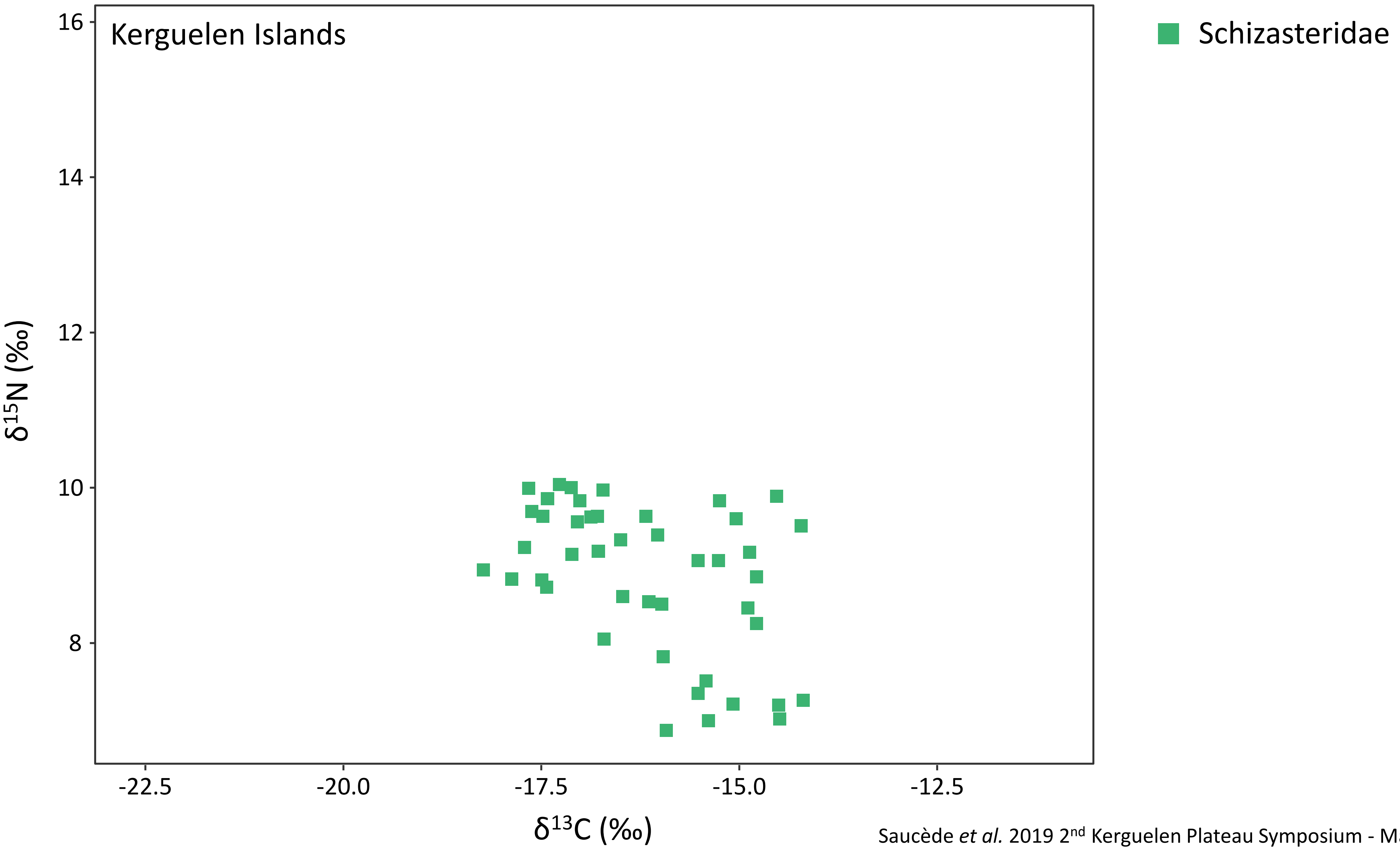
Schizasteridae: *Abatus cordatus*

Echinidae: *Sterechinus diadema*

Cidaridae: *Ctenocidaris nutrix*

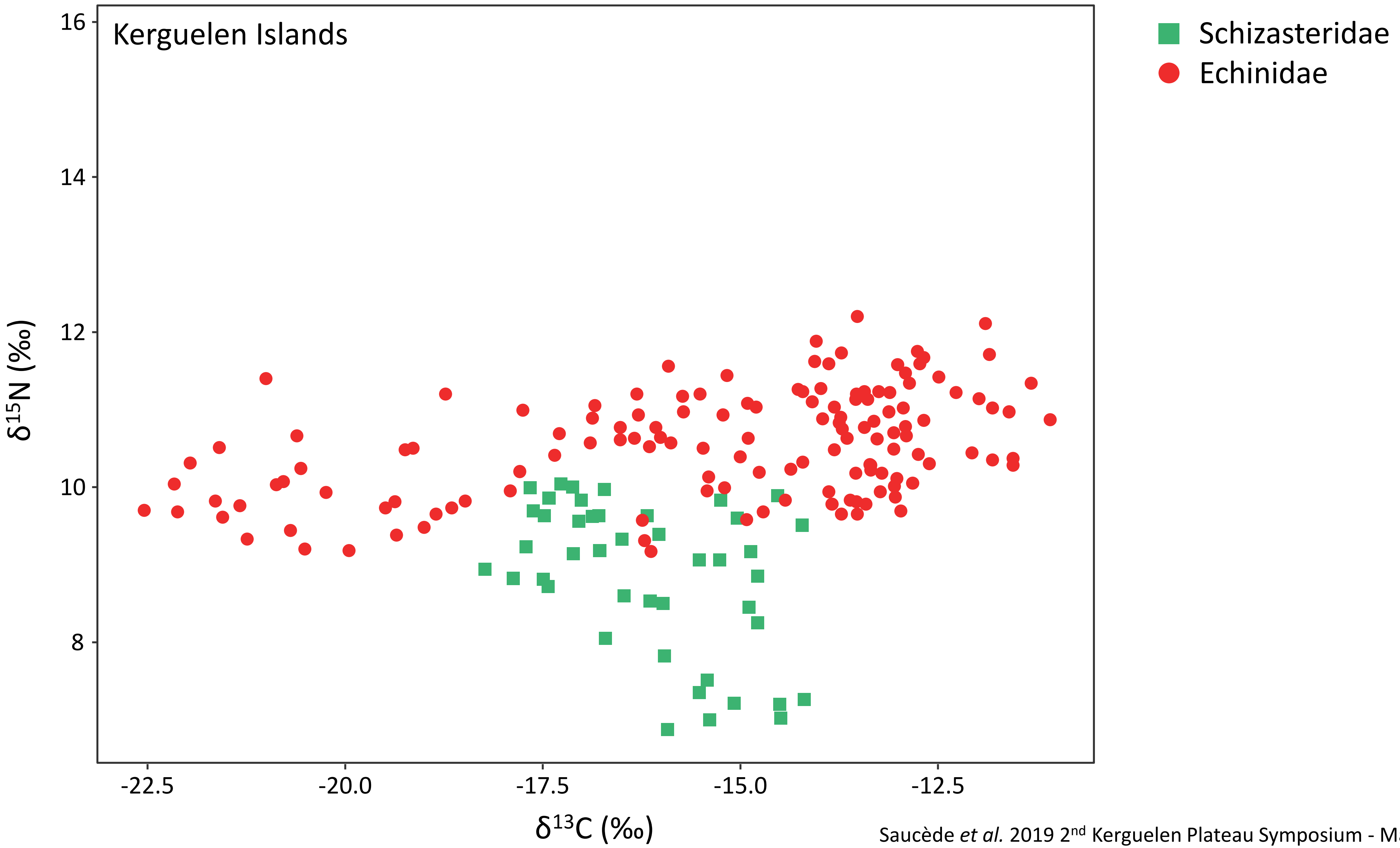


Trophic plasticity: Echinoids



Saucède *et al.* 2019 2nd Kerguelen Plateau Symposium - Marine ecosystem and fisheries: 95-116

Trophic plasticity: Echinoids



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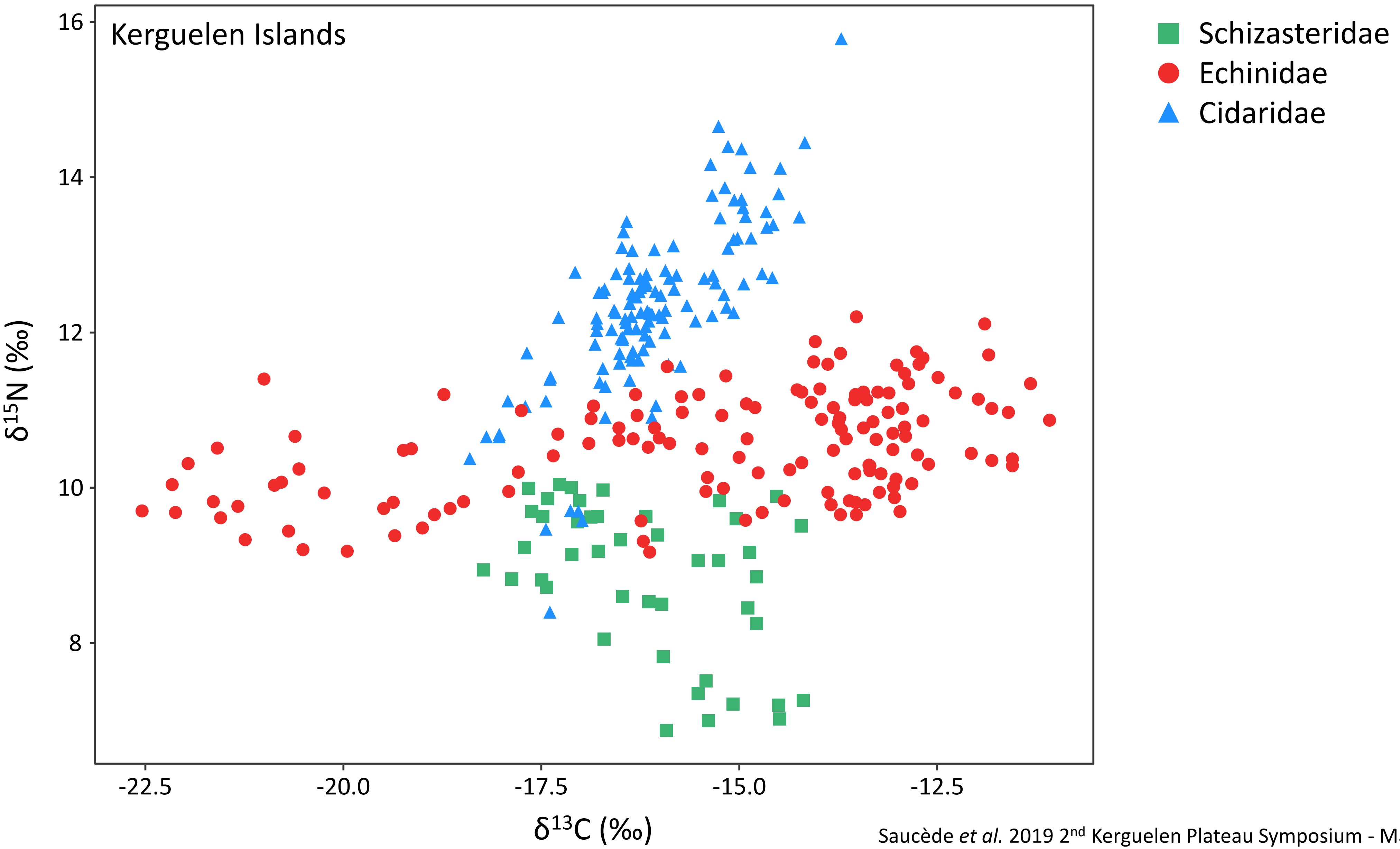

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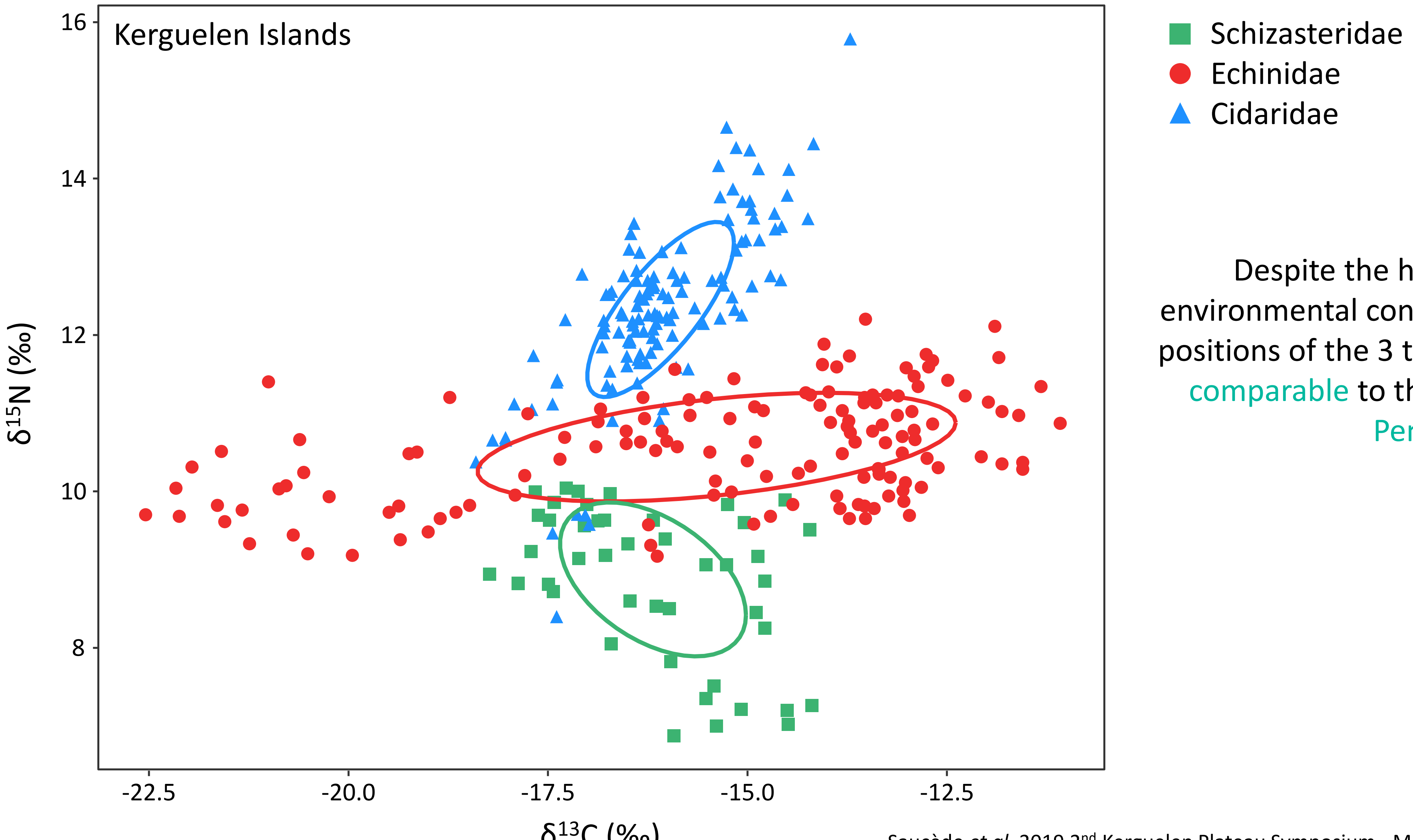
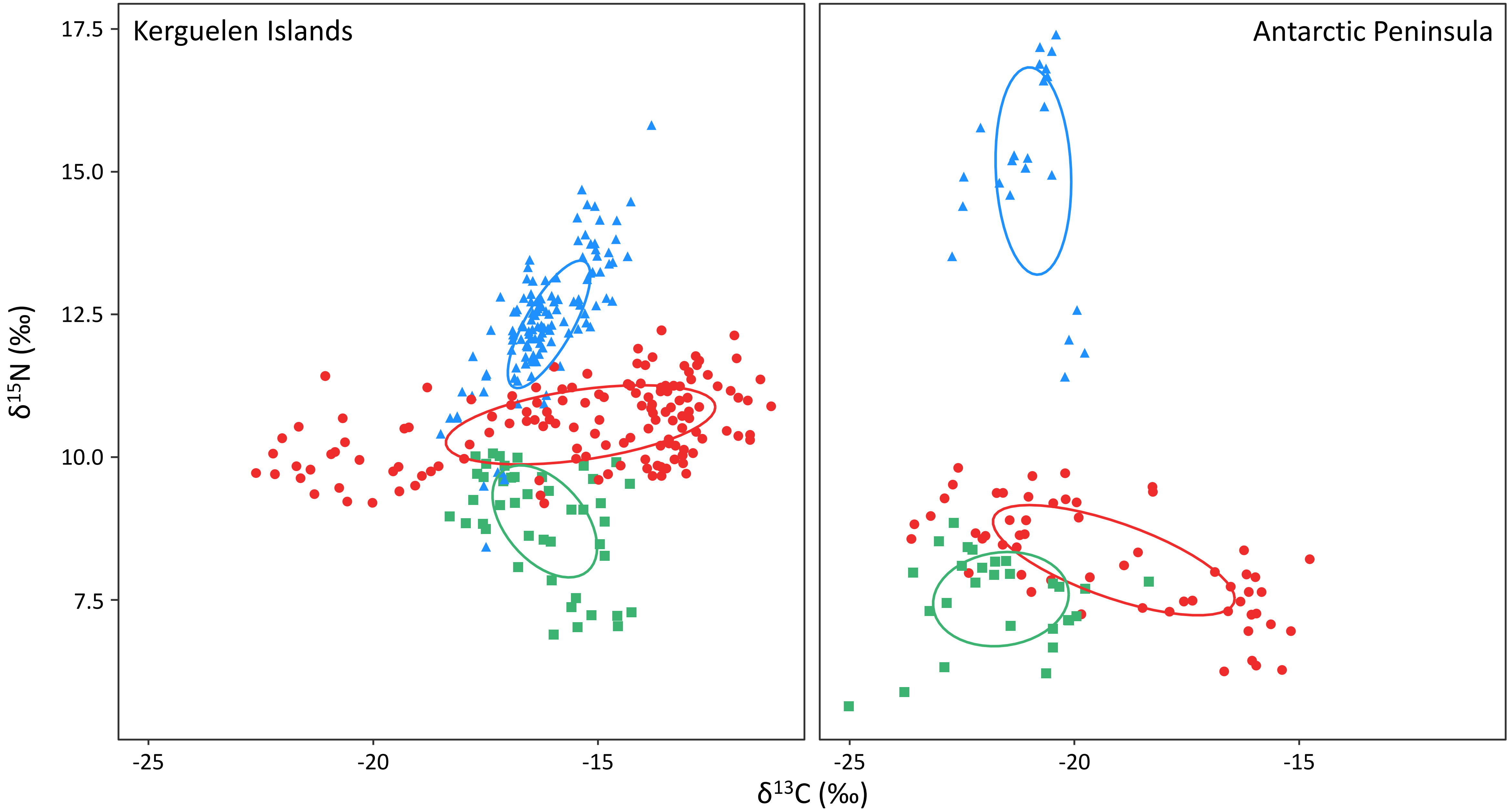


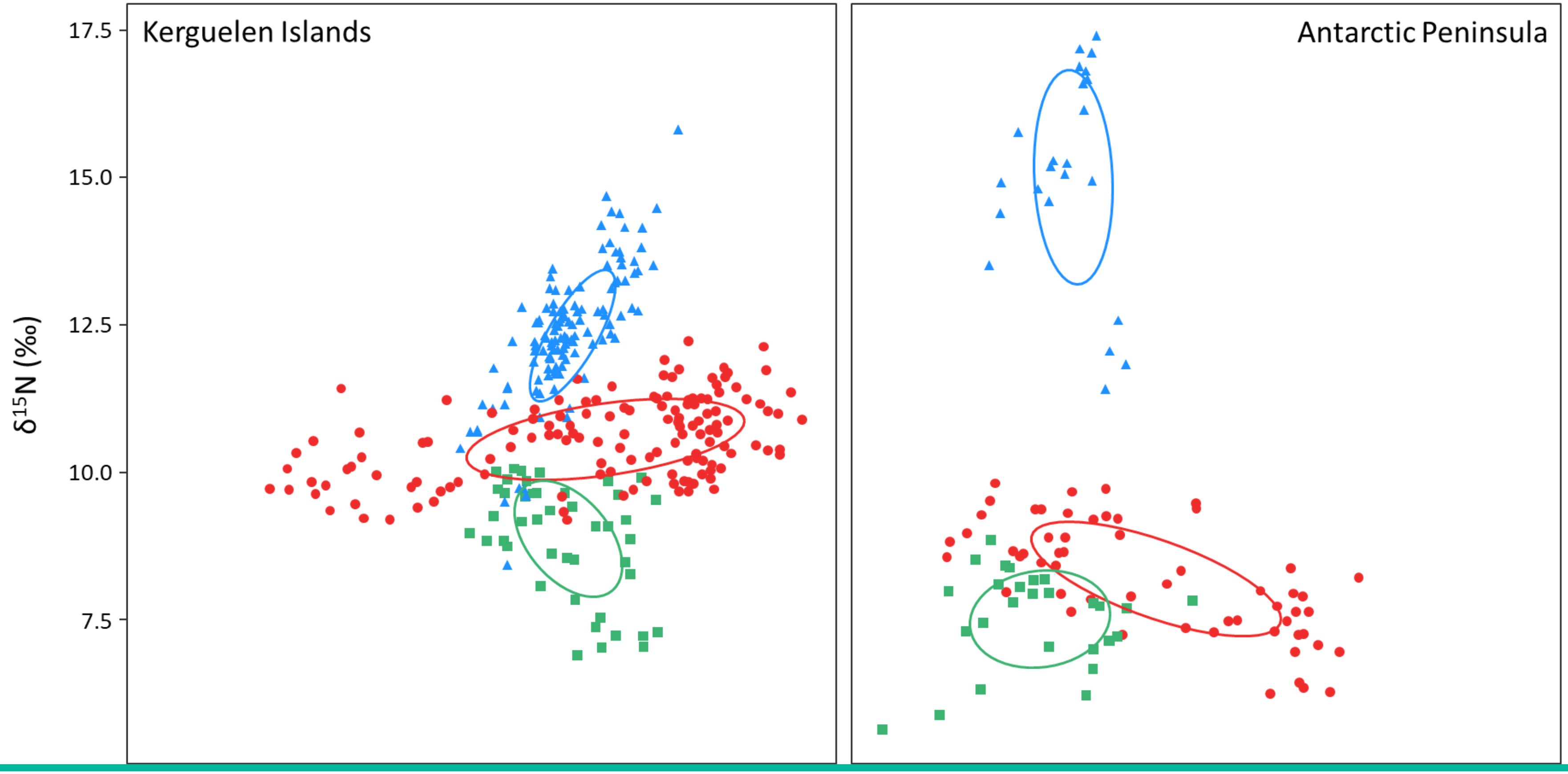
Despite the huge difference in environmental conditions, the respective positions of the 3 taxa isotopic niches are comparable to those of the Antarctic Peninsula

Saucède *et al.* 2019 2nd Kerguelen Plateau Symposium - Marine ecosystem and fisheries: 95-116

Trophic plasticity: Echinoids



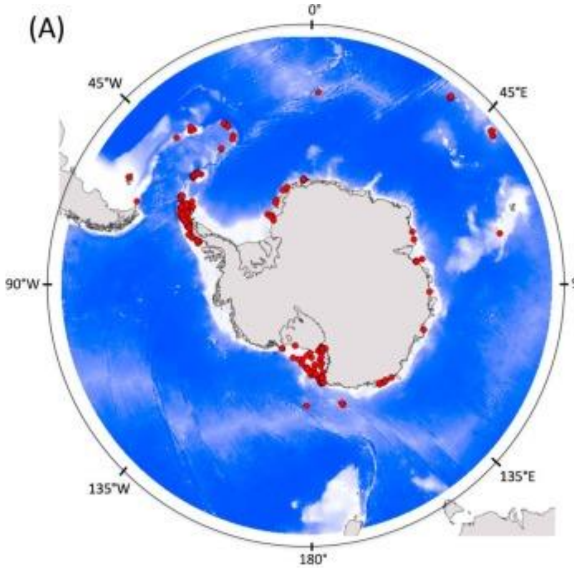
Trophic plasticity: Echinoids



Environmental variations have contrasted influence on Echinoid trophic ecology: different taxa have different degrees of plasticity, and this plasticity seems underlied by different feeding behaviours

The way in which each taxon exploited trophic resources across environmental gradients seemed conserved in different food webs

Trophic plasticity: *Odontaster validus*



Circumantarctic distribution + some Subantarctic locations

One of the most common benthic consumers in coastal Antarctica, can reach high densities (up to 20 ind.m^{-2})

Considered a keystone species: can influence benthic community structure through direct (spongivory) and indirect (echinodermivory) control of sponge populations

Map from Guillaumot *et al*. 2019 Progr. Oceanogr. 175: 198-207

Trophic plasticity: *Odontaster validus*

Pack hunting on larger sea stars

Scavenging

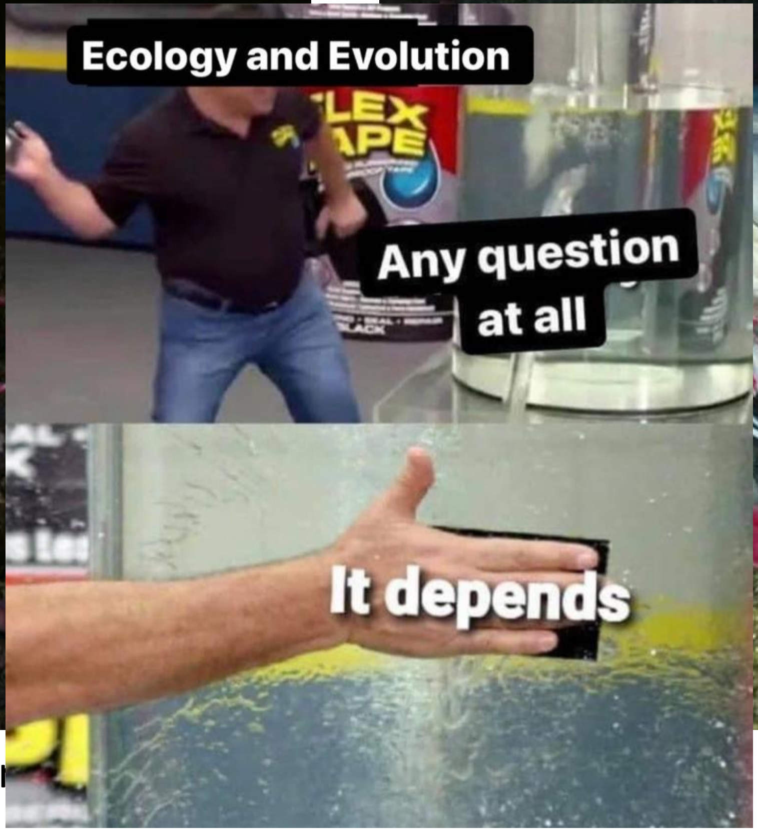
Multiple ecosystem roles mediated by feeding habits

According to behavioural observations: generally considered a predator / scavenger

Is this assumption backed up by trophic markers?

Images: Norbert Wu & Peter Brueggeman

Trophic plasticity: *Odontaster validus*



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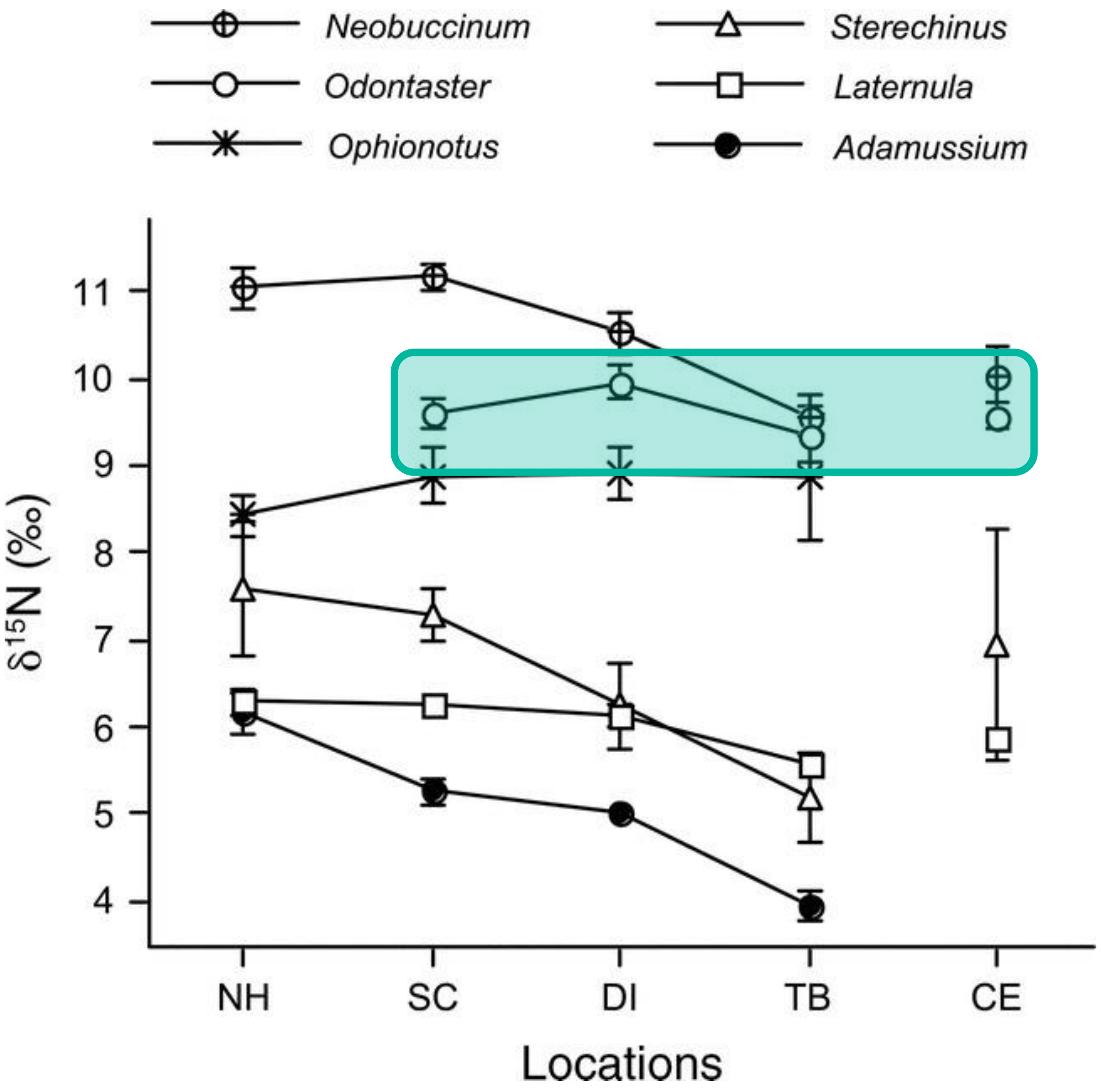
Trophic plasticity: *Odontaster validus*

McMurdo Sound, Ross Sea



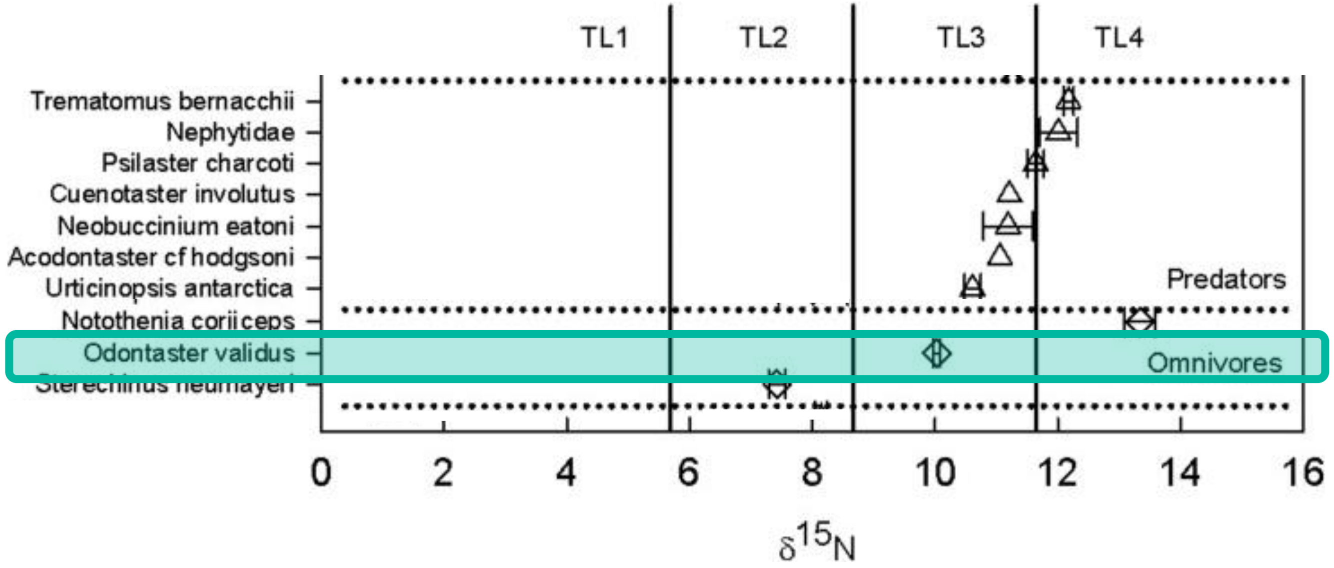
O. validus feeds at relatively high trophic level (at least one trophic level higher than *Laternula elliptica* or *Adamussium colbecki*) in all stations

Compatible with predation / scavenging

Norkko *et al.* 2007 Ecology 88: 2810-2820

Trophic plasticity: *Odontaster validus*

Windmill Islands, East Antarctica

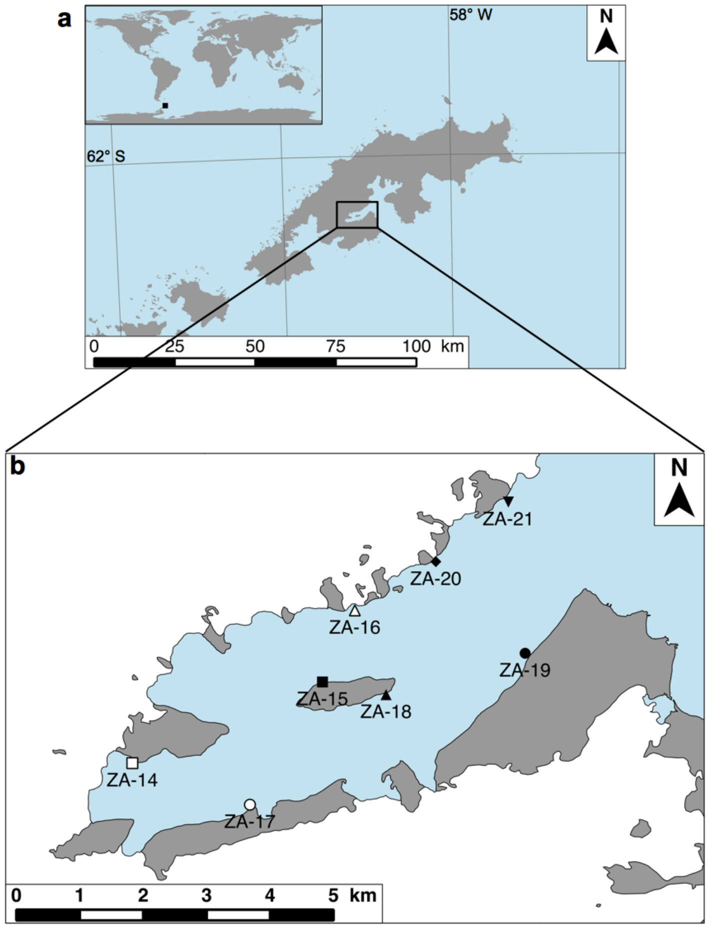


O. validus' trophic position notably lower than many predators, including other sea stars: omnivore

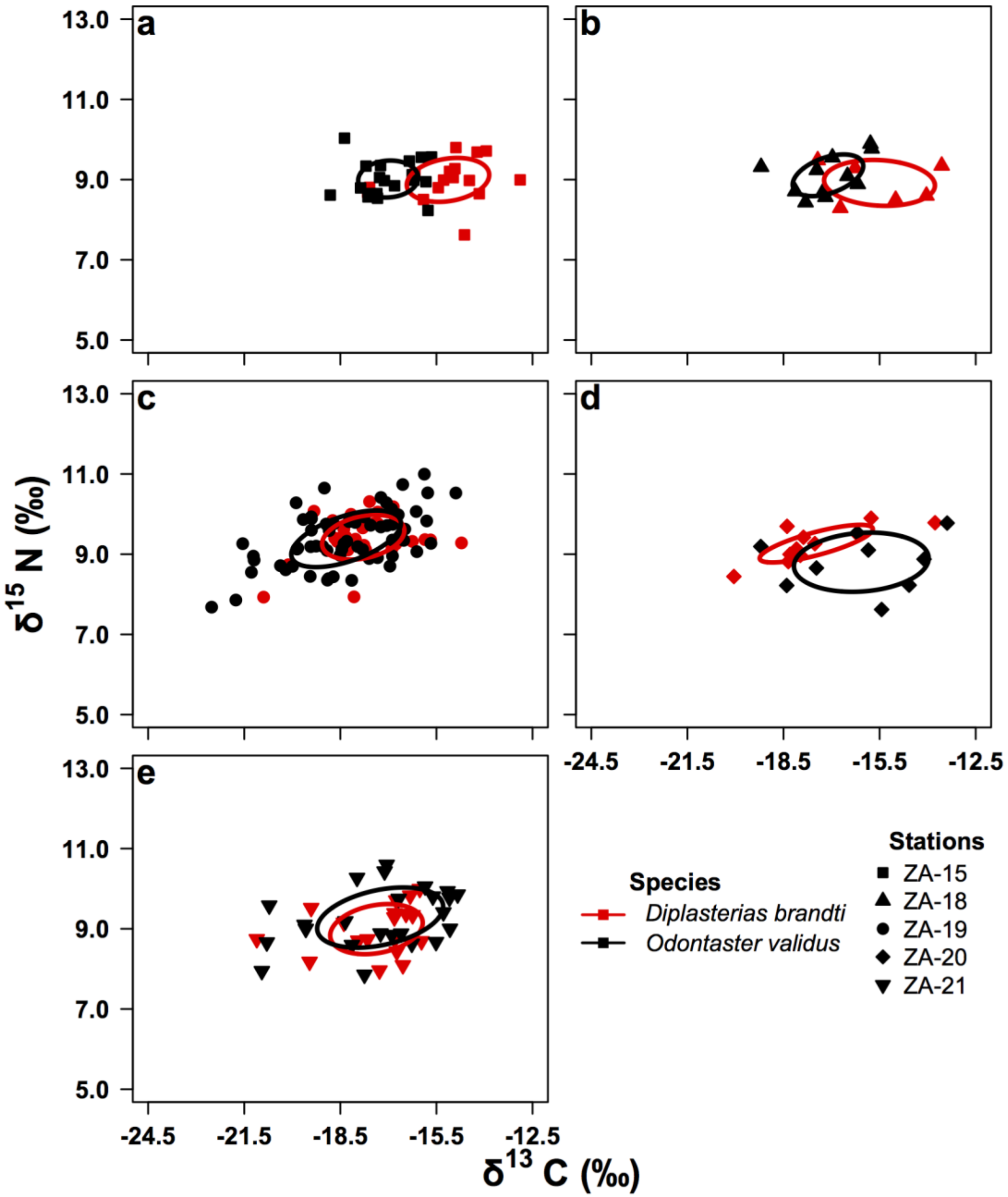
Gillies *et al.* 2012 Est. Coast. Shelf Sci. 97: 44-57

Trophic plasticity: *Odontaster validus*

Ezcurra Inlet, King George Island



Environmental gradient from inner (strong glacier influence) to outer inlet

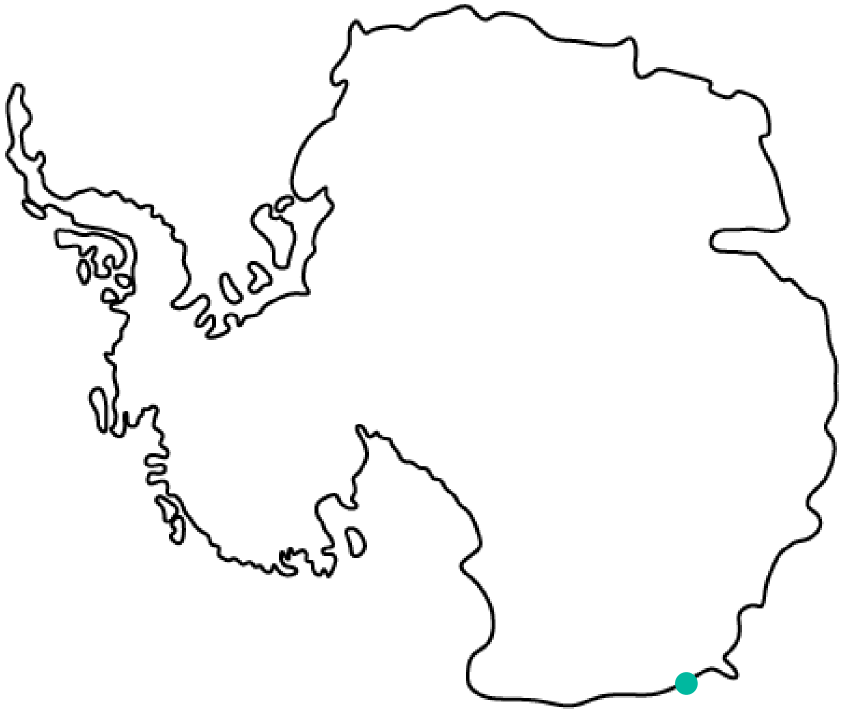


Differences across the gradient

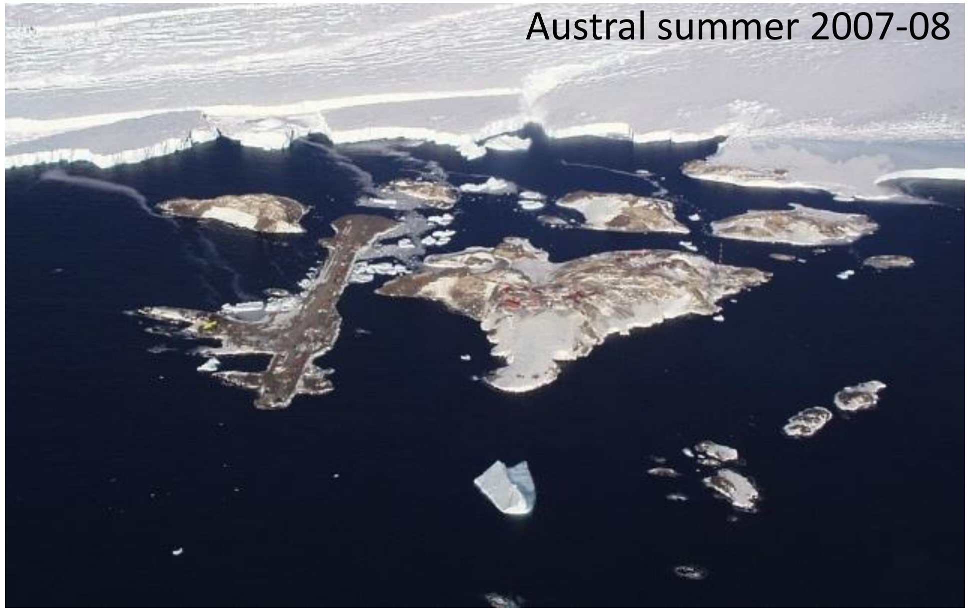
- Diet composition (ellipse position)
- Trophic diversity (ellipse area)
- Diet similarity with other species (ellipse overlap)

Le Bourg *et al.* 2021 Mar. Ecol. Progr. Ser. 674: 189-202

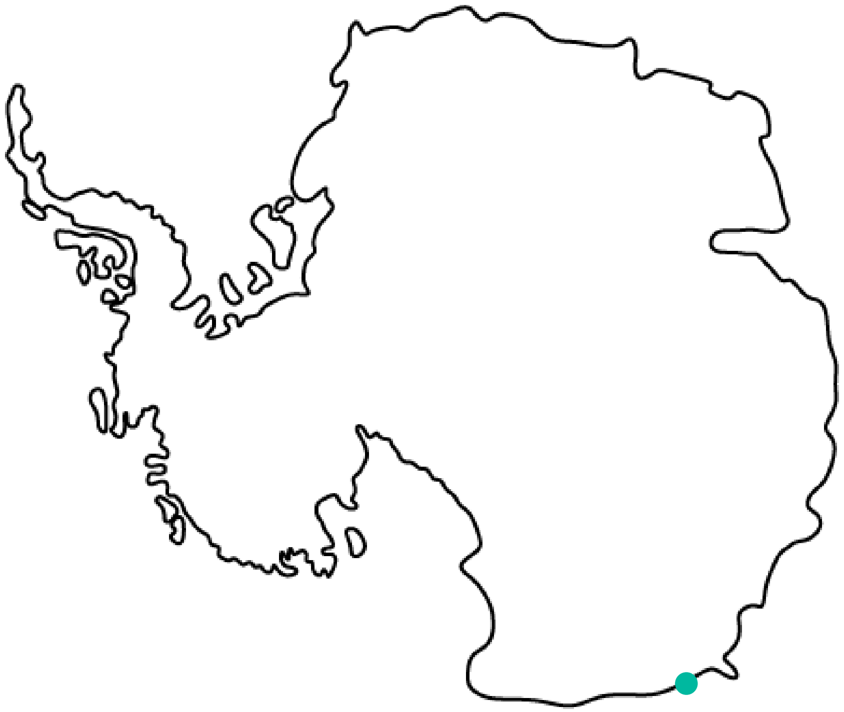
Trophic plasticity: *Odontaster validus*



East Antarctica, Adélie Land, Petrels Island



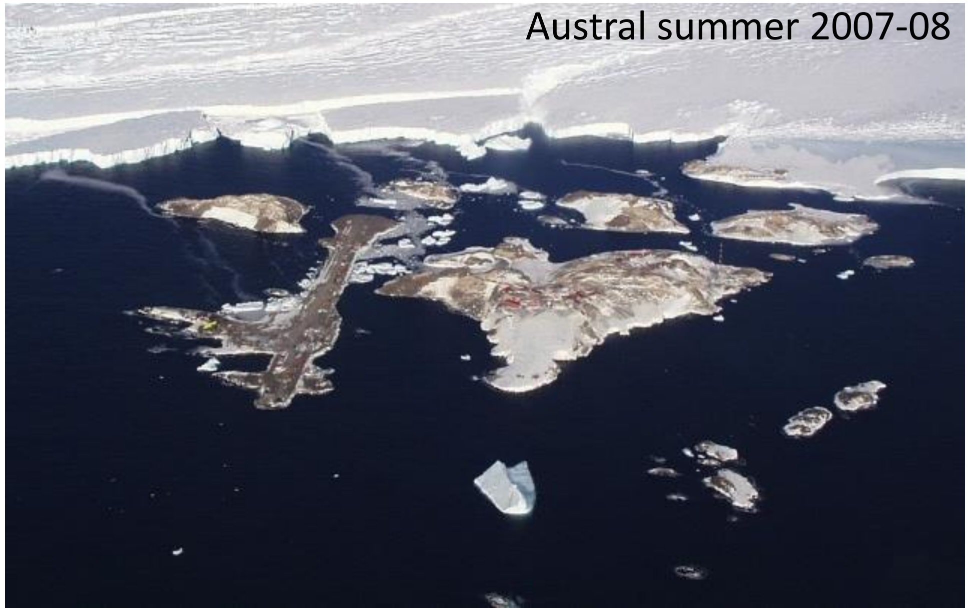
Trophic plasticity: *Odontaster validus*

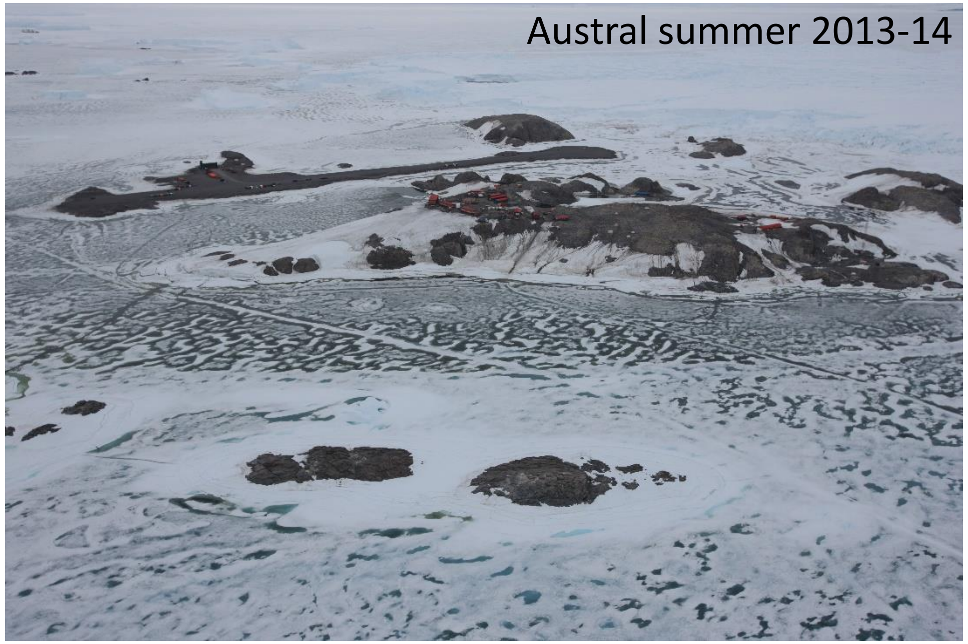


East Antarctica, Adélie Land, Petrels Island

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

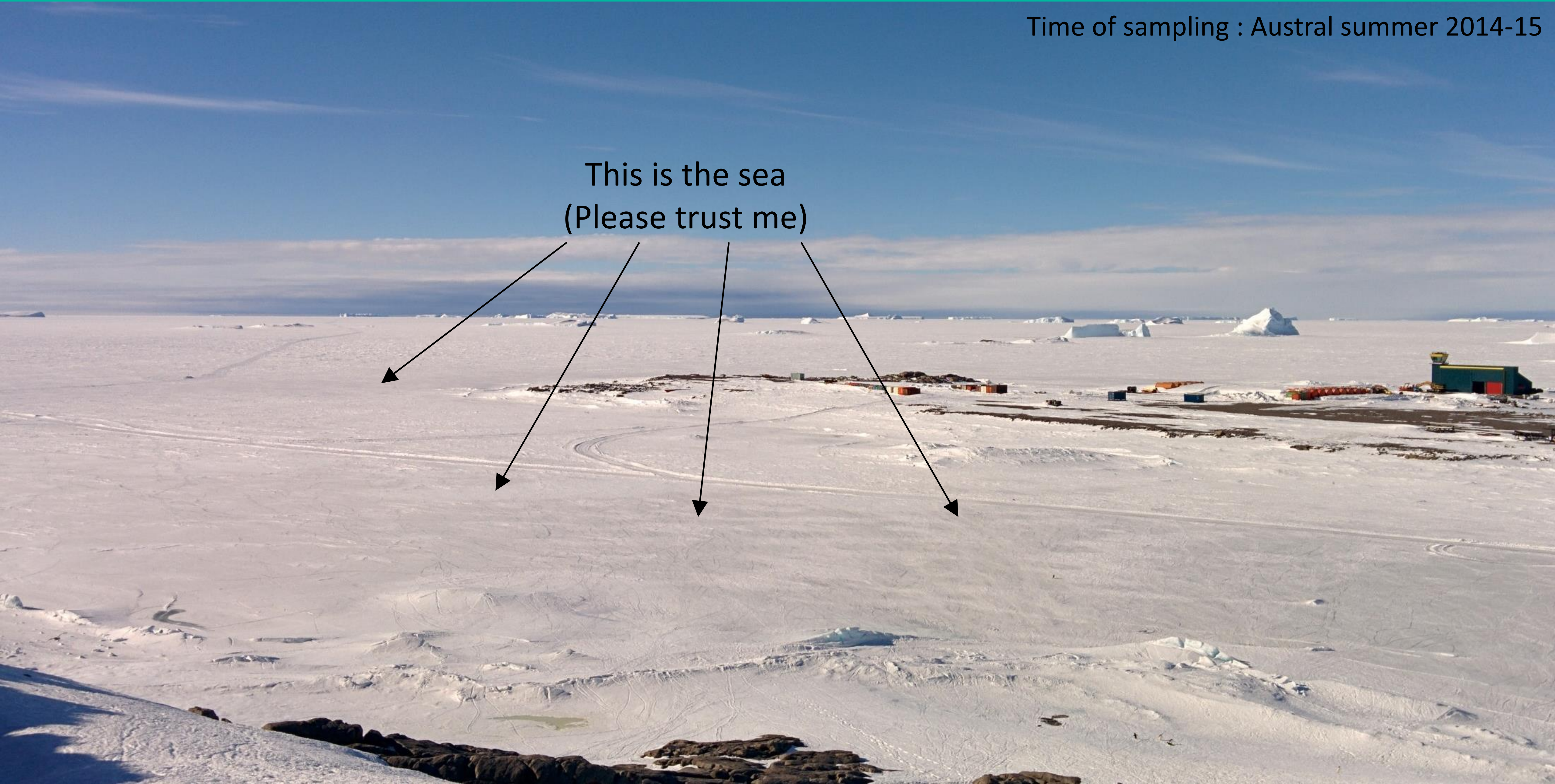
No seasonal breakup during austral summers 2013-14 and 2014-15





Trophic plasticity: *Odontaster validus*

Time of sampling : Austral summer 2014-15



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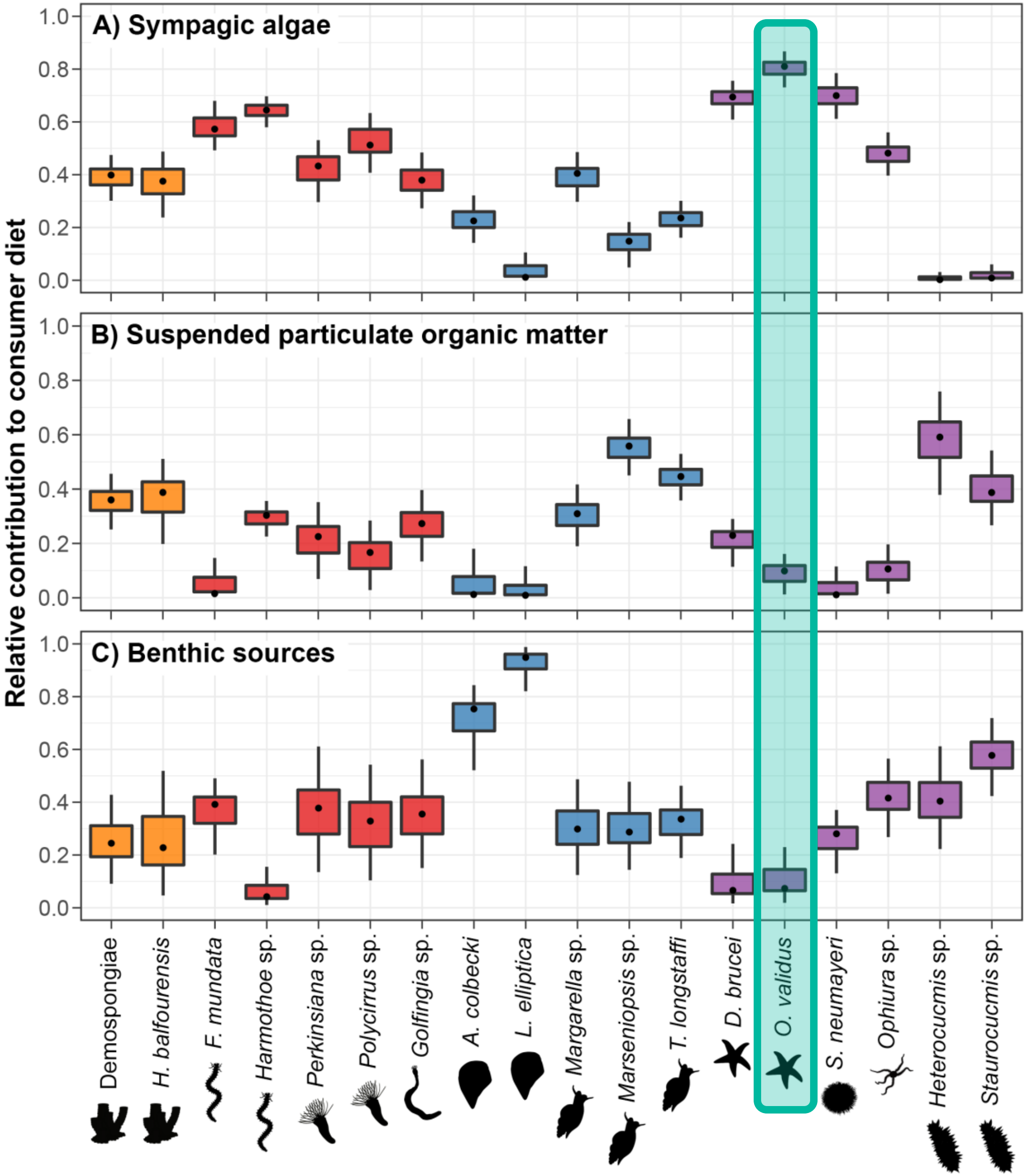
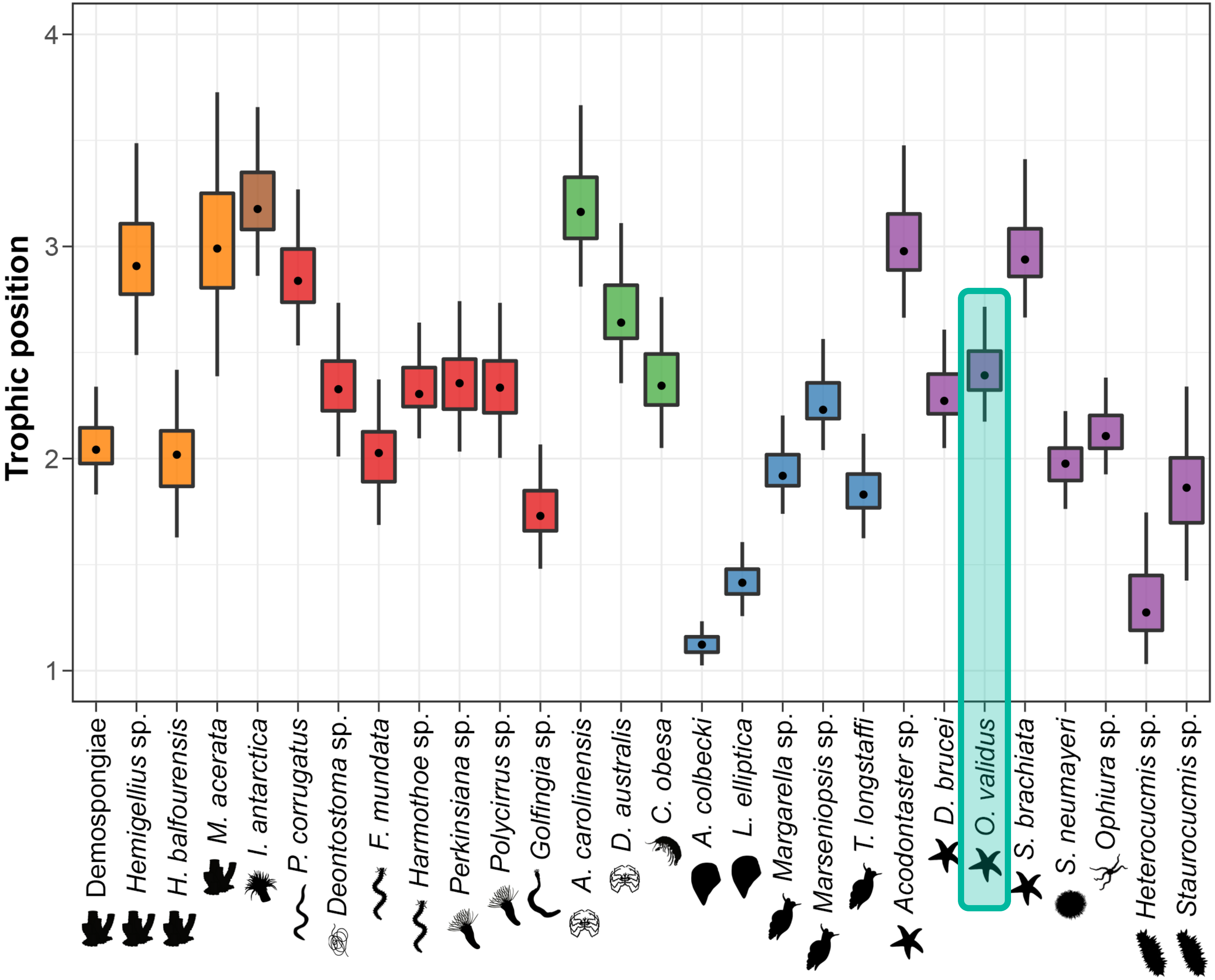


O. validus mostly relies on sympagic production (73-87% of its diet is derived of sea ice algae)

Michel *et al.* 2019 Sci. Rep. 9: 8062

Trophic plasticity: *Odontaster validus*



Low trophic position (2.4)

Omnivore with predominantly herbivore feeding habits

Michel *et al.* 2019 Sci. Rep. 9: 8062

Trophic plasticity

Trophic plasticity: the ability of a species to display different feeding habits according to varying environmental conditions

+: could allow species to shift their diet to match their new environments

-: consumers feeding on less profitable items could not meet their nutritional requirements

Trophic plasticity

What is the extent of trophic plasticity in key benthic species?

How could trophic plasticity influence resilience of Antarctic zoobenthos in the face of environmental changes?

How will it modulate their role in food webs?

Trophic plasticity

Estimating Tipping points in habitability of ANtarctic benthic ecosystems under GlObal future climate change scenarios - TANGO (2021-2025)

TANGO EXPEDITION ANTARCTICA - 2023

belspo

TANGO

Martin DOGNIEZ

Gilles LEPOINT

Anthony VOISIN

LIÈGE université FOCUS

Trophic plasticity

What is the extent of trophic plasticity in key benthic species?

How do environmental factors drive this plasticity?

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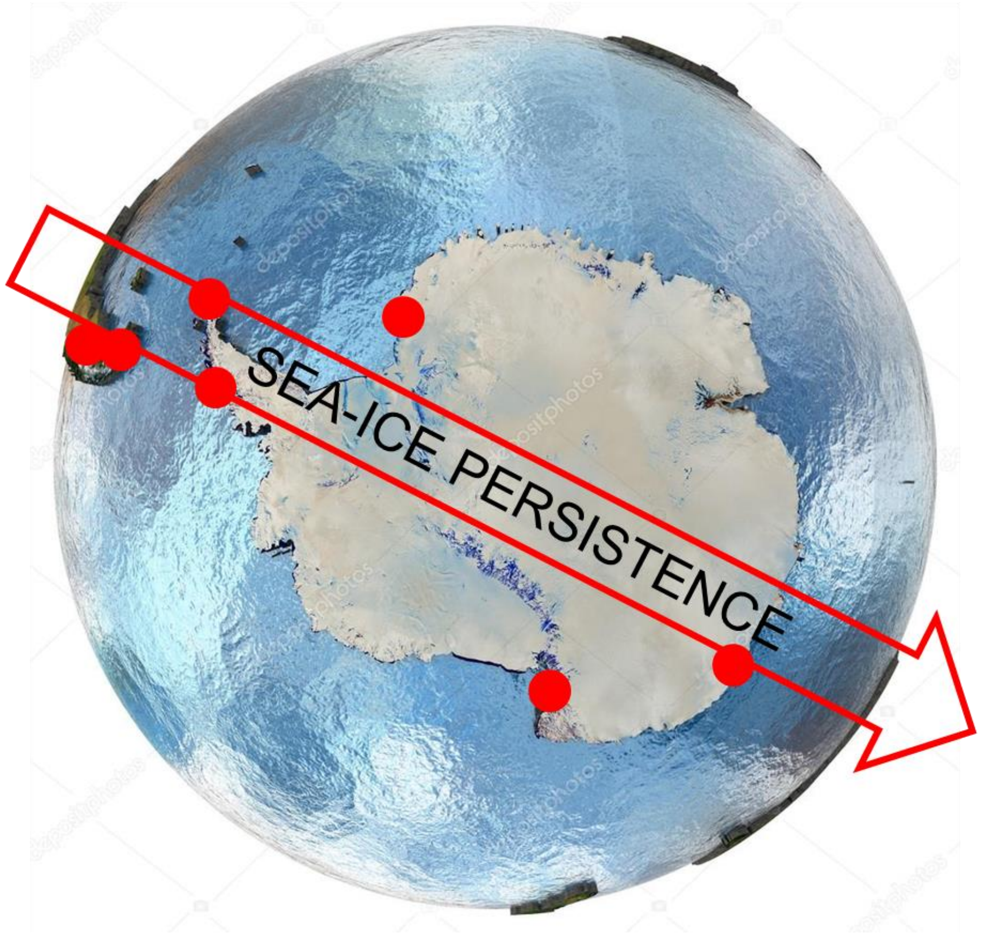
Trophic plasticity

Pan-ANtarctic IsotopiC ecology (PANIC)

A continental-scale field study to understanding effects of sea ice dynamics on Antarctic benthic ecology



Edoardo CALIZZA

Sara BRUNORI

SAPIENZA
UNIVERSITÀ DI ROMA

Trophic plasticity

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How do environmental factors drive this plasticity?

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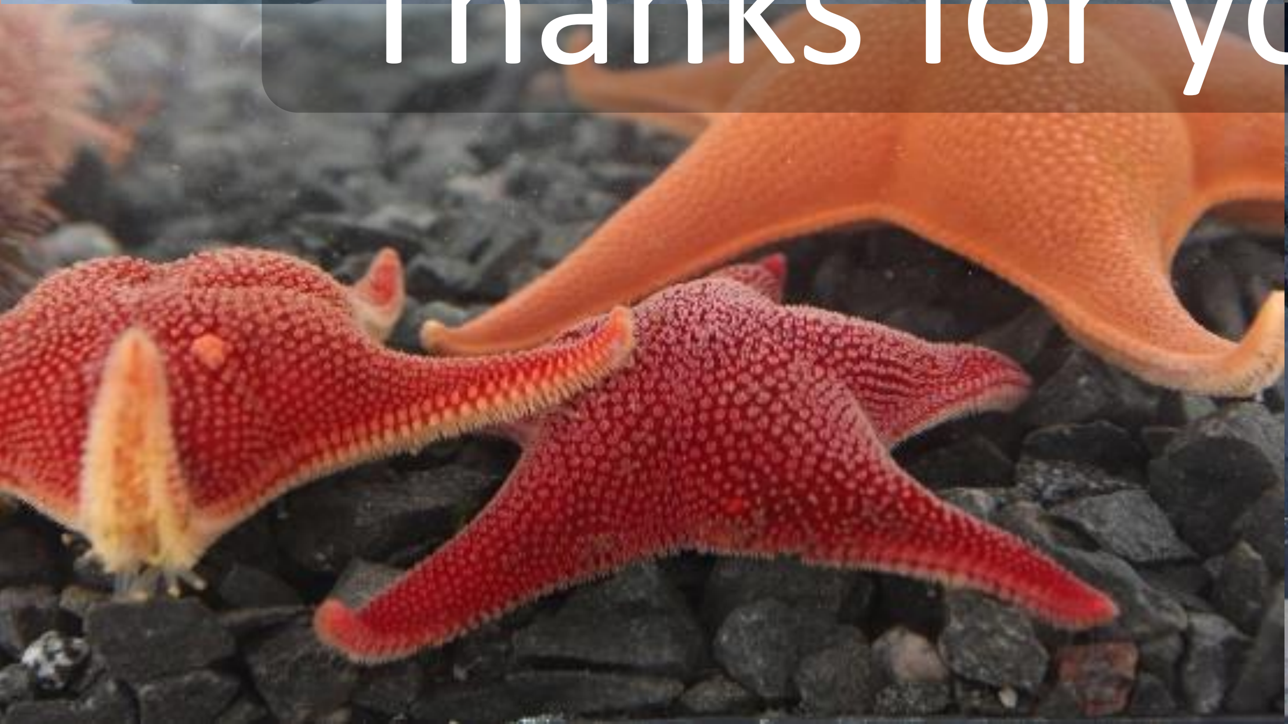
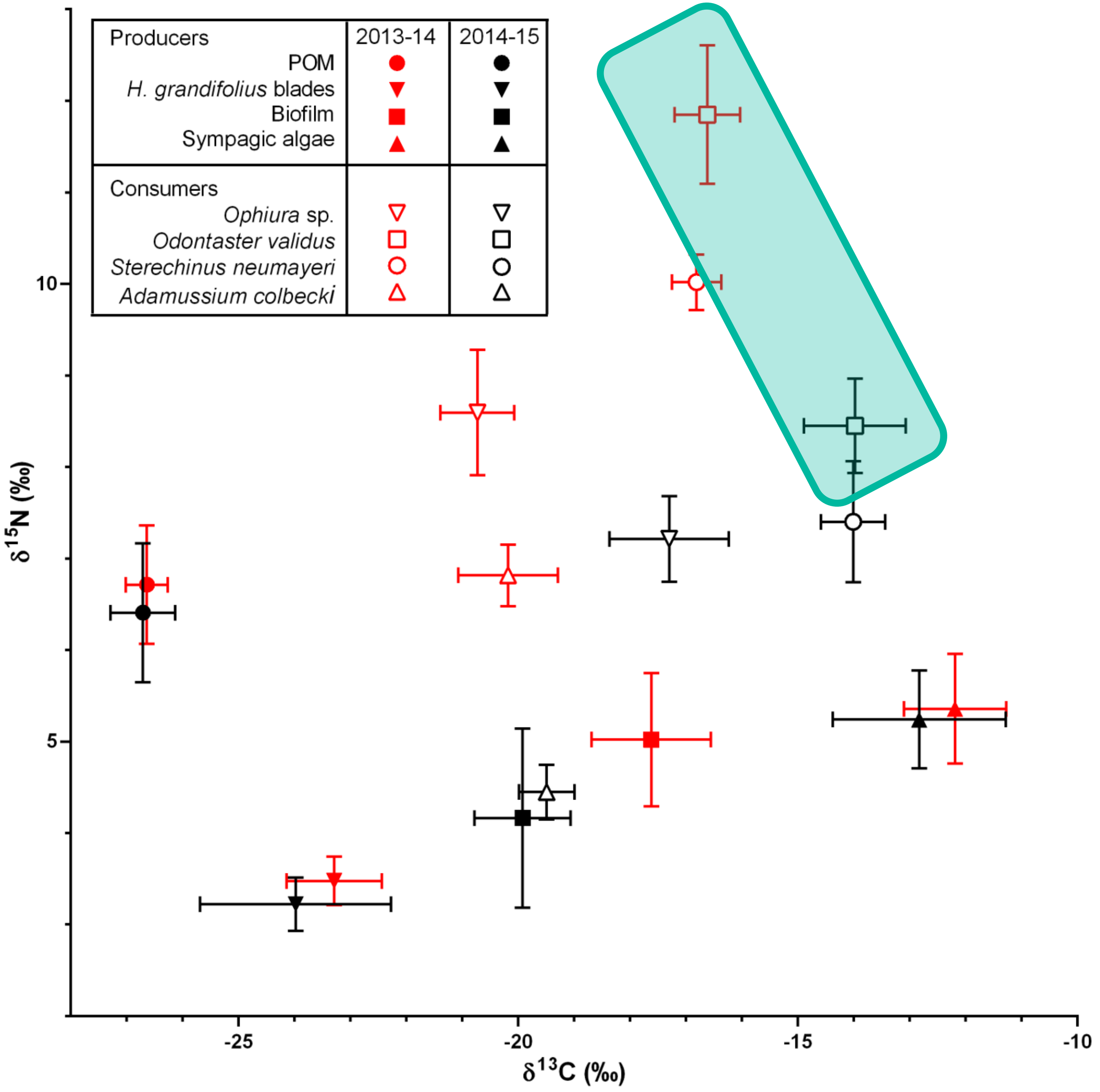
How will it modulate their role in food webs?

How does trophic plasticity impact consumer metabolism & fitness?

Thanks for your attention



Trophic plasticity: *Odontaster validus*



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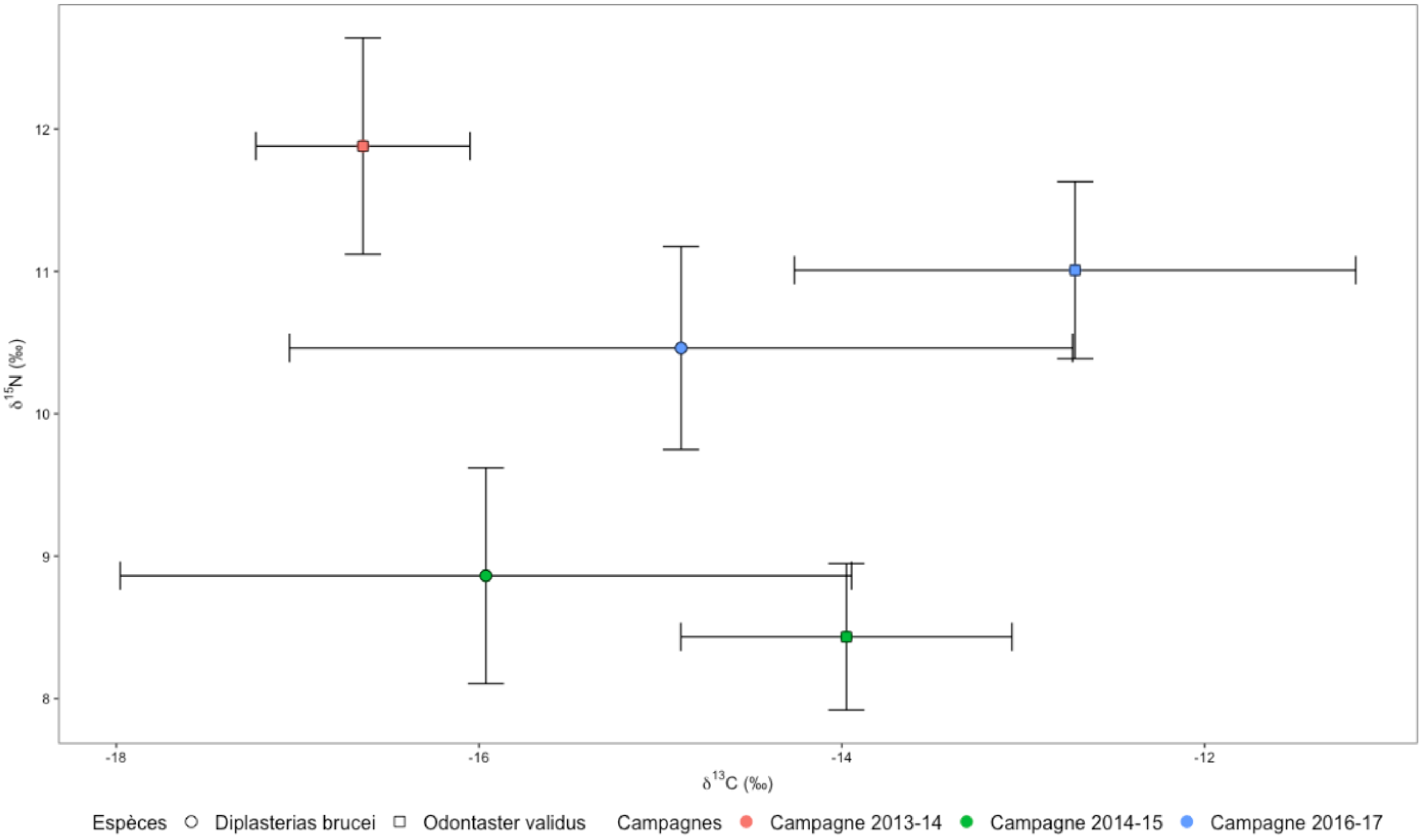
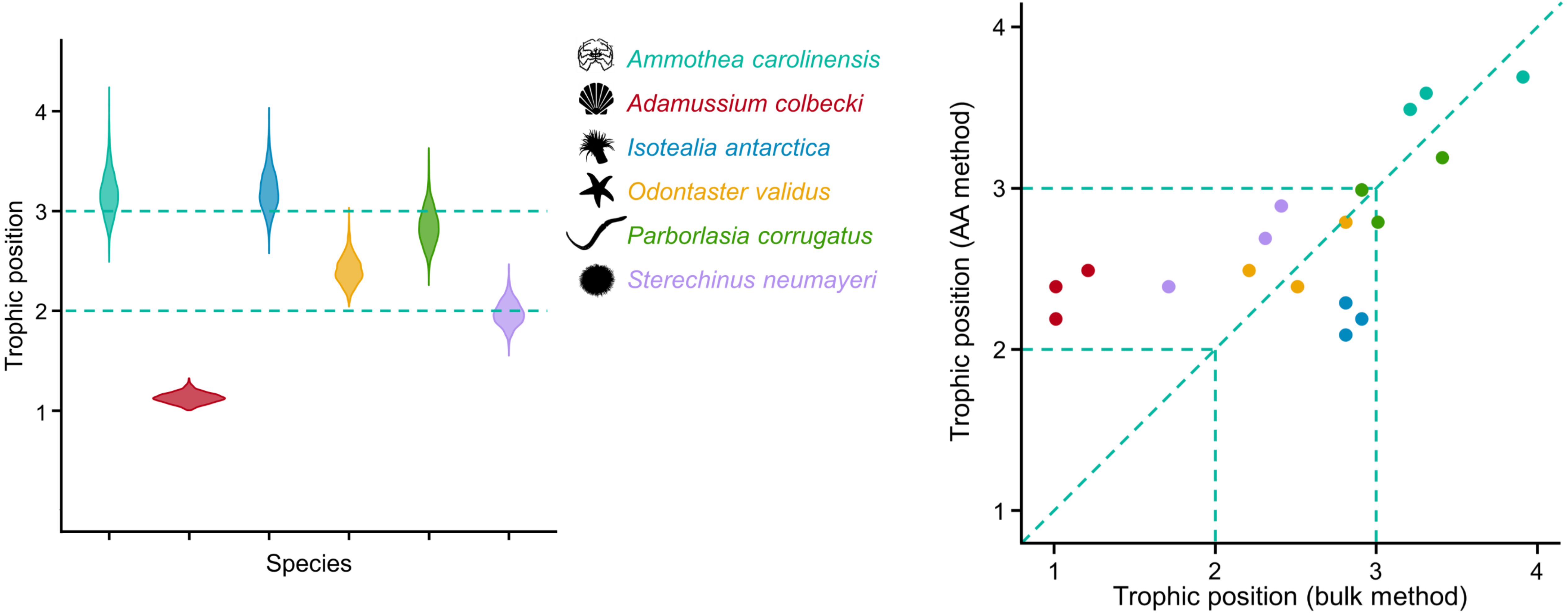
Trophic plasticity: *Odontaster validus*



Trophic plasticity: *Odontaster validus*



Trophic plasticity: *Odontaster validus*