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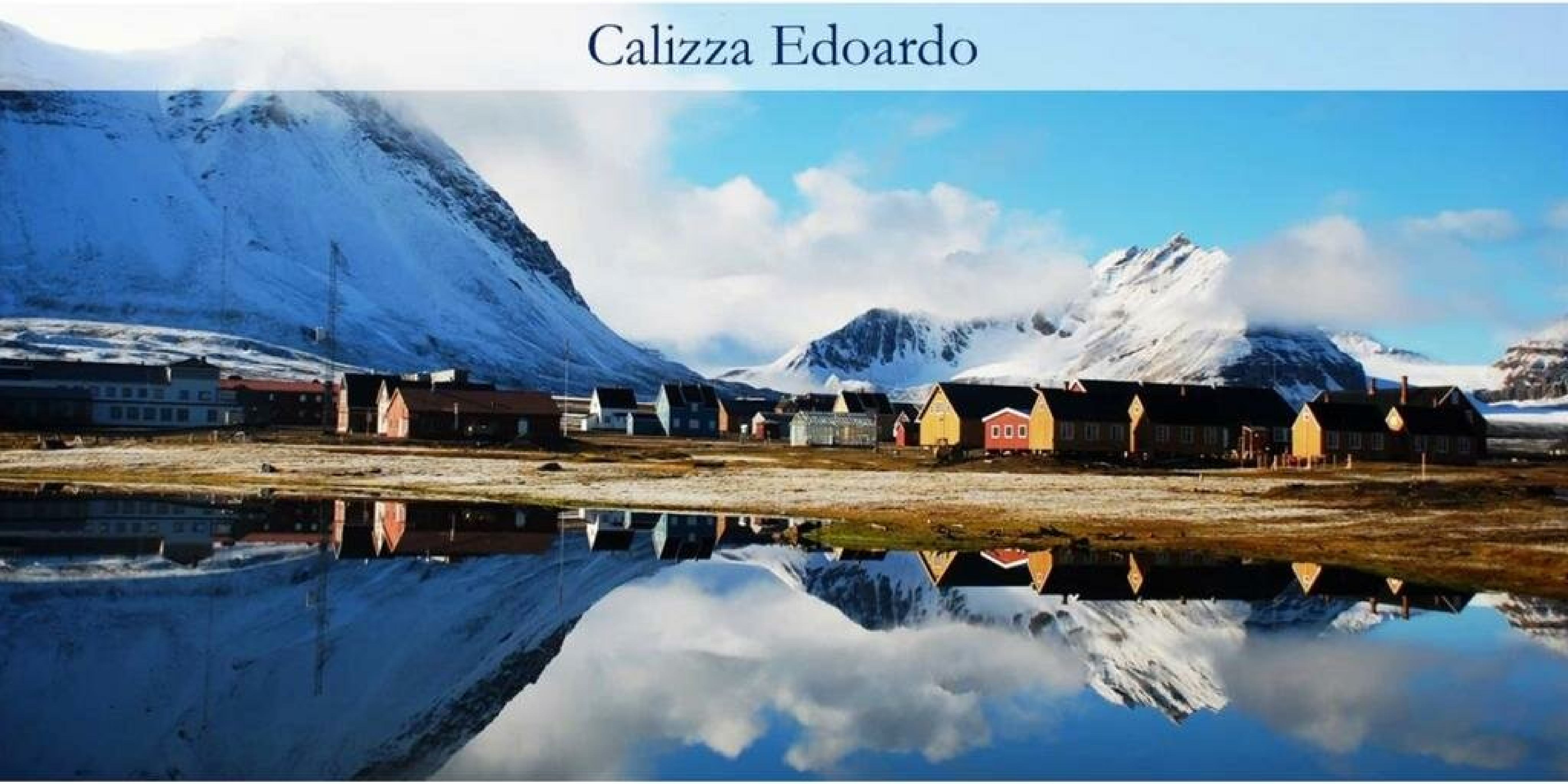
Climate-related drivers of nutrient inputs and food web structure in shallow Arctic lake ecosystems

Calizza Edoardo



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Climate-related drivers of nutrient inputs and food web structure in shallow Arctic lake ecosystems

Edoardo Calizza[1,2], Rosamaria Salvatori[3], David Rossi[4], Vittorio Pasquali[5], Giulio Careddu[1,2]✉, Simona Sporta Caputi[1,2], Deborah Maccapan[1], Luca Santarelli[1], Pietro Montemurro[1], Loreto Rossi[1,2] & Maria Letizia Costantini[1,2]

TEMPERATURE

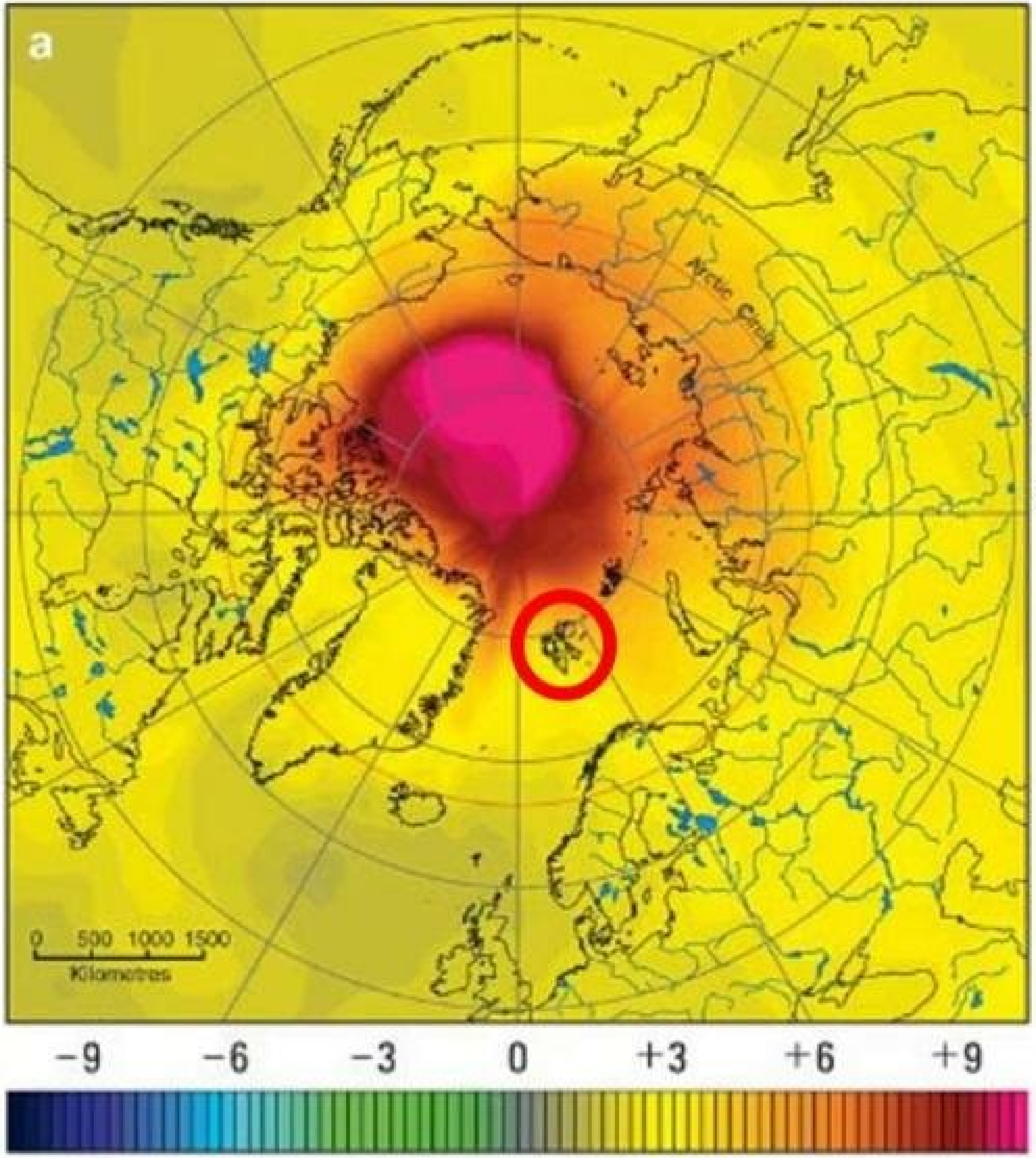


Figure 1. Changes in mean monthly air temperature (°C) between 1981–2000 and 2071–2090 projected by the ACIA-designated models (five-model average) for (a) October and (b) November.

PRECIPITATION

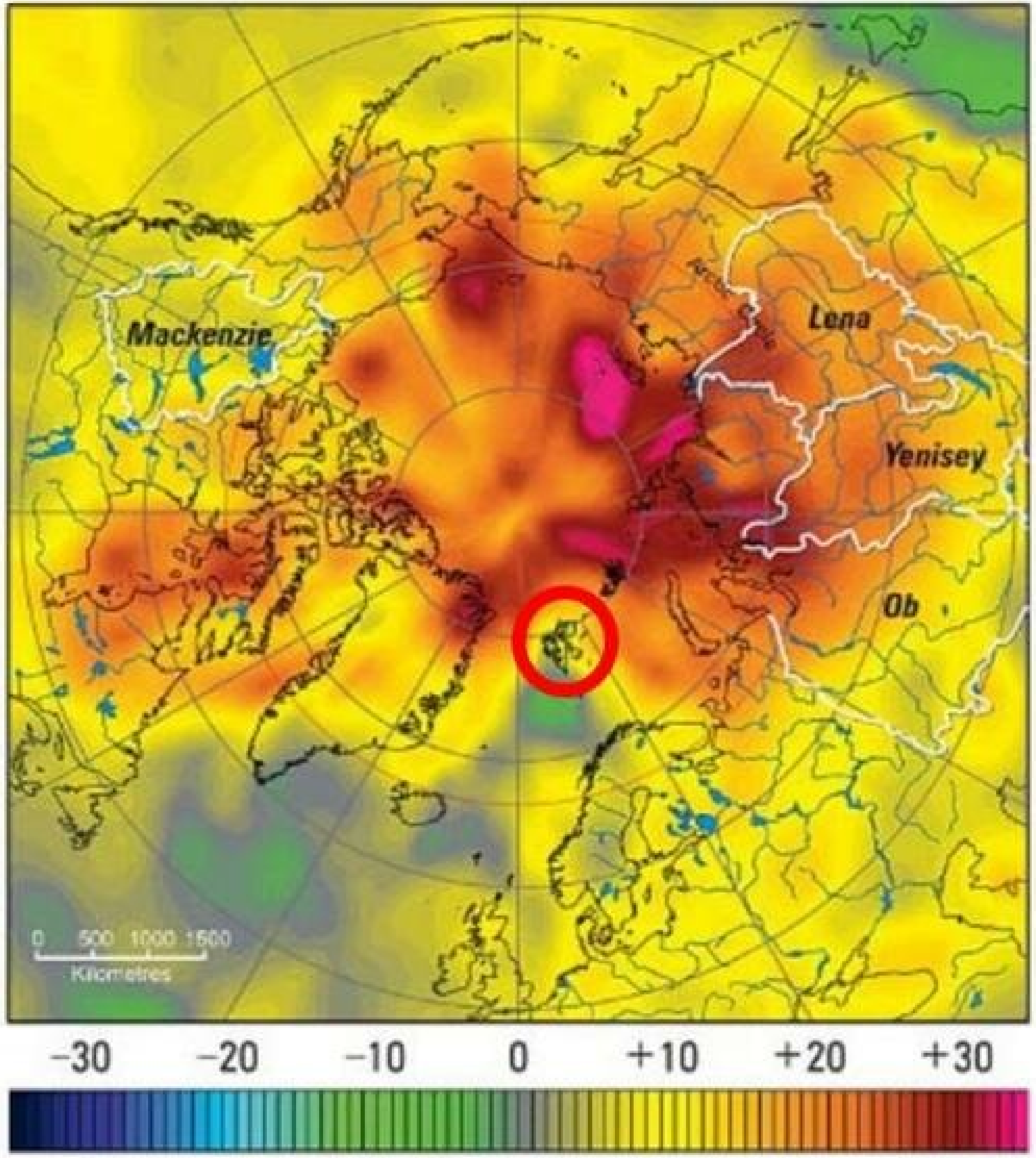
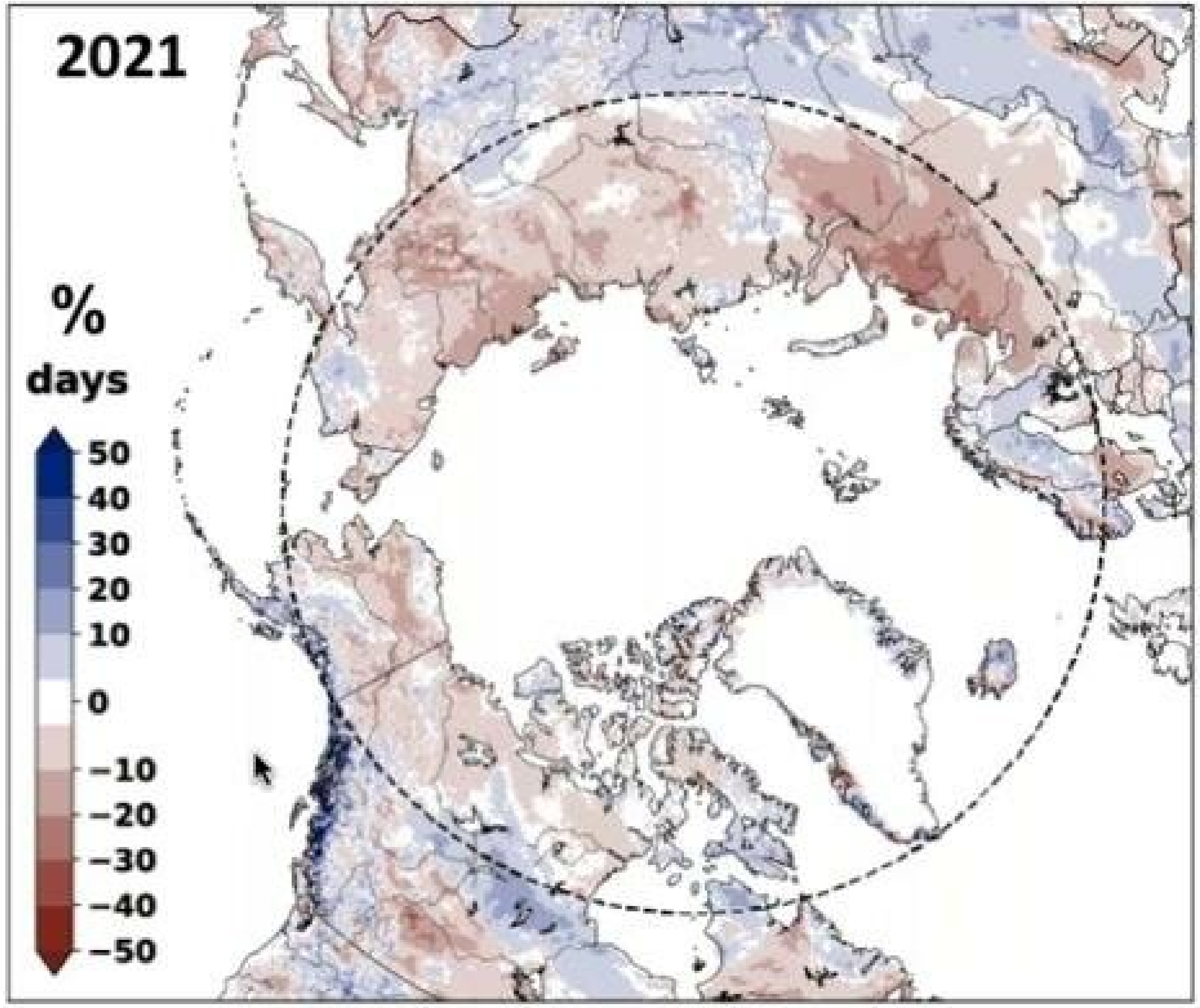


Figure 2. Percentage changes in November to April precipitation between 1981–2000 and 2071–2090 projected by the ACIA-designated models (five-model average). The basins of four major arctic rivers are also shown.

Source: Climate State

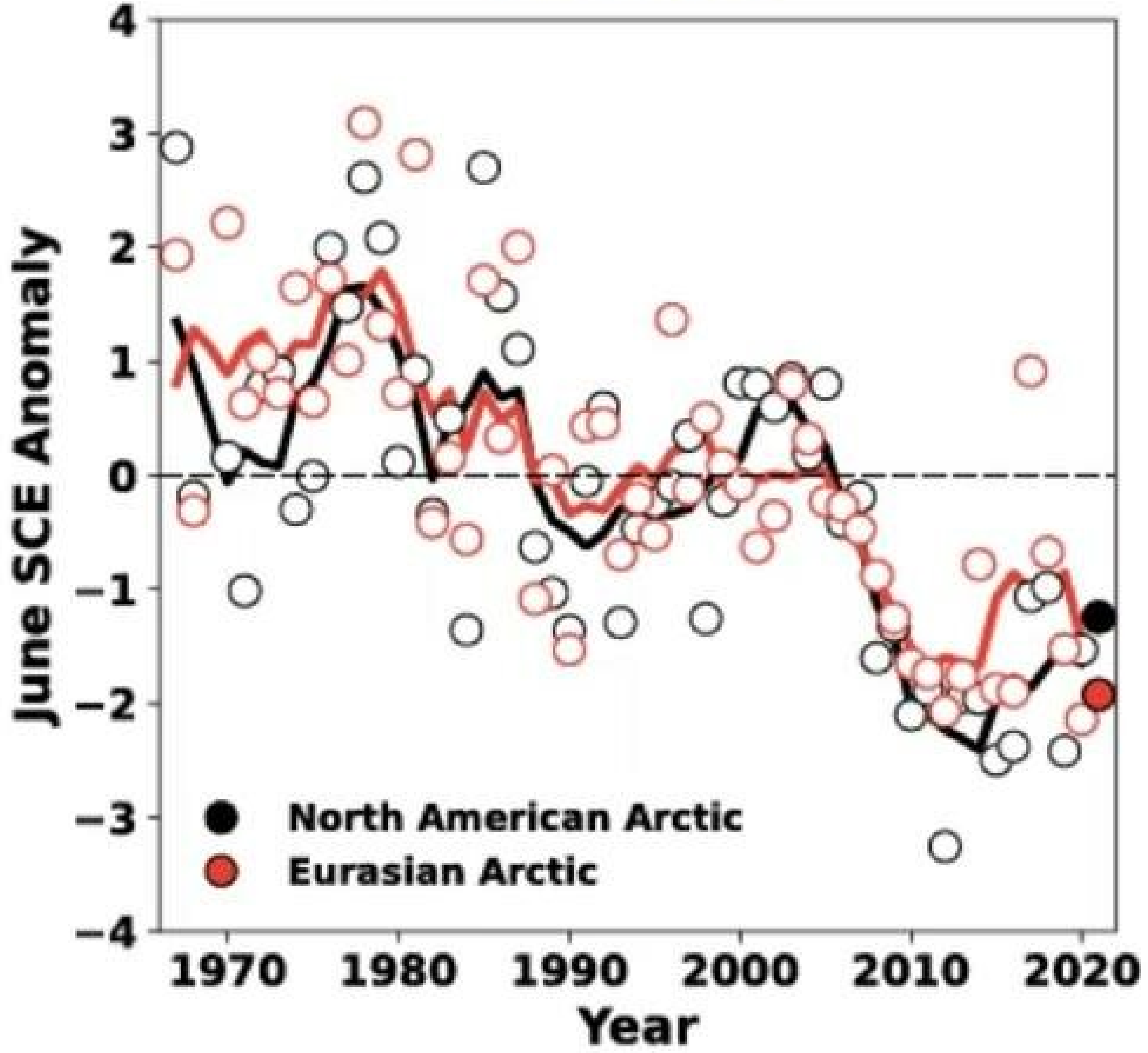
CHANGES IN SNOW COVER

Duration



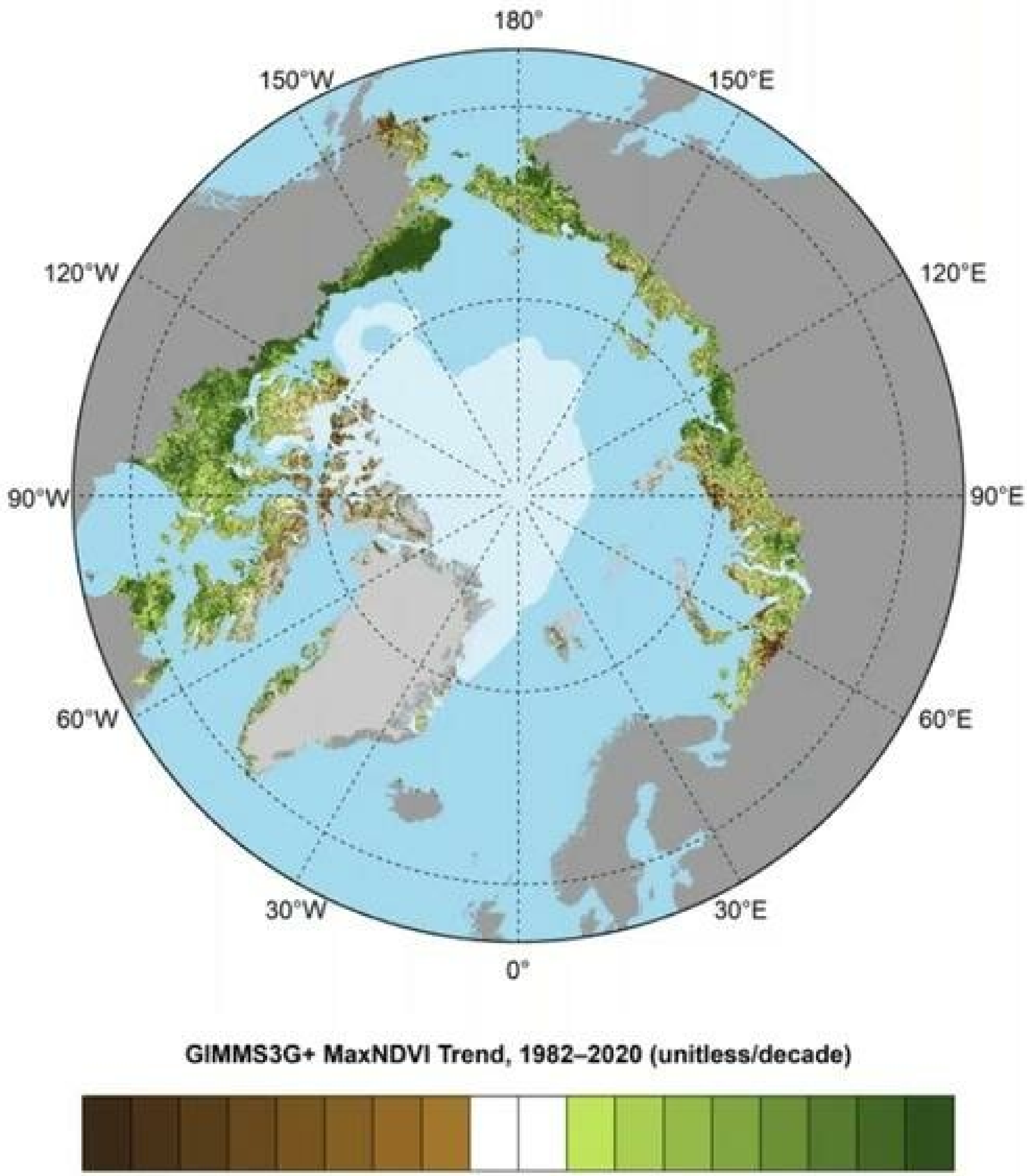
(ref.: 1982-2020)

Extent

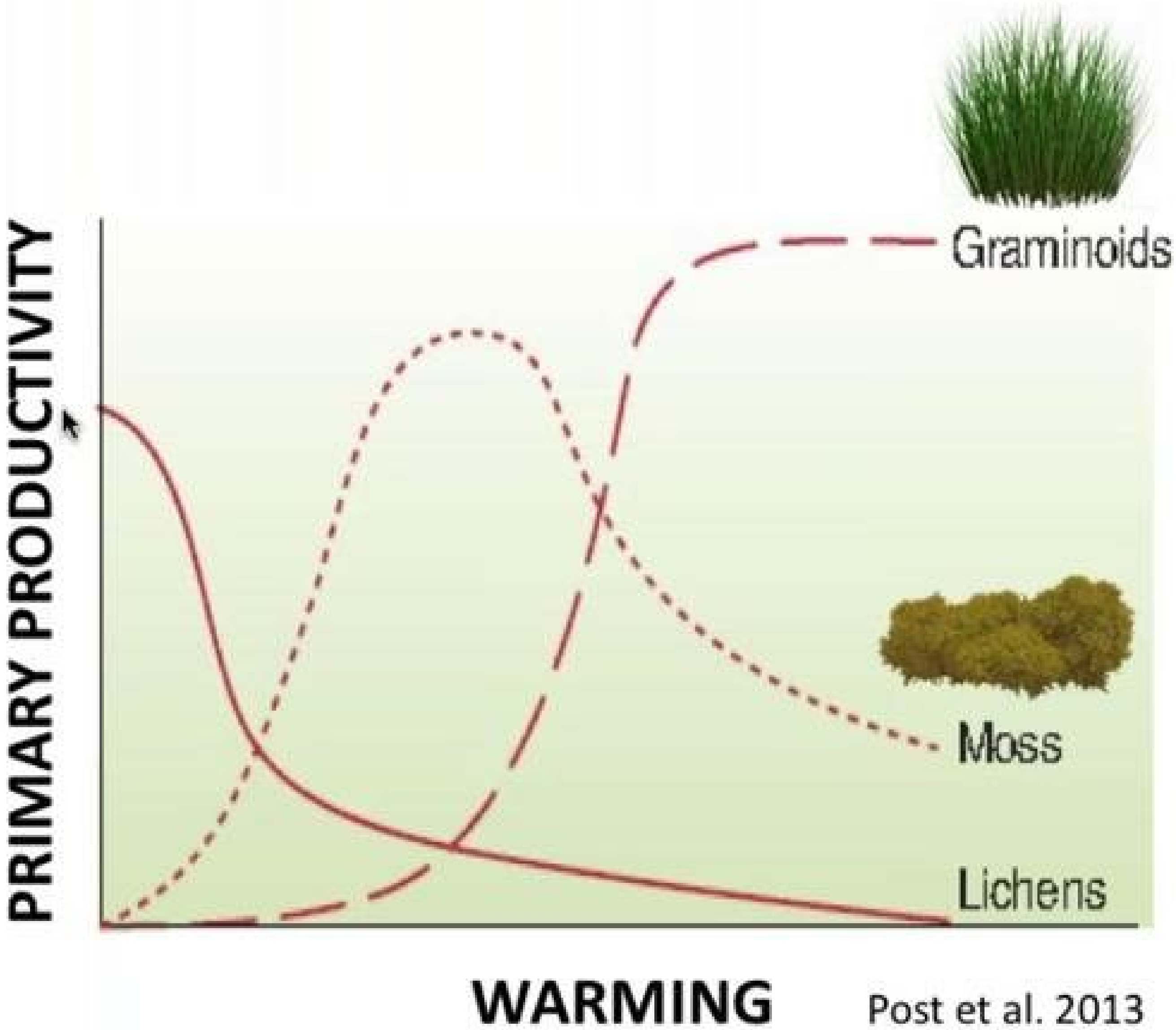


Source: NOAA IMS data record.

CHANGES IN VEGETATION



Magnitude of the trend in MaxNDVI for the 39-year period 1982-2020



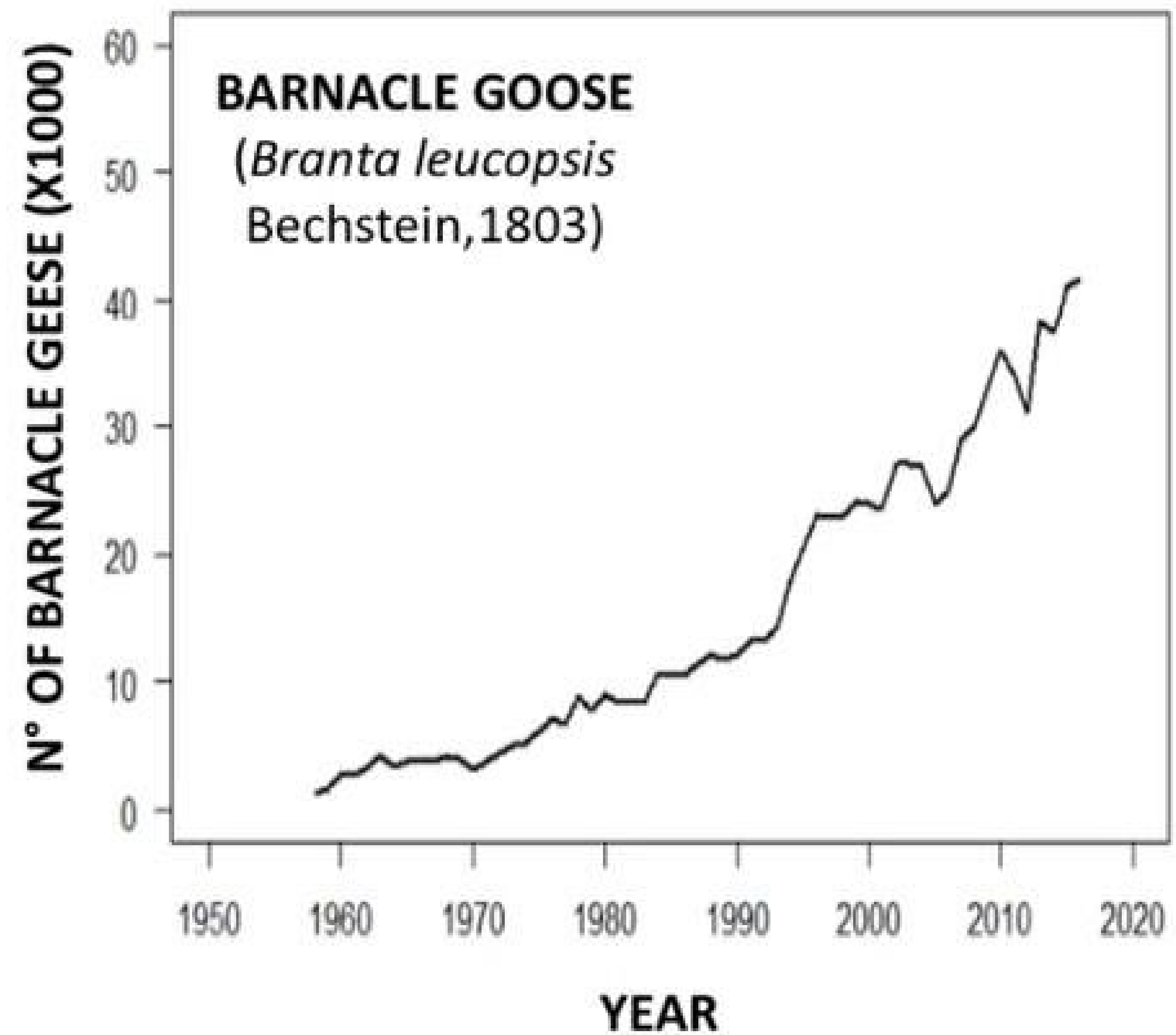
Post et al. 2013

Source: NOAA IMS data record.

CHANGES IN MIGRATORY GEESE

ARCTIC

SVALBARD / SOUTH SCOTLAND



G. H. Jensen et al. 2018.

- Very few studies addressing interacting effects on lake ecosystems

- Paucity of studies at the landscape scale along natural gradients

Reduced ability to predict local-scale effects of climate change on Arctic lake ecosystems and associated services

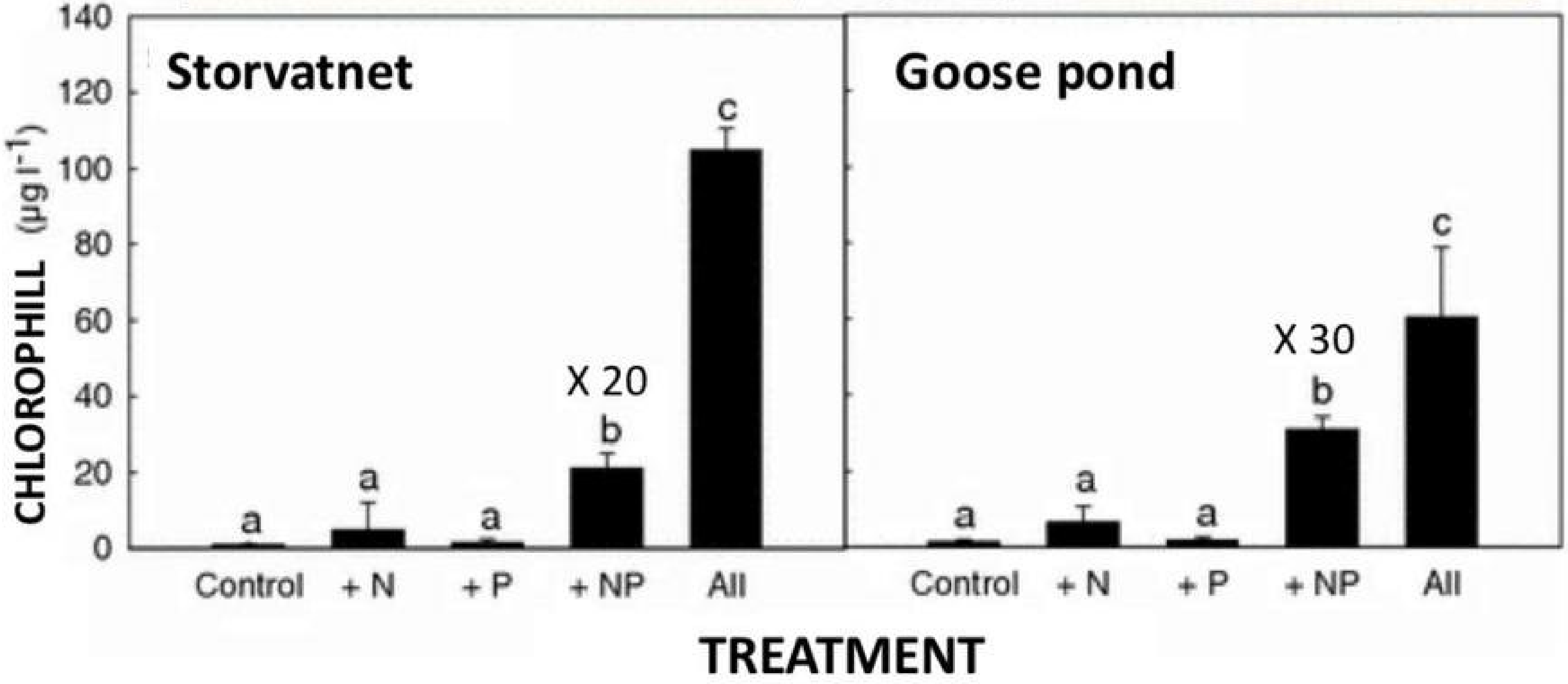
Vincent et al. 2008; Post et al. 2009; Box et al. 2019

KEY AREAS FOR CARBON SEQUESTRATION

Net uptake: 60-80 gC m^{-2} $year^{-1}$

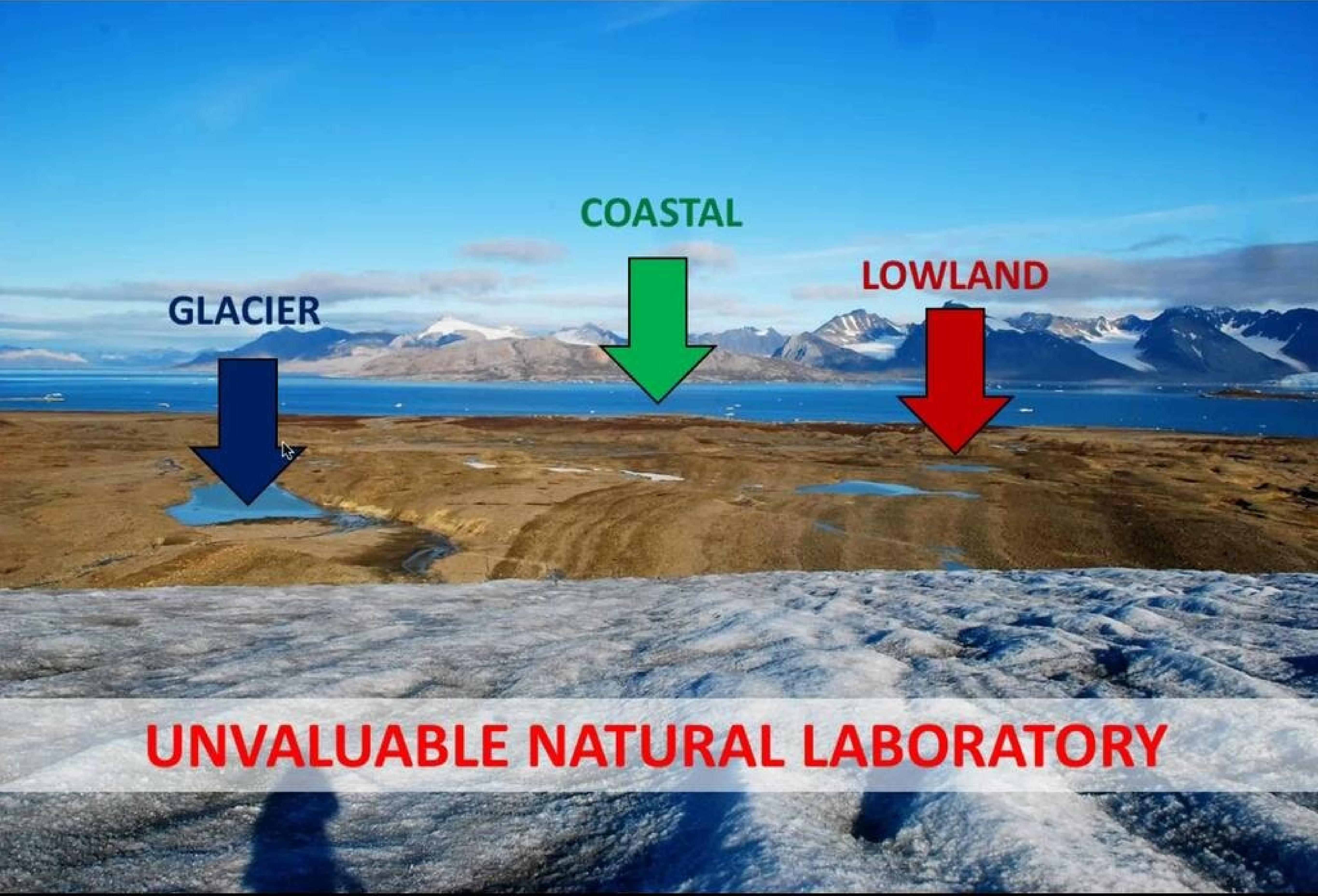
Carbon release limited by permafrost and nutrients (mainly N)

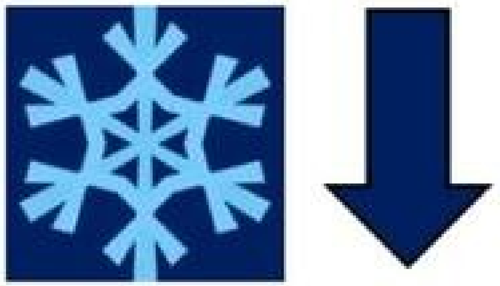
NUTRIENTS ALSO LIMIT AQUATIC PIRMARY PRODUCTIVITY



Van Geest et al. 2007

KEY ELEMENTS FOR TERRESTRIAL-MARINE CONNECTIVITY





SNOW COVERAGE

PRIMARY PRODUCTIVITY

ORGANIC INPUTS

AIM:

To quantify direct and indirect effects of climate-related drivers on nutrient inputs and food web structure in Arctic lake ecosystems

Study area: Brøggerhalvøya peninsula, Svalbard Islands

Sampling: 18 shallow lakes (end of summer)

Soil (5cm) 6X

Terrestial vegetation 6X

Sediment (5cm) 6X

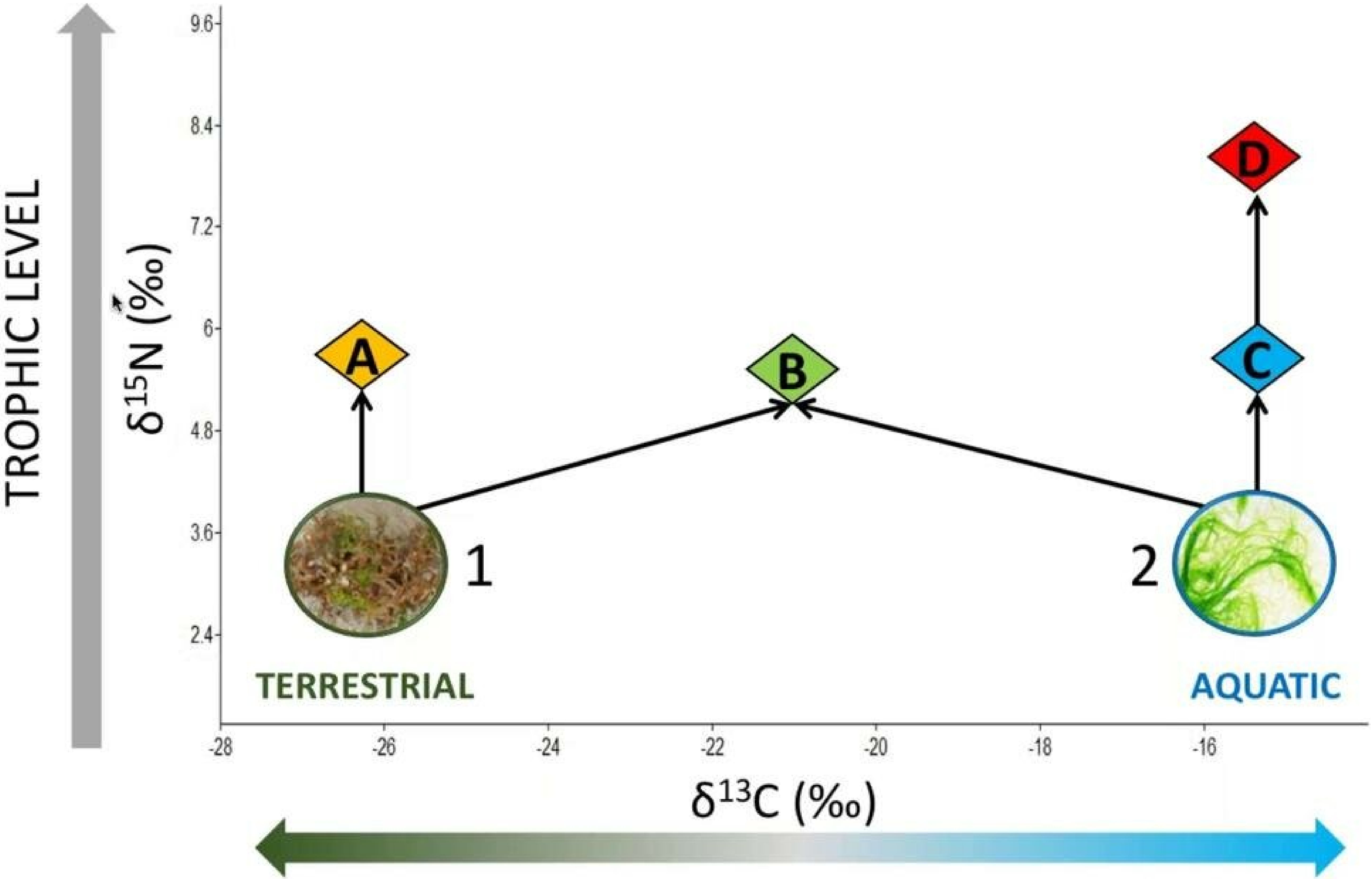
Aquatic vegetation 6X

Phytoplankton 3X

Lepidurus arcticus

Macroinvertebrates up to 20 ind. each

C and N Stable isotopes analysis

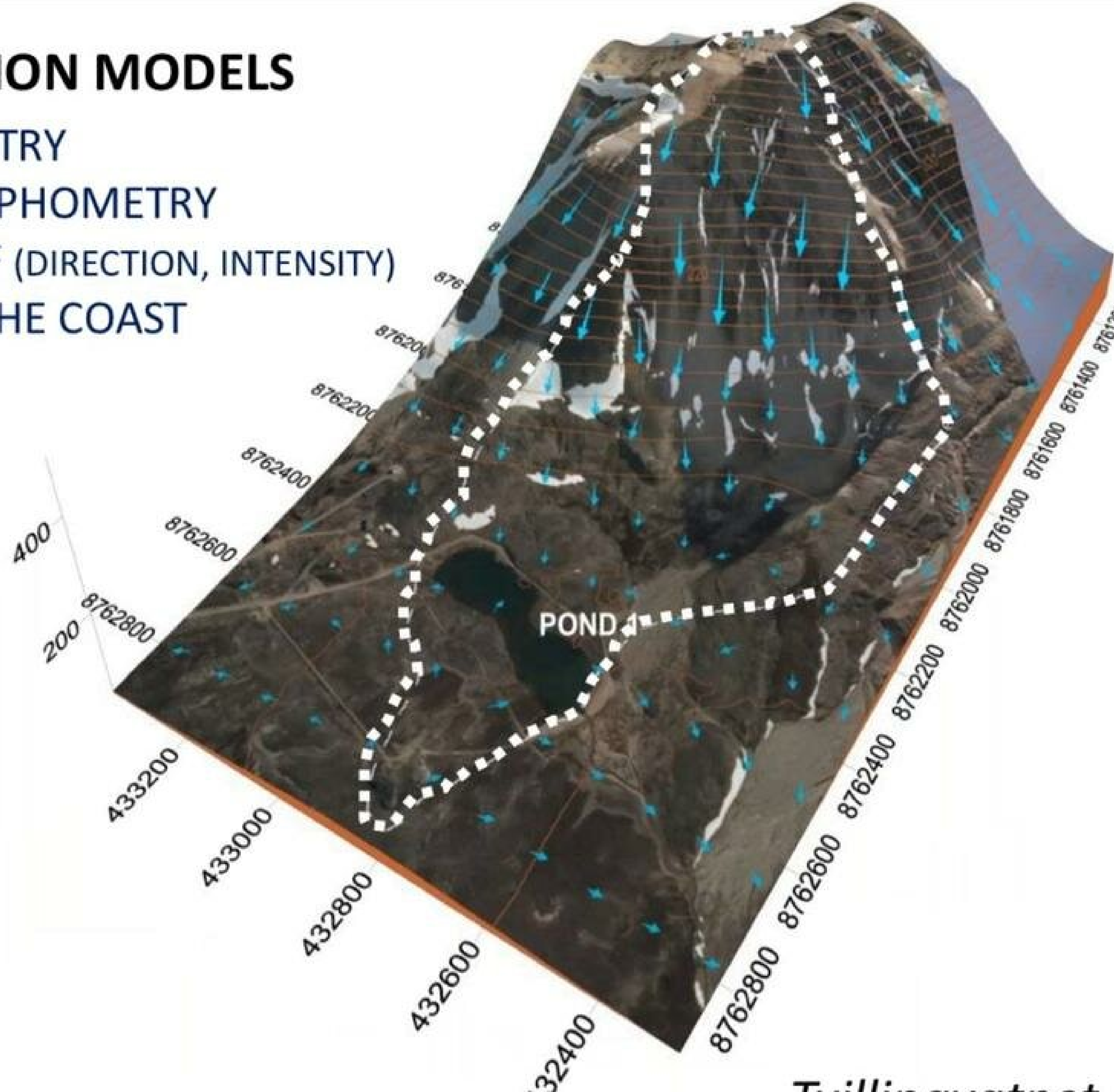


Careddu et al. 2015, Calizza et al. 2016, 2022: Rossi et al. 2010, 2015, 2019

DIGITAL ELEVATION MODELS

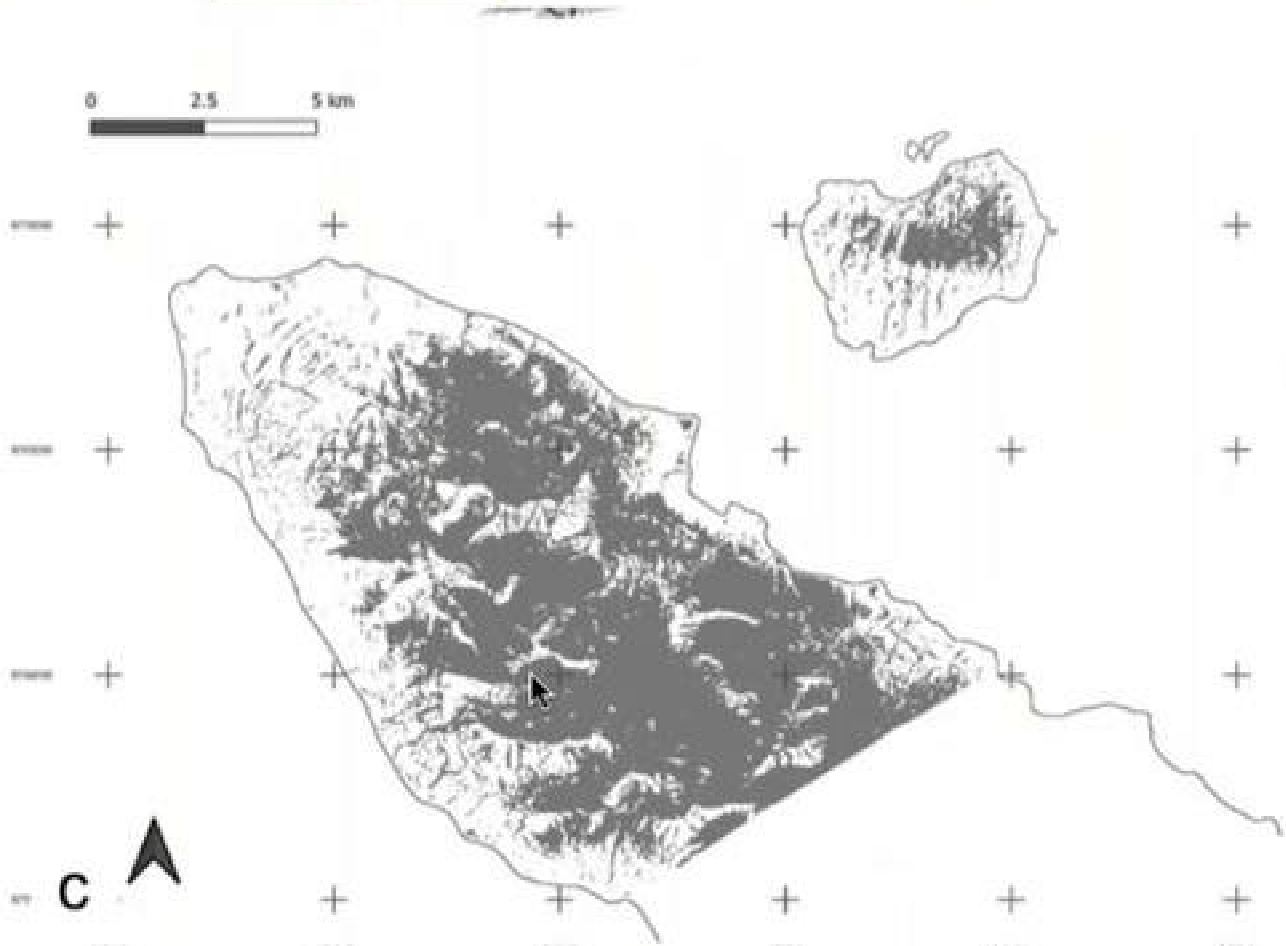
- LAKE MORPHOMETRY
- CATCHMENT MORPHOMETRY
- SURFACE RUN-OFF (DIRECTION, INTENSITY)
- DISTANCE FROM THE COAST

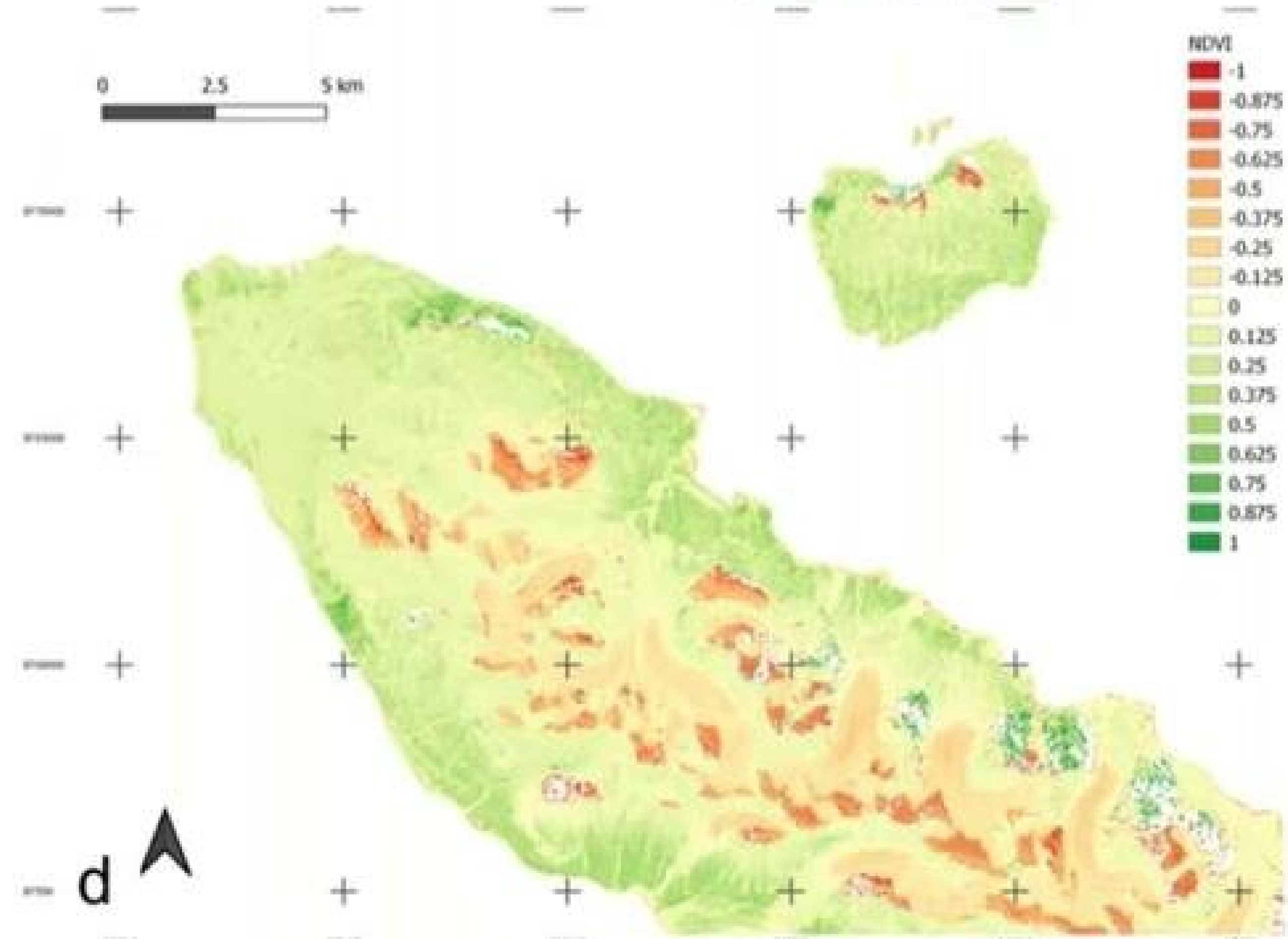
Calizza et al. 2016



Tvillingvatnet

Monthly
from April to September





Snow coverage
SCA
0 to 1

$$NDSI = \frac{Green - SWIR}{Green + SWIR}$$

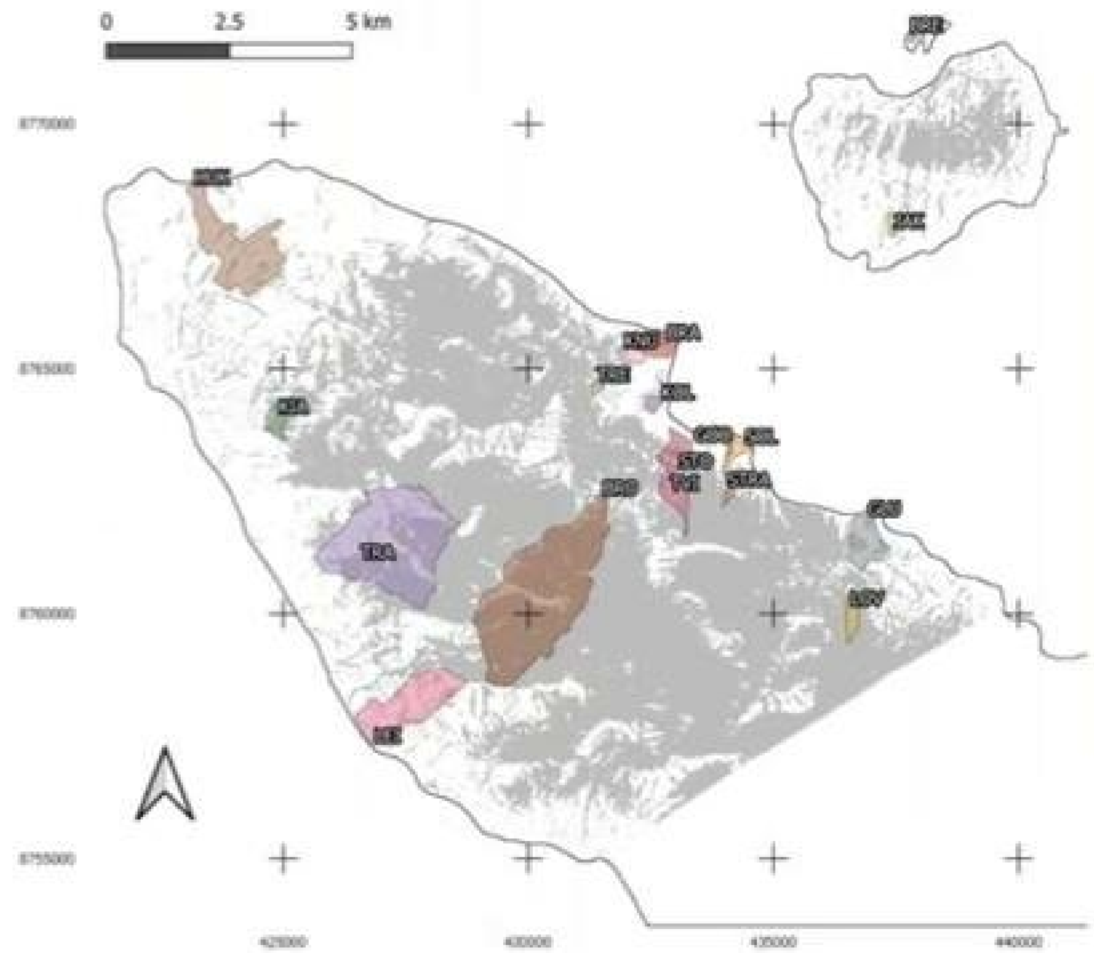
Landsat 8
30x30 m

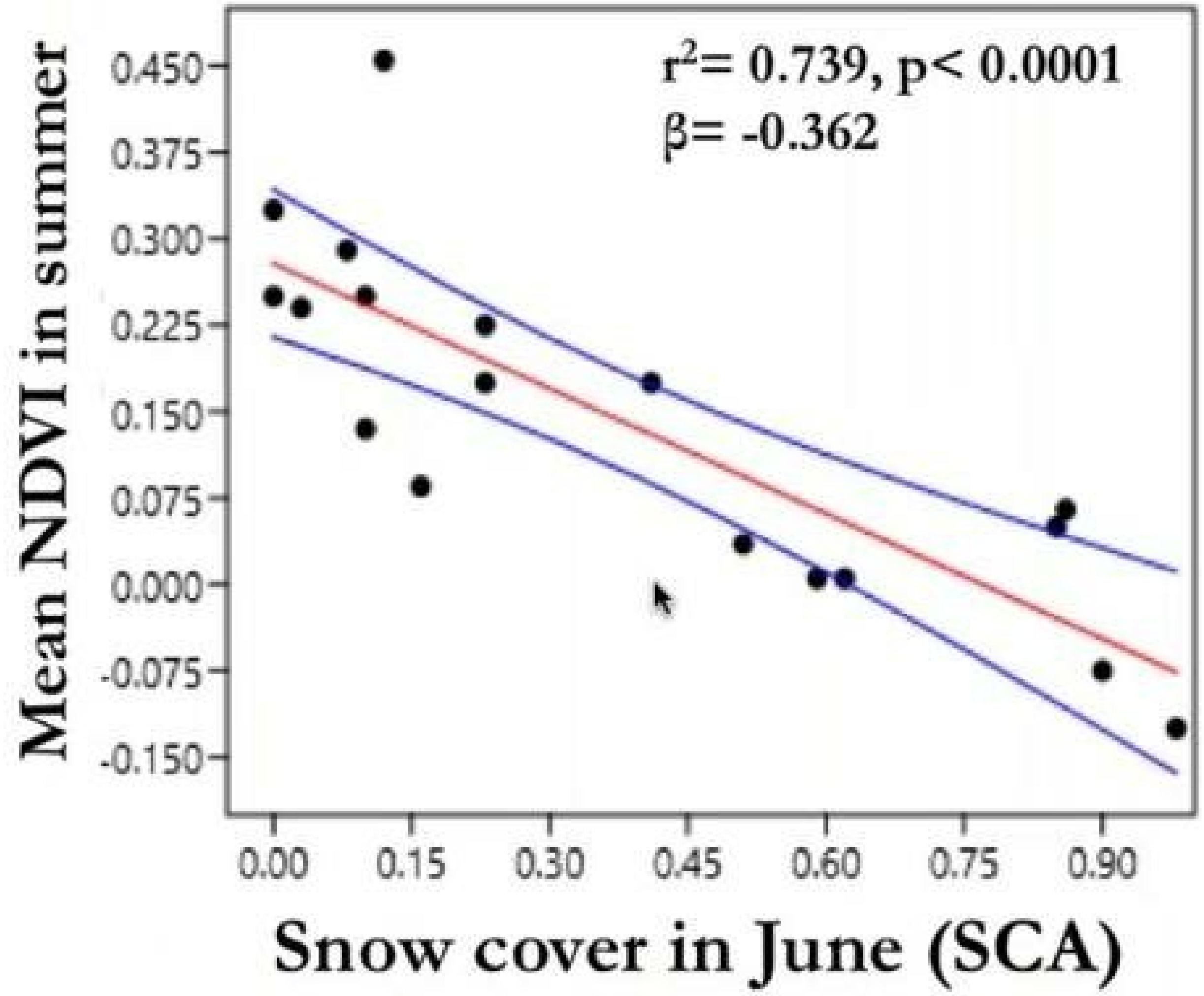
Vegetation productivity
NDVI
-1 to 1

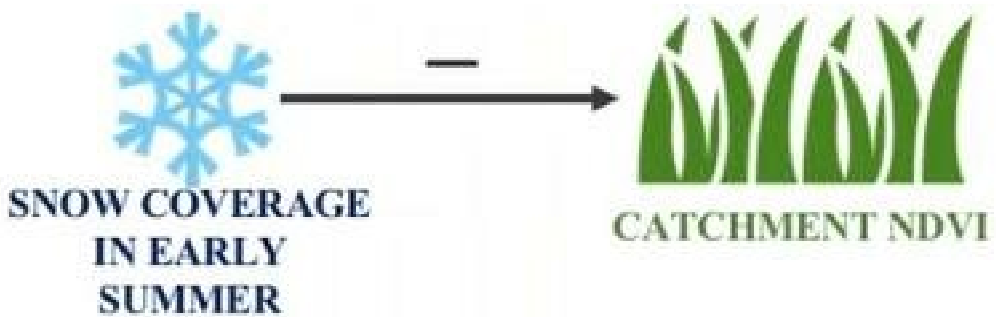
$$NDVI = \frac{NIR - Red}{NIR + Red}$$

Stow *et al*. 2004; Riedel *et al*. 2005; Gascoin *et al*. 2015; Pimentel *et al*. 2017; Aalstad *et al*. 2020

Effect of snow on vegetation productivity

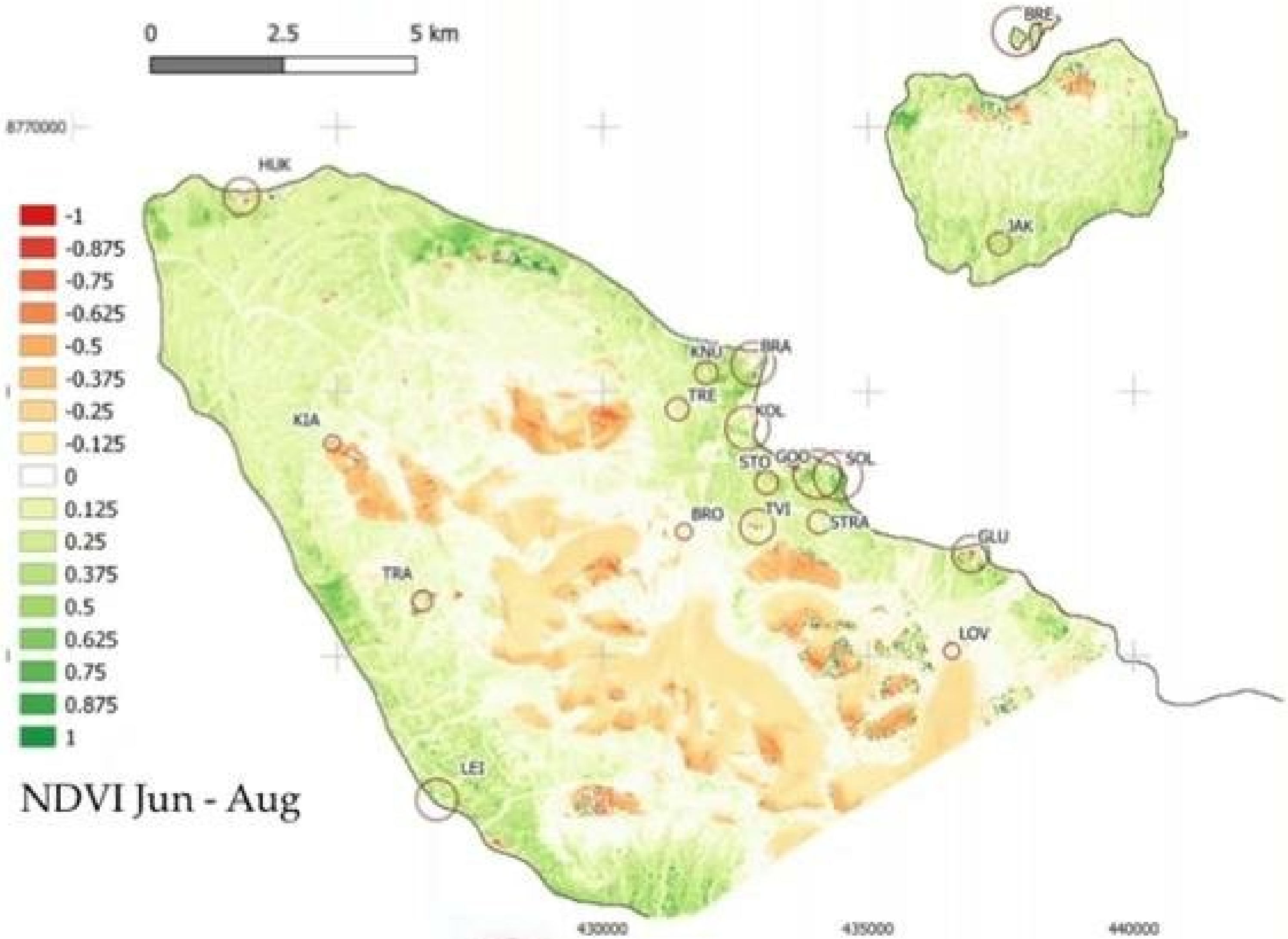


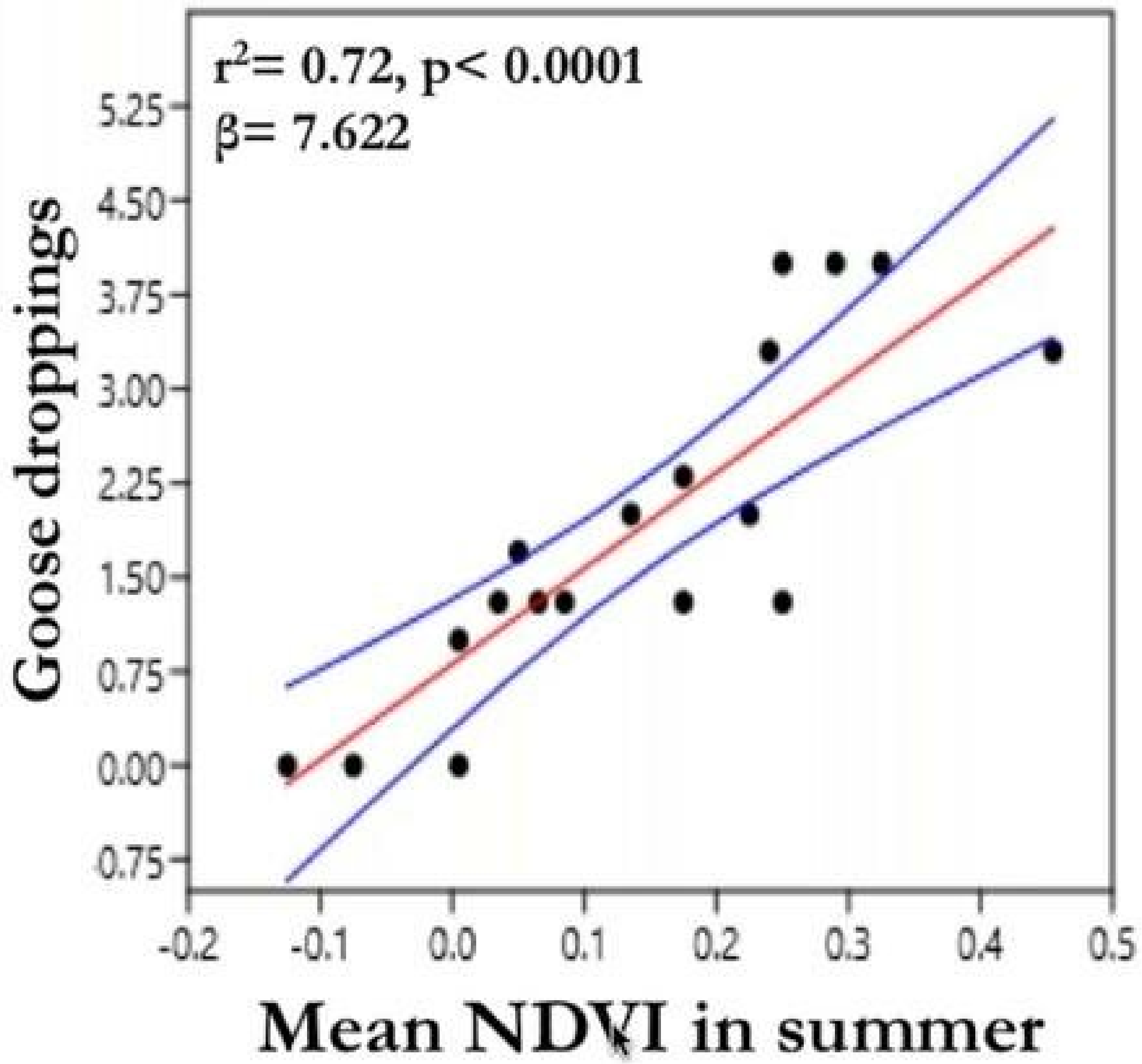


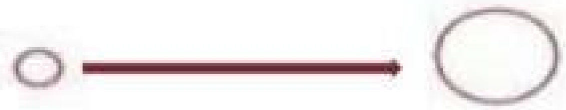


OLSRegression: SCA June-mean NDVI summer			
Slope a:	-0,36166	**Std. error a:**	0,059749
Intercept b:	0,27889	**Std. error b:**	0,030153
95% bootstrapped confidence intervals (N=1999):			
Slope a:	(-0,46501, -0,24467)		
Intercept b:	(0,20943, 0,33787)		
Correlation:			
r:	-0,85978	t:	-6,7345
p (uncorr.):	4,79E-06	Perm. p:	0,0001

Effect of vegetation on geese distribution



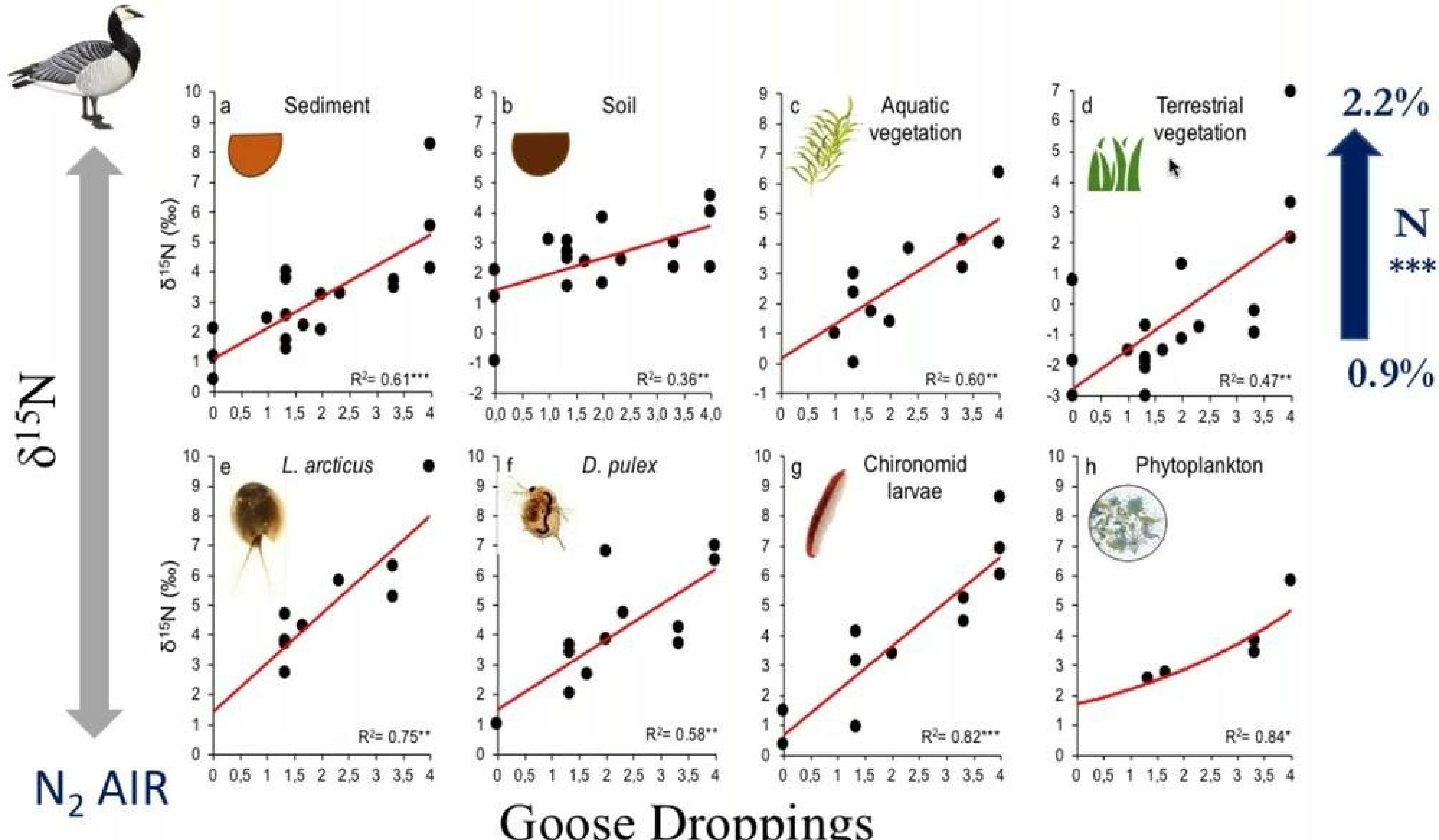




0 - GOOSE DROPPINGS - 4

Bos et al. 2005; Van Geest et al. 2007; Jensen et al. 2019; Barrio et al. 2021

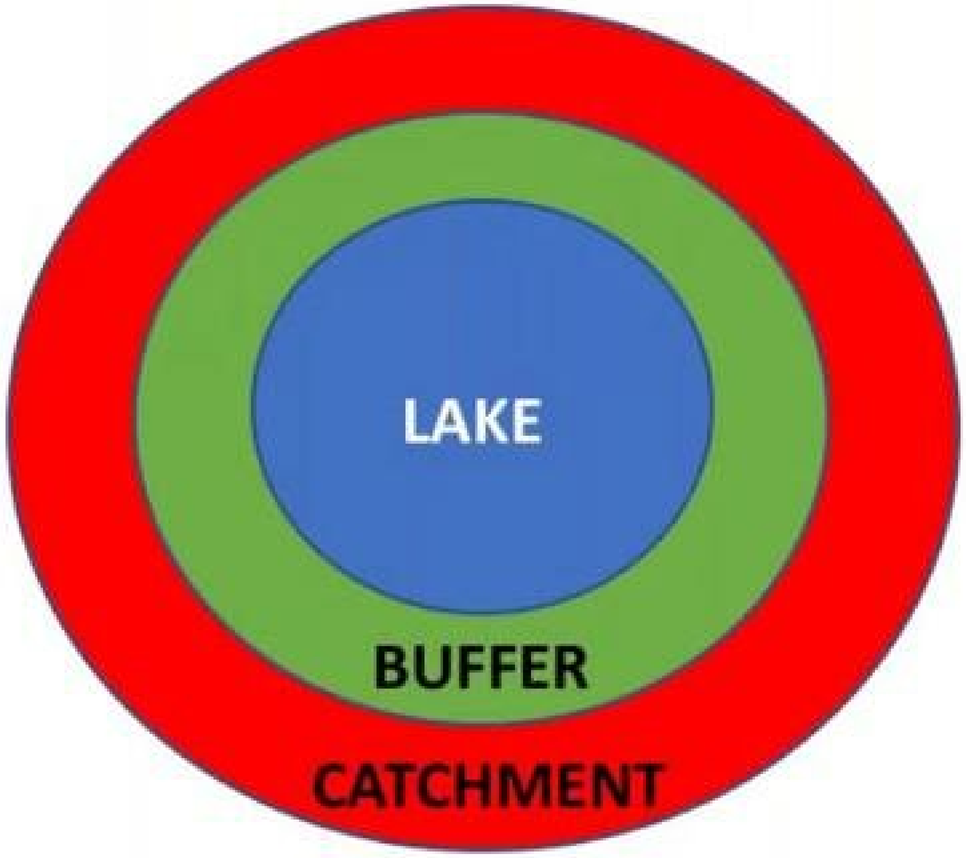
Organic Vs. Inorganic origin of N inputs in food web components



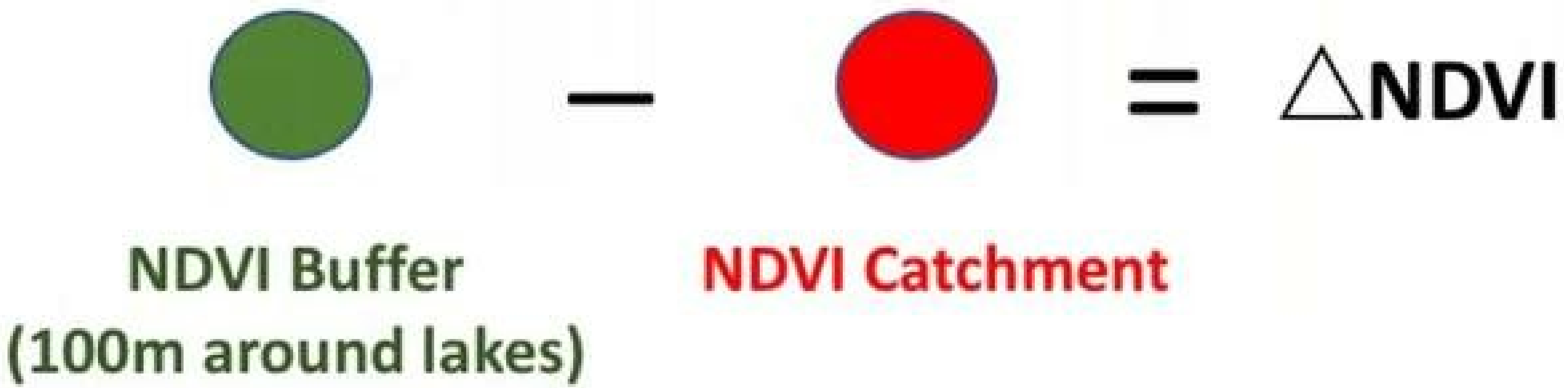
$\delta^{15}N$ in goose droppings: from 5.3±0.4‰ to 7.8±2.7‰

$\delta^{15}N$: Blais et al. 2005; Calizza et al. 2016; Rossi et al. 2018

* $p< 0.05$; ** $p< 0.01$; *** $p< 0.001$

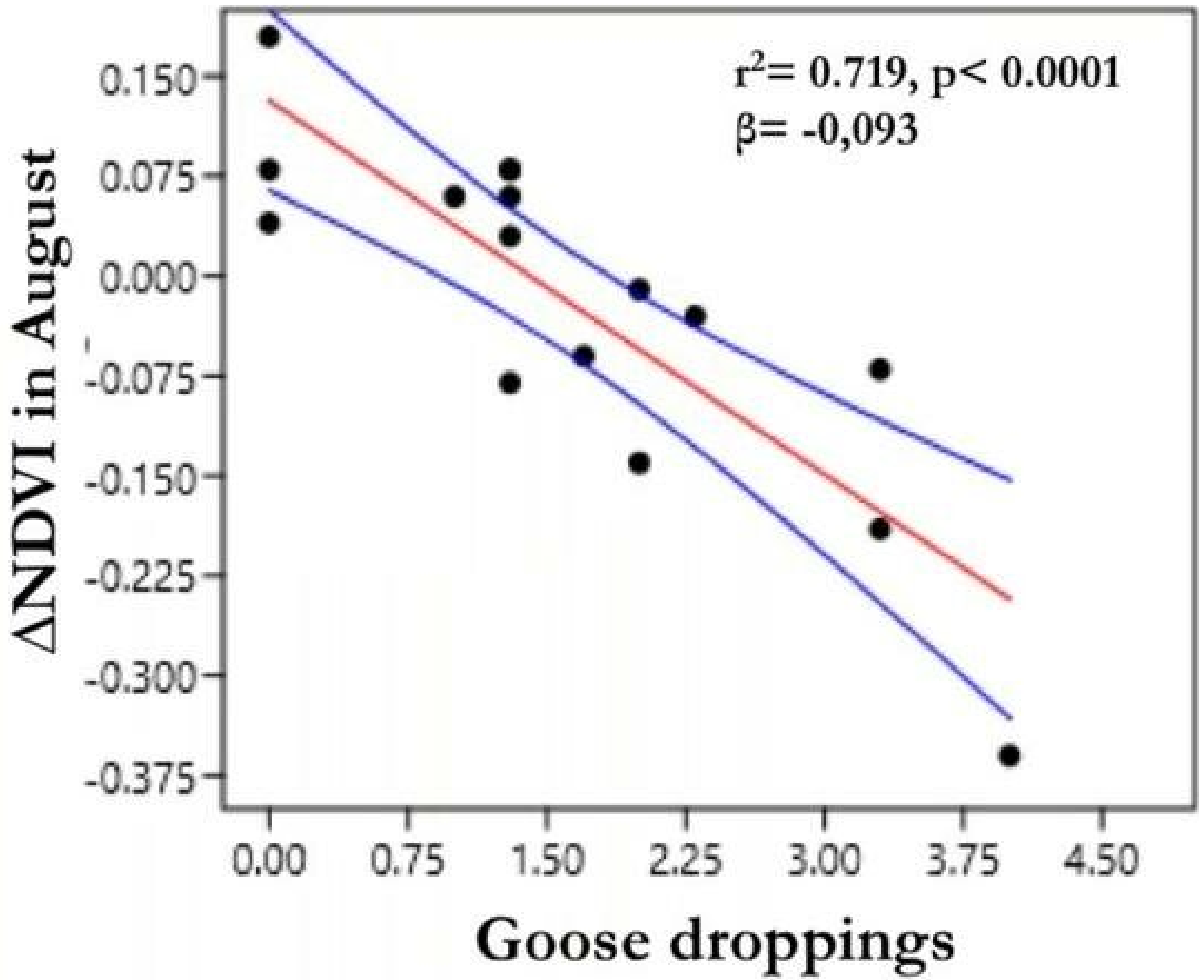


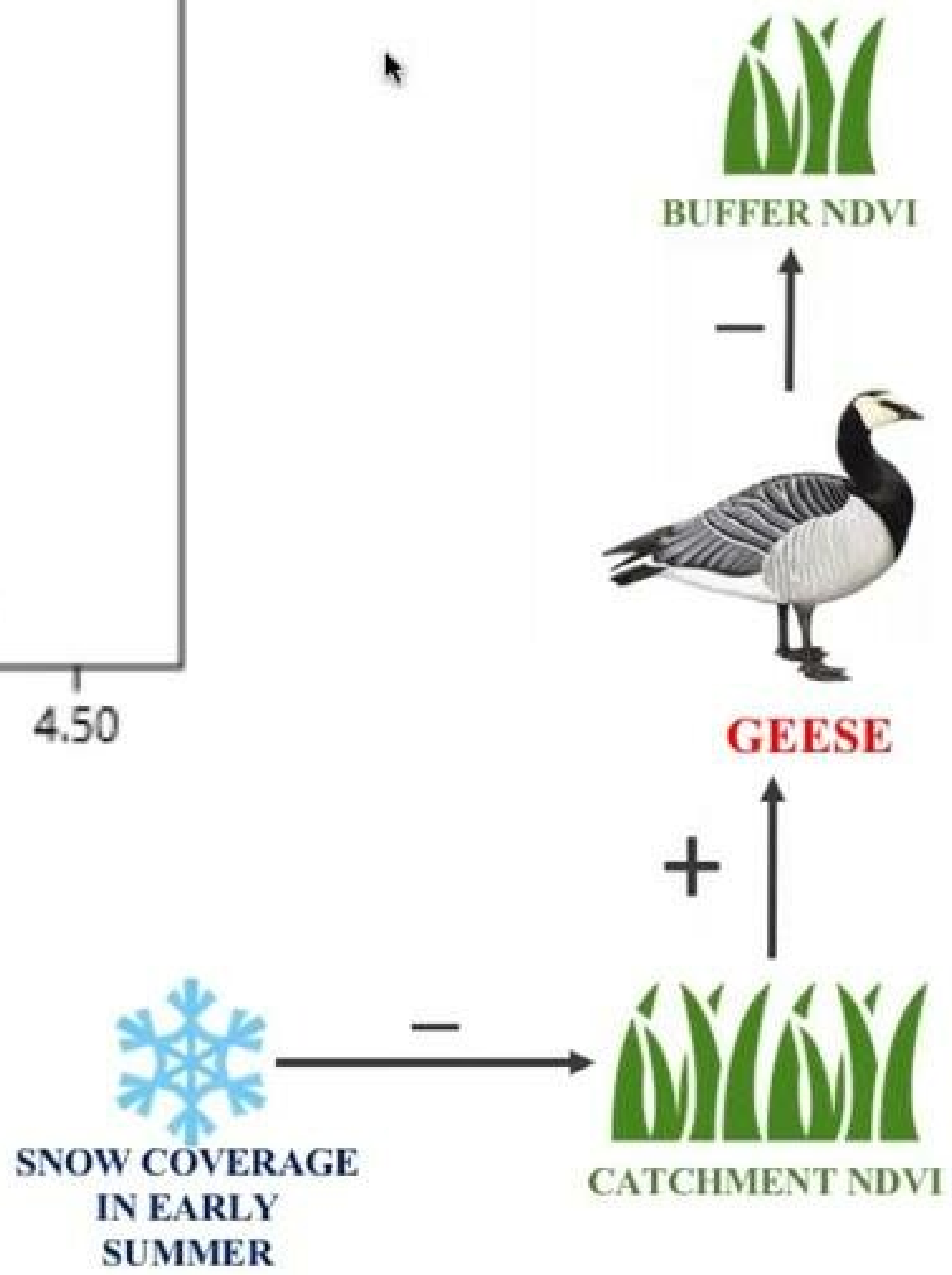
Mehlum et al. 1998; Drent et al. 1998



Local impact of geese indicated by a negative value

Effect of geese on vegetation around lakes





EFFECTS OF GEESE' DIET ON GRASS PRODUCTIVITY

Goose droppings

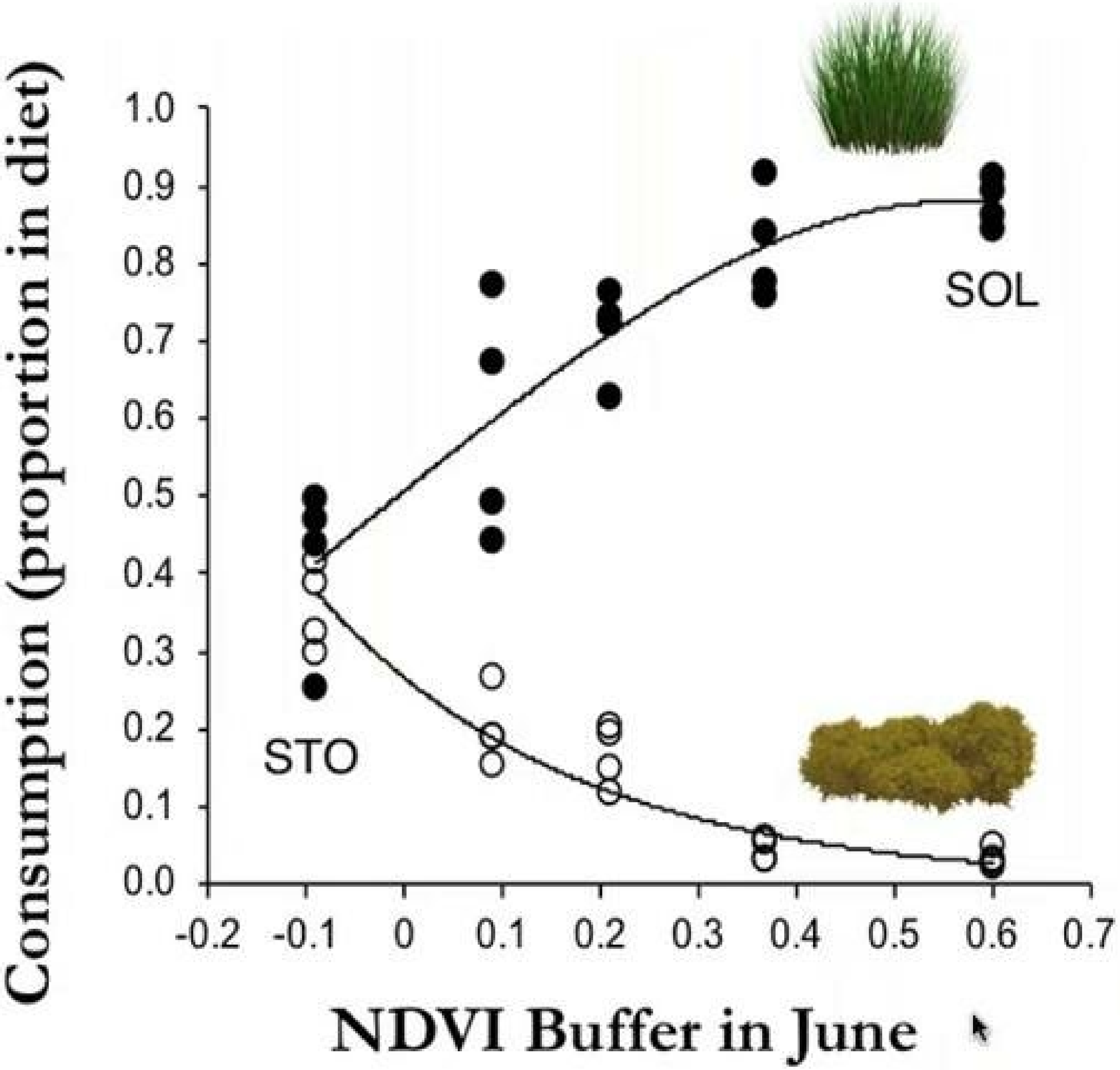
Van Geest et al. 2007

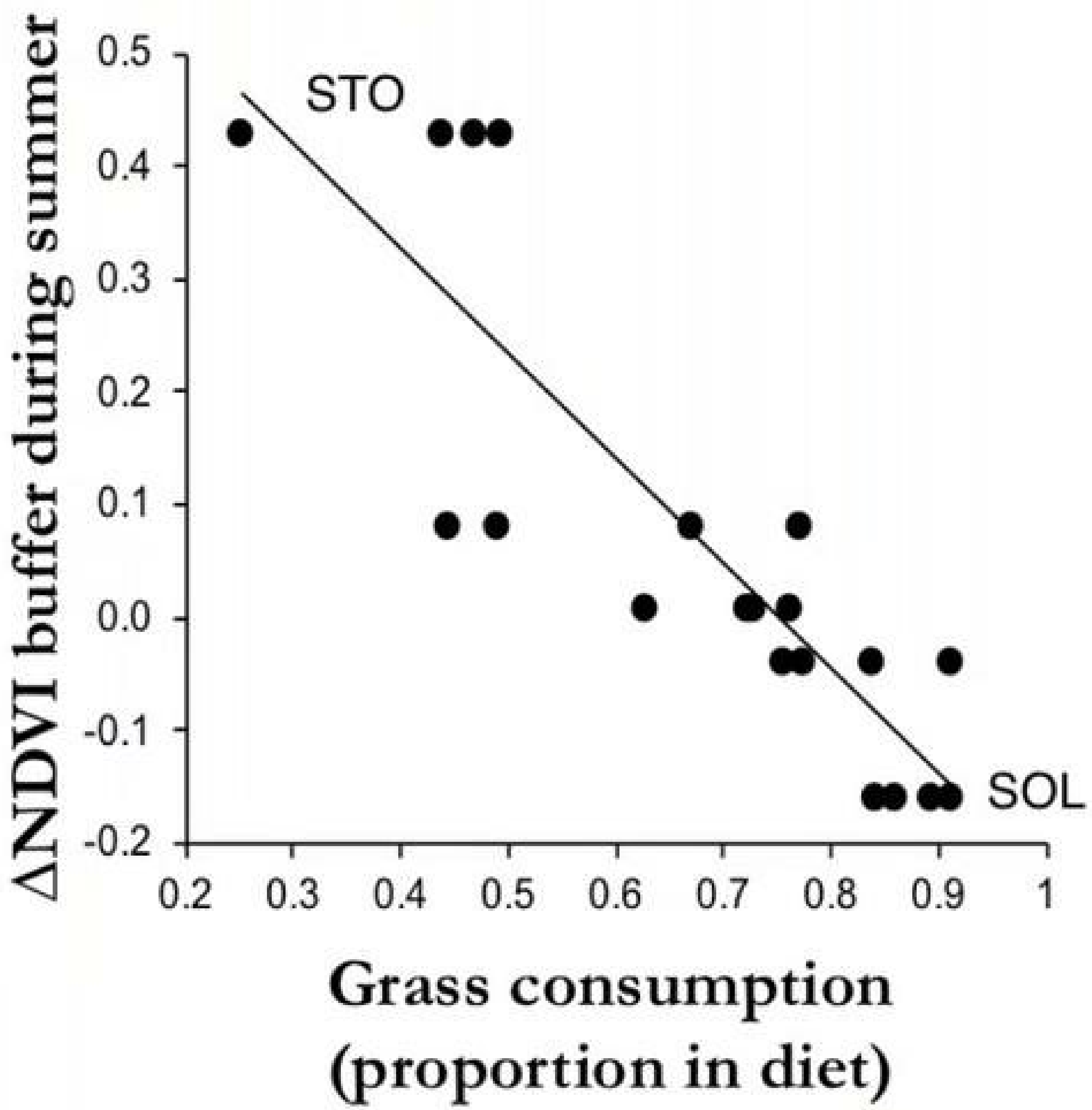
Grass

Moss

Aquatic Veg.

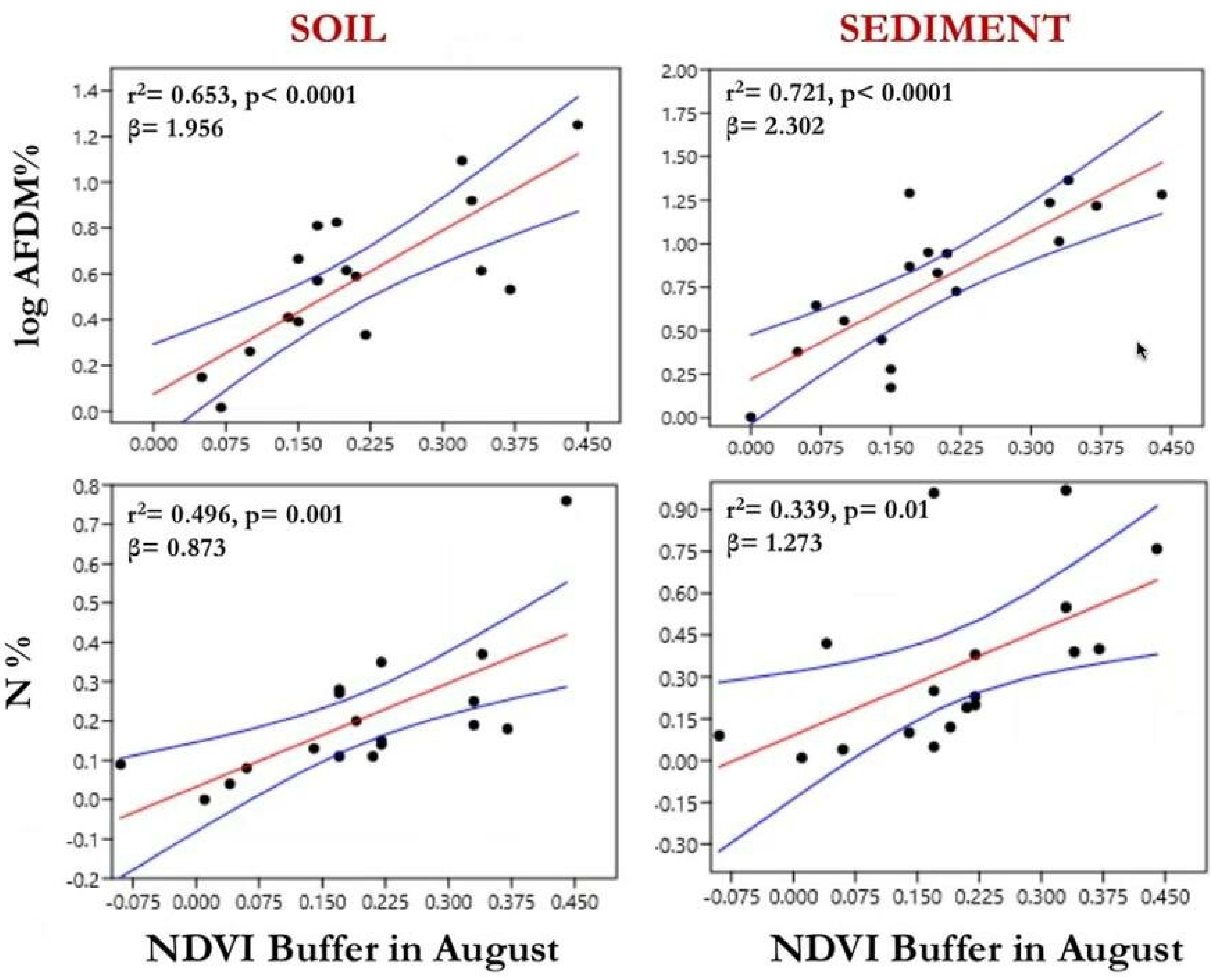
Stable isotopes ($\delta^{15}N$; $\delta^{13}C$) and Bayesian mixing models



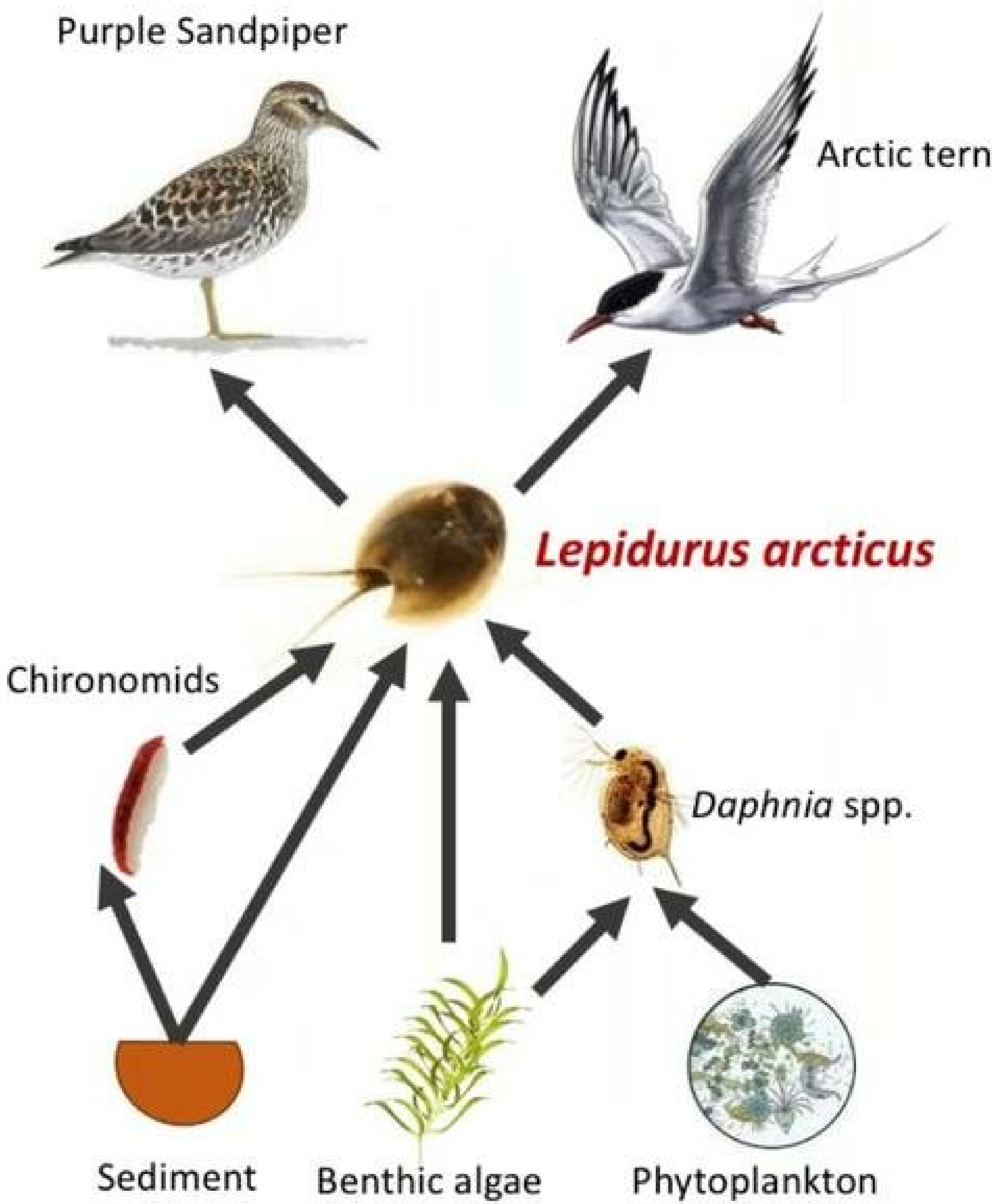


	Values in droppings		van der Wal & Loonen, 1998		
	C/N*	N*(mg/g)	N (mg/g)*	P (mg/g)*	Energy (kj/g dry mass)*
	25.8 ± 3.4	21.1 ± 3.2	27.1 ± 7.9	94.5 ± 32.7	19.2 ± 0.2
	38.1 ± 2.6	12.7 ± 0.7	15.3 ± 2.4	65.5 ± 22.7	17.3 ± 0.7

Mann-Whitney test: *p<0,05



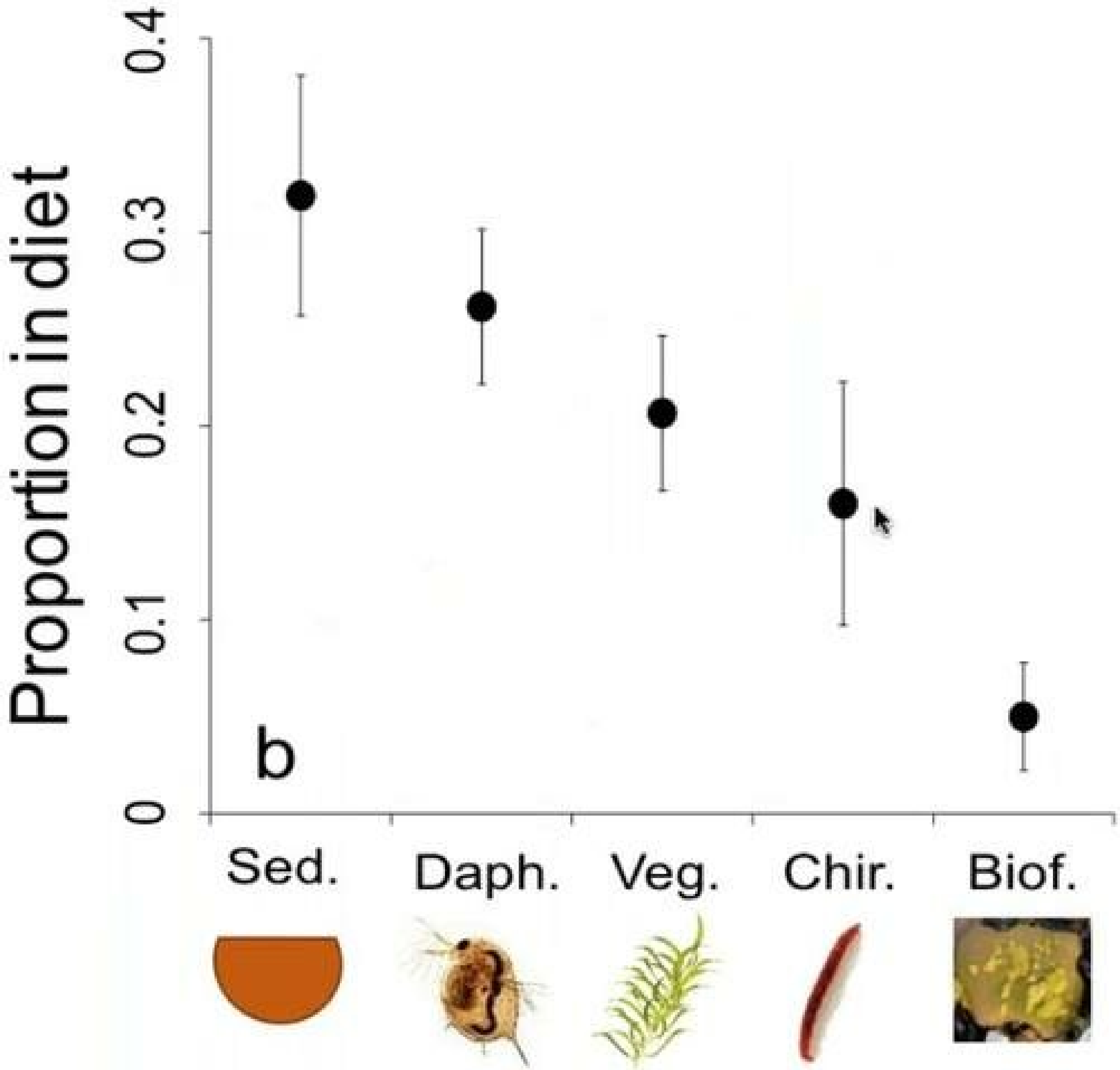
AFDM= Ash Free Dry Matter (%)



Calizza et al. 2022

diet of *Lepidurus arcticus*

(found in 9 lakes)



Basal resource quality

C/N

SEDIMENT = 14.7±1.9

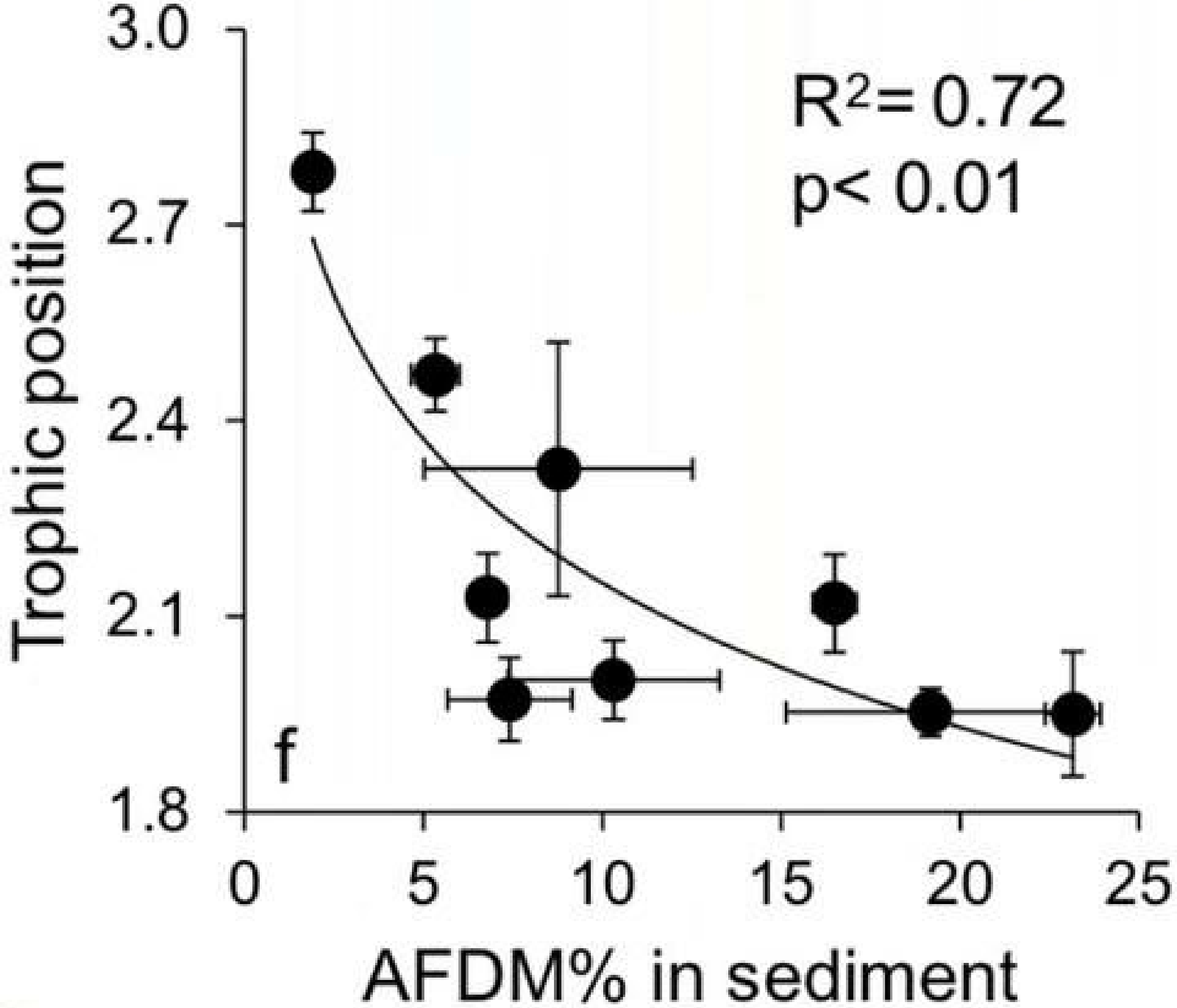
AQUATIC VEG.= 21.1±1.6

paired t-test, $t = 3.7$, $p < 0.01$

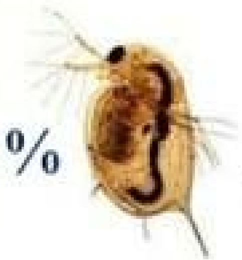
Diet reconstruction through C and N stable isotopes and Bayesina Mixing Models:
Calizza et al., 2018; Rossi et al., 2019; Sporta Caputi et al. 2020

C% as proxy for (bad) sediment quality:
Helser et al. 2000; Hessen et al. 2004; Hall 2009

Trophic position of *L. arcticus*



79 ± 8 %



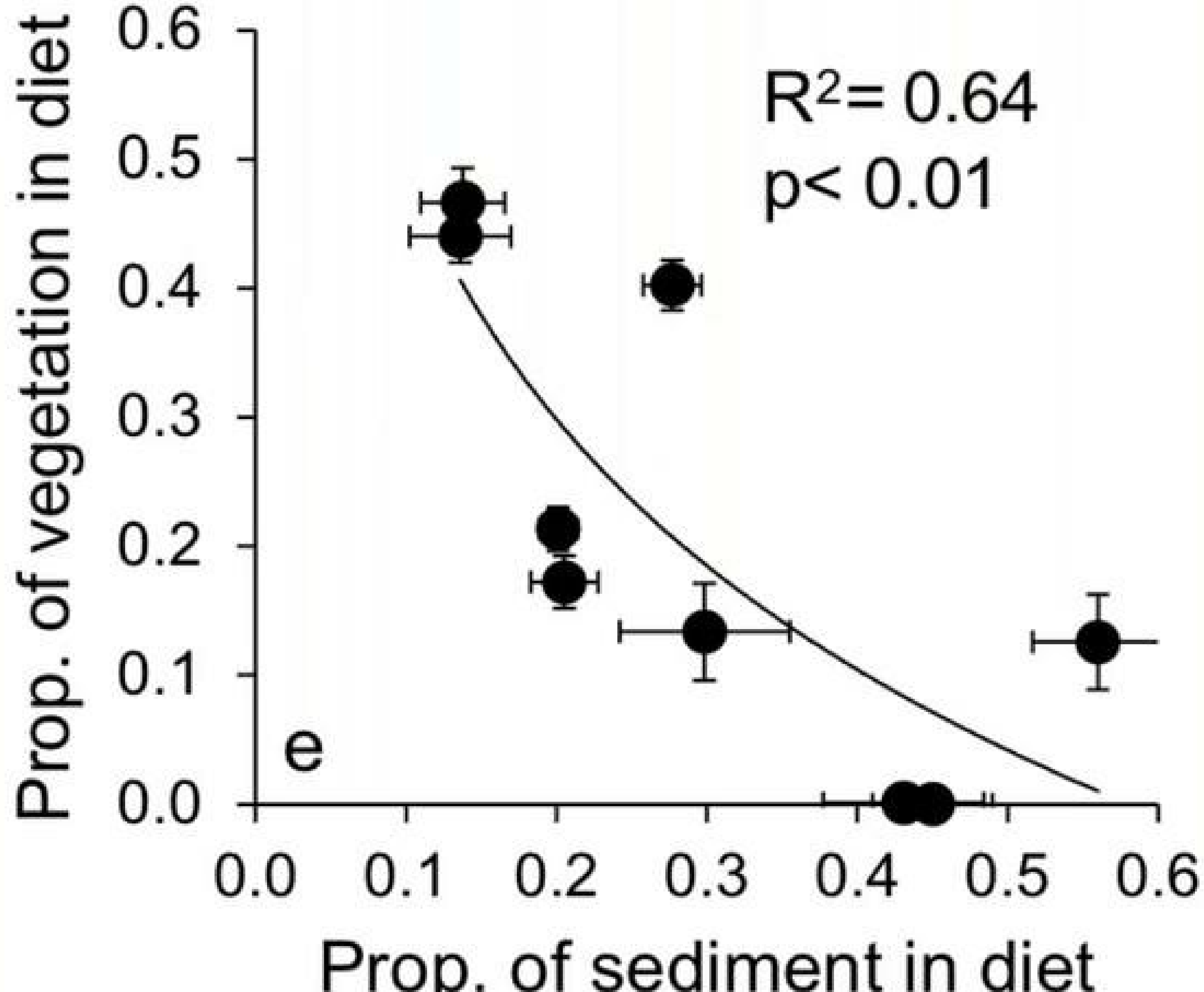
2 ± 1 %

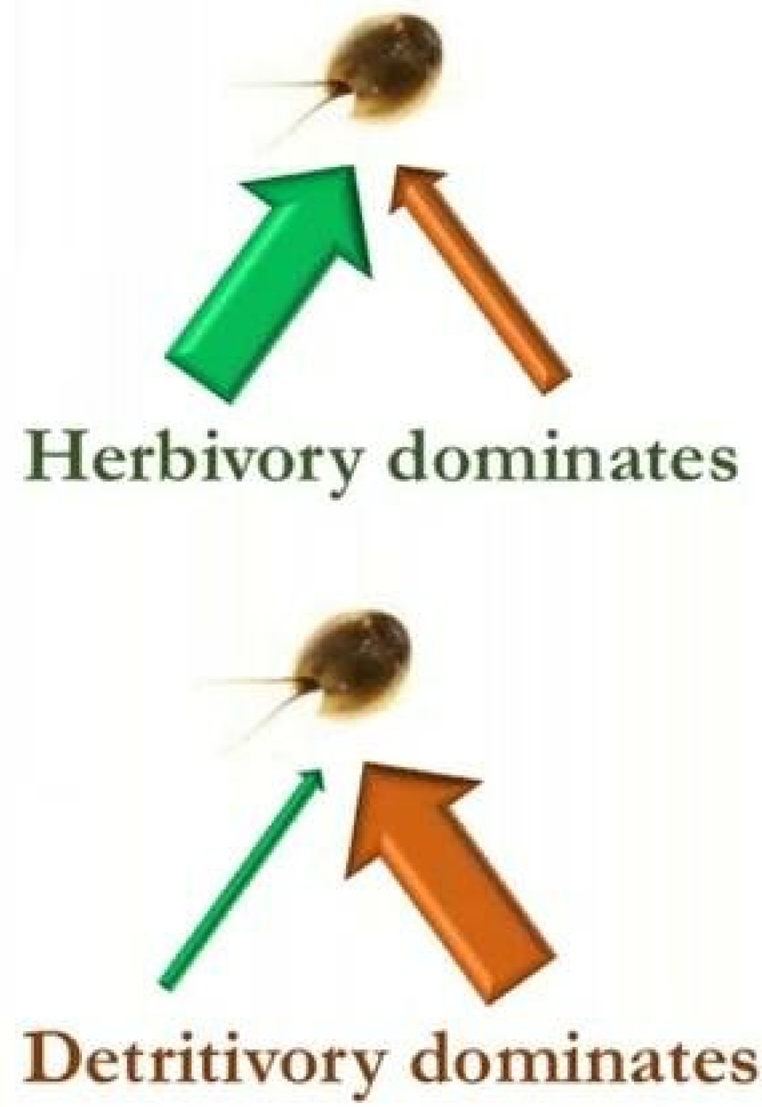
Consumption of other invertebrates by *L. arcticus*

$r^2 = 0.69$, $p < 0.01$

AFDM% as proxy for resource availability:
Calizza et al. 2012, 2017; Rossi et al. 2015

Detritivory vs. Herbivory of *L. arcticus*

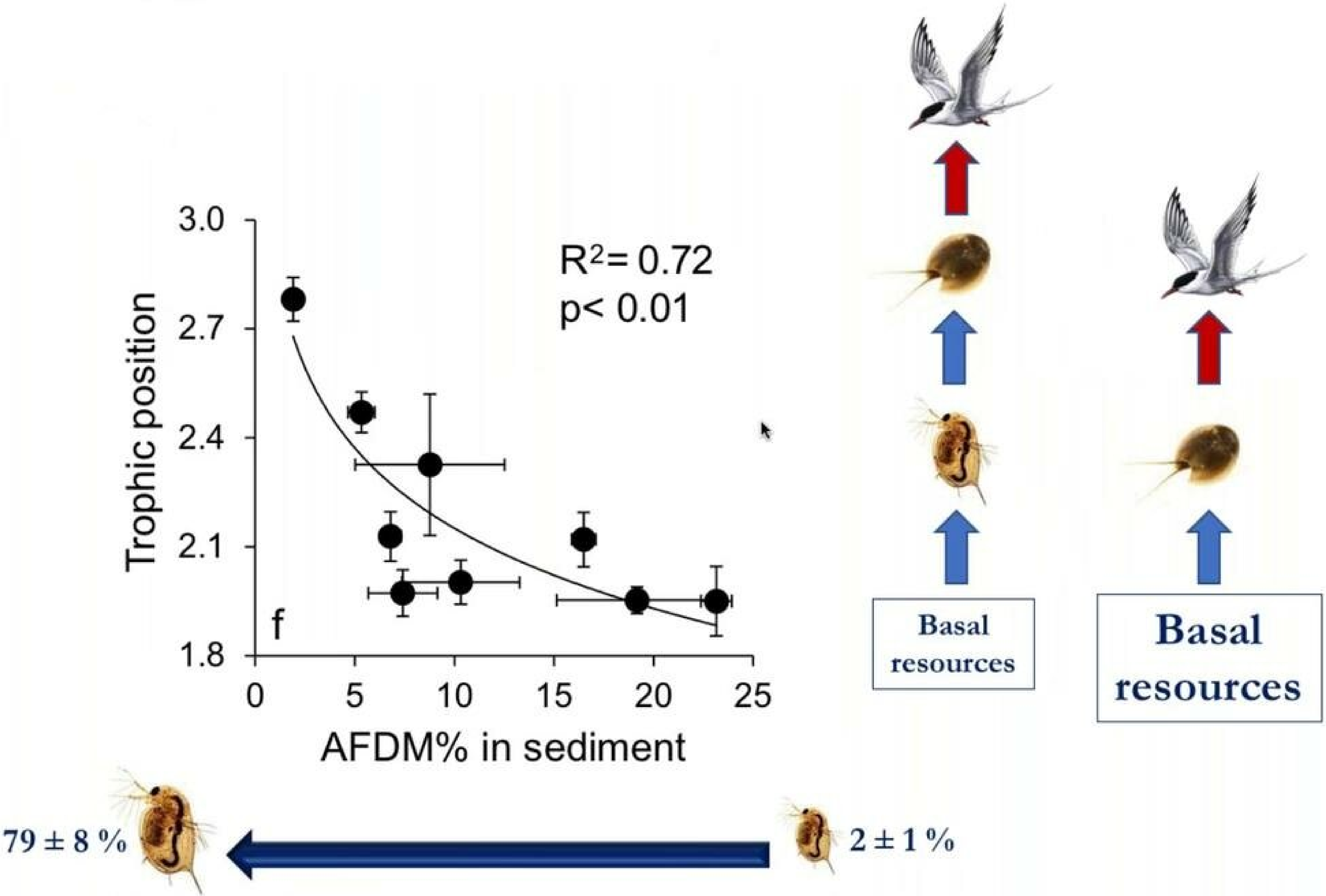




19.3 ± 1.8 → 9.1 ± 2.1

SEDIMENT QUALITY (**C/N**)

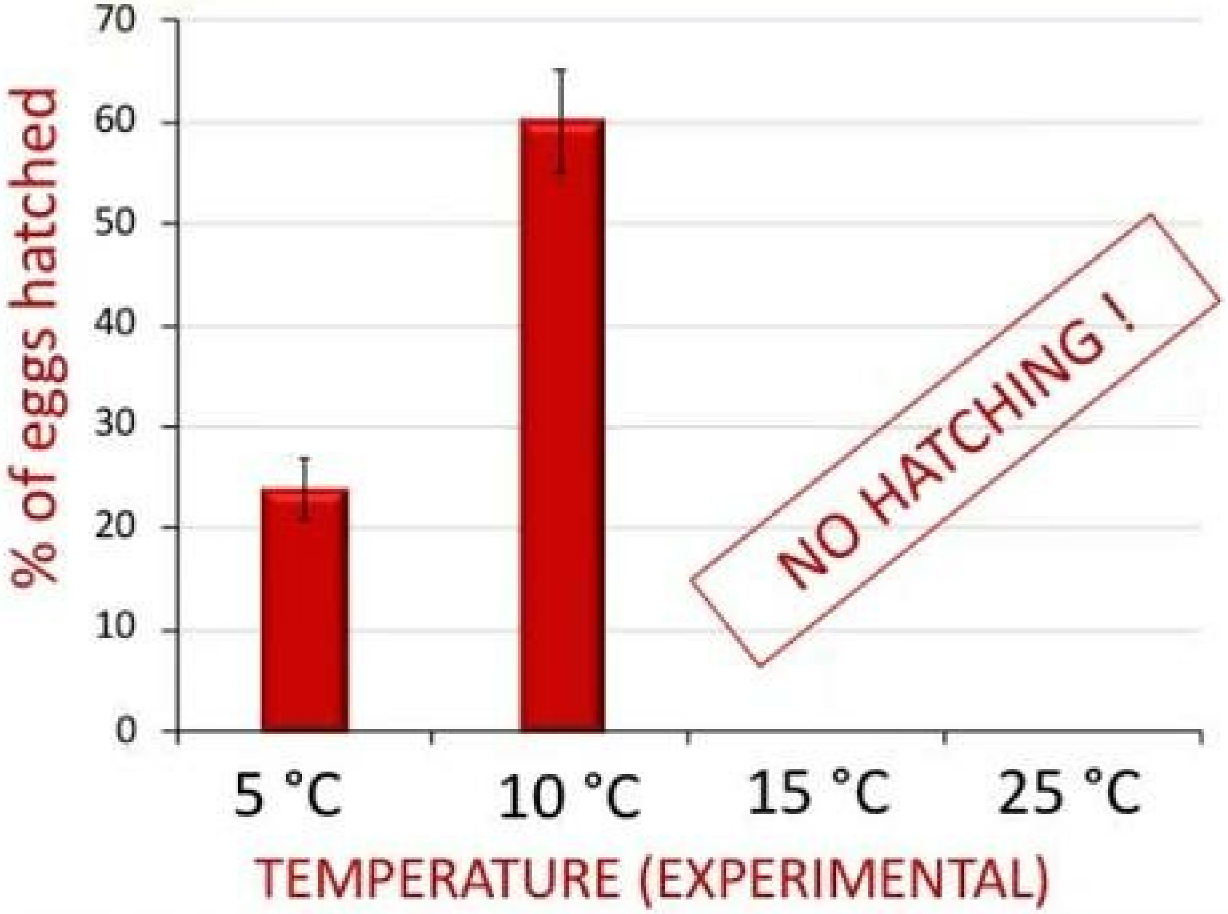
$r^2 = 0.72$, $p < 0.01$



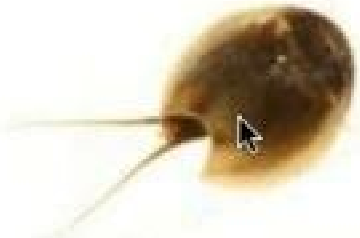
Consumption of other invertebrates by *L. arcticus*

$r^2 = 0.69$, $p < 0.01$

Future T (°C) may limit survival of *L. arcticus*



Pasquali, Calizza* et al. 2019, Ethol. Ecol. Evol.*



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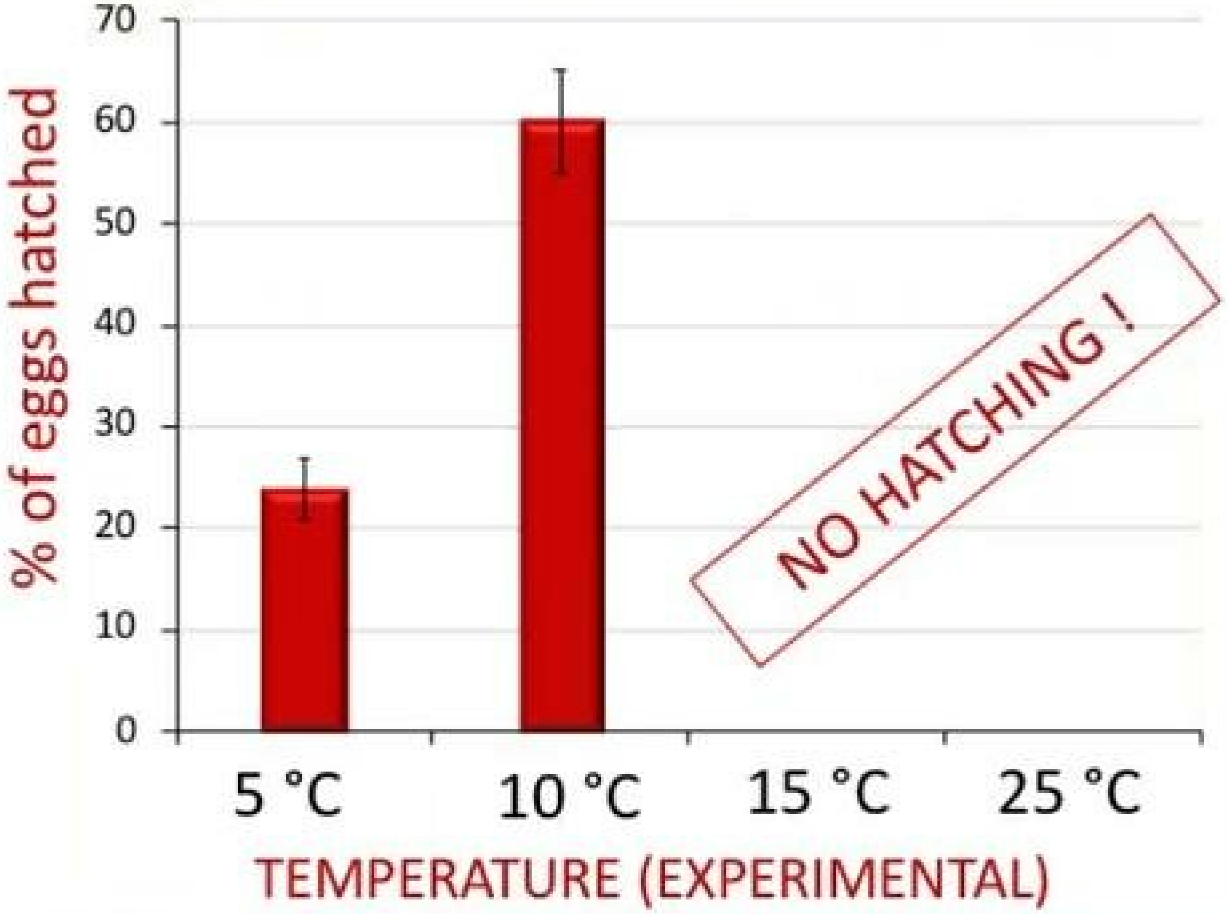
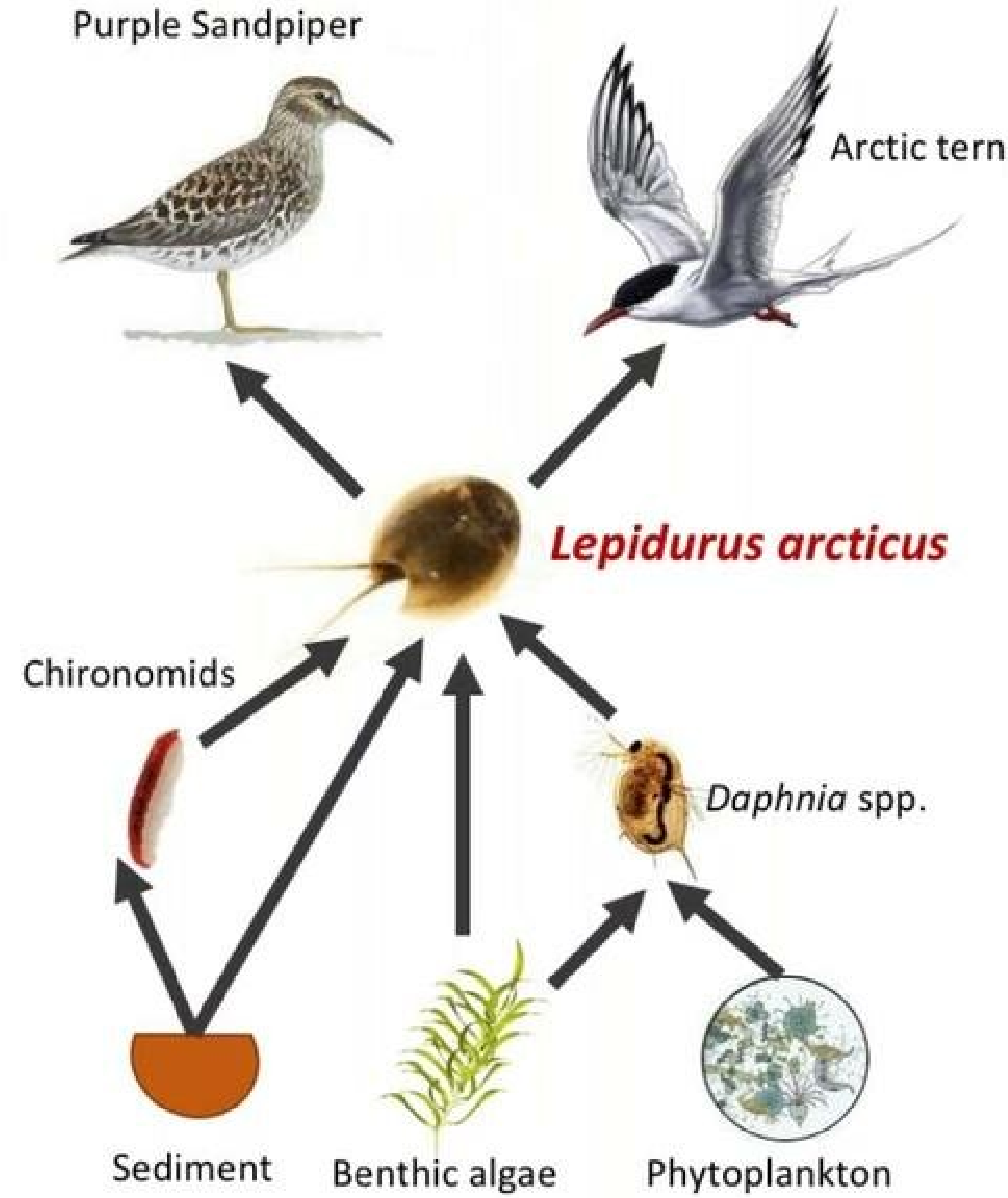


Pasquali, Calizza* et al. 2019, Ethol. Ecol. Evol.*

… with cascade effects on the entire food web



CONCLUDING REMARKS

Snow coverage, vegetation and geese will interact in a complex yet predictable way in determining the quality and amount of nutrient inputs in Tundra ecosystems

This will have significant effects on resource-consumer interactions both in the terrestrial and aquatic food web compartments

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Snow coverage, vegetation and geese will interact in a complex yet predictable way in determining the quality and amount of nutrient inputs in Tundra ecosystems

This will have significant effects on resource-consumer interactions both in the terrestrial and aquatic food web compartments

PREVISIONS:

- Increased N content in soil and sediment
- Increased energy flow through the grass-based food chain
- Increased enegy flow through the SOM-based food chain in lakes

Overall, the results contribute to our mechanistic understanding of cascade effects of climate change on nutrient cycling and ecosystem functioning in the Tundra

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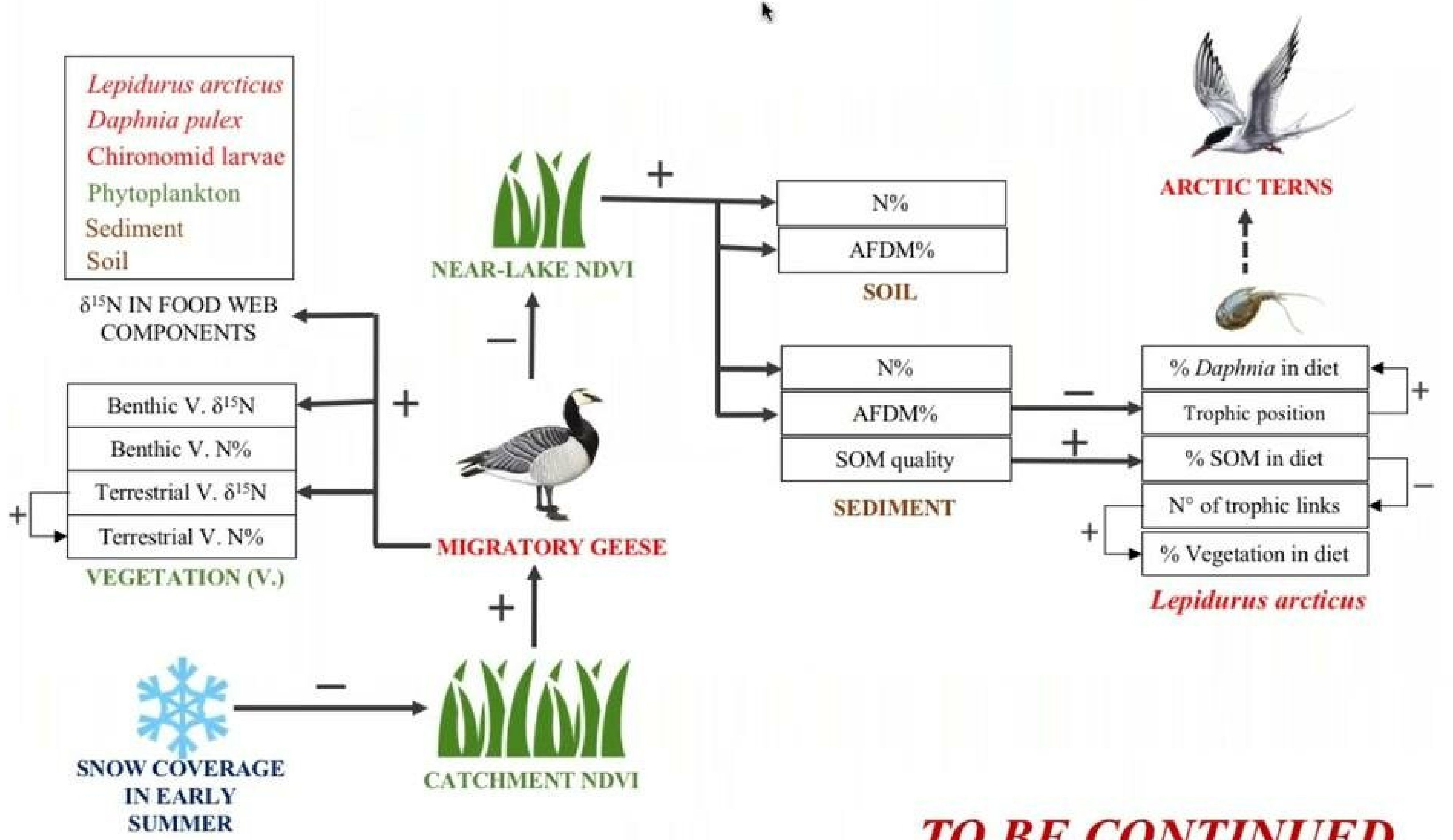

TO BE CONTINUED …

NUTRIENT CYCLING, ECOSYSTEM FUNCTIONING AND CLIMATE CHANGE IN ARCTIC LAKE ECOSYSTEMS (**PRA ECO-CLIMATE**)

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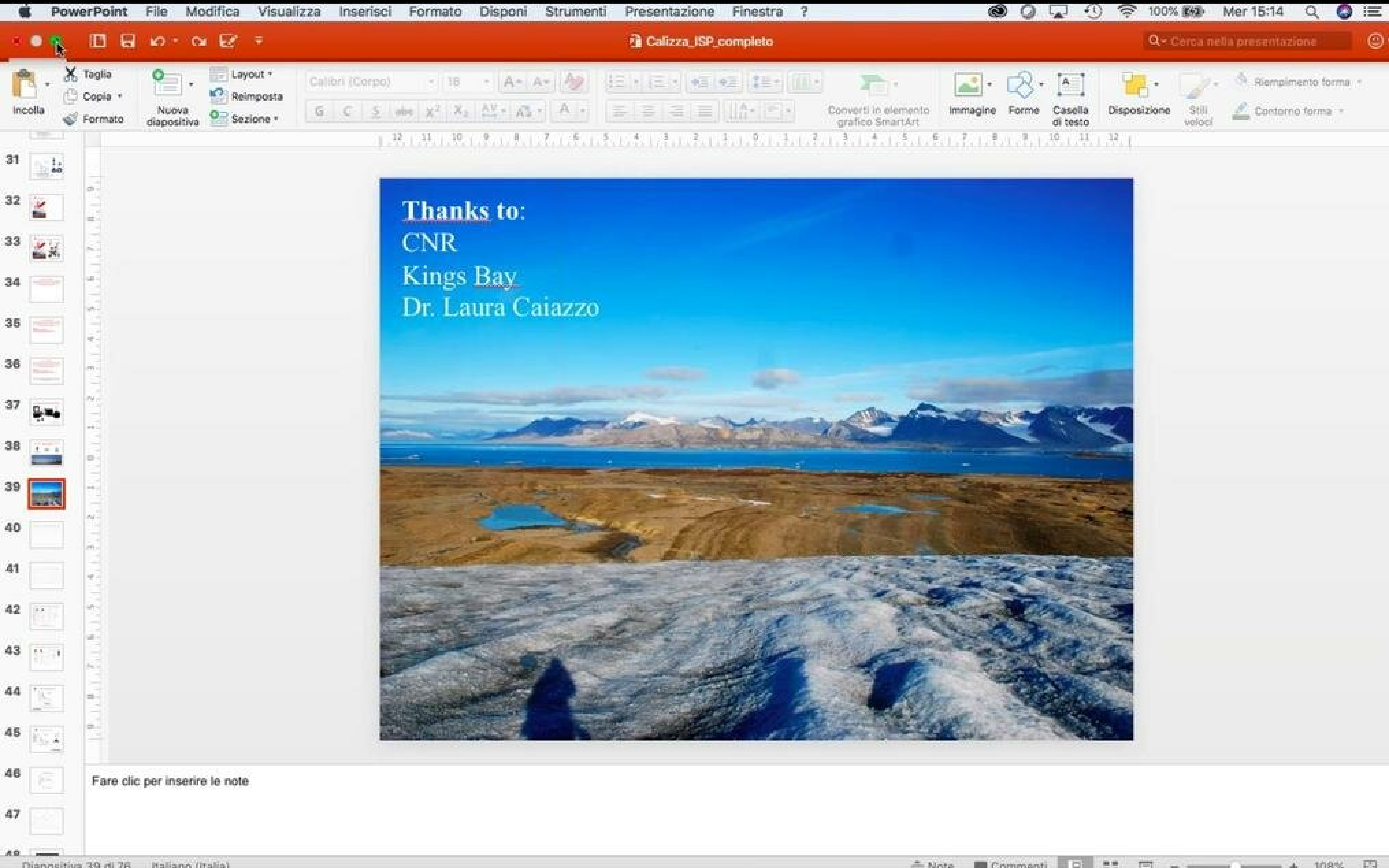
ISP Istituto di Scienze Polari
Consiglio Nazionale delle Ricerche

IRSA CNR

" The aim of the project is to provide a mechanistic understanding of carbon sequestration, carbon cycling, and organic matter decomposition in high Arctic lake ecosystems, and their vulnerability to changes in snow cover and abundance of migratory birds."


Thanks to:
CNR
Kings Bay
Dr. Laura Caiazzo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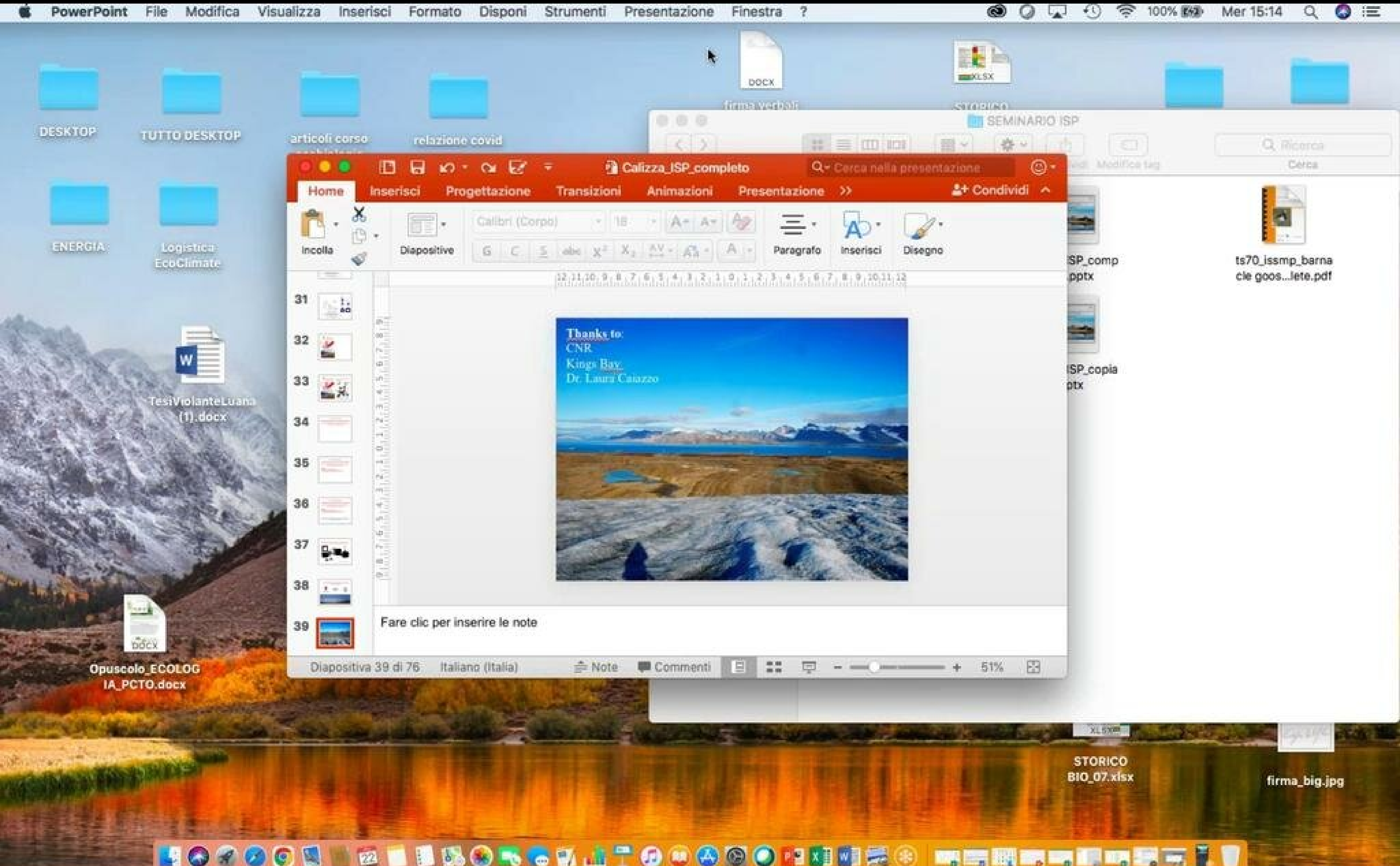
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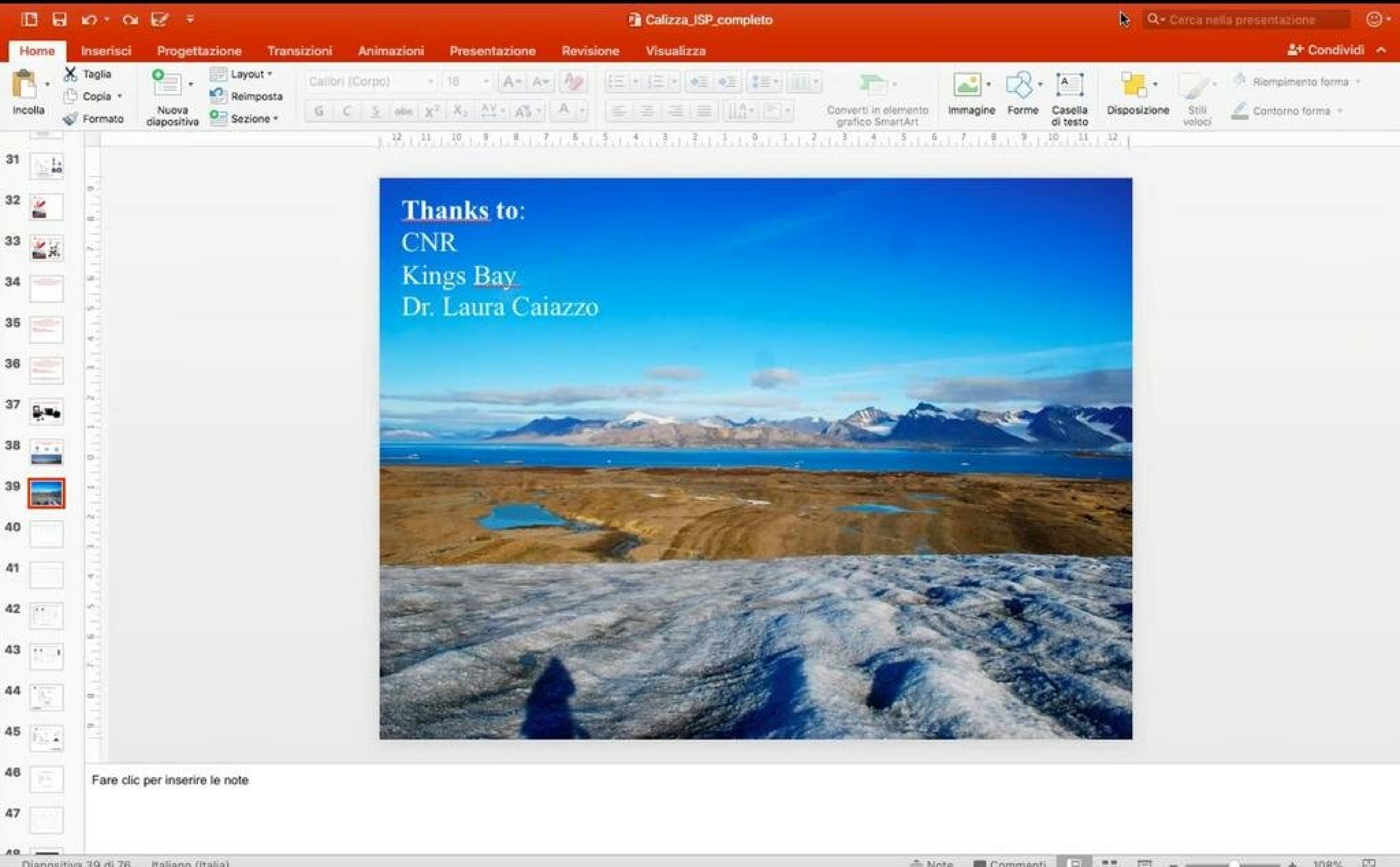
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