Ecologia e biodiversità degli ambienti glaciali

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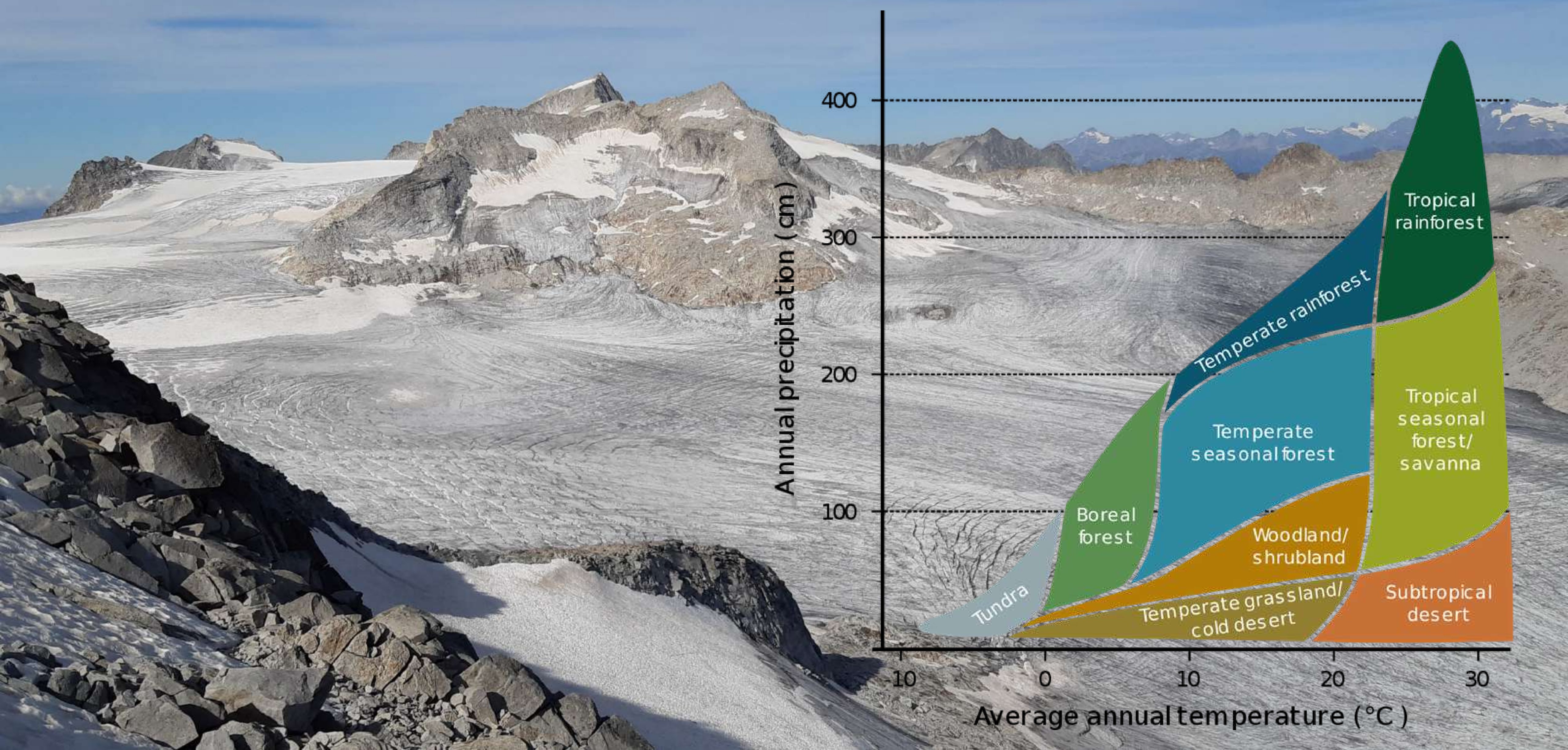
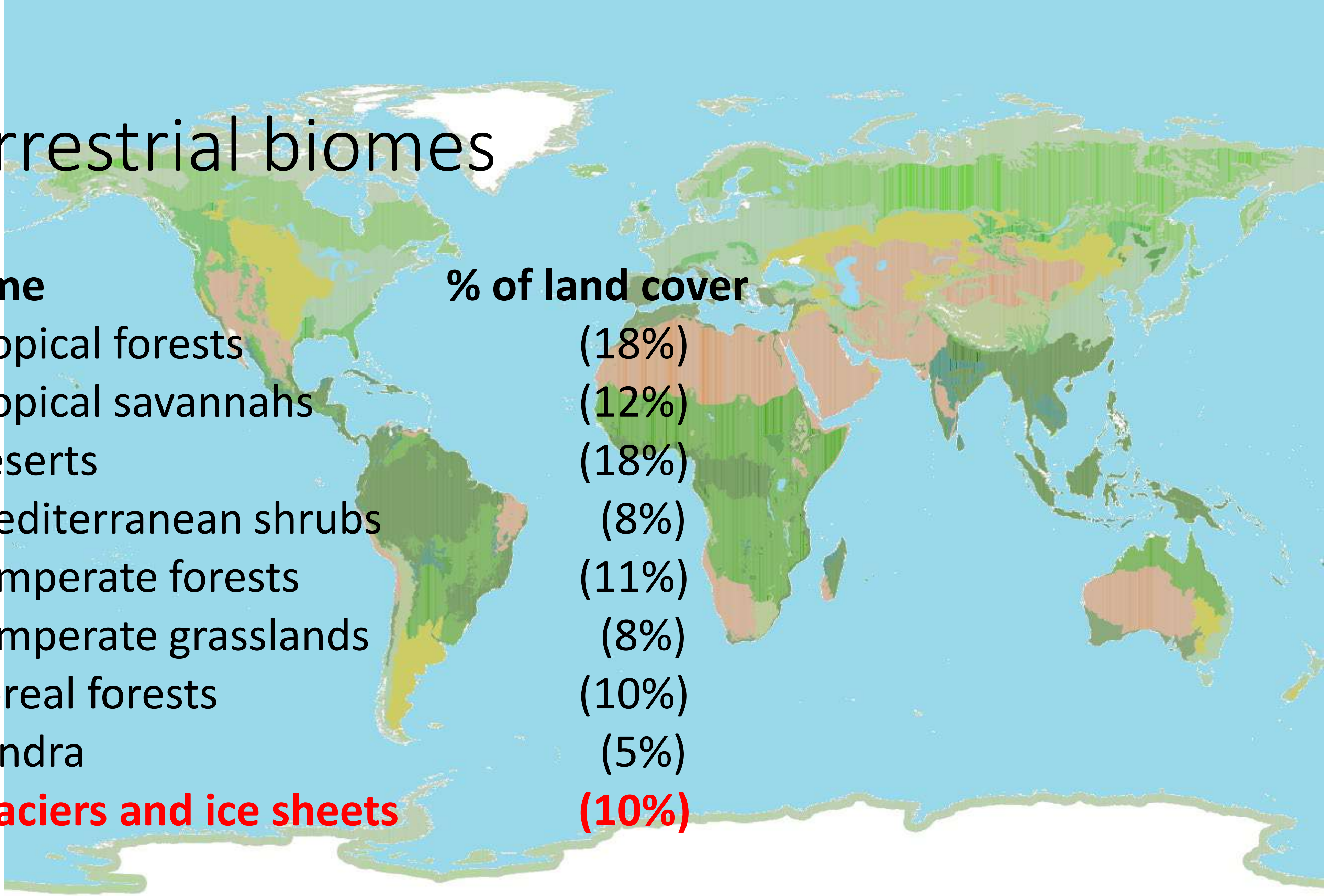
Terrestrial biomes



Terrestrial biomes



Biome	**% of land cover**
• Tropical forests	(18%)
• Tropical savannahs	(12%)
• Deserts	(18%)
• Mediterranean shrubs	(8%)
• Temperate forests	(11%)
• Temperate grasslands	(8%)
• Boreal forests	(10%)
• Tundra	(5%)
• **Glaciers and ice sheets**	**(10%)**

Opinion

Trends in Ecology and Evolution, April 2012

Cell PRESS

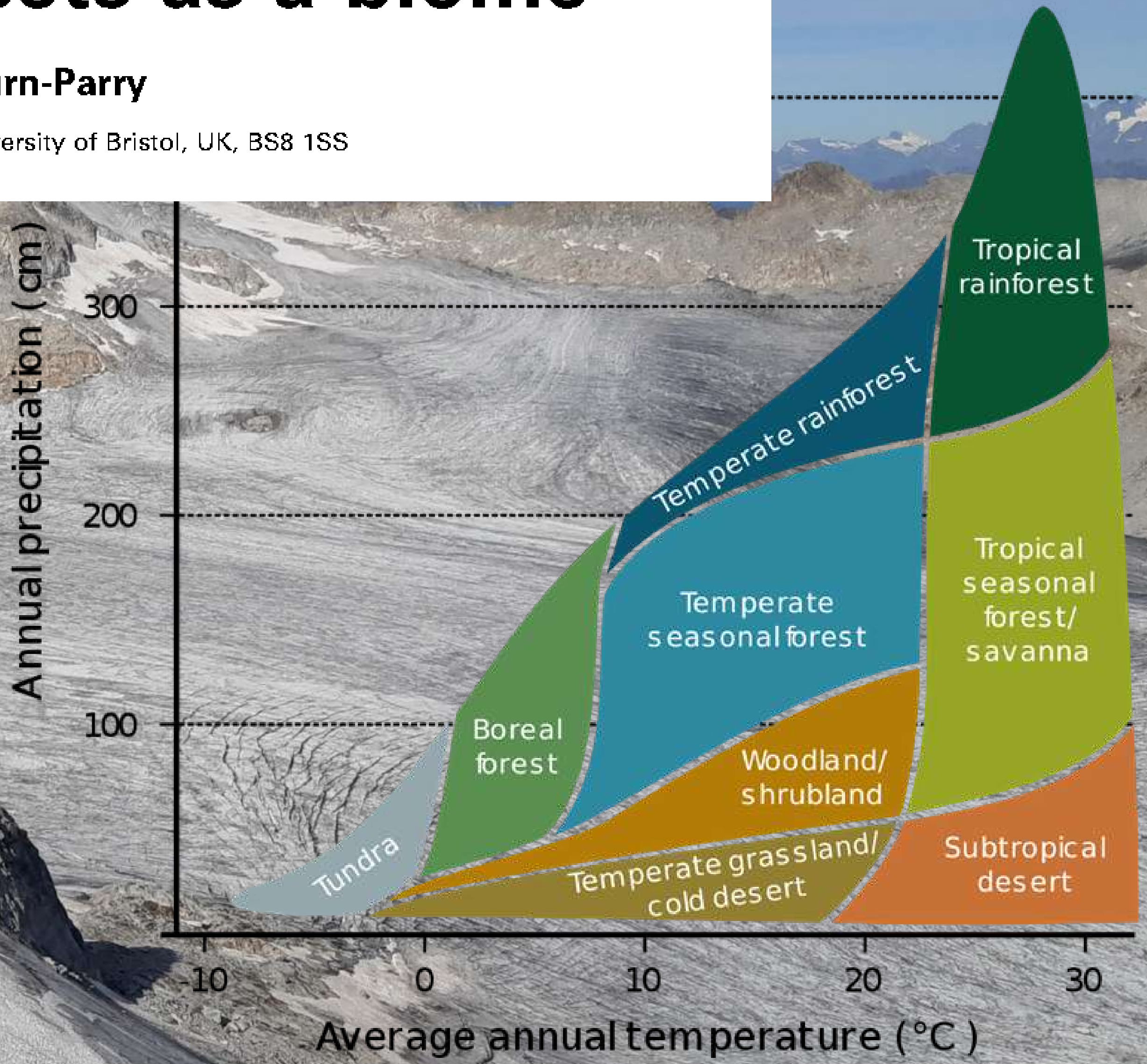
Glaciers and ice sheets as a biome

Alexandre M. Anesio and Johanna Laybourn-Parry

Bristol Glaciology Centre, School of Geographical Sciences, University of Bristol, UK, BS8 1SS

Typically dominant taxa

- Cyanobacteria
- Sphingobacteriales
- Pseudomonadales
- Rhodospirillales
- Burkholderiales
- Clostridiales



Glacier ecosystems

Glaciers host living organisms and active ecological communities

Andiperla willinki

Glacier ecosystems

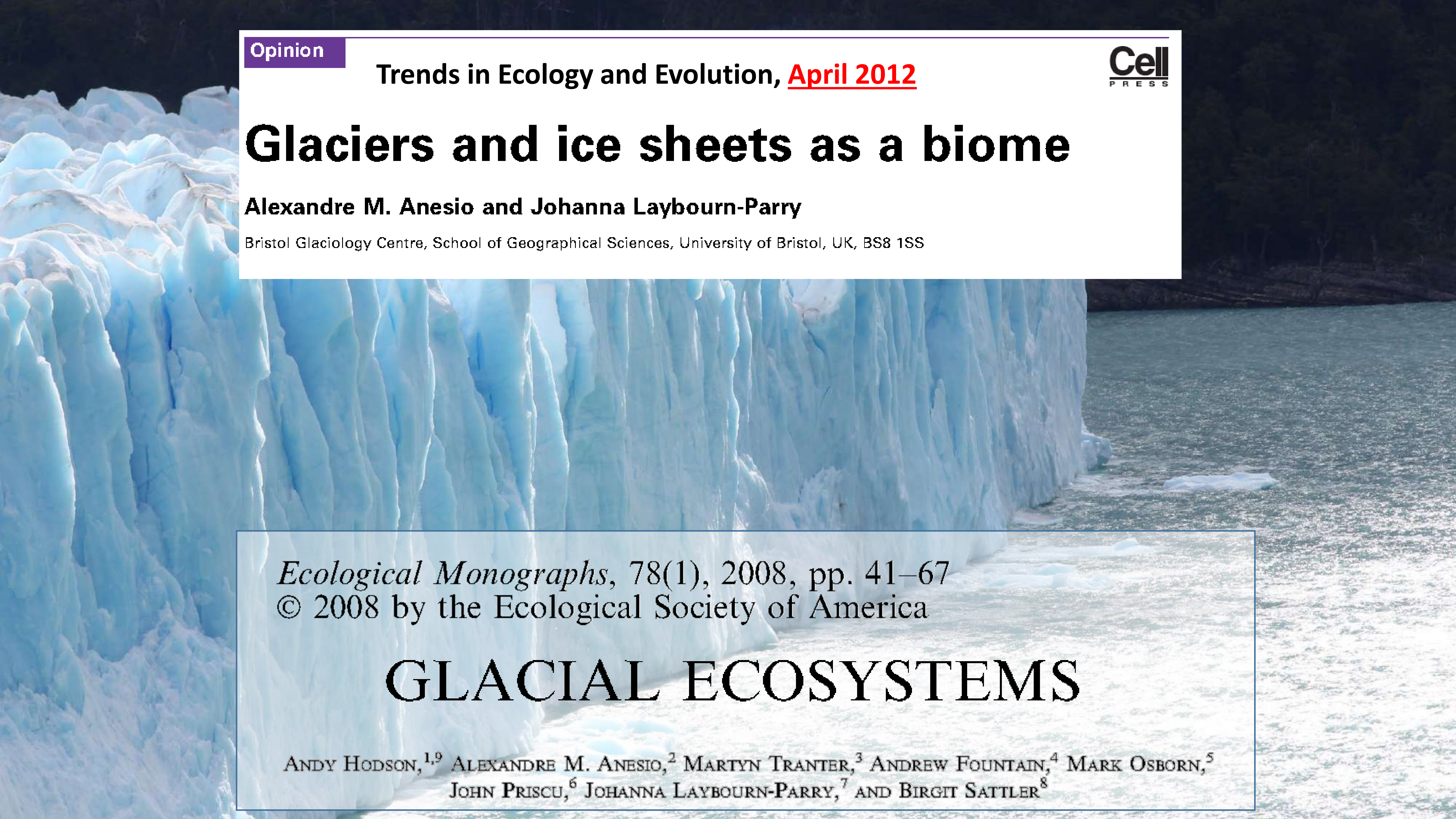
Glaciers host living organisms and active ecological communities

Diuca speculifera

Foto: BBC

Glacier ecosystems

Glaciers host living organisms and active ecological communities



Opinion

Trends in Ecology and Evolution, April 2012

Glaciers and ice sheets as a biome

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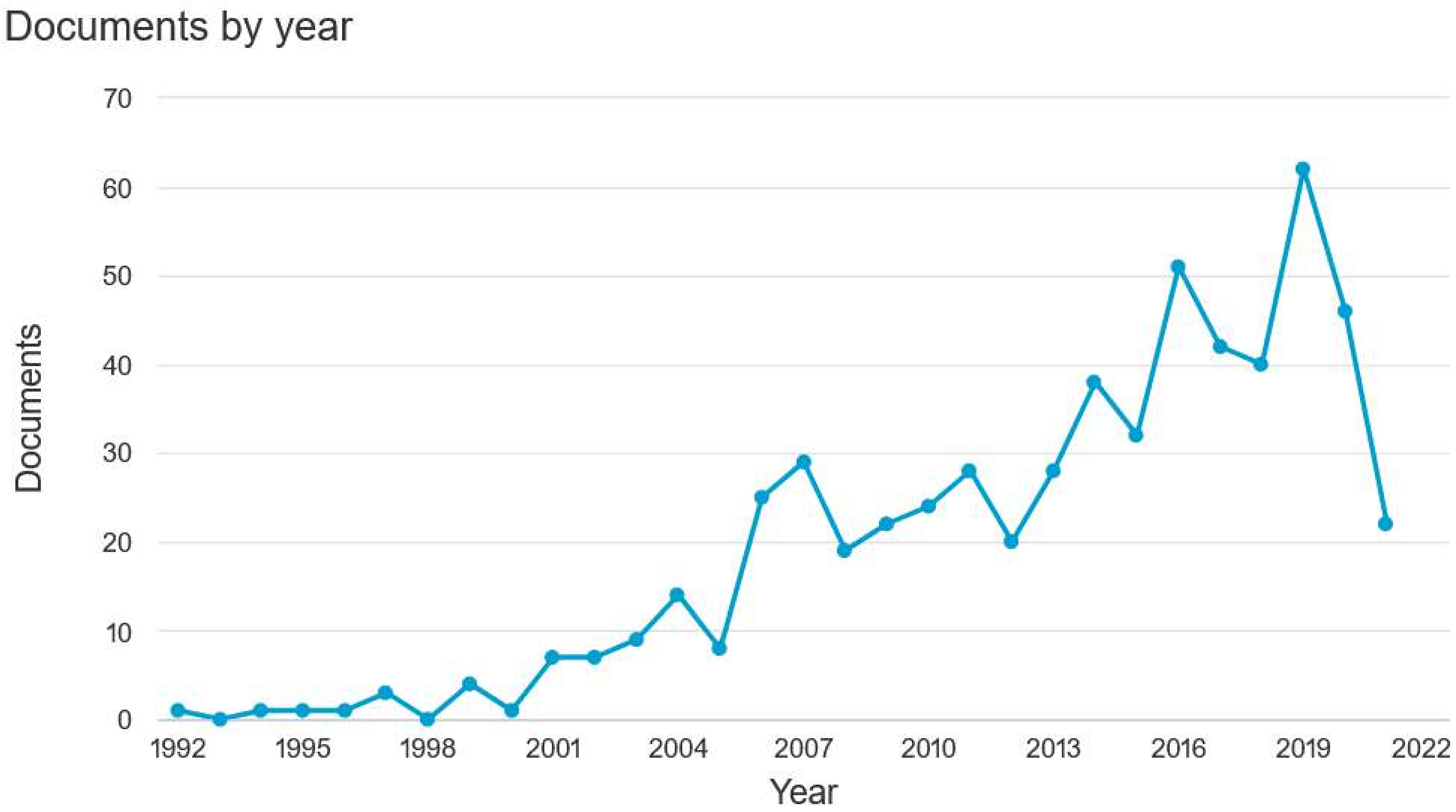
Ecological Monographs, 78(1), 2008, pp. 41–67

GLACIAL ECOSYSTEMS

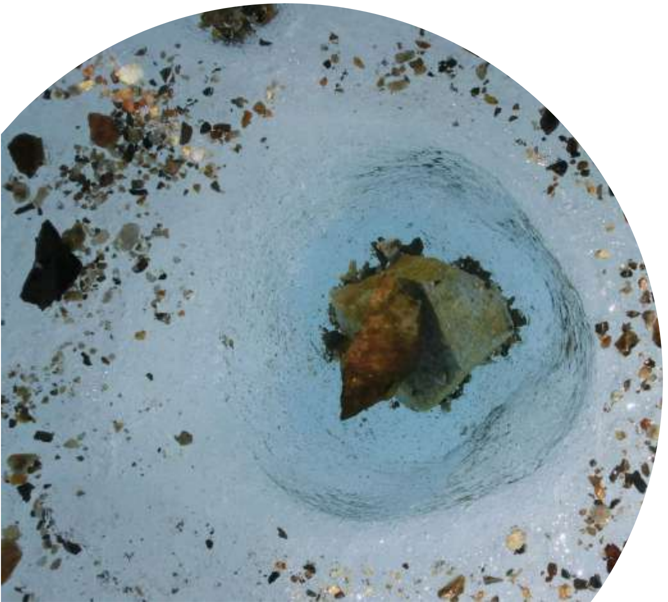
ANDY HODSON,[1,9] ALEXANDRE M. ANESIO,[2] MARTYN TRANTER,[3] ANDREW FOUNTAIN,[4] MARK OSBORN,[5] JOHN PRISCU,[6] JOHANNA LAYBOURN-PARRY,[7] AND BIRGIT SATTLER[8]

«Glacier» AND «Biodiversity» in Scopus



Biological processes and glacier dynamics

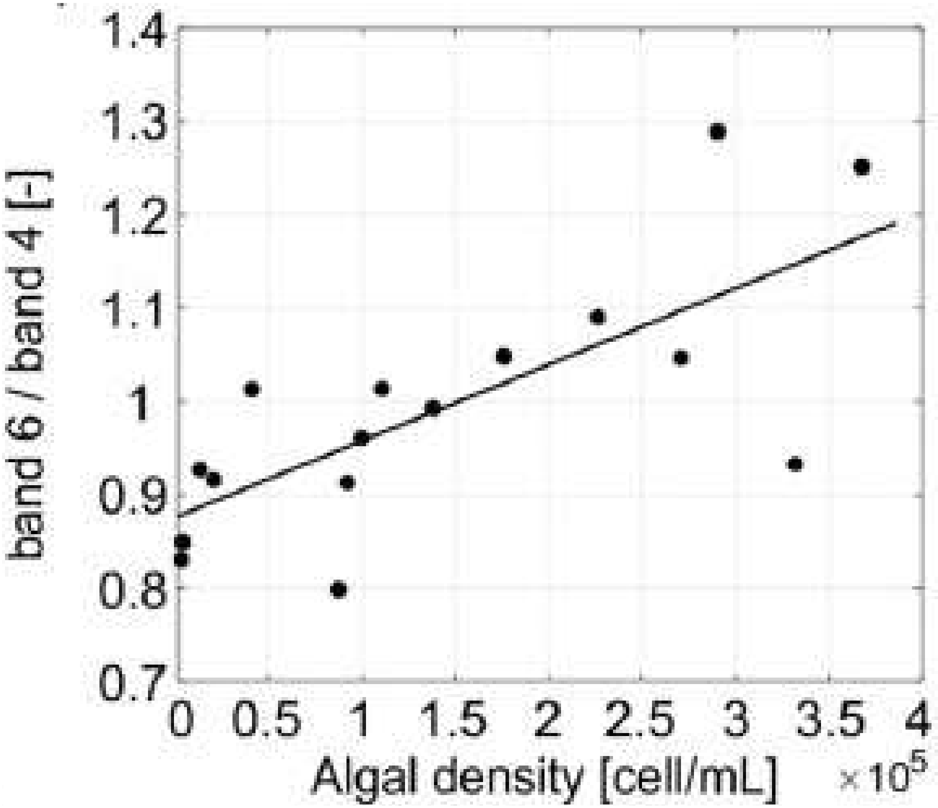
https://www.nature.com/news/algae-are-melting-away-the-greenland-ice-sheet-1.20265



Albedo and Bioalbedo

- Ice/snow surface darkening decreases the albedo and increases melting rates
- Dark particles can be both inorganic and organic
- When biotic (e.g. algae) can start a melt-enhancing positive feedback

Bioalbedo feedback

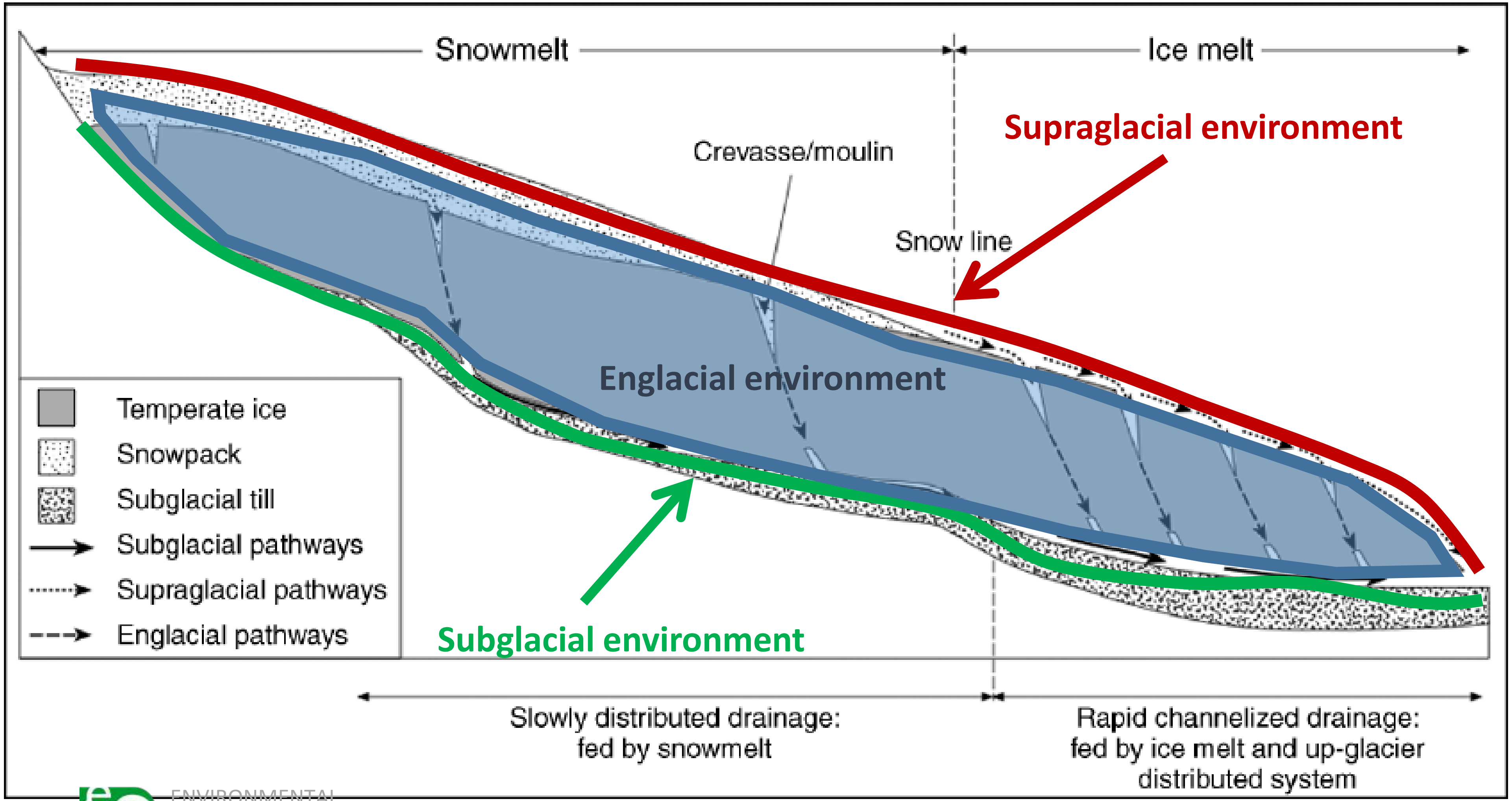


Glacier Algae impact the optical properties of ice.

The spectral ratio between the reflectance at 740 nm and 665 nm may be useful to map the presence of algae on ice using remote sensing

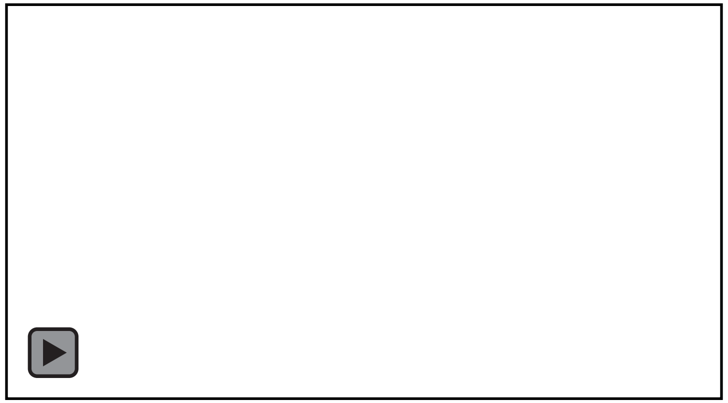
B. Di Mauro *et al.*, "Glacier algae foster ice-albedo feedback in the European Alps," *Sci. Rep.*, pp. 1–9, 2020.

Glacial environments



ENVIRONMENTAL
SCIENCE AND POLICY

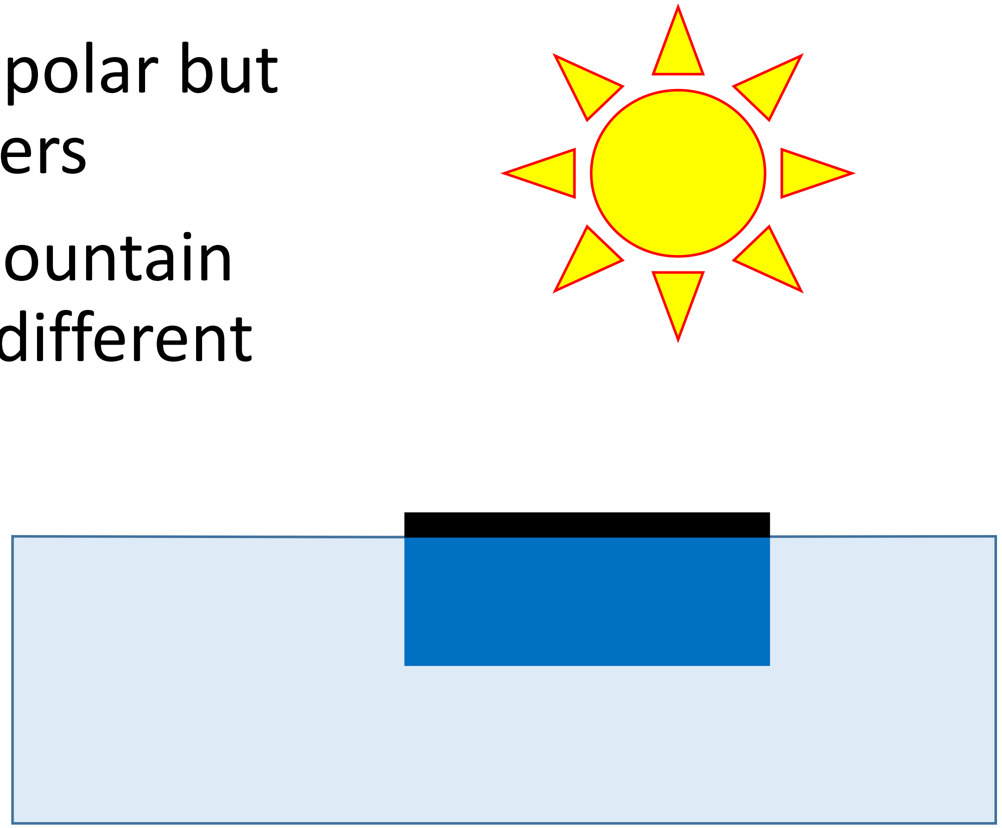
On the supraglacial environment there are different substrates to colonize



Cryoconite holes

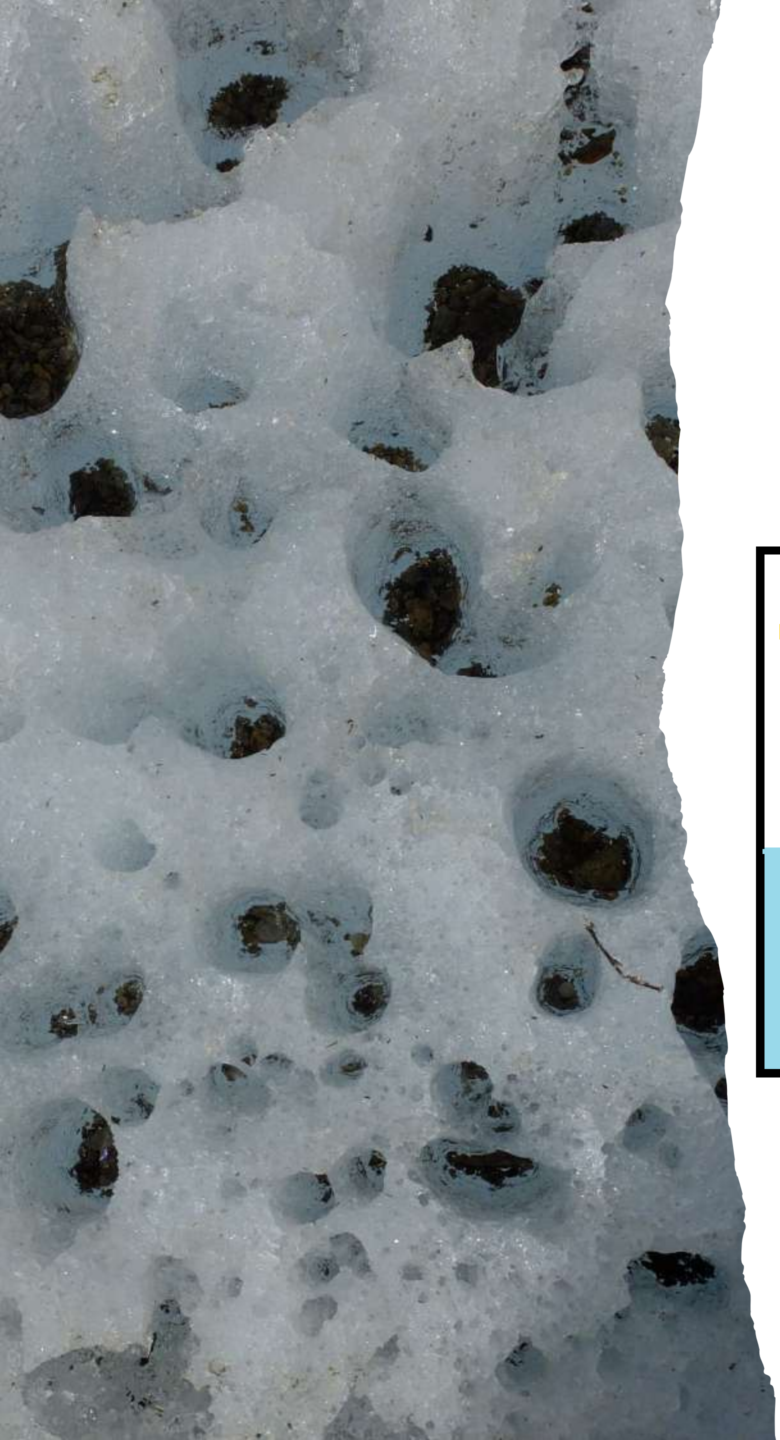
Ecology of cryoconite holes

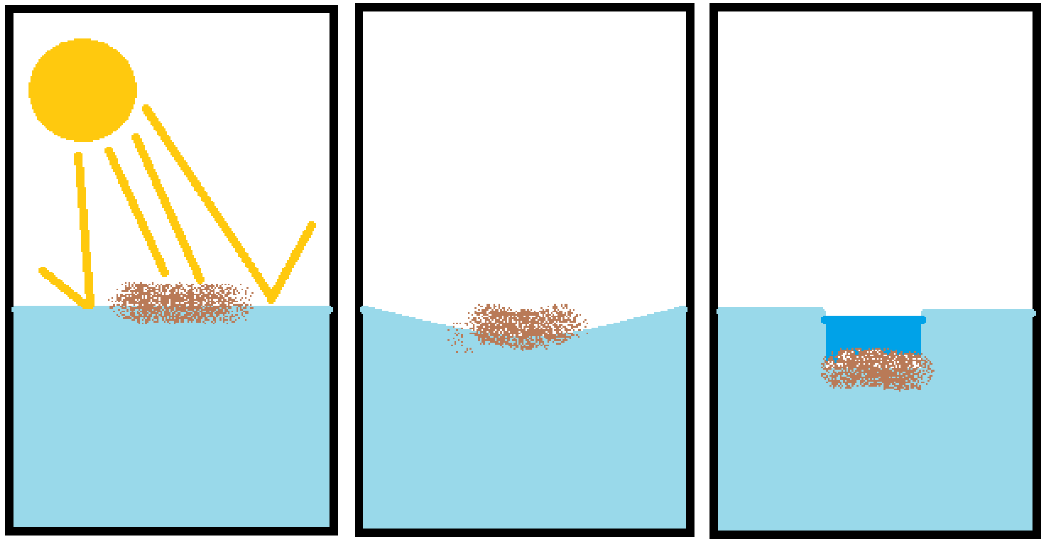
- The most productive environment on glaciers
- Extensively investigated in polar but less in high-mountain glaciers
- Cryoconite holes in high-mountain and polar glaciers present different features



  - Ephemeral structures
  - Sediment and bacteria mostly from surroundings areas

Cryoconite holes





Kryo = ice, *Konis* = dust

NORDENSKIÖLD ON THE INLAND ICE OF GREENLAND.[1]

Adolf Erik Nordenskiöld

Science, Vol. 2, No. 44 (Dec. 7, 1883), pp. 732-738

close to each other that it would be very difficult to find a spot on the ice as large as the crown of a hat free from them. In the night, at a few degrees below freezing-point, new ice forms on these hollows; but they do not freeze to the bottom, even under the severest frost, and the sheet which covers them is never strong enough to support a man, more particularly if the hole is, as was the case during half our journey, covered with a few inches of newly-fallen snow.

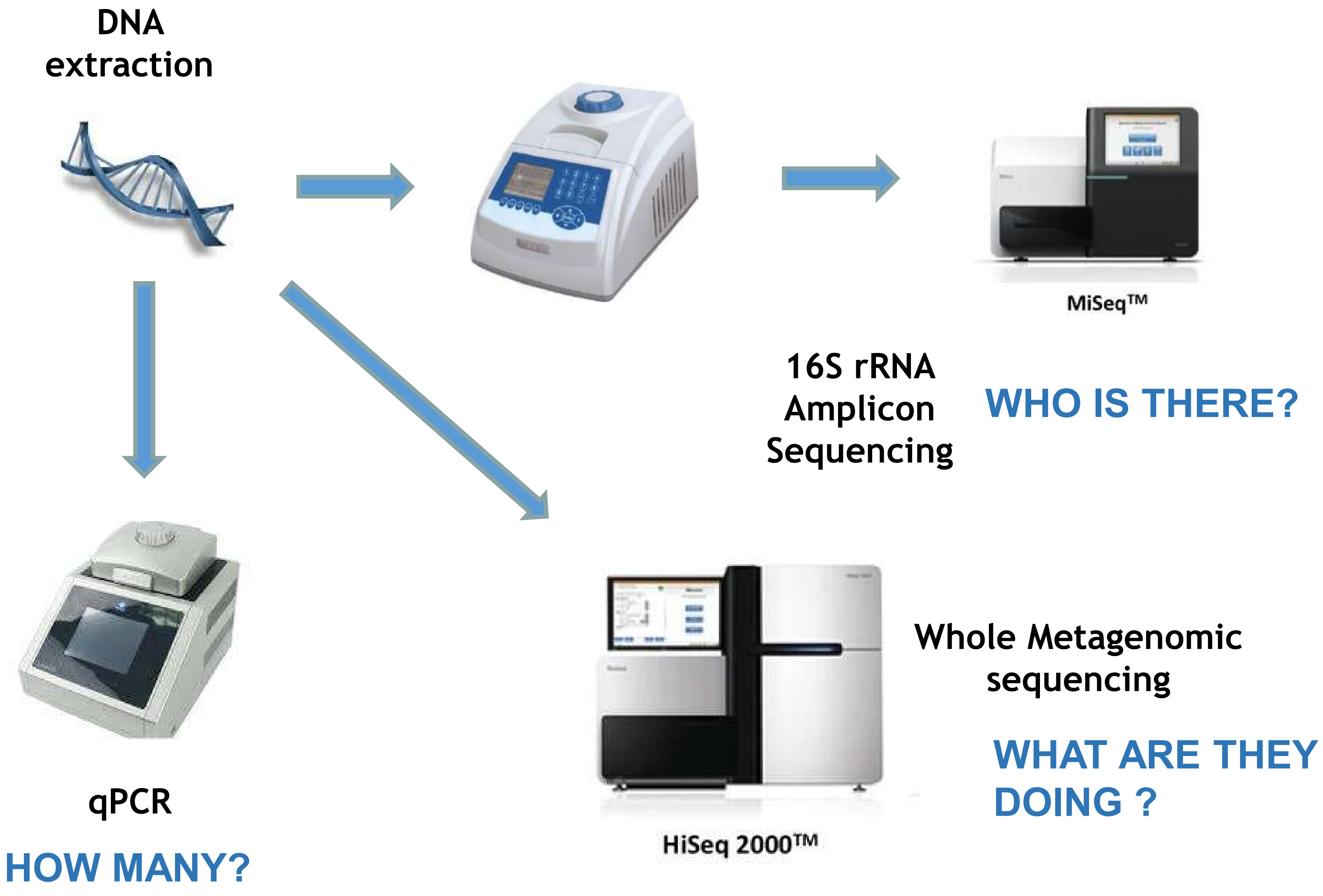
The kryokonite cavities were perhaps more dangerous to our expedition than any thing else we were exposed to. We passed, of course, a number of crevasses without bottom as far as the eye could penetrate, and wide enough to swallow up a man; but they were 'open,' i.e., free from a cover of snow, and could with proper caution be avoided; and the danger of these could further be minimized by the sending of the two-men sledges in front, and, if one of the men fell into the crevasse, he was supported by the runners and the alpenstock, which always enabled him to get up on the ice again. But this was far from being the case with the kryokonite hollows. These lie, with a diameter just large enough to hold the foot, as close

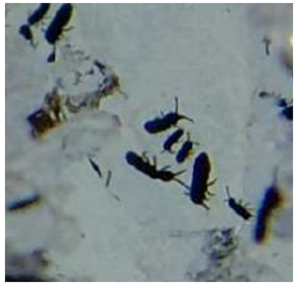
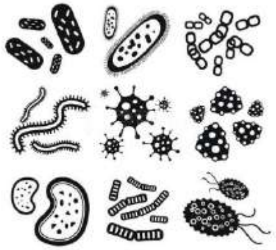
Glaciology
Zoology

Ecology
Microbiology

Investigation boosted by recent technological advances

BioMolecular Tools



WHO

- Bacteria
- Algae
- Artropods
- Viruses
- Fungi
- Rotifers
- Tardigrades
- (Nematodes)

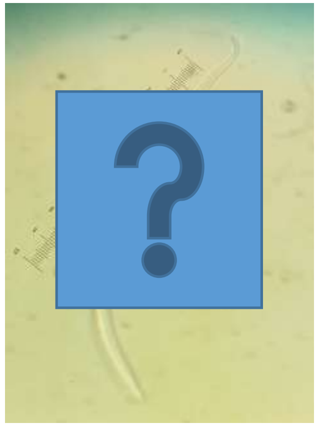
CHALLENGES

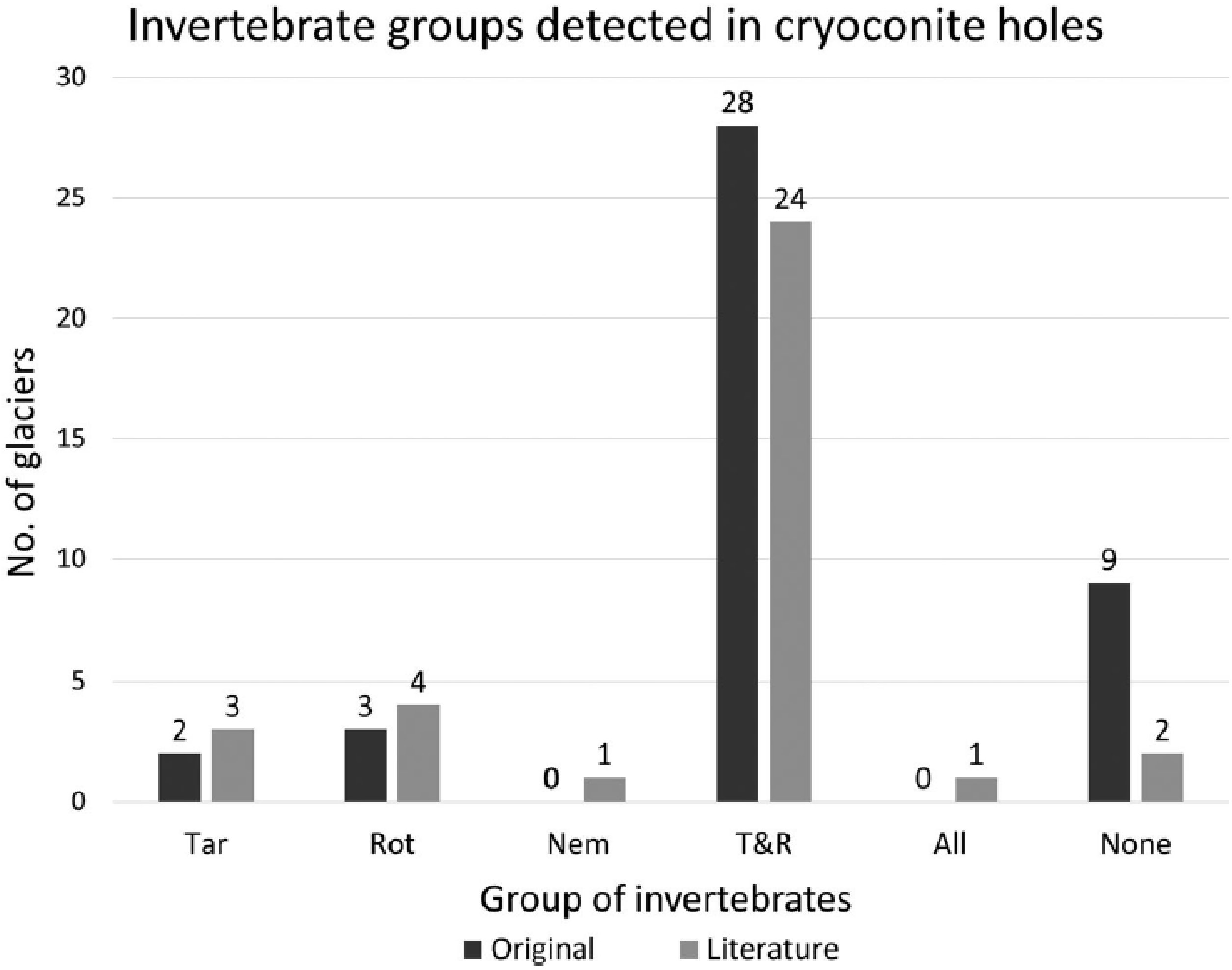
- High radiation
- Oligotrophic environment
- Low temperatures
- Low availablity of liquid water

Cryoconite: holes in the nematosphere

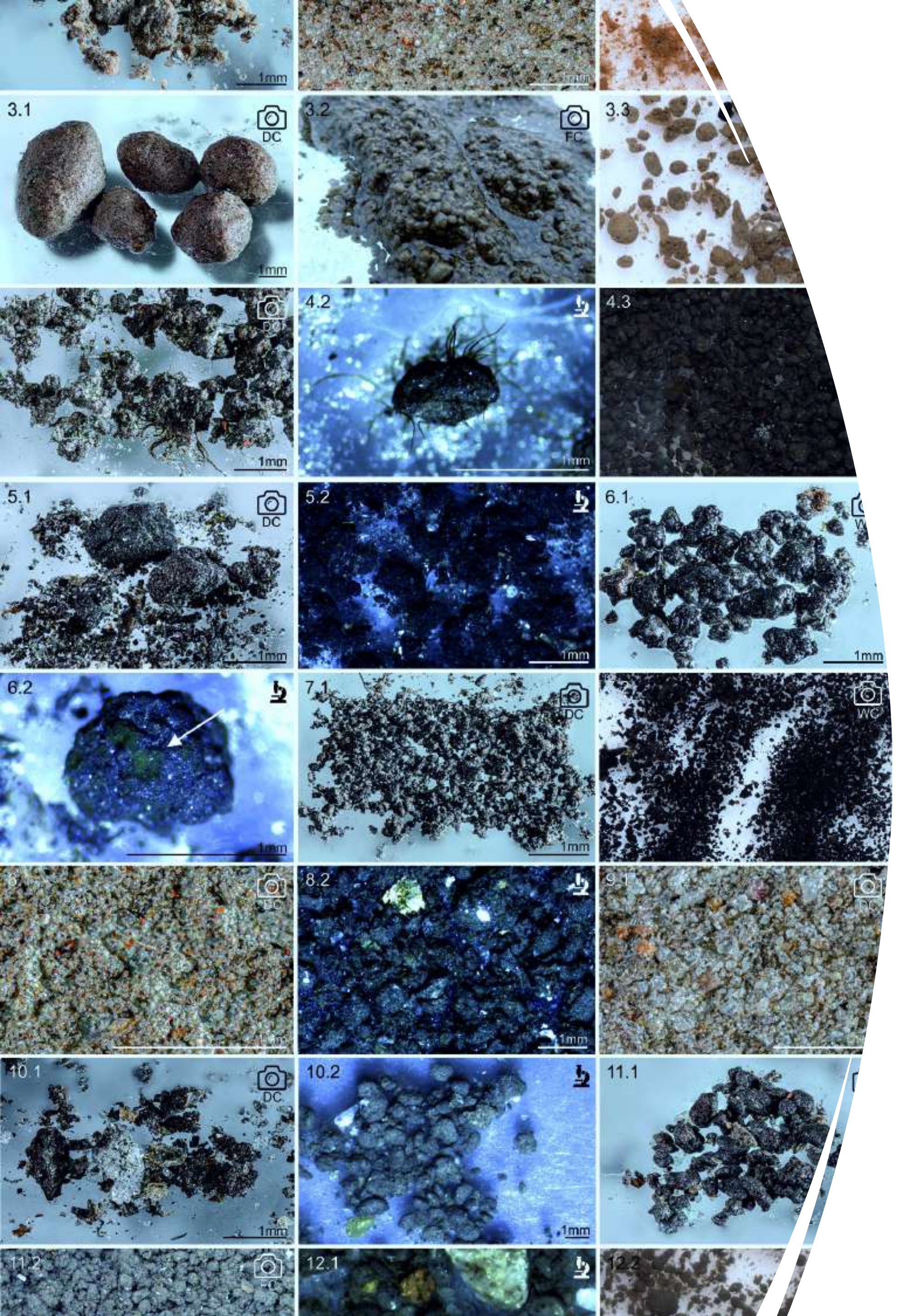
Rotifers, tardigrades and nematodes

- Similar feeding strategies
- Passively dispersed
- Ubiquitous presence of rotifers and tardigrades in cryoconite holes

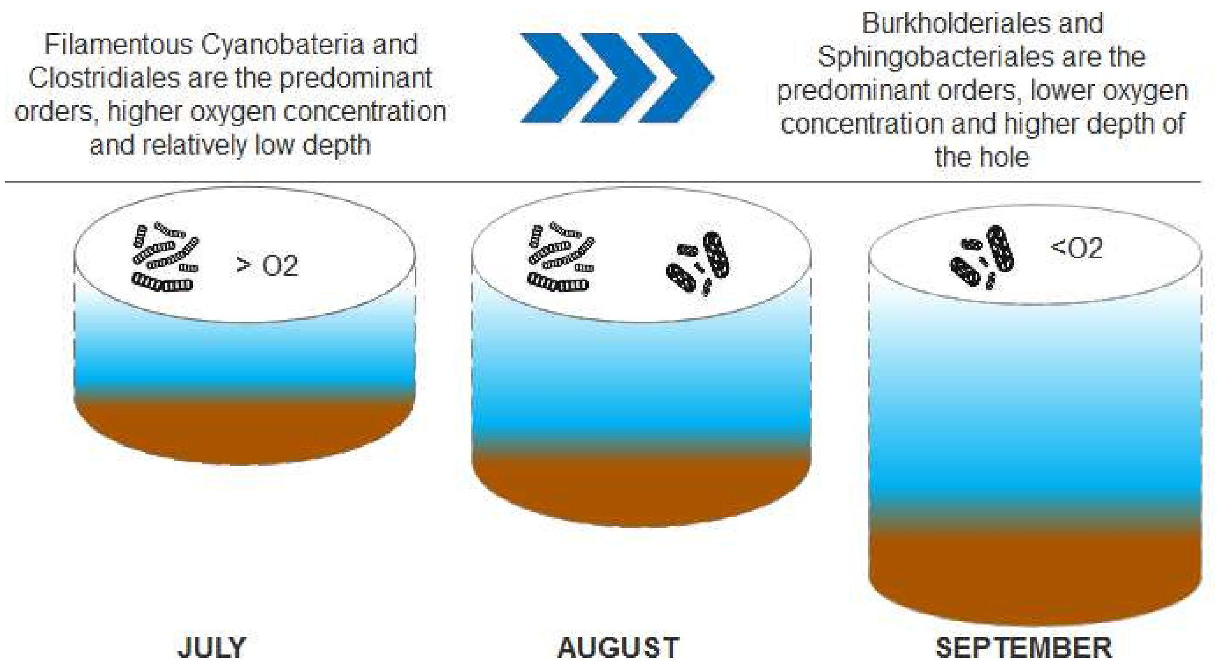




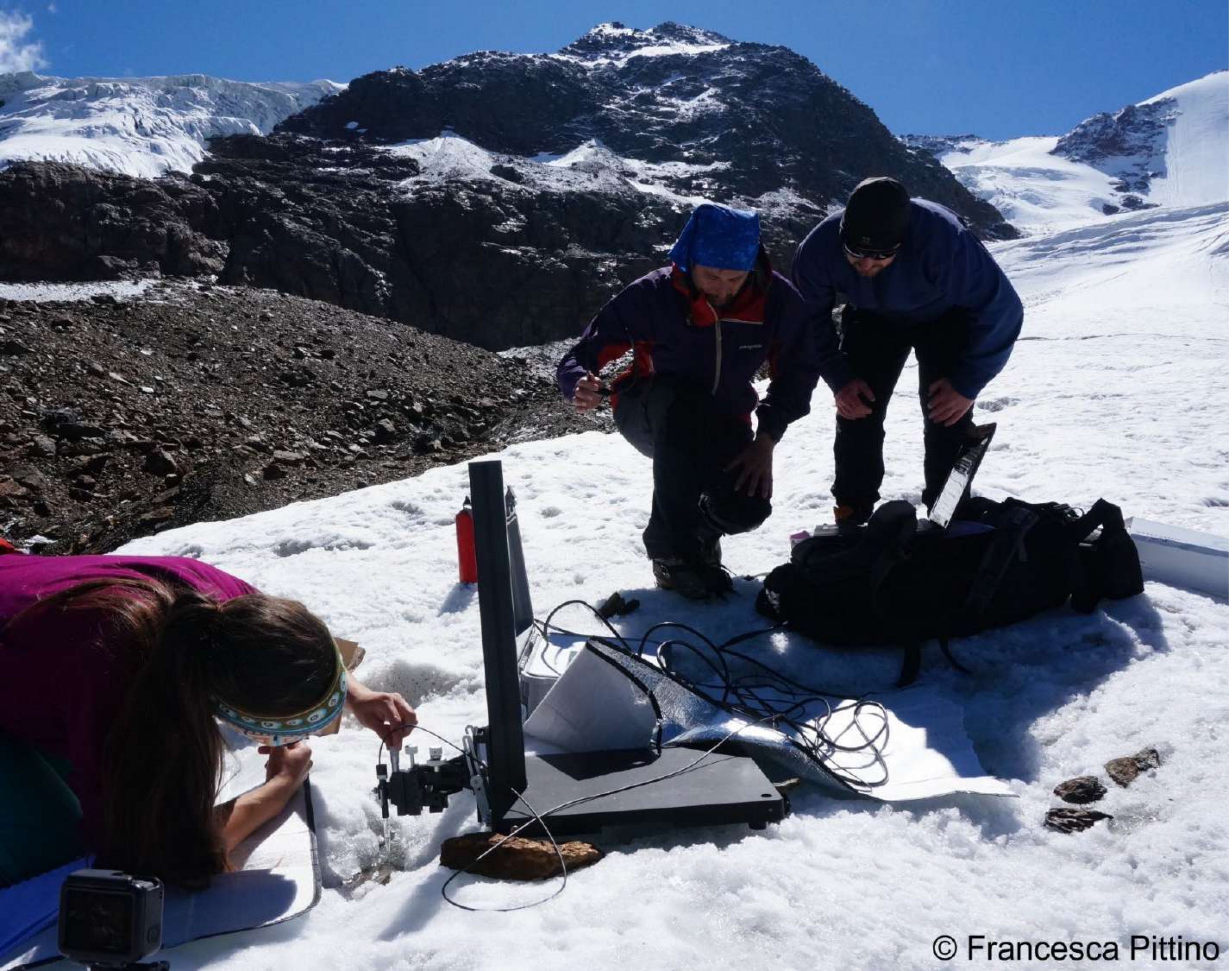
K. Zawierucha et al (2020) A hole in the nematosphere tardigrades and rotifers dominate the cryoconite hole environment, whereas nematodes are missing. *J Zool*. https://doi.org/10.1111/jzo.12832



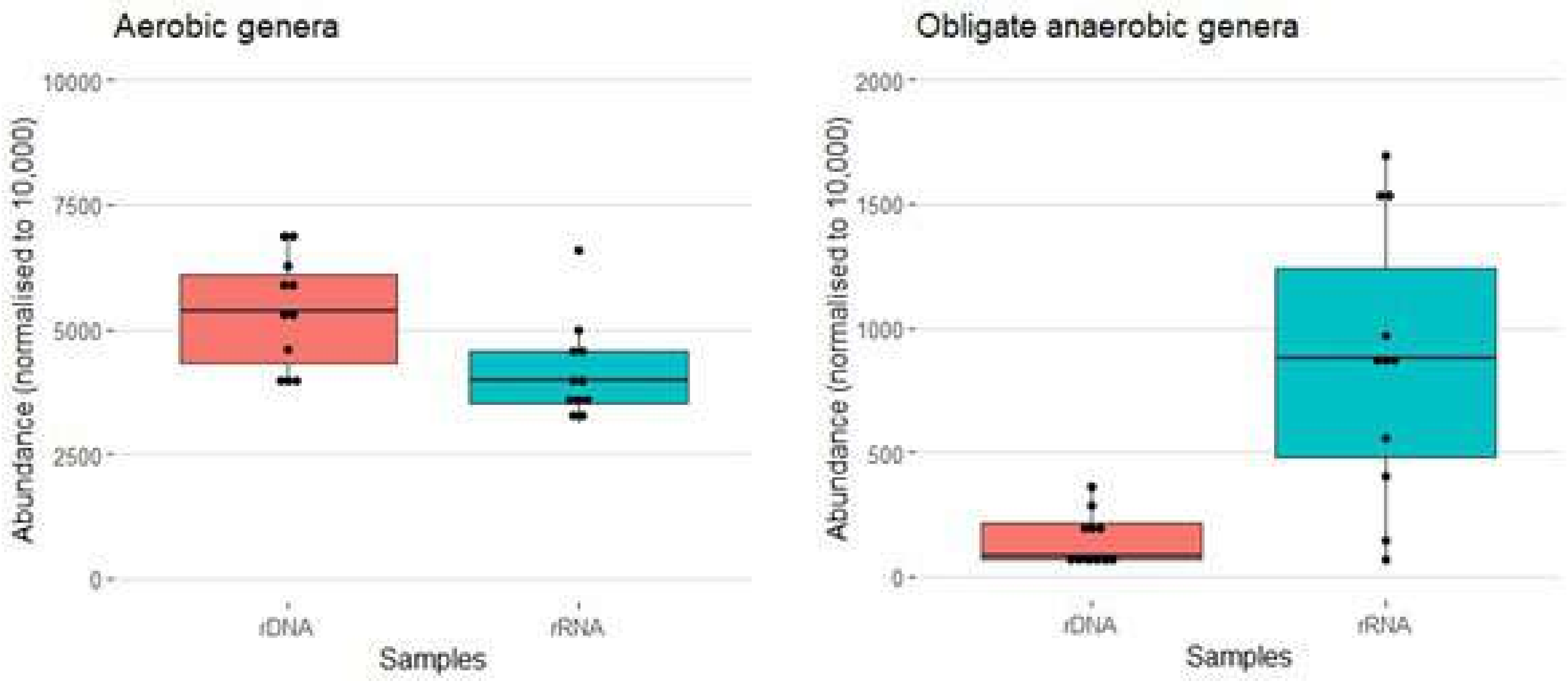
Cyanobacteria are the engeneers of cryoconite grains



Franzetti, A. et al. (2017). Temporal variability of bacterial communities in cryoconite on an alpine glacier. *Environmental Microbiology Reports*, *9*(2), 71–78. https://doi.org/10.1111/1758-2229.12499



Cryoconite is an anoxic environment



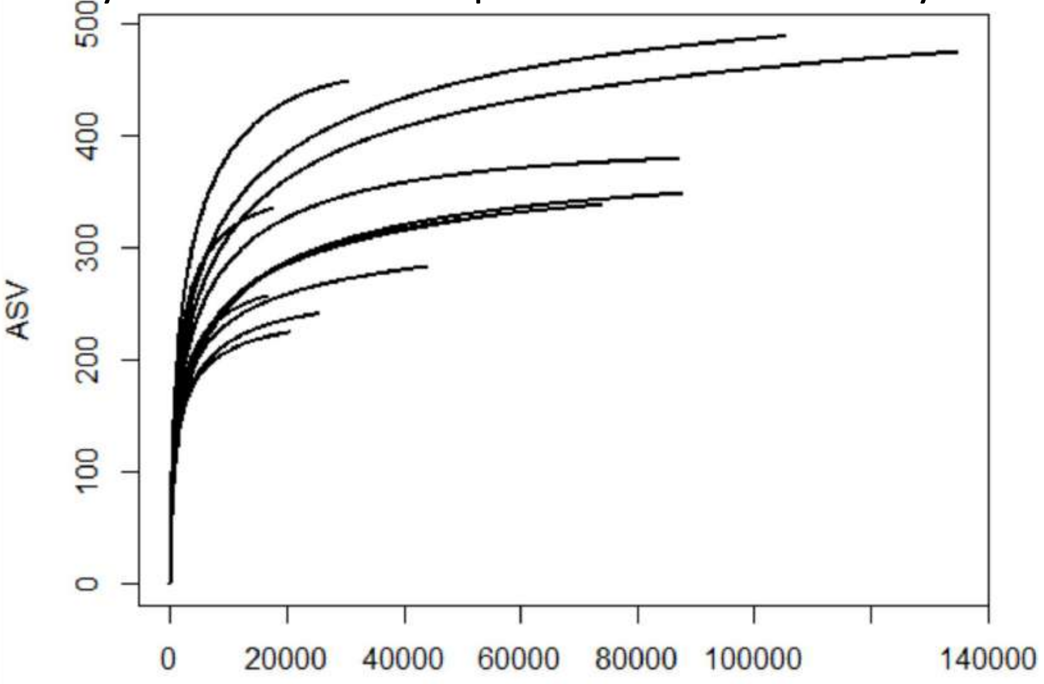
Pittino et al., 2022, Functional and taxonomic diversity of anaerobes in supraglacial microbial communities. Submitted


• **448** cryoconite holes
• **Fully consistent field methods**
• **12** glaciers
• Years **2012-2020**

- Annual sampling campaigns since 2012

Cryoconite holes in the same day

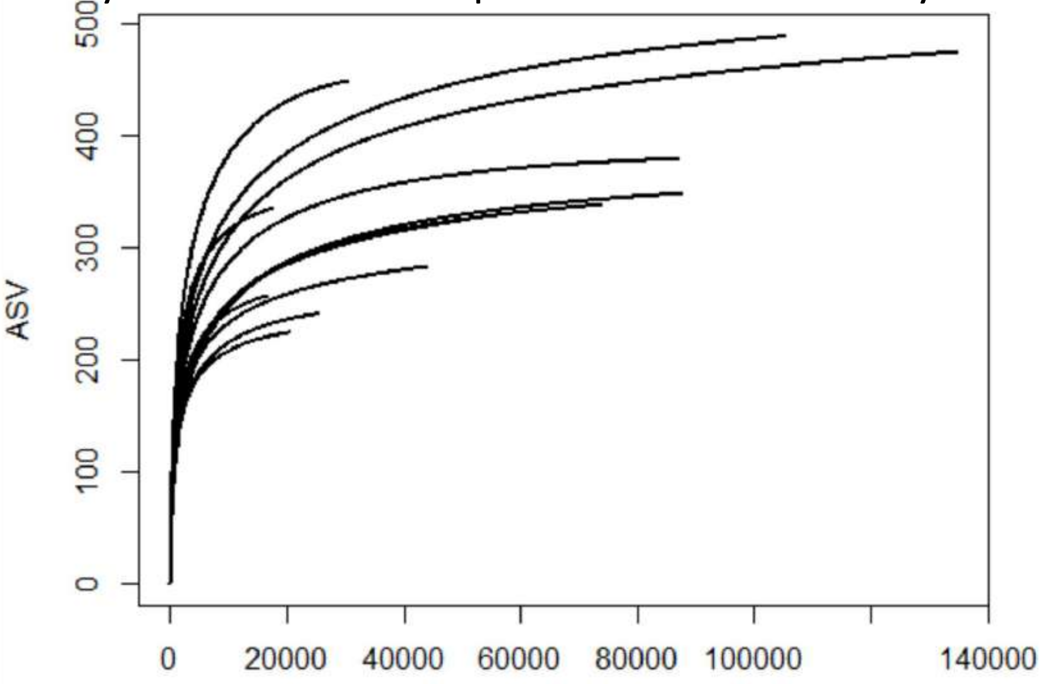
12 cryoconite holes sampled on Forni on 22 July 2018



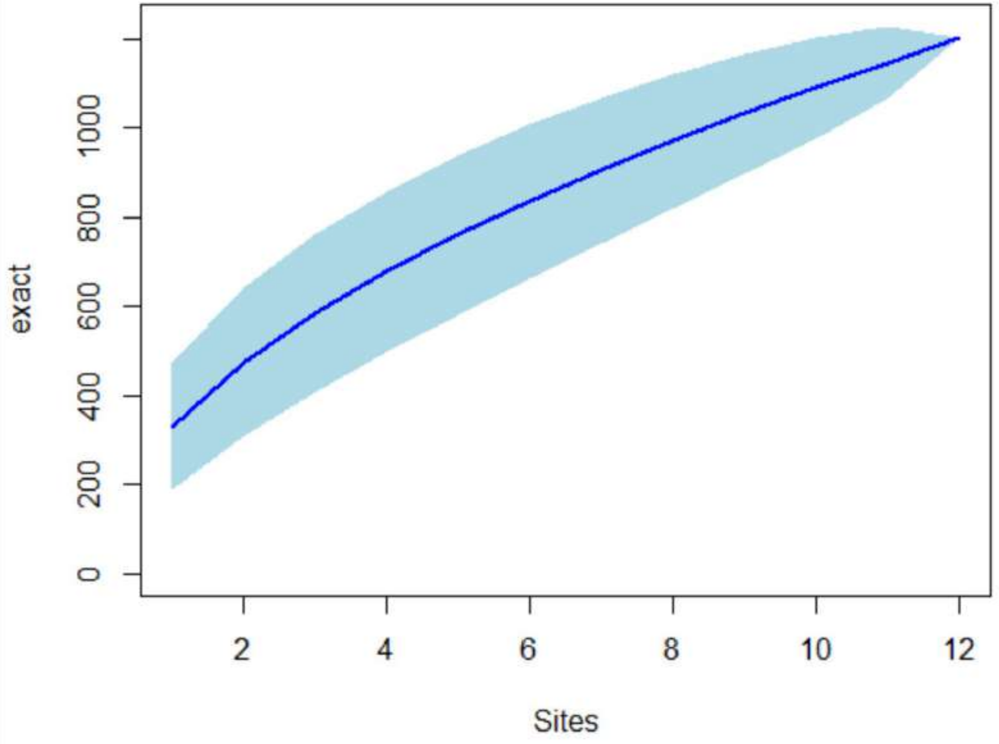
Observed ASVs
1290

Cryoconite holes in the same day

12 cryoconite holes sampled on Forni on 22 July 2018

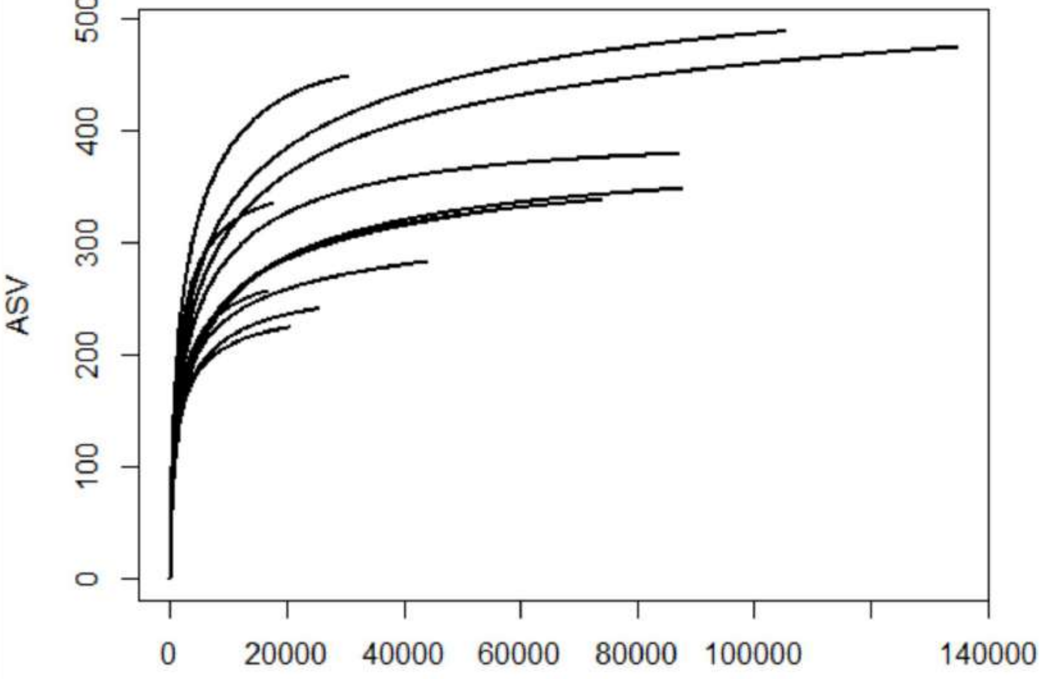


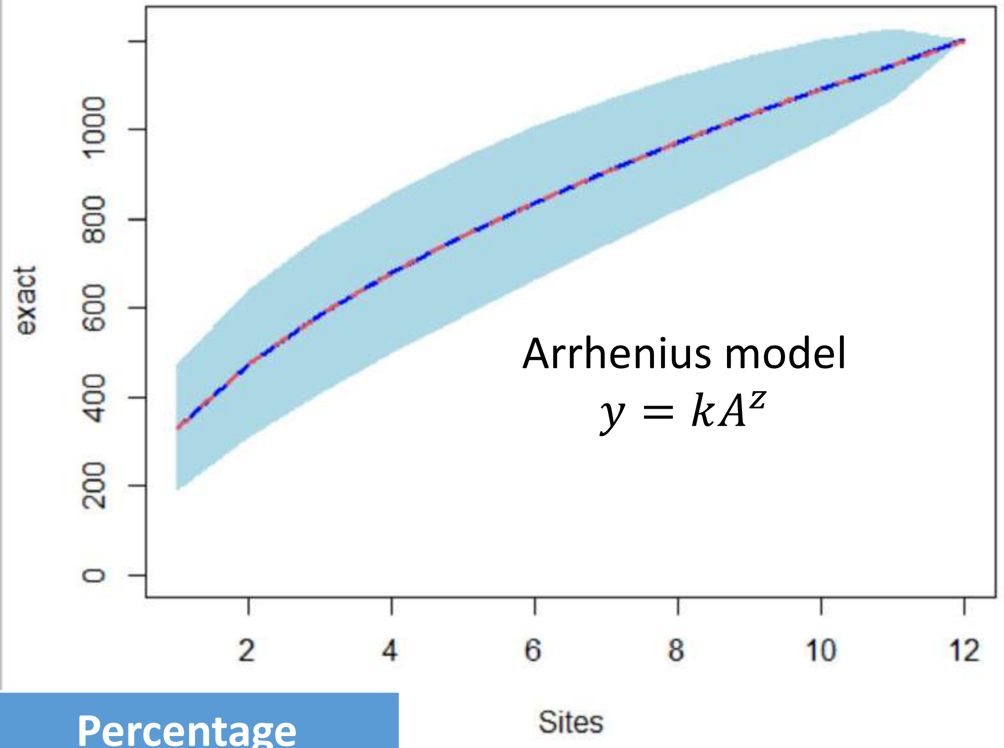
Observed ASVs
1290



Cryoconite holes in the same day

11 cryoconite holes sampled on Forni on 22 July 2018



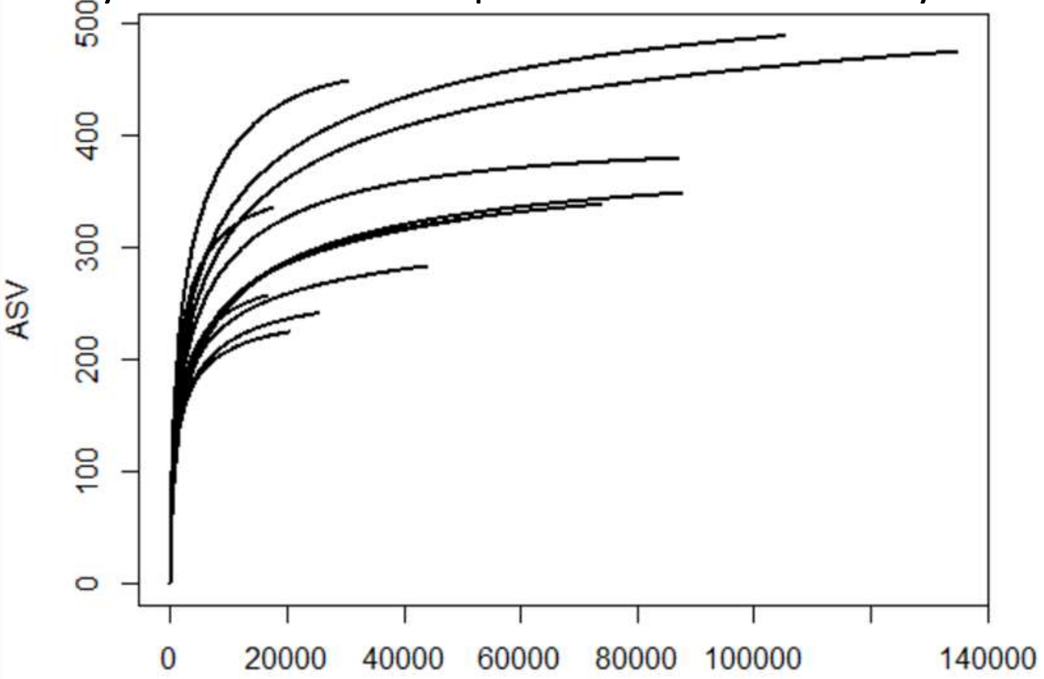


Arrhenius model
$y = kA^z$

Observed ASVs (pre-rarefaction)	Estimated ASV (kA)	Percentage
1290	3959	32.6%

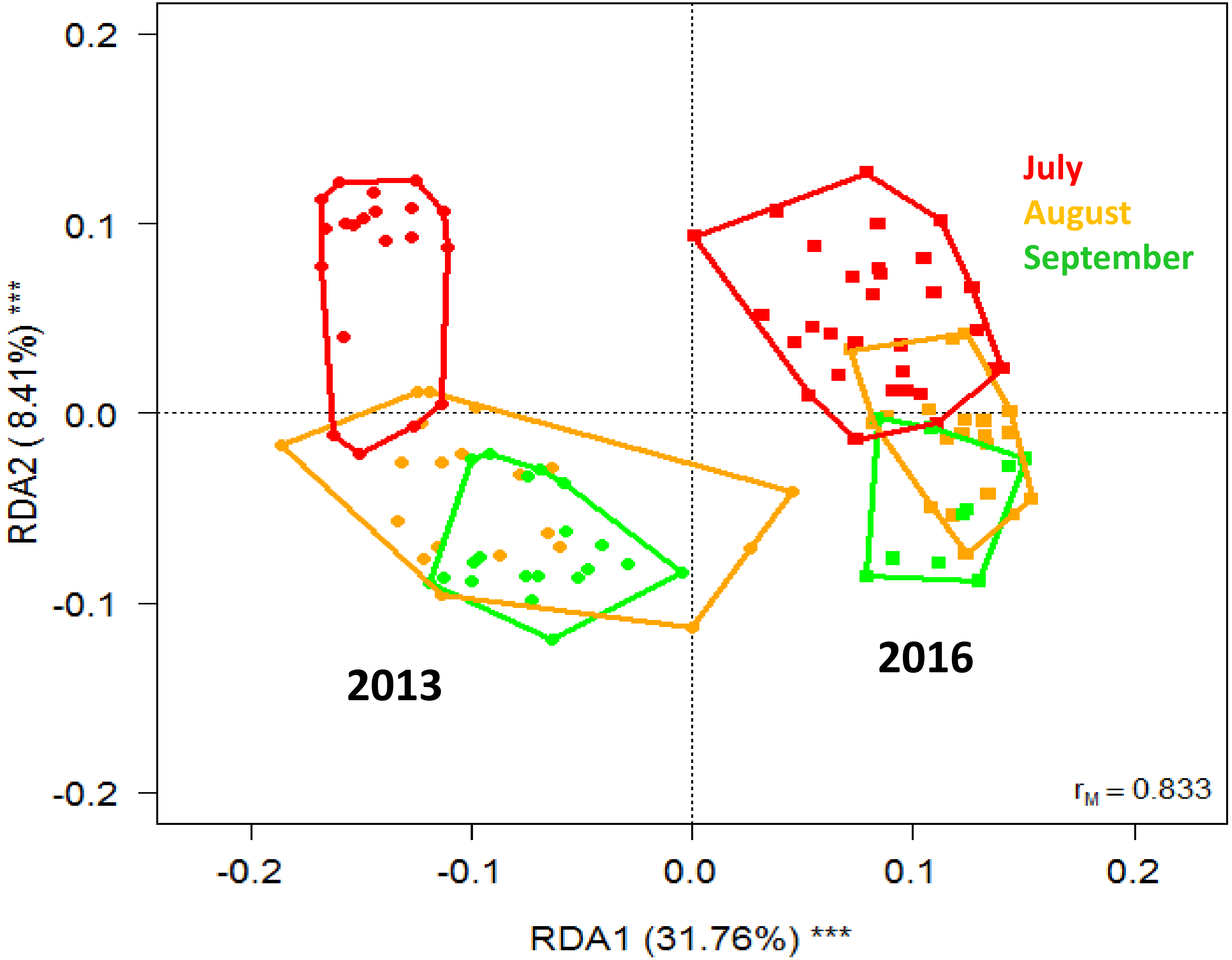
Cryoconite holes in the same day

11 cryoconite holes sampled on Forni on 22 July 2018



- A set of different methods
  - Chao 1 index
  - First order jackknife estimator
  - Breakaway (parametric estimate via frequency ratios)
  - Bayes species richness estimate with the negative binomial model

Observed ASV	Estimated ASV (*A*)	Percentage
1290	1027-4896	36.6-86.6%



RDA:

Year: $F_{1,116} = 63.25$, P = 0.001

Month: $F_{2,116} = 10.72$, P = 0.001

Post-hoc tests between months

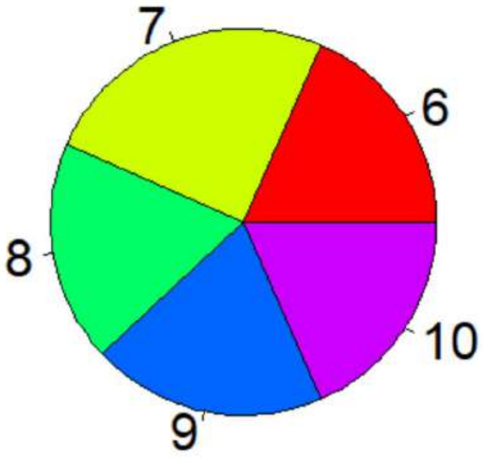
$F_{1,116} \geq 12.01$,

$P_{FDR} \leq 0.001$

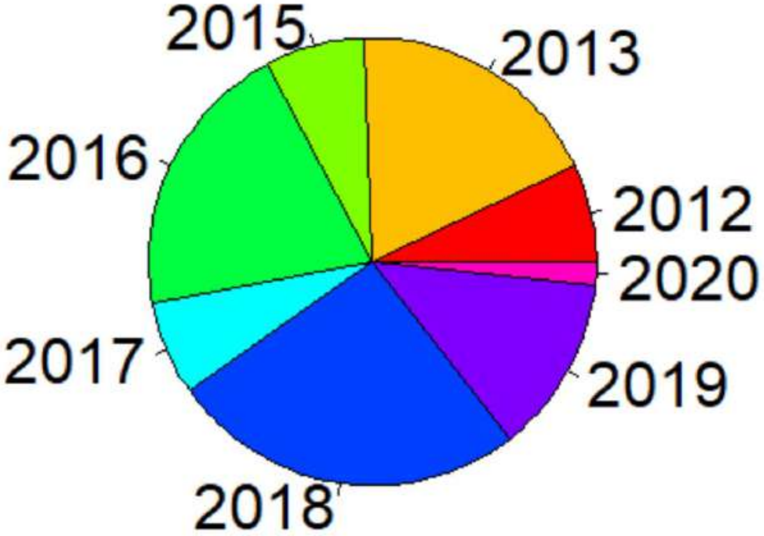
Pittino et al. 2018 Annals of glaciology 59:1-9

Same exercise with different samples

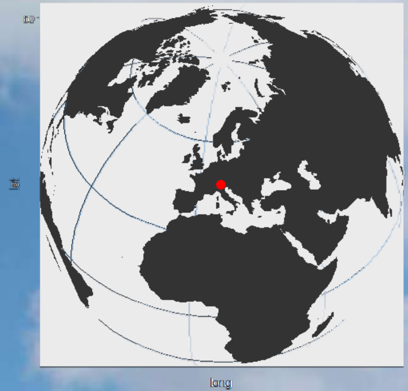
Different months of 2018

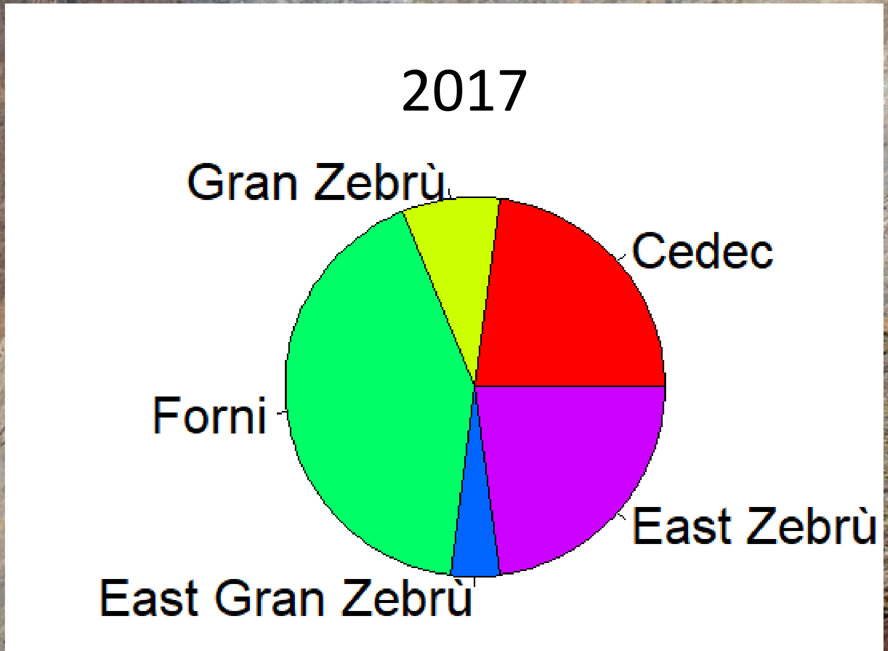


All months in all years

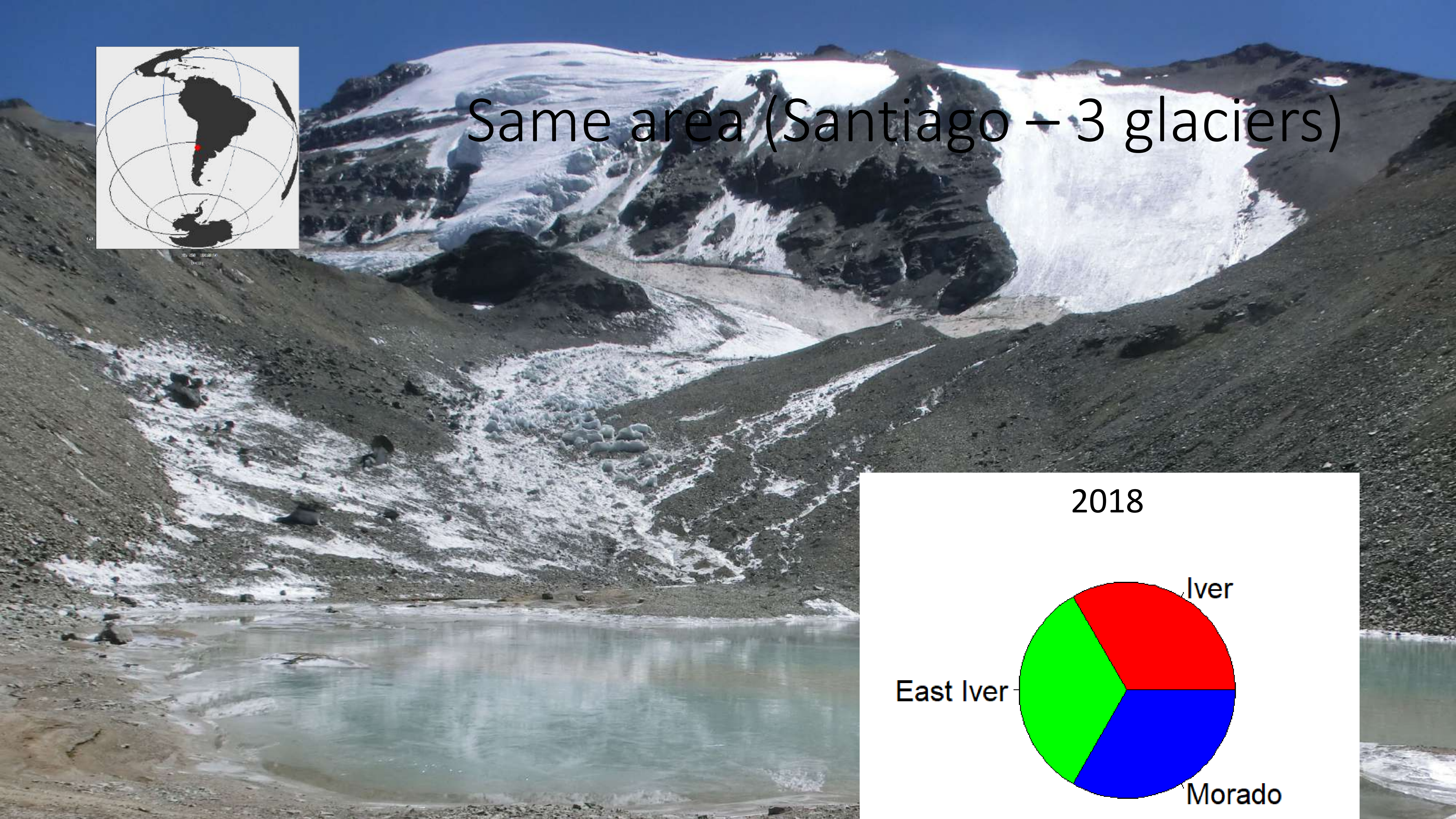


Same area (Stelvio – 5 glaciers)

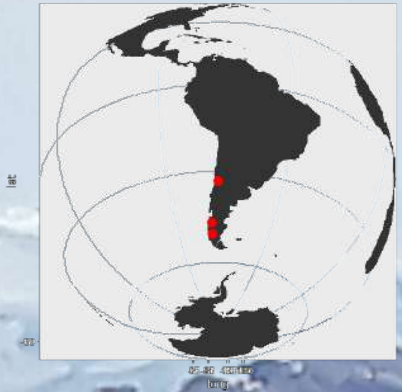


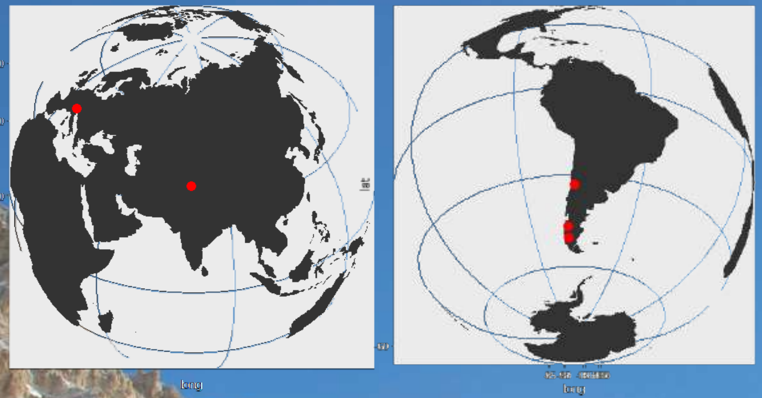


Same area (Santiago – 3 glaciers)

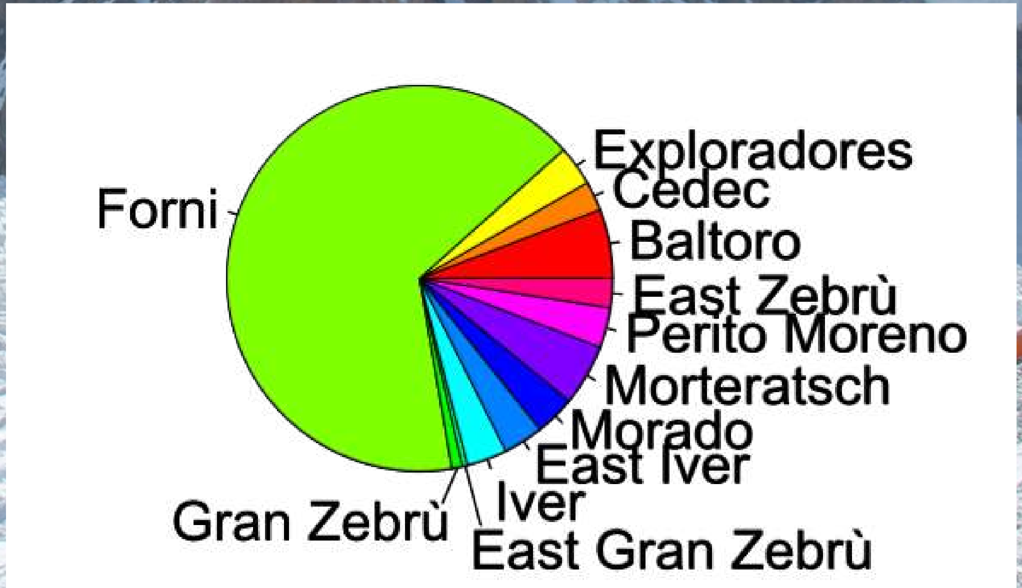


South America (5 glaciers)

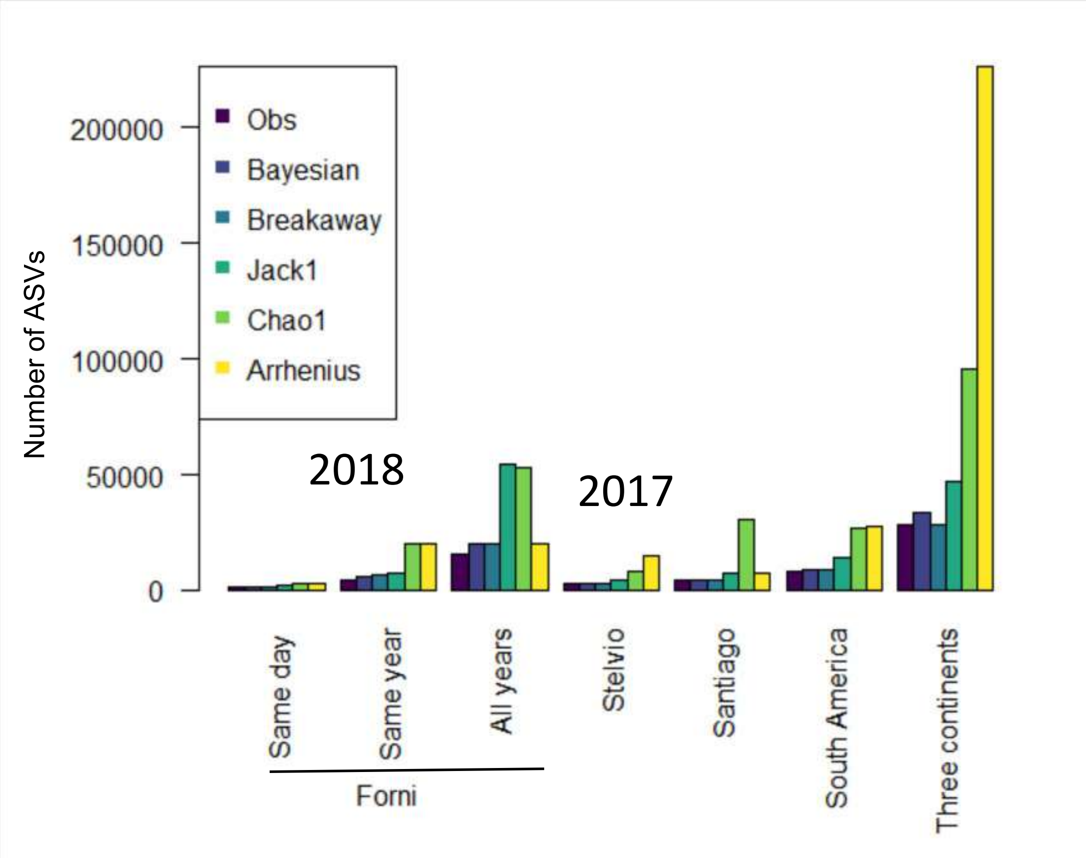


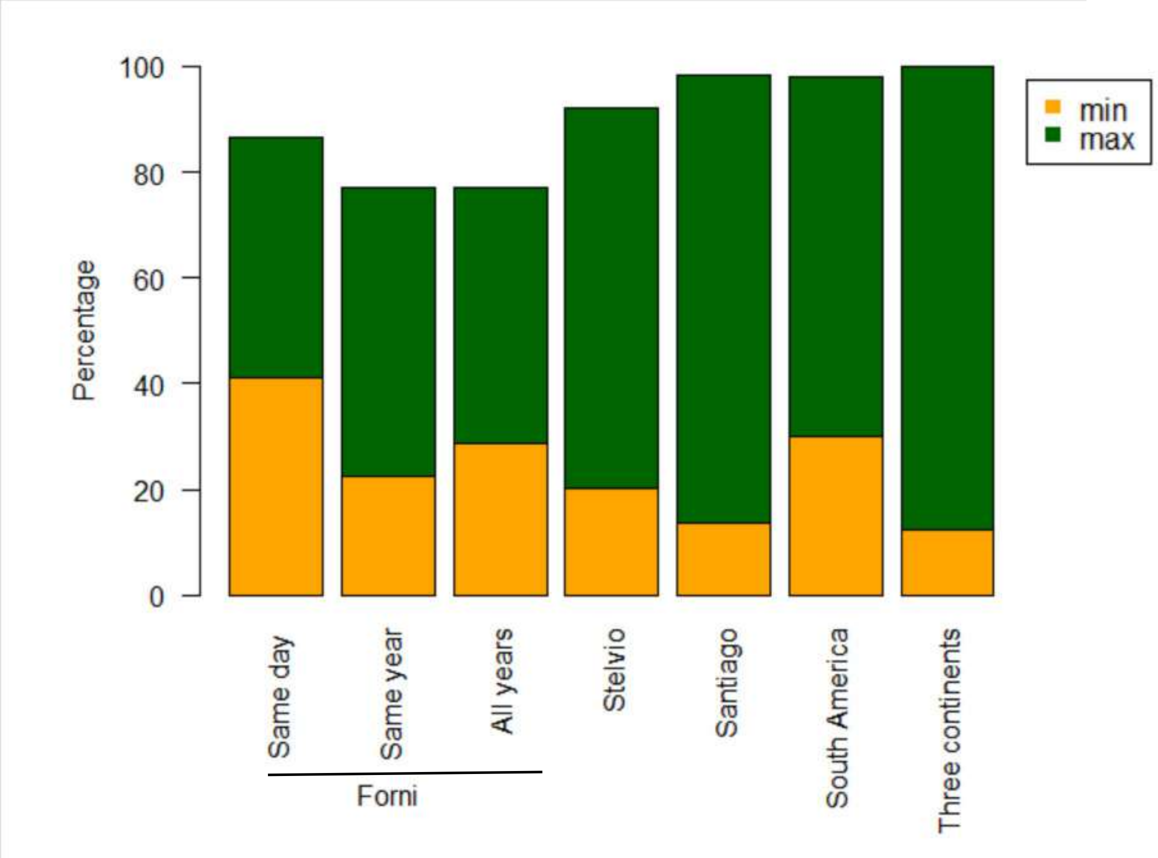


Three continents (12 glaciers)

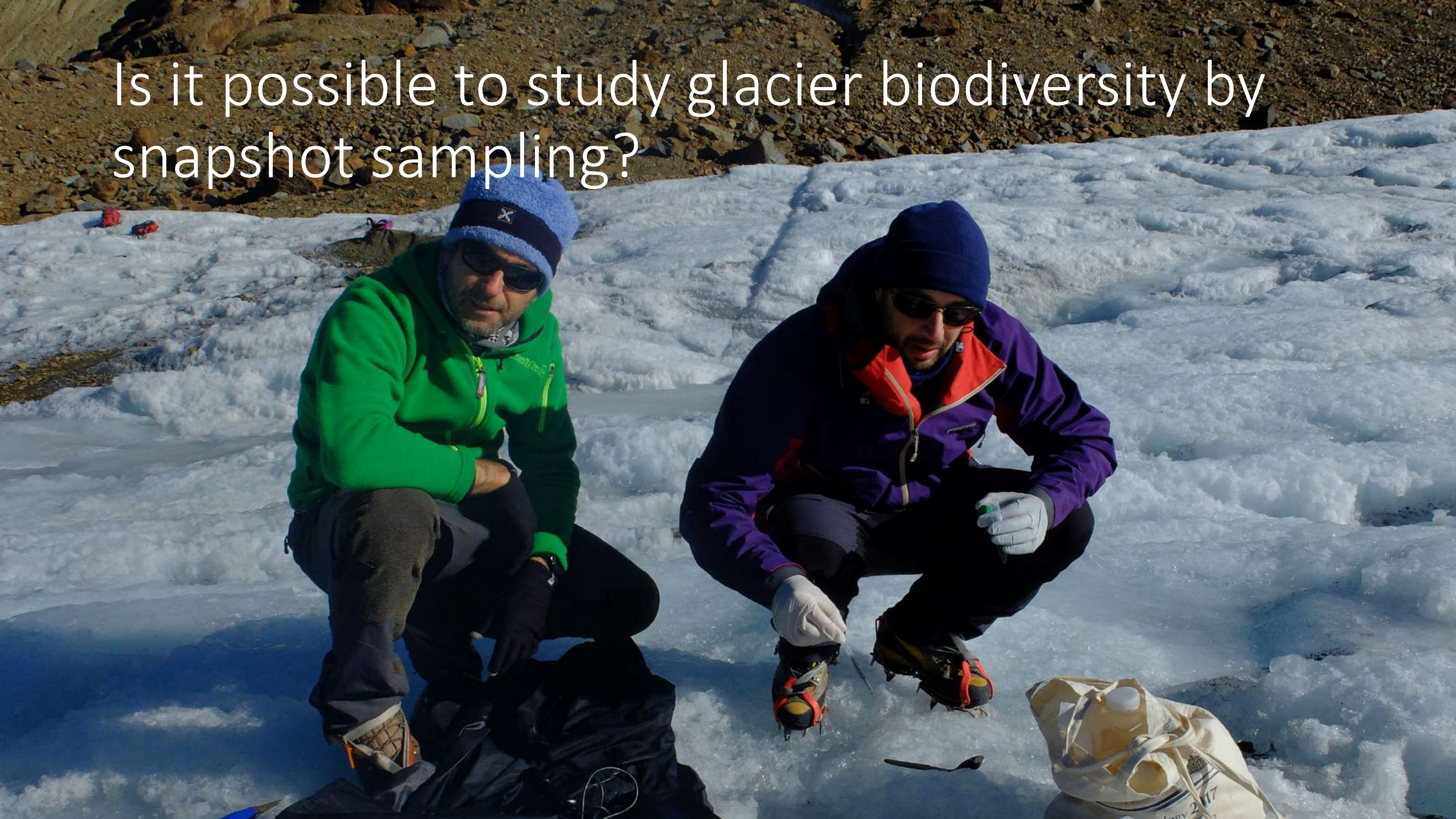


Observed vs. estimated number of ASVs

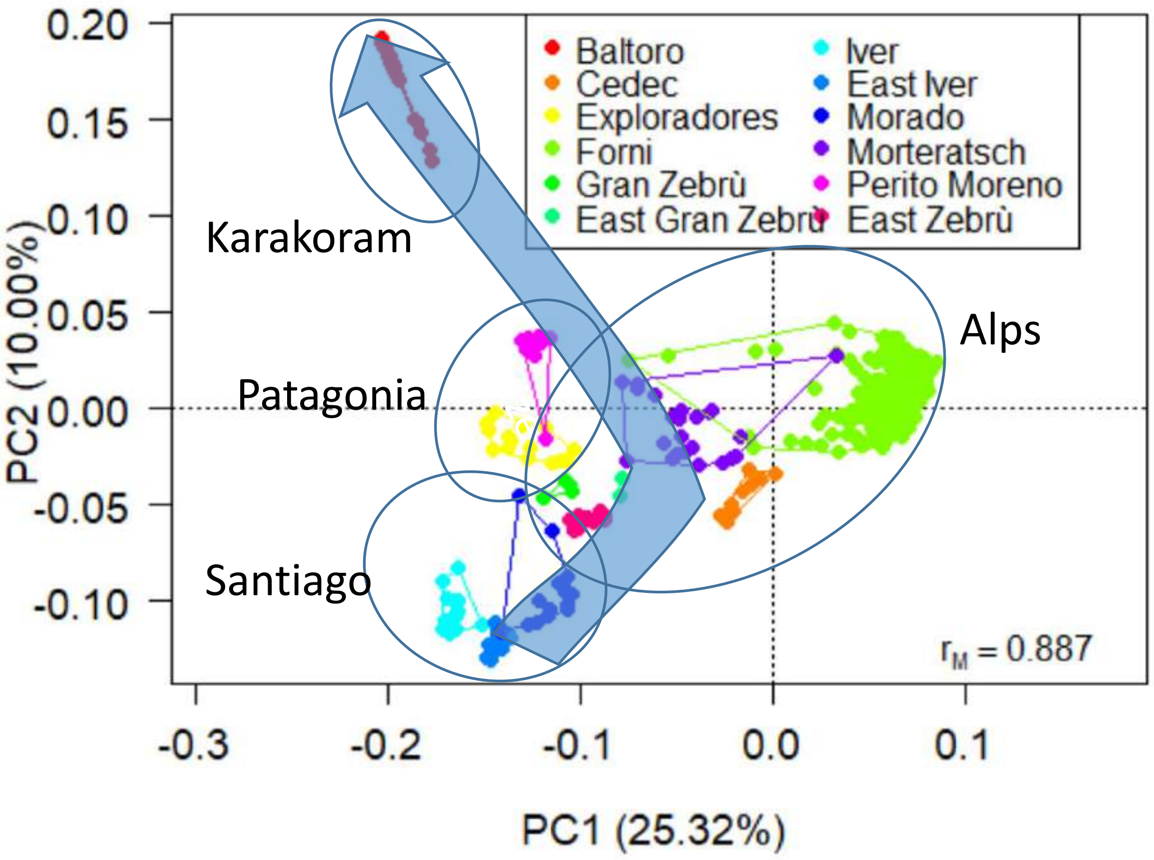




Is it possible to study glacier biodiversity by snapshot sampling?

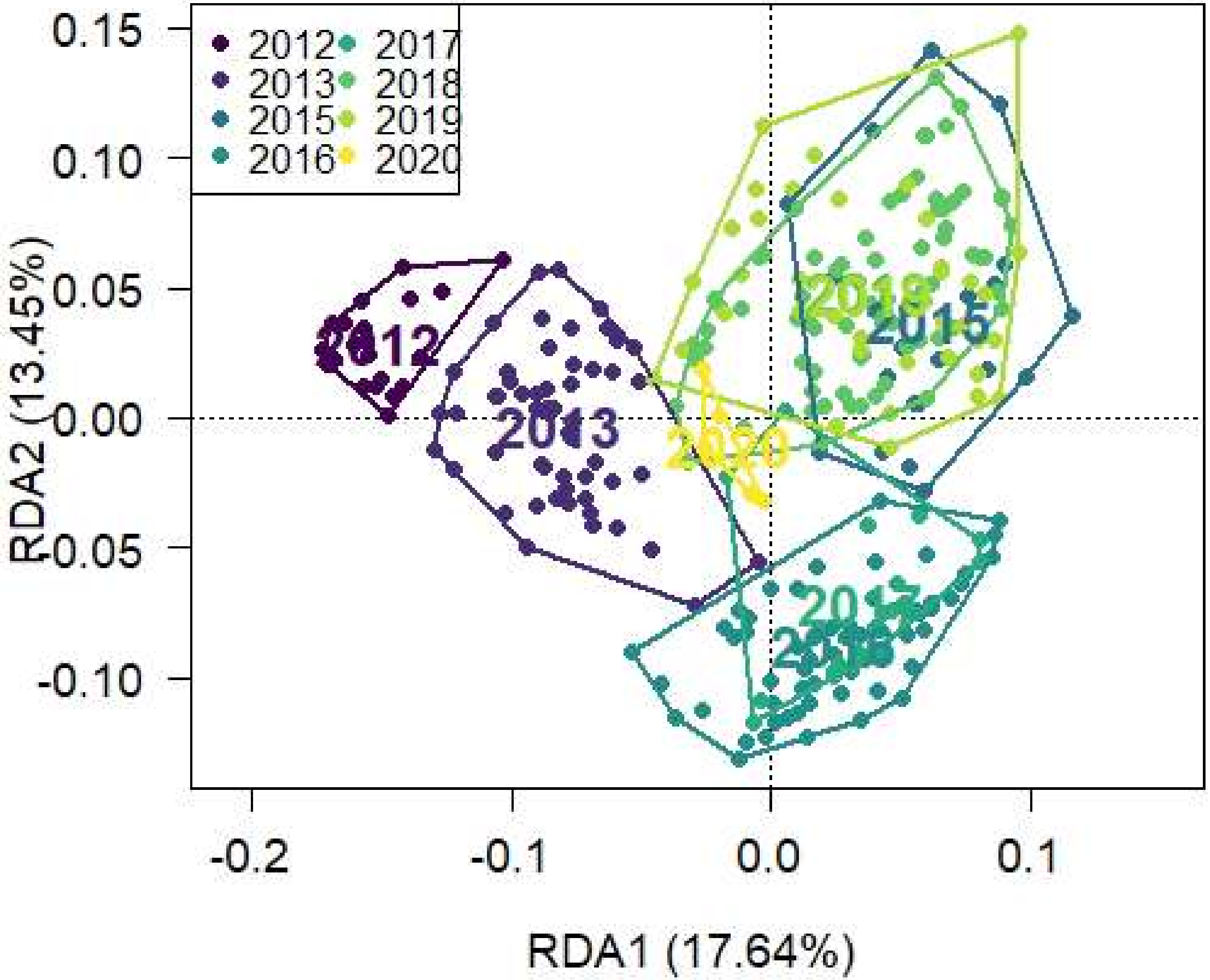


Principal Component Analysis

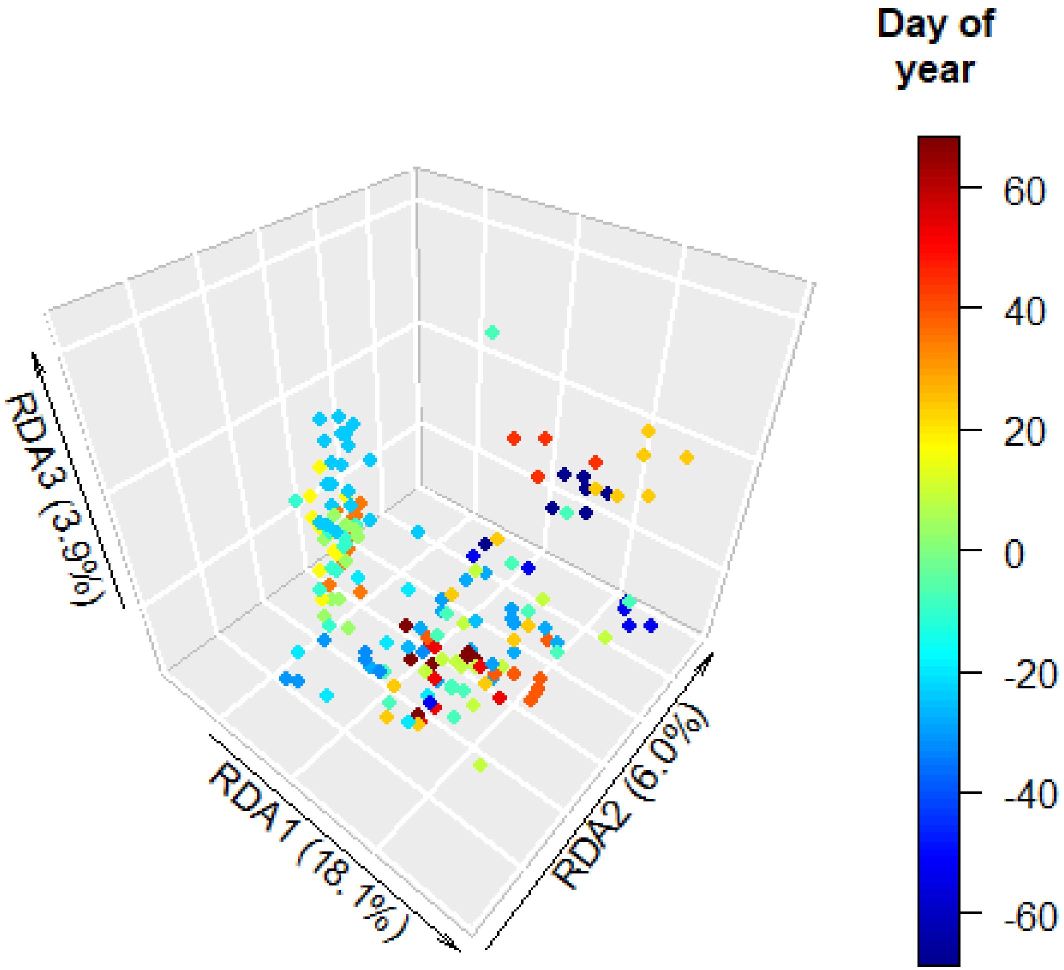


- **448** samples collected from different holes
- **12** glaciers
- Years **2012-2020**

Principal Component Analysis

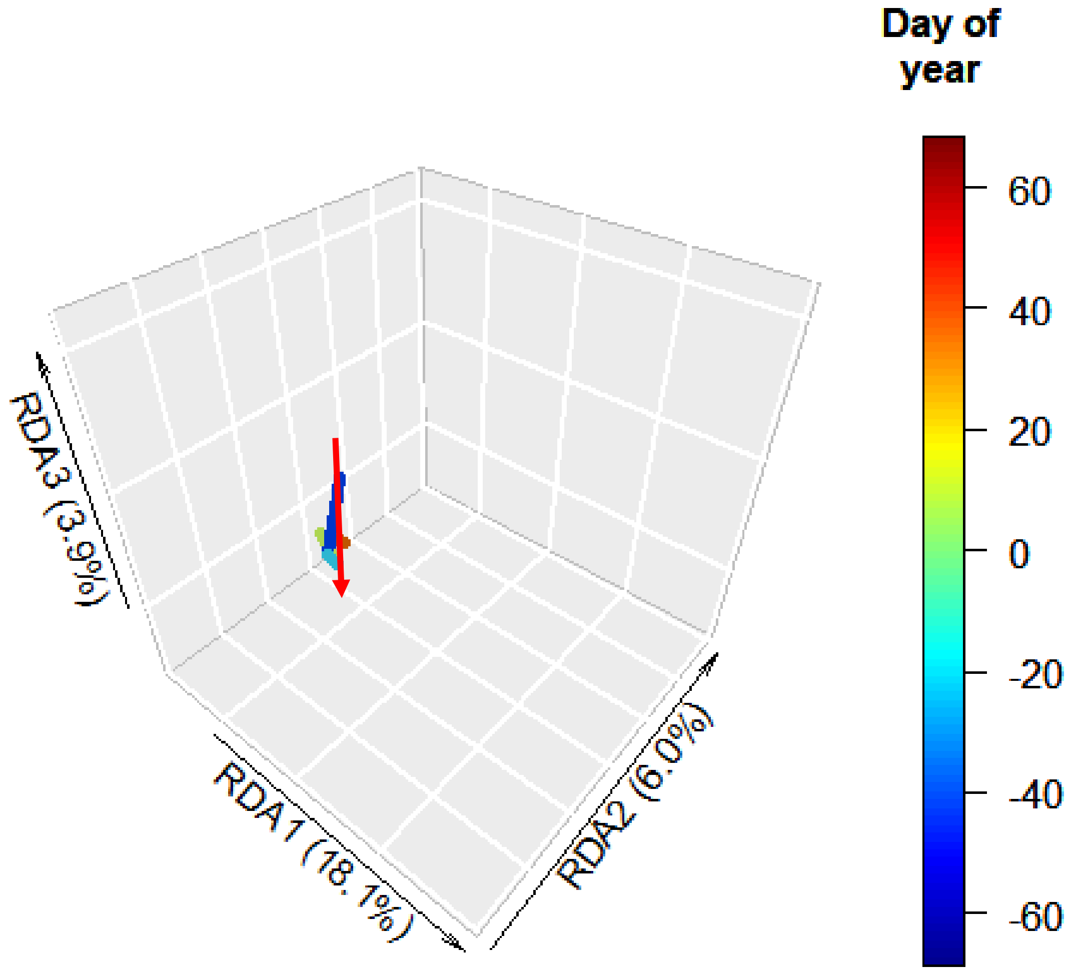


Redundancy analysis (RDA)



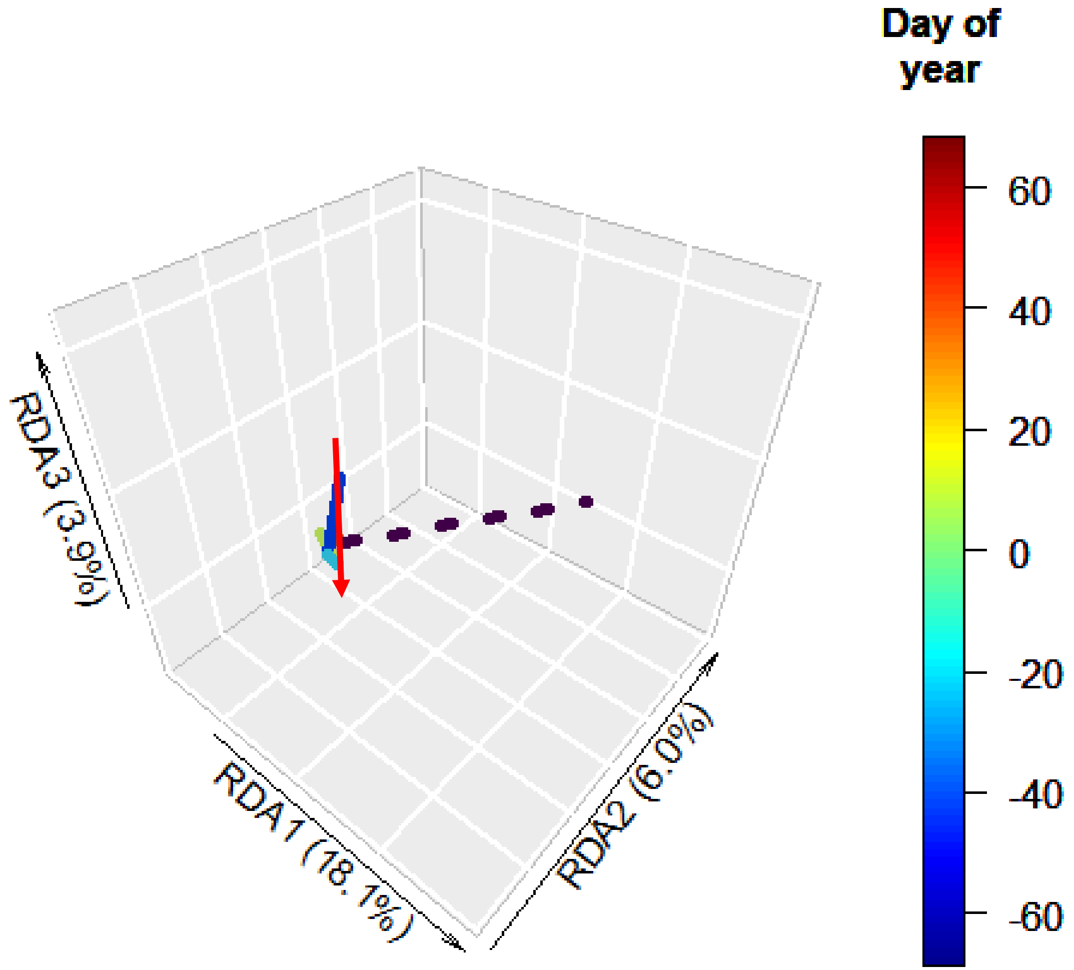
- RDA with year (3-level factor), day-of-year, and their interaction as predictors
- Higly significant interaction
- $F_{1,166} = 8.98$, $P = 0.001$
- Trends exist but go in different «directions»

Summary representation



- 2016: 60 samples in July-September

Summary representation



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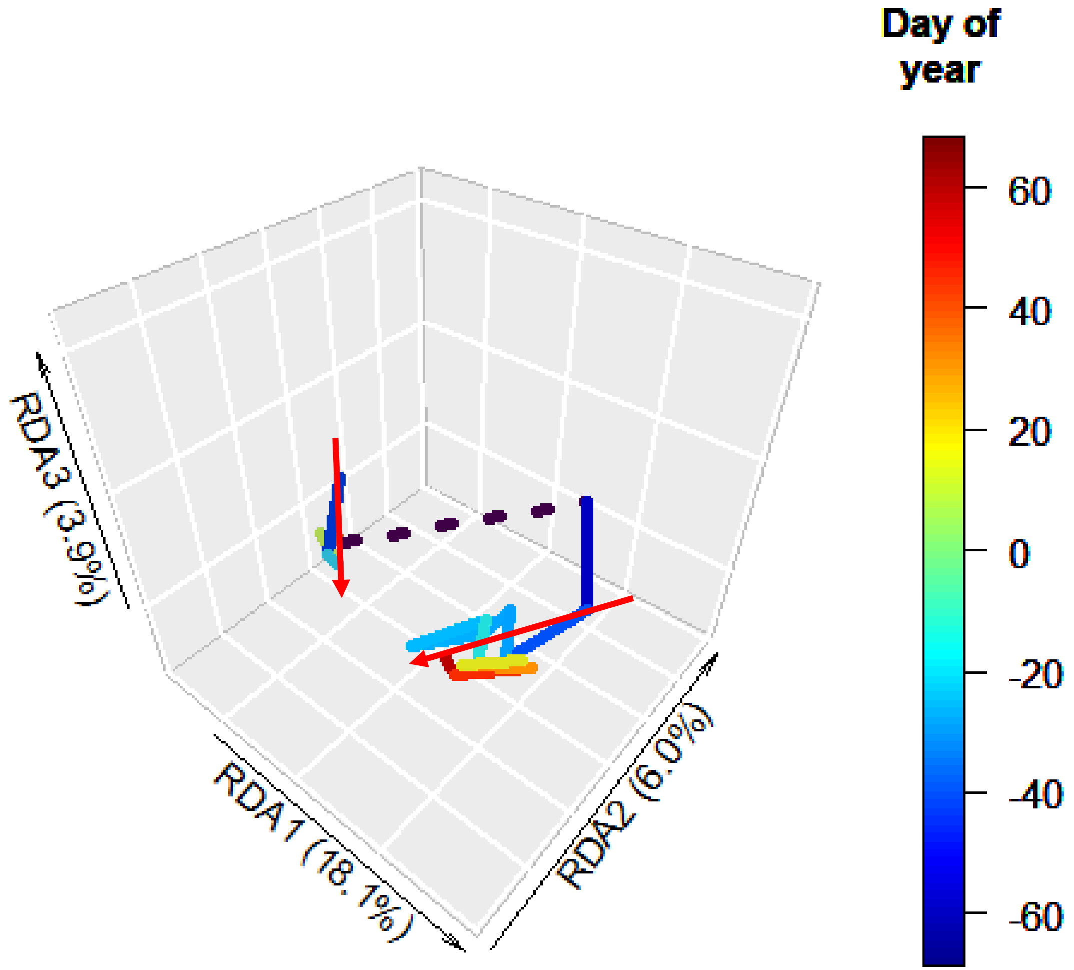
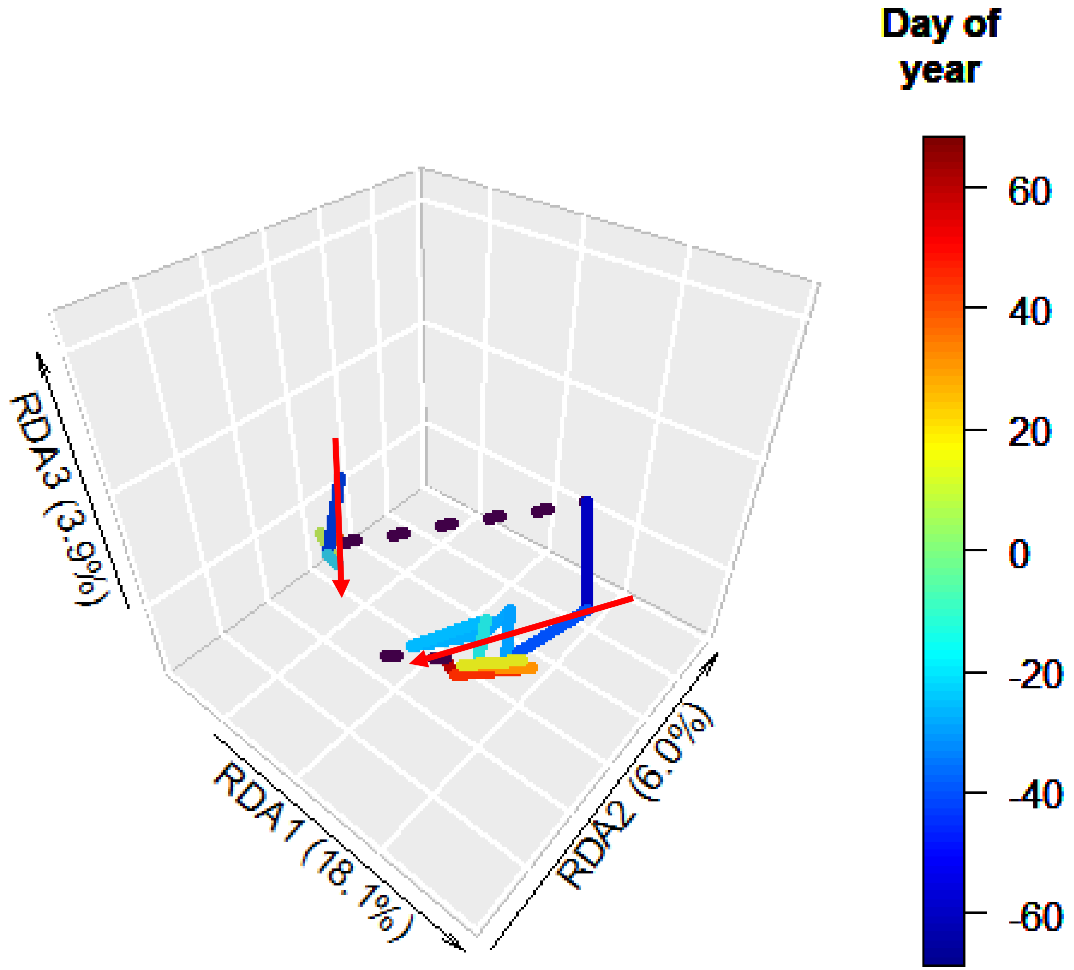
Summary representation



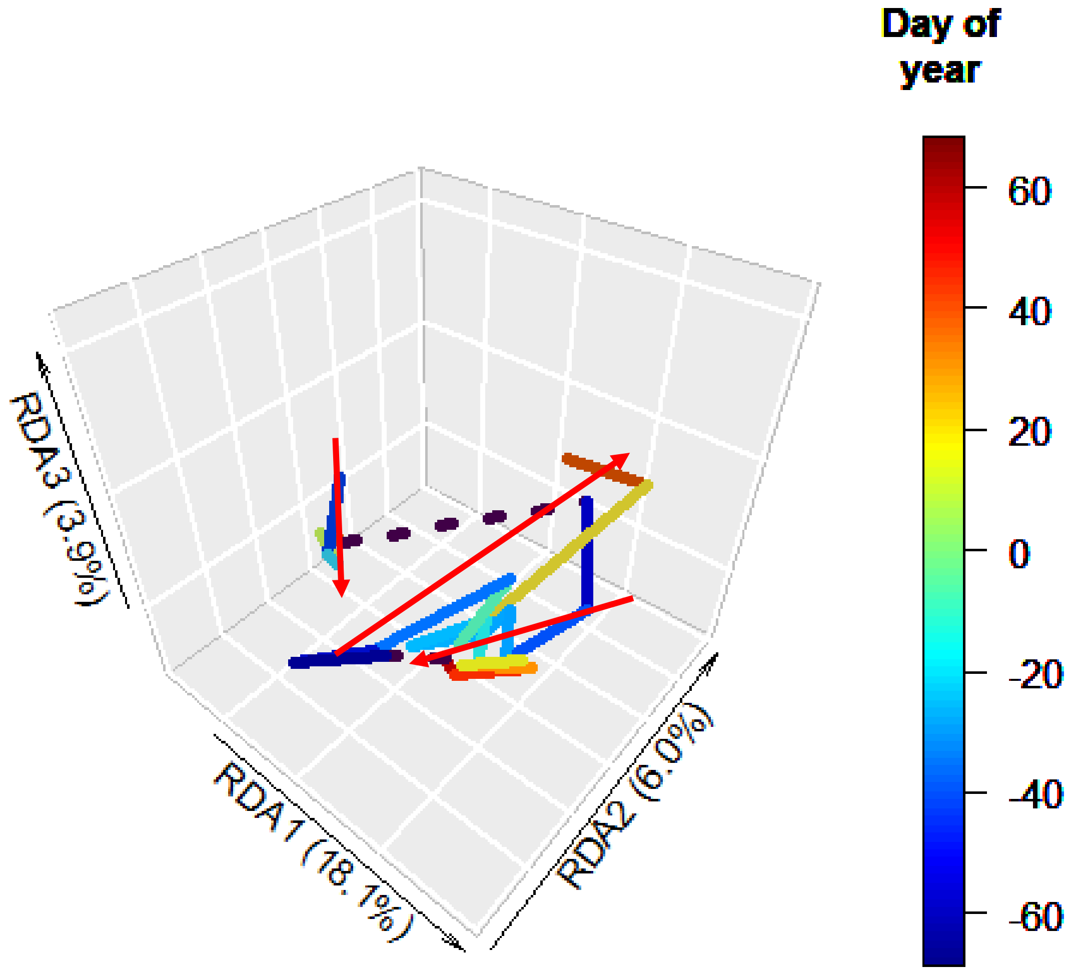
- 2018: 75 samples in June-October

Summary representation



- 2018: 75 samples in June-October

Summary representation



- 2019: 37 samples in July-September

Conclusions

- Snapshot sampling can capture only a fraction of glacier biodiversity
- Different glaciers seem to host very different bacterial communities
- Even a snapshot sampling may be sufficient to differentiate bacterial communities of different glaciers
- An overall biogeographical pattern seem to appear, maybe linked to glacier size
- Temporal trends seem to exist and to change from year to year
- The bacterial communities of a glacier seem to stay in a limited «space»

A threatened biodiversity

Biodiversity and Conservation (2021) 30:2267–2276
https://doi.org/10.1007/s10531-021-02185-9

COMMENTARY

Check for updates

Vanishing permanent glaciers: climate change is threatening a European Union habitat (Code 8340) and its poorly known biodiversity

M. Gobbi[1] · R. Ambrosini[2] · C. Casarotto[3] · G. Diolaiuti[2] · G. F. Ficetola[2] · V. Lencioni[1] · R. Seppi[4] · C. Smiraglia[2] · D. Tampucci[5] · B. Valle[5] · M. Caccianiga[5]

A threatened biodiversity

Bacteria contribute to pesticide degradation in cryoconite holes in an Alpine glacier☆

Claudia Ferrario [a], Francesca Pittino [a], Ilario Tagliaferri [a], Isabella Gandolfi [a], Giuseppina Bestetti [a], Roberto Sergio Azzoni [b], Guglielmina Diolaiuti [b], Andrea Franzetti [a, *], Roberto Ambrosini [a], Sara Villa [a]

Environmental Pollution 230 (2017) 919–926

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Università degli Studi di Milano Bicocca

DISAT

EX UMBRA IN SOLEM

IceCommunities

UAM Adam Mickiewicz University in Poznań

ORTOVOX

Bormioli Rocco

STANLEY SINCE 1913

On the Trail of the Glaciers

Thank you for your kind attention