Morphological traits of zooplankton reveal ecological patterns along ice melt dynamics in the Arctic

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Jean-Olivier Irisson and Sakina-Dorothée Ayata

Ecosystem Structure and Processes in a Changing Arctic
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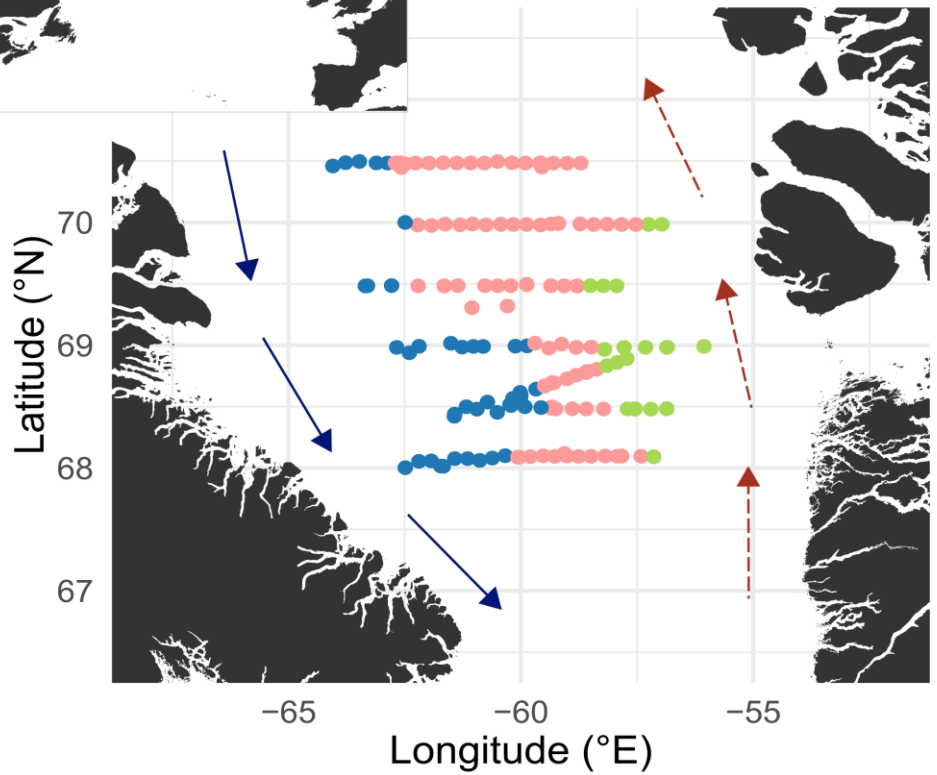
GREEN EDGE → **Fate of ice-edge blooms**



- Ice-covered Waters
- Transition Zone
- Open Waters

Baffin Bay, 2016
163 sampling stations

→ Arctic-derived Baffin Island Current
⇢ Atlantic-derived West Greenland Current

PCA + clustering :

↓

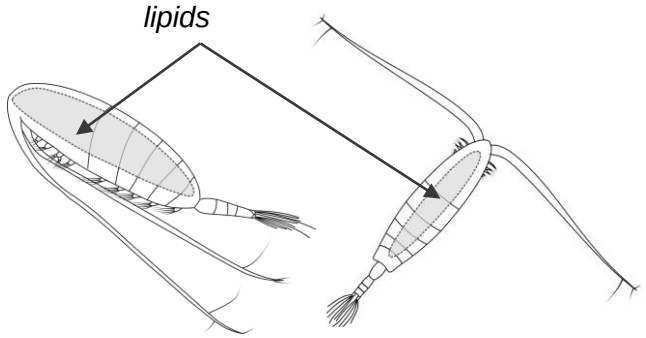
3 clusters

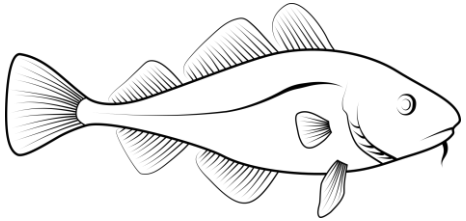
↓

Ice-covered Waters
Cold
High [NO3]

Transition Zone
Recent ice melt
High stratification

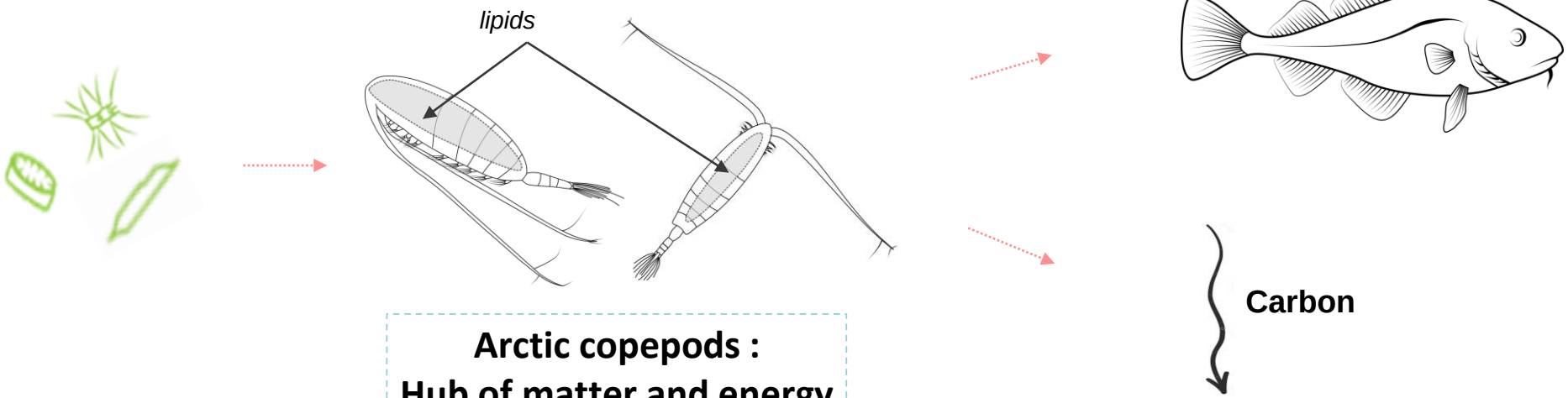
Open Waters
High [Chl *a*]
Deep Chl *a* maximum





Carbon

Arctic copepods :
Hub of matter and energy

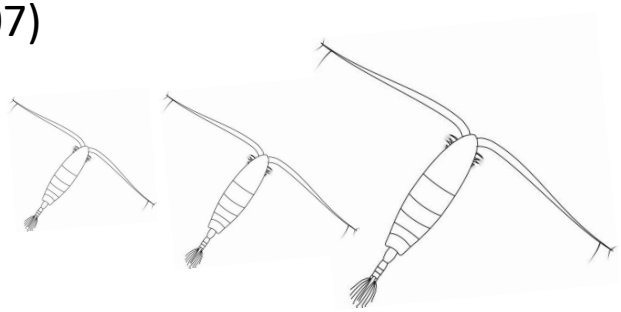


Arctic copepods :
Hub of matter and energy

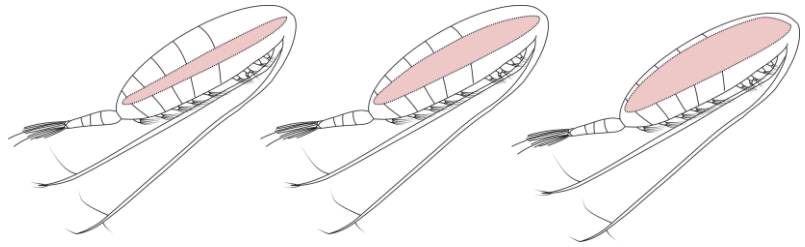
- <u>Trait-based approach:</u>

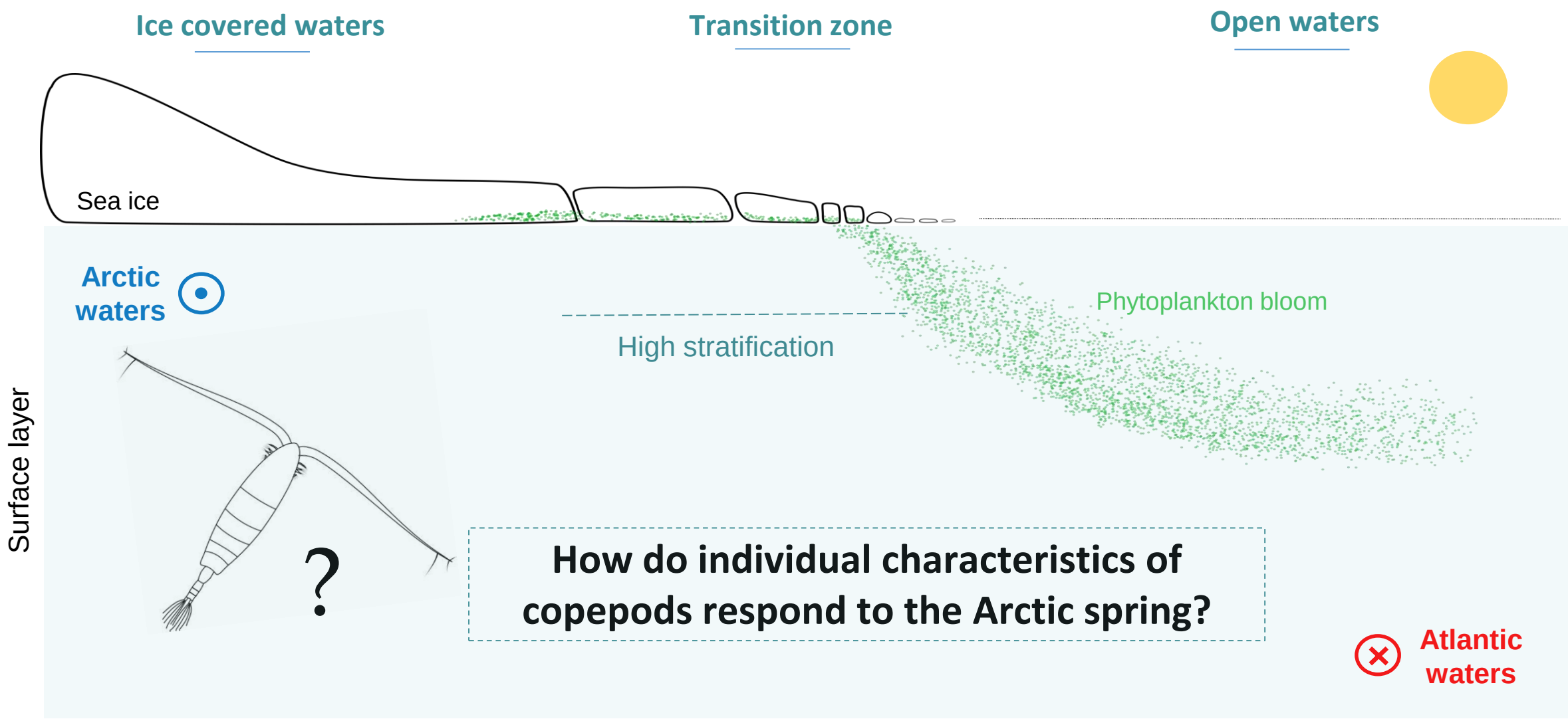
Functional trait = any property measurable at the individual level impacting organisms' fitness and ecosystem functions (Violle et al., 2007)

Ex: *Size*



Ex: *Lipid content*




Ice covered waters
Transition zone
Open waters
Sea ice
Arctic waters
Phytoplankton bloom
High stratification
Surface layer
?
How do individual characteristics of copepods respond to the Arctic spring?
Atlantic waters

~ 28 000 images

Underwater Vision Profiler (UVP5)

Picheral *et al*., 2010

Underwater Vision Profiler (UVP5)

Picheral *et al*., 2010

~ 28 000 images

18 morphological descriptors:

	Area	Major axis	Minor axis	Perim.	Elongation	Mean grey level	Median grey level	Fractal	…….
Object 1									
Object 2									
……									

Underwater Vision Profiler (UVP5)

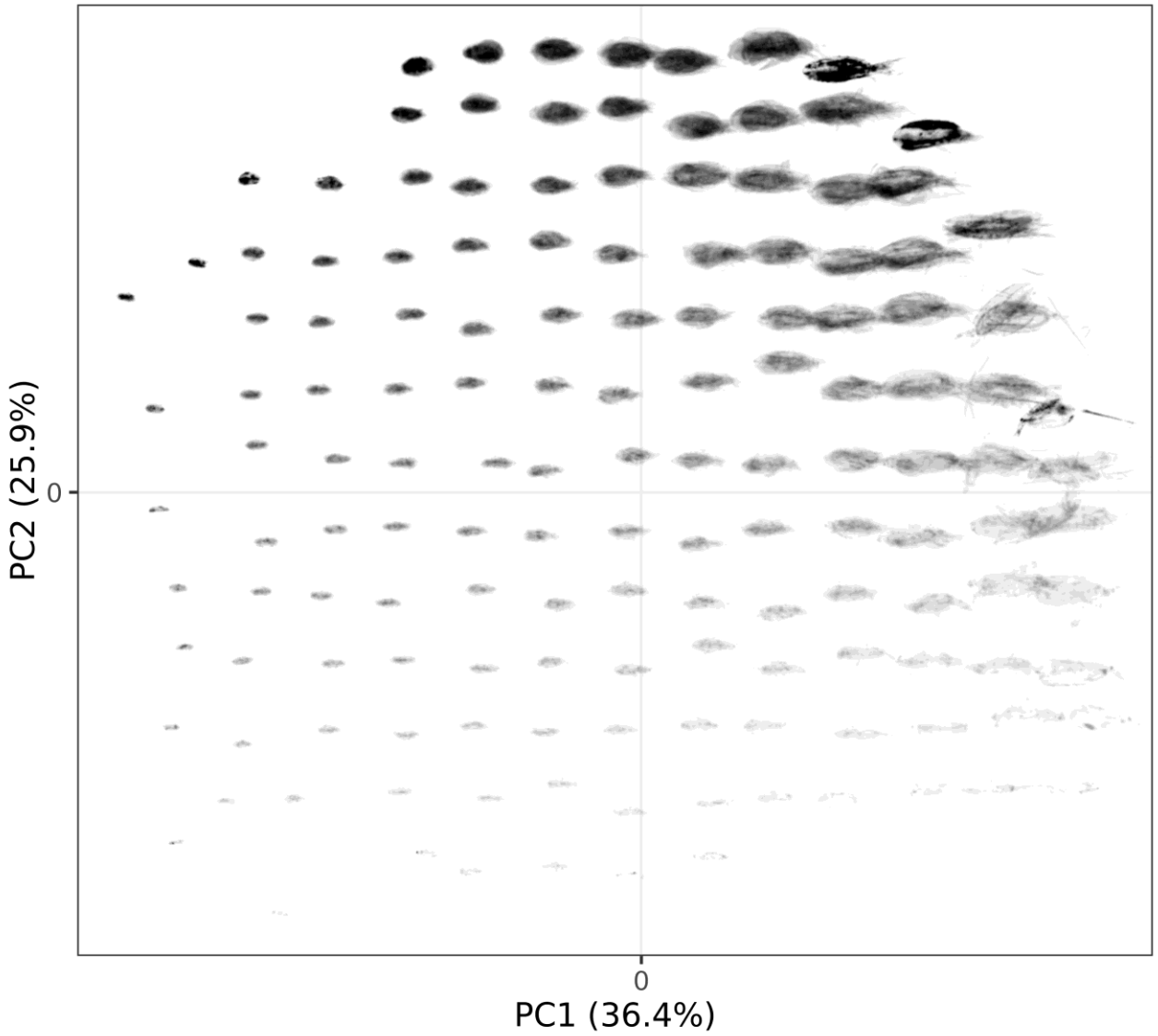
Picheral *et al*., 2010

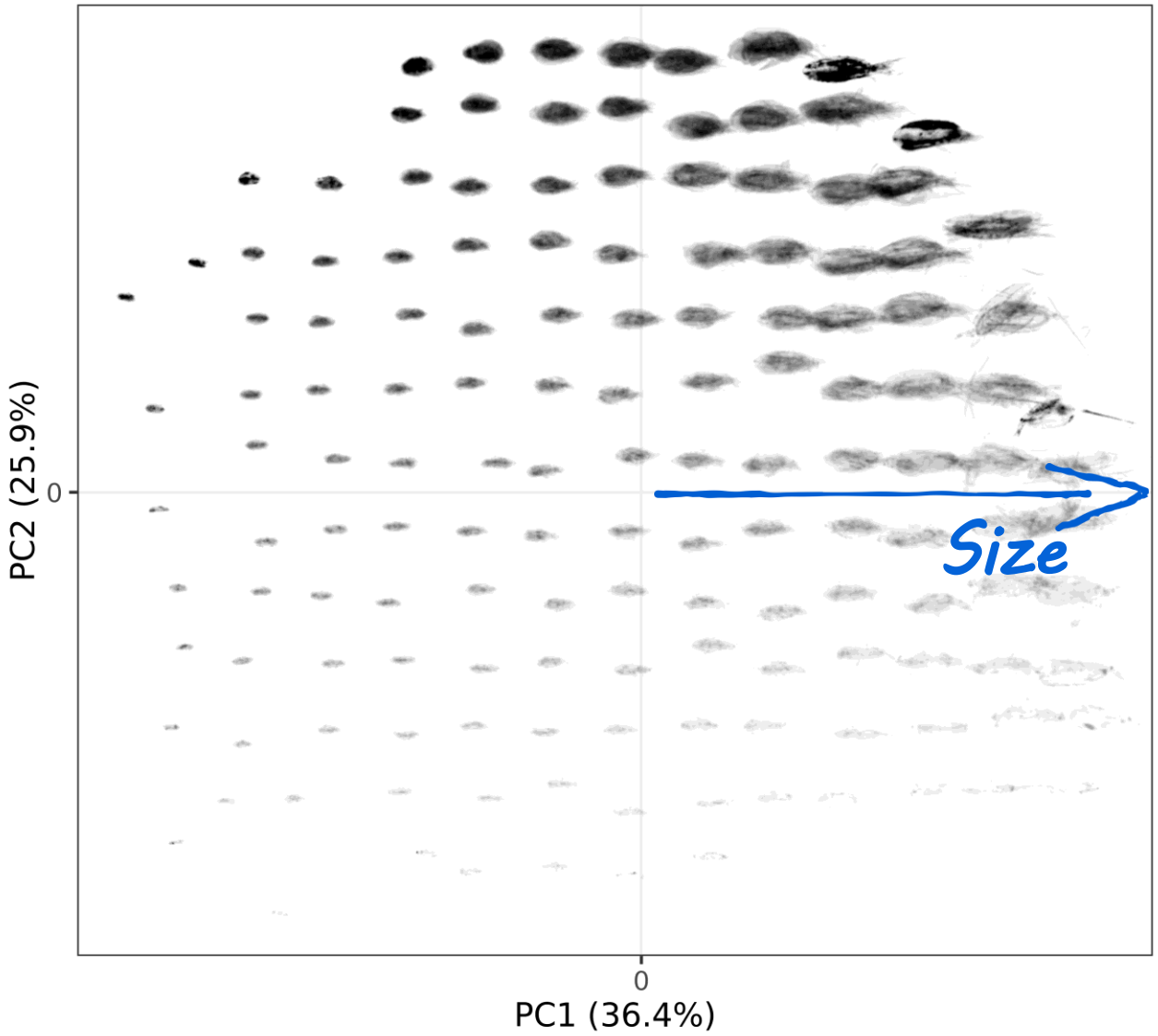
~ 28 000 images

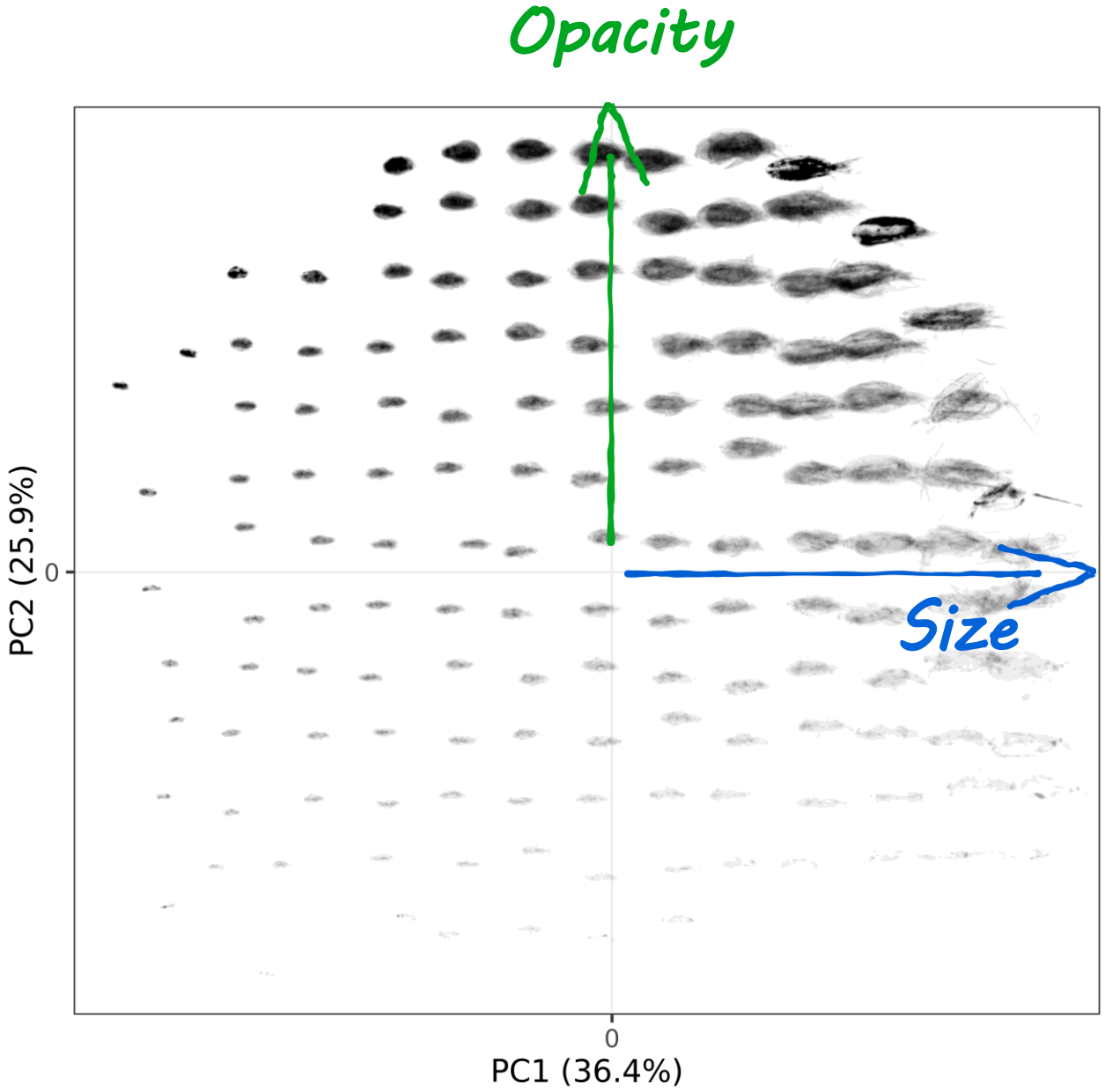
18 morphological descriptors:

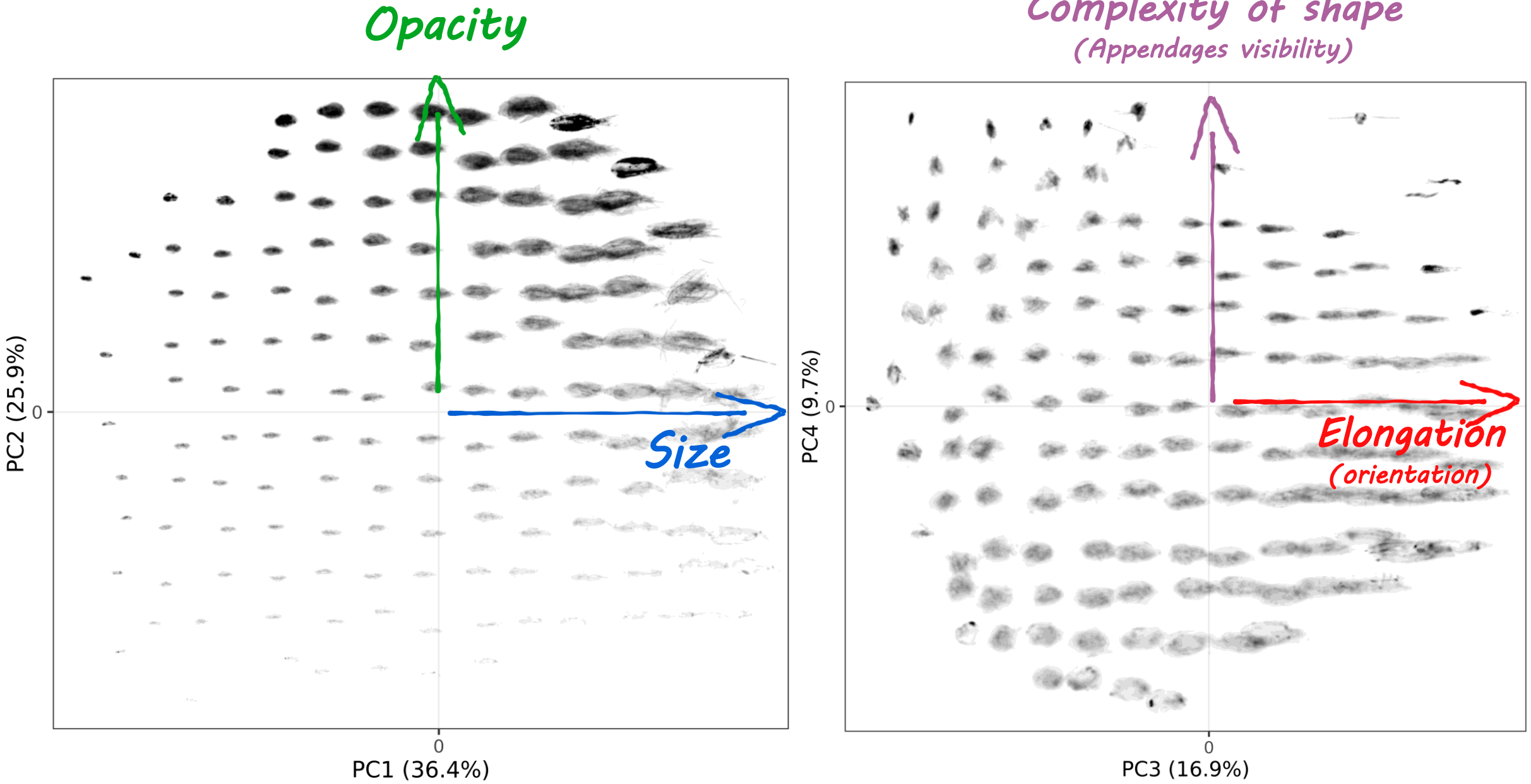
	Area	Major axis	Minor axis	Perim.	Elongation	Mean grey level	Median grey level	Fractal	…….
Object 1									
Object 2									
……									

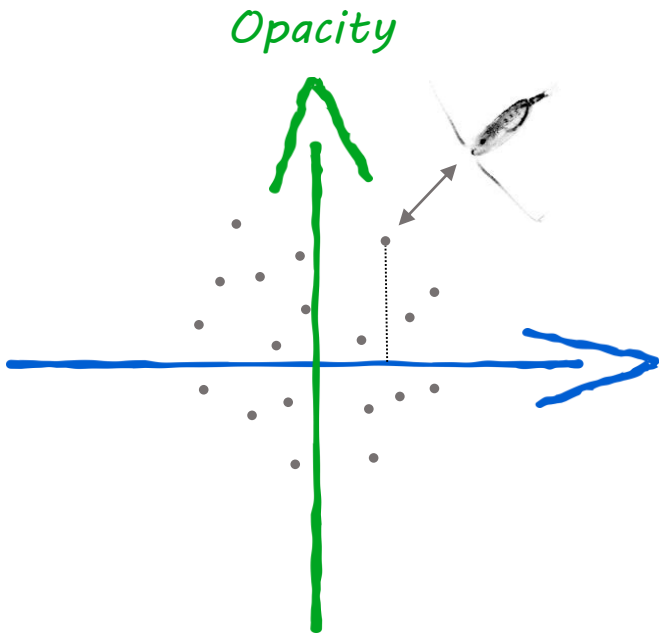
4 significant axis of a PCA
(90% variance explained)
=
Morphological space


PC2 (25.9%)
0
0
PC1 (36.4%)


PC2 (25.9%)
0
0
PC1 (36.4%)
Size

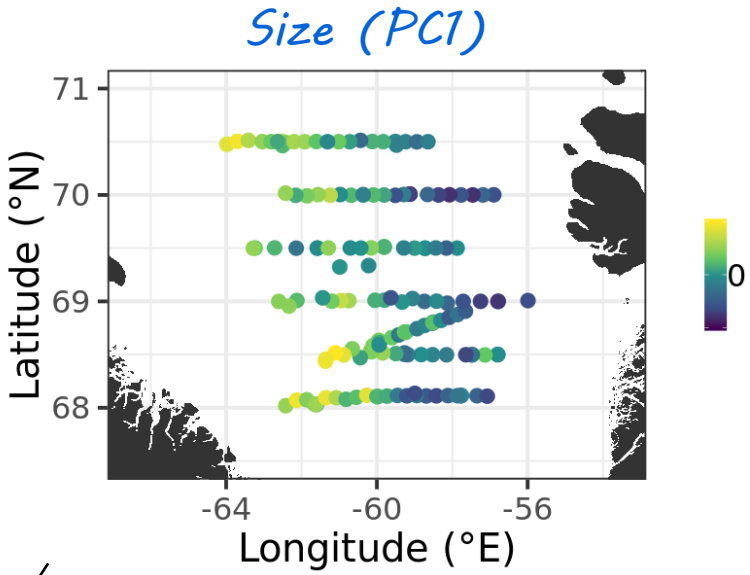

Opacity
Size
PC2 (25.9%)
PC1 (36.4%)
0
0


Opacity
Size
PC2 (25.9%)
0
0
PC1 (36.4%)
Complexity of shape
(Appendages visibility)
Elongation
(orientation)
PC4 (9.7%)
0
0
PC3 (16.9%)

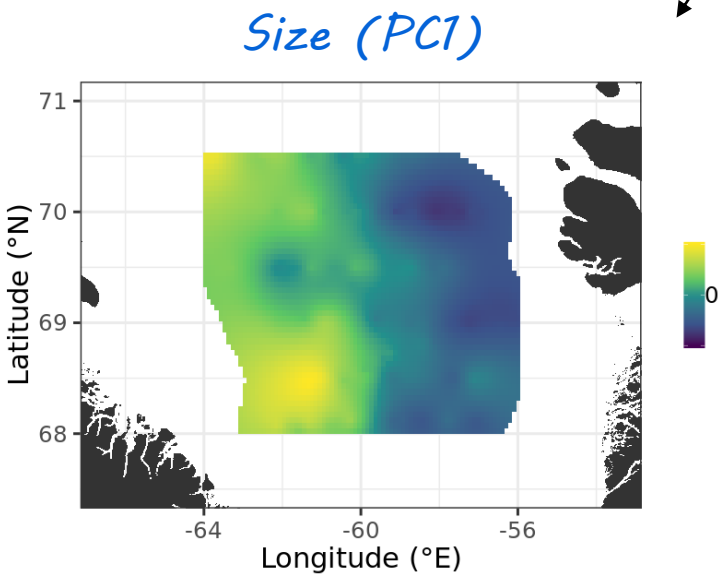


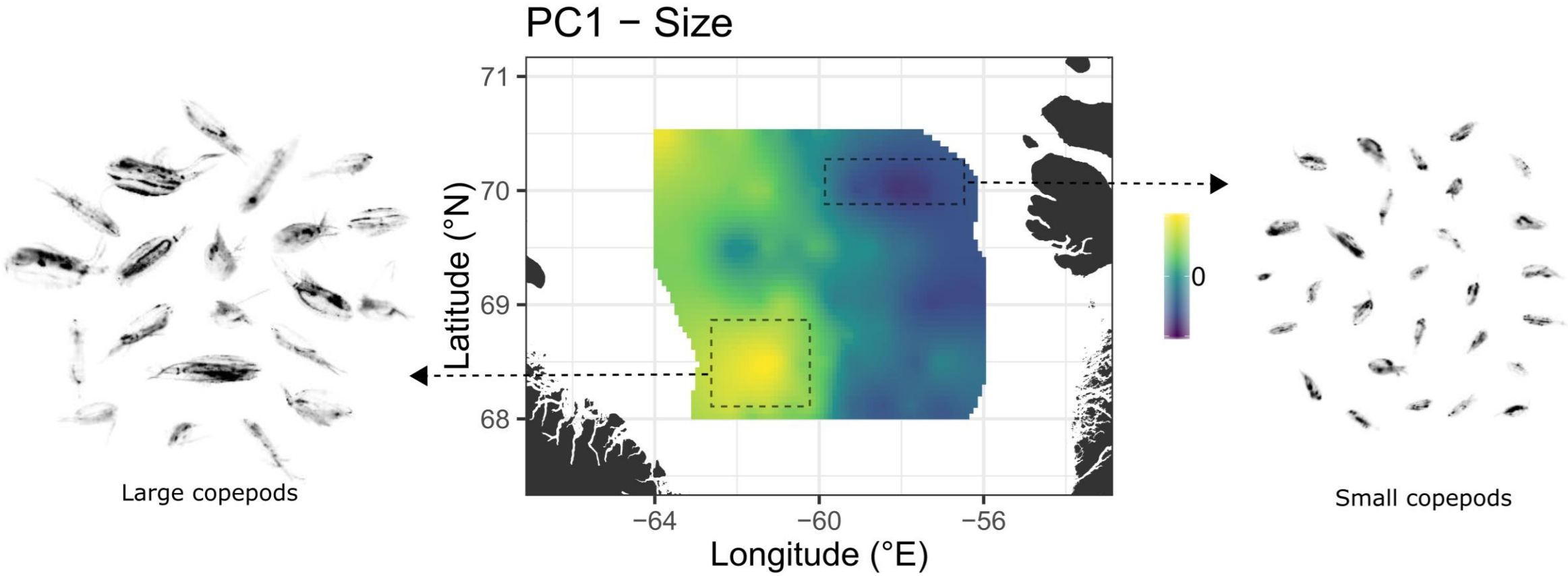
Morphological space

Mapping

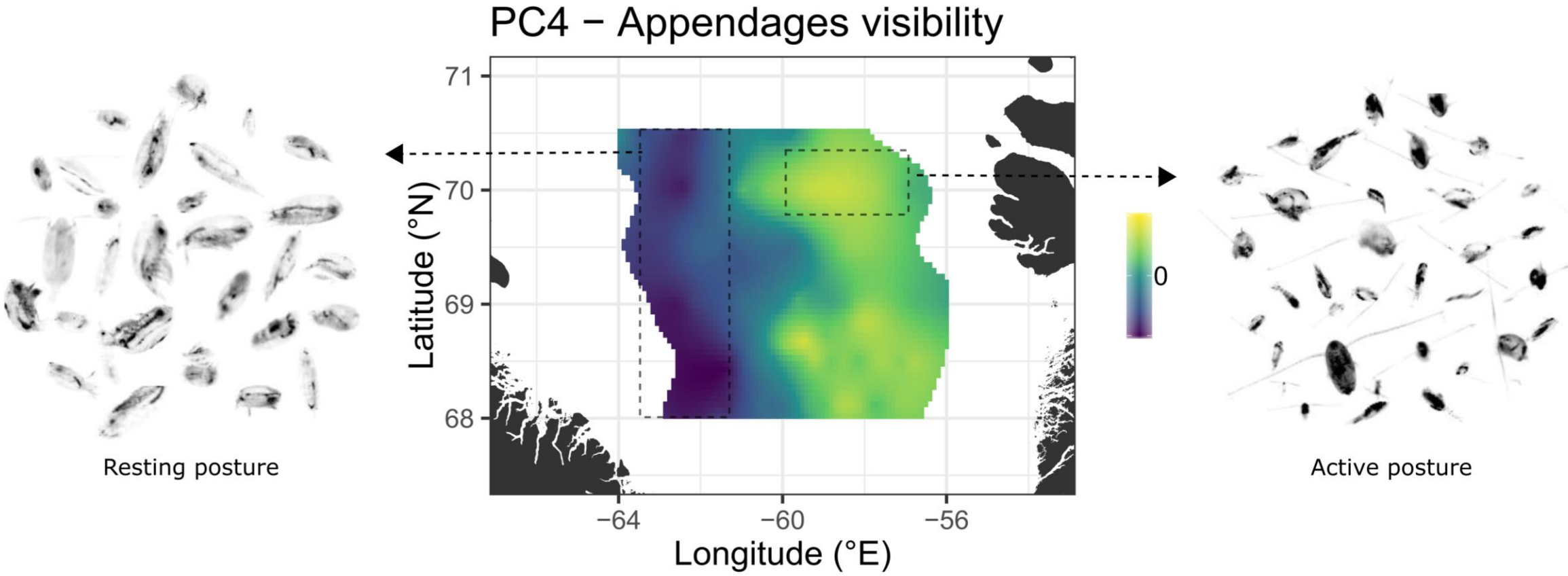


Kriging



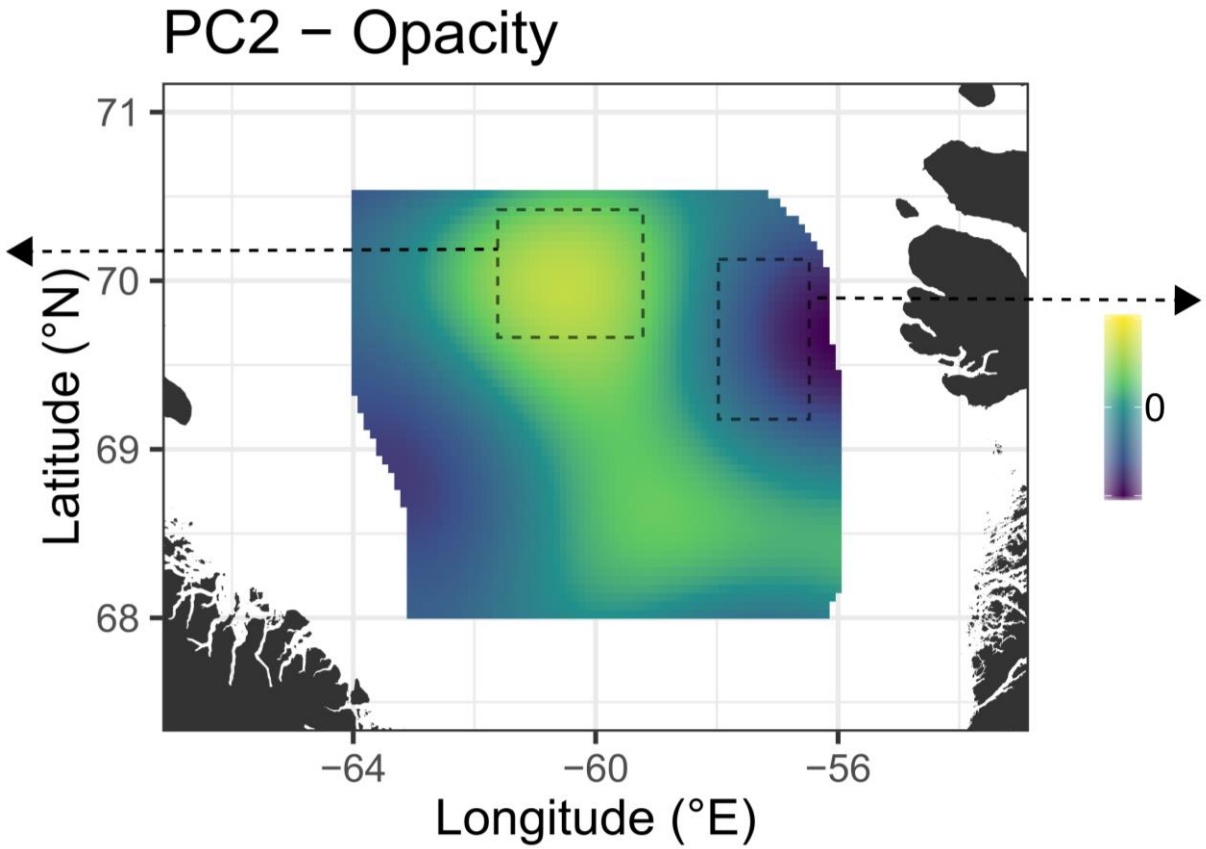


- East/West gradient
- Big organisms associated with ice conditions
- Small copepods in eastern open waters



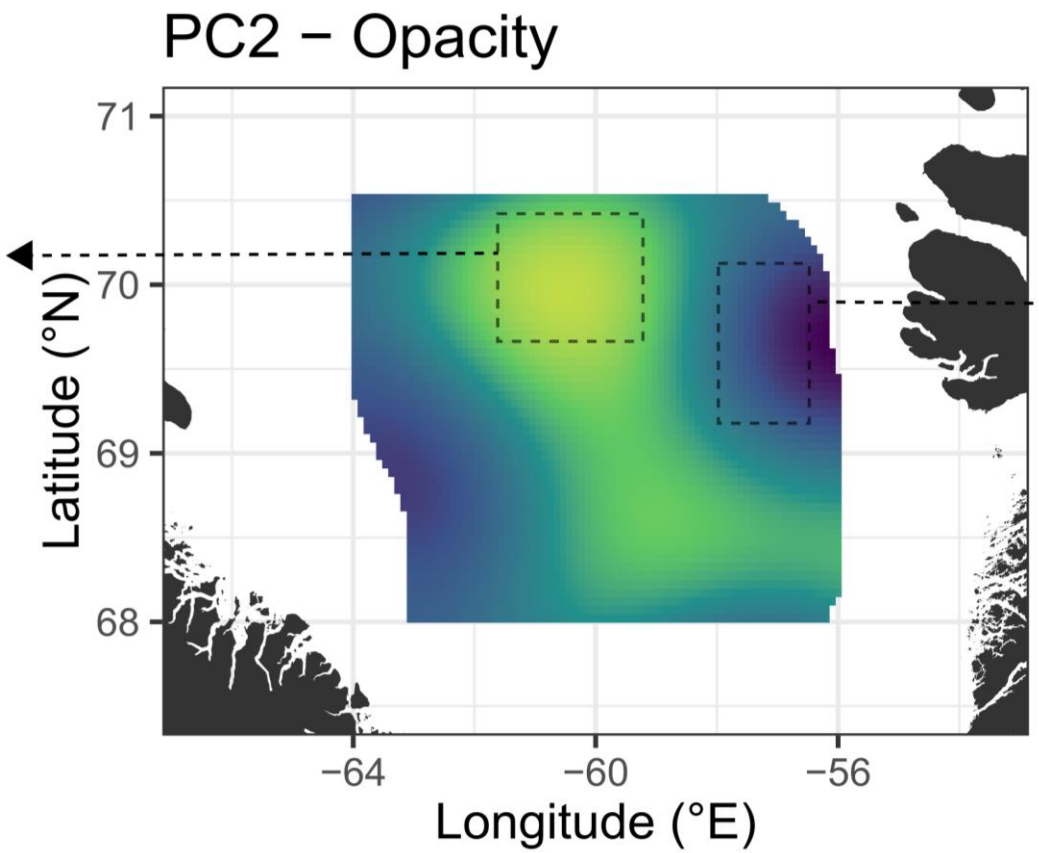
- Visibility of appendages: **feeding activity** for *feeding-current feeders as copepods*
- Higher activity in productive zones with small copepods

Opaque copepods

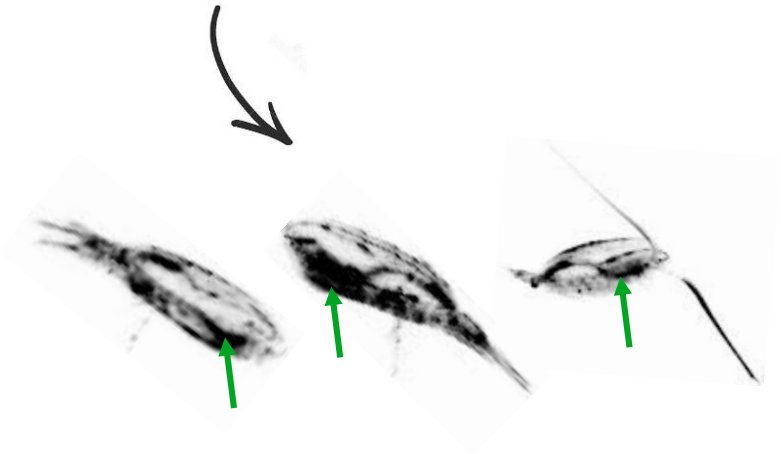


Transparent copepods

Opaque copepods

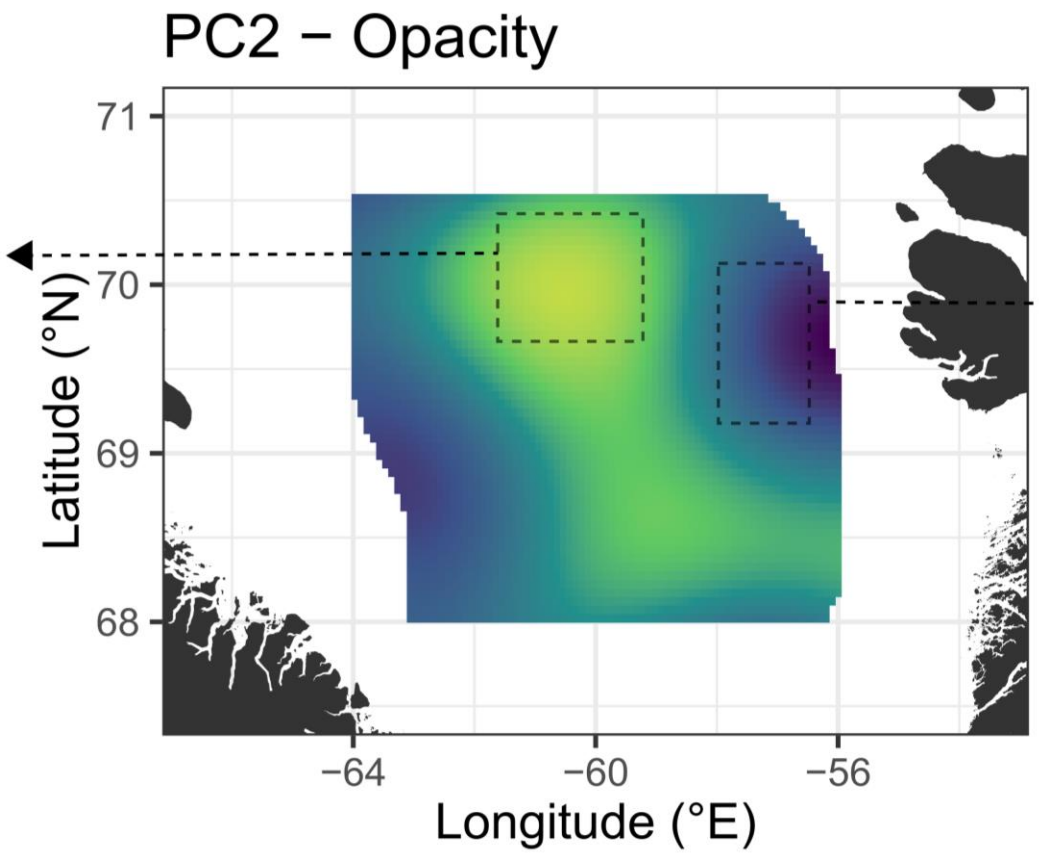


Transparent copepods

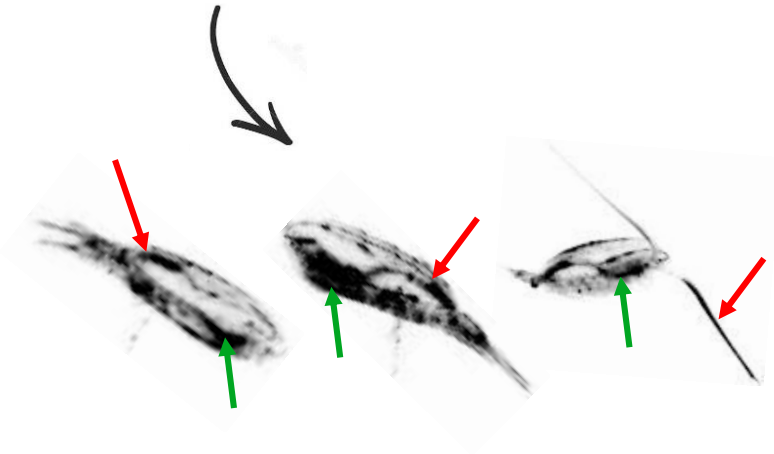


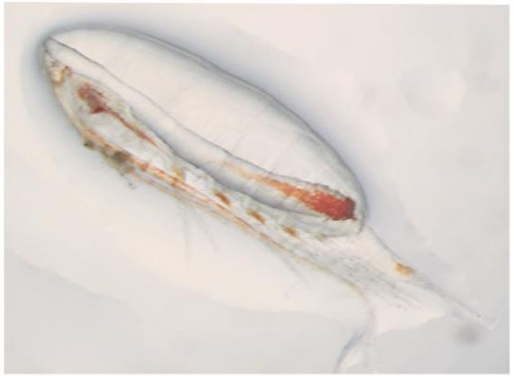
- **Gut content**

Opaque copepods



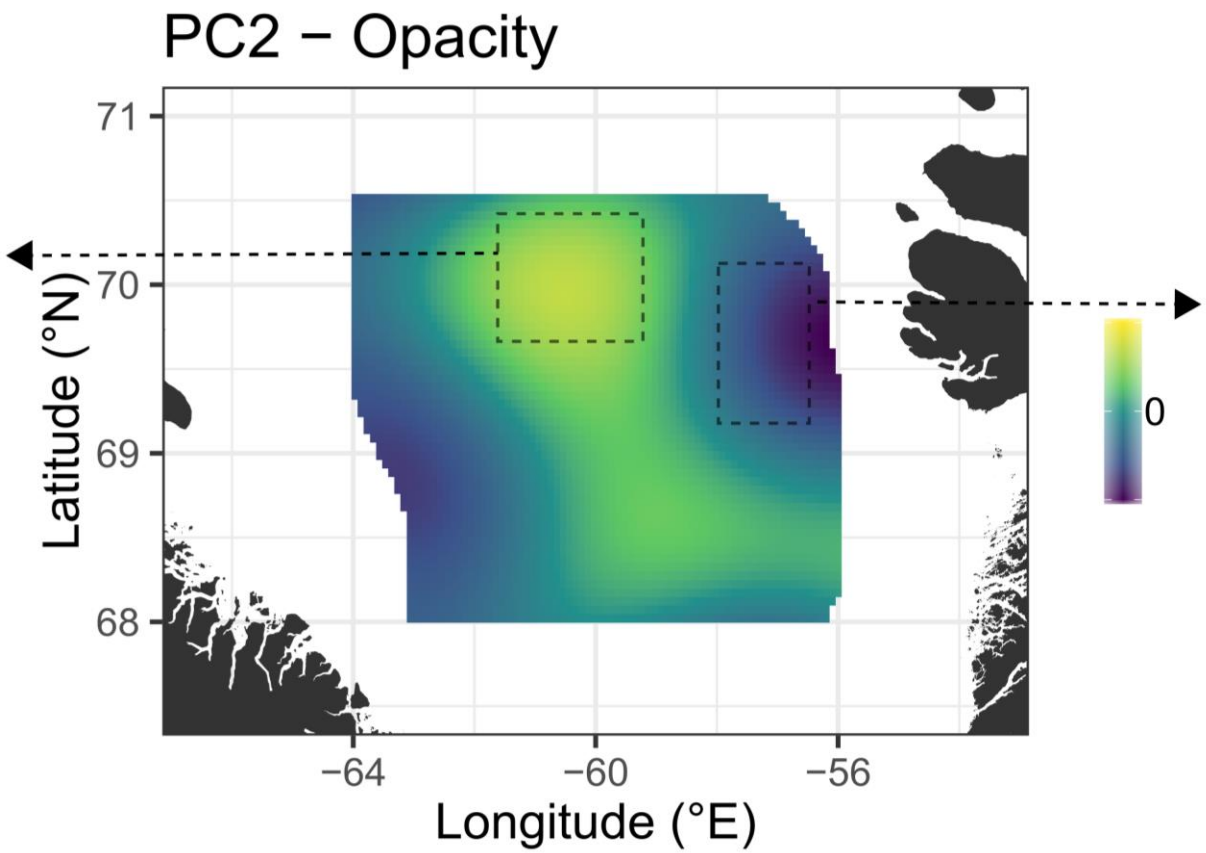
Transparent copepods



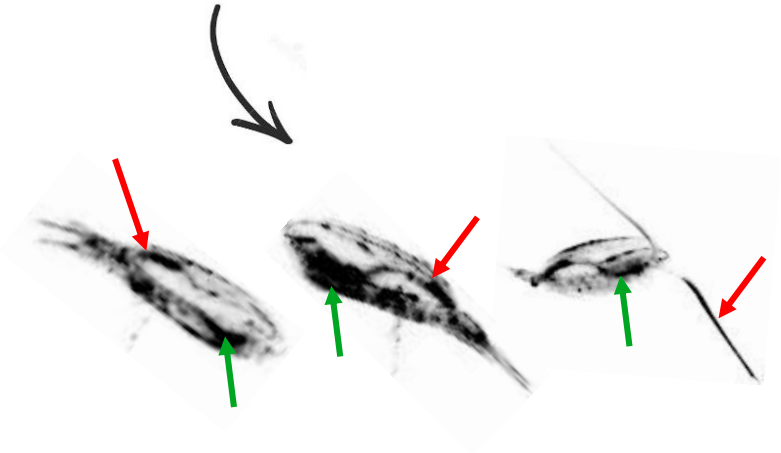


- **Gut content**
- **Antioxidant red pigments (astaxantine)**

Opaque copepods



Transparent copepods



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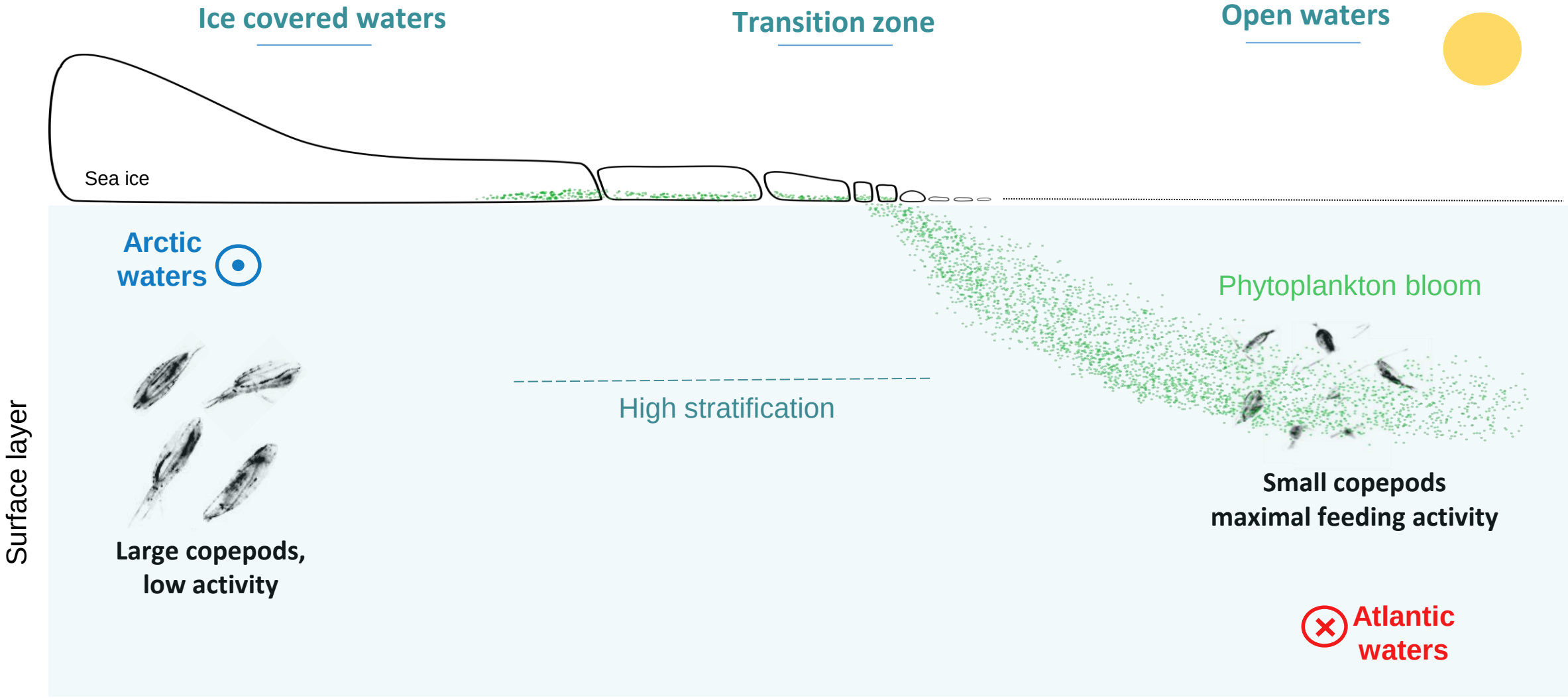
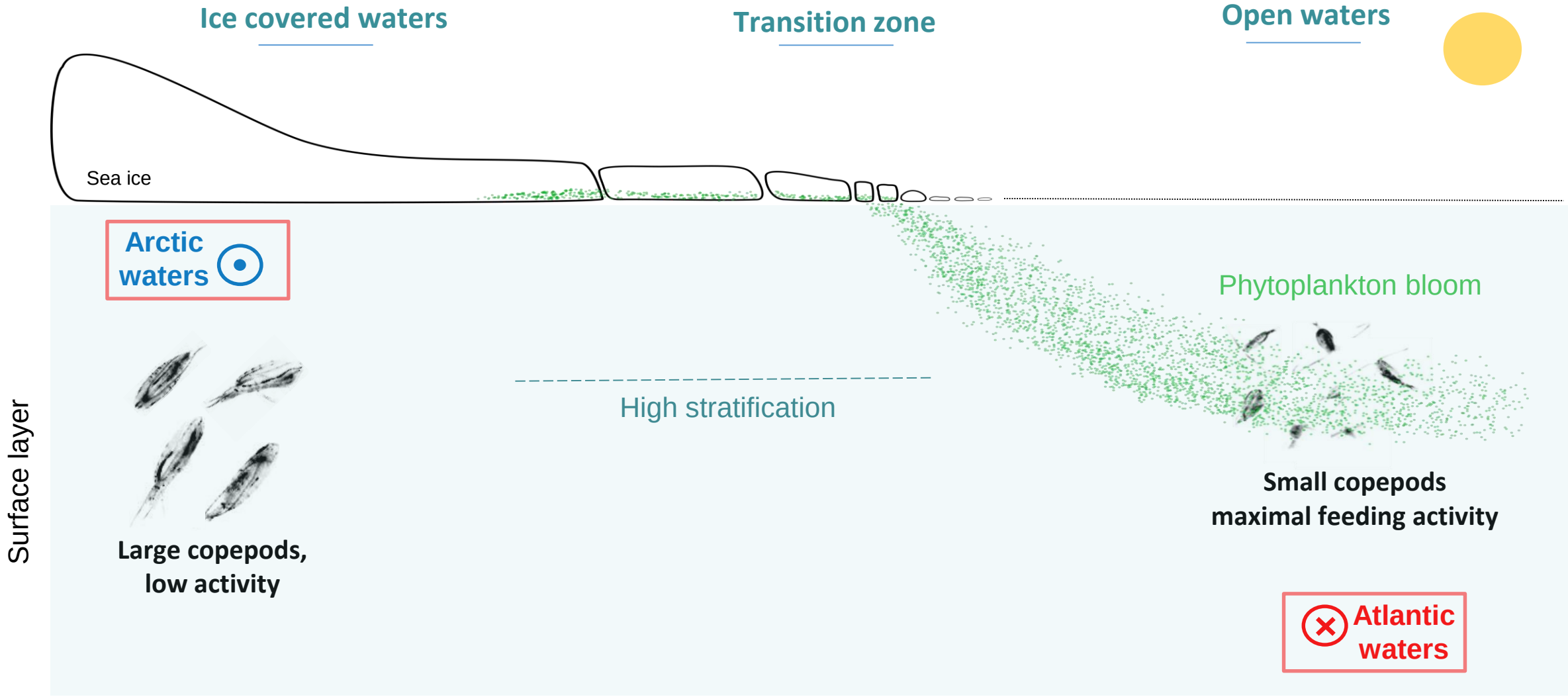
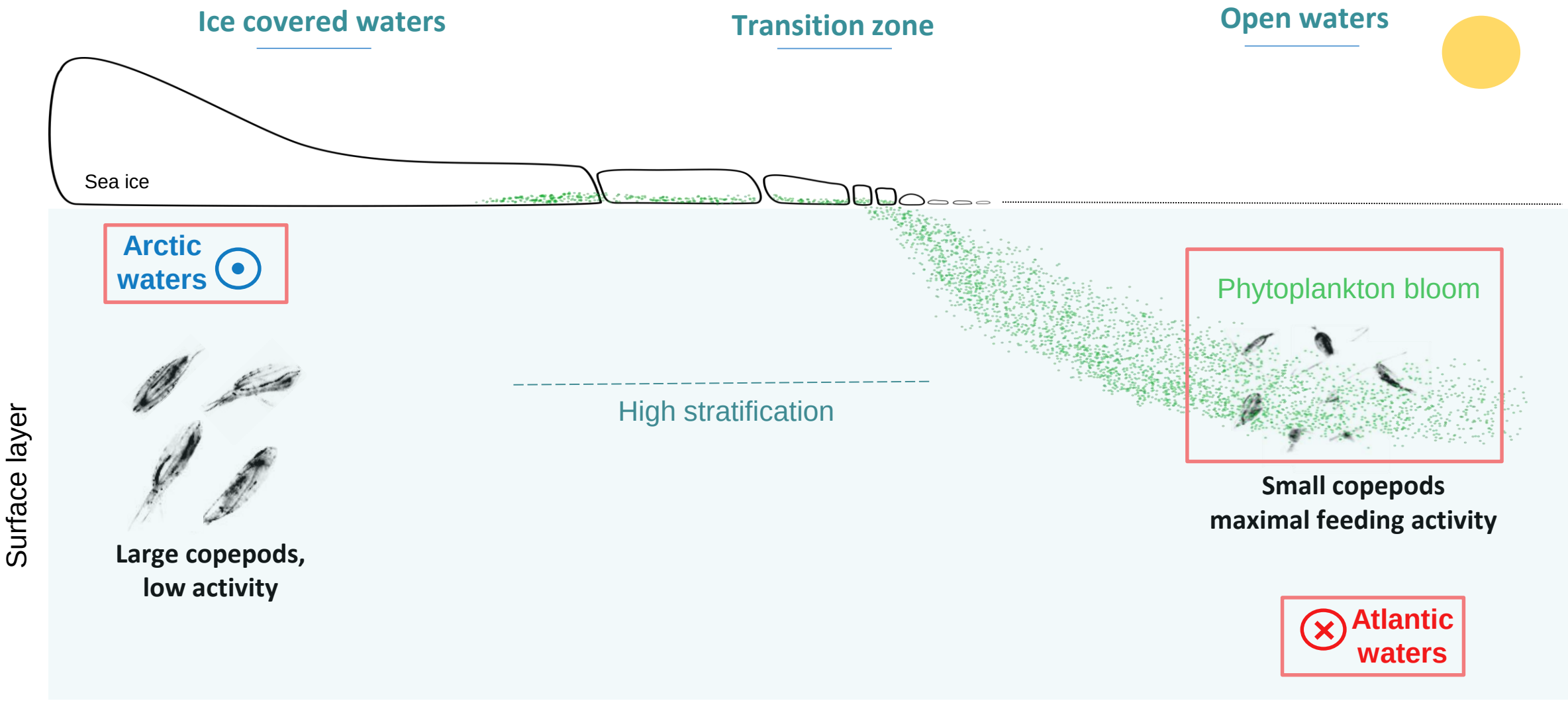

Ice covered waters
Transition zone
Open waters
Sea ice
Surface layer
Arctic waters
Large copepods, low activity
High stratification
Phytoplankton bloom
Small copepods maximal feeding activity
Atlantic waters



- Arctic communities

Advection from current

- Atlantic communities

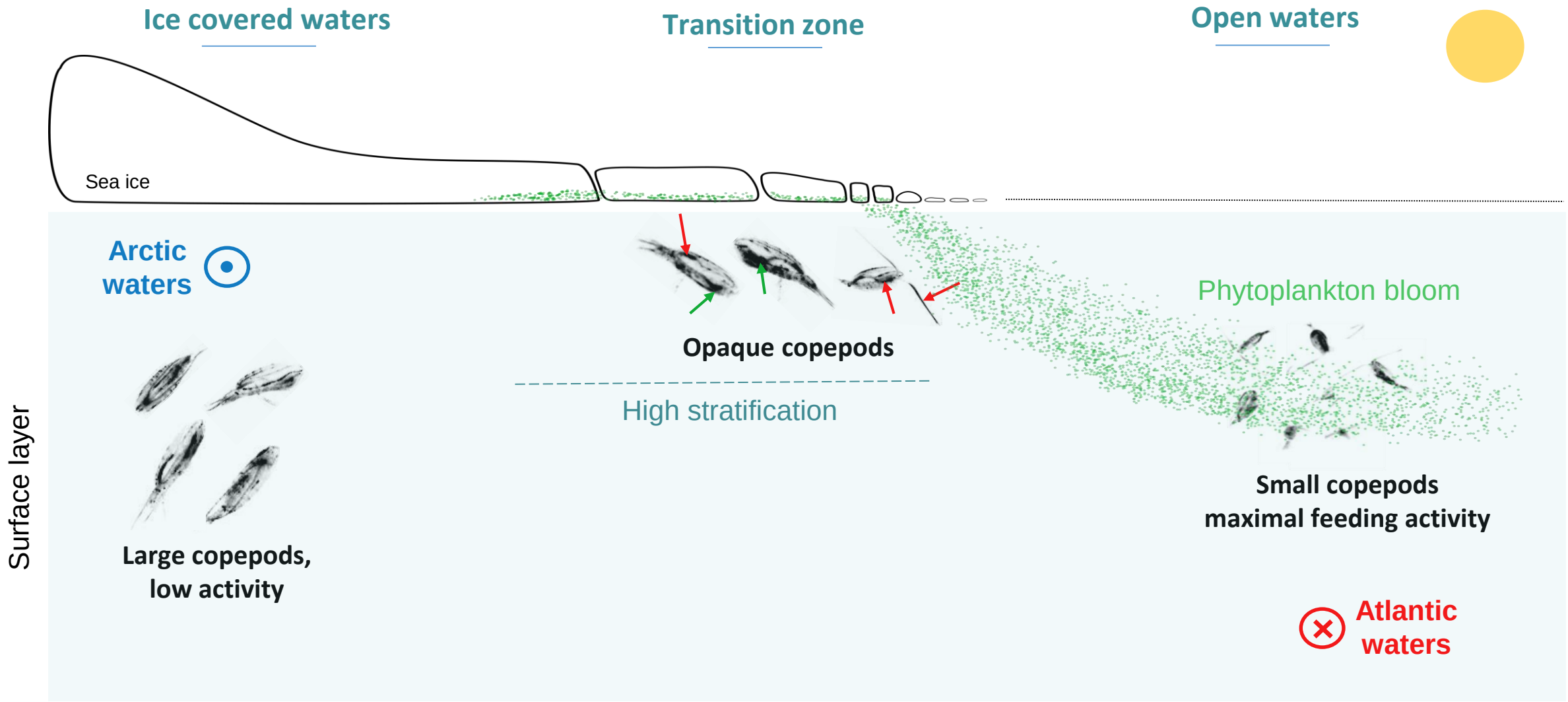


- Arctic communities
- Resting posture (overwintering?)

Advection from current

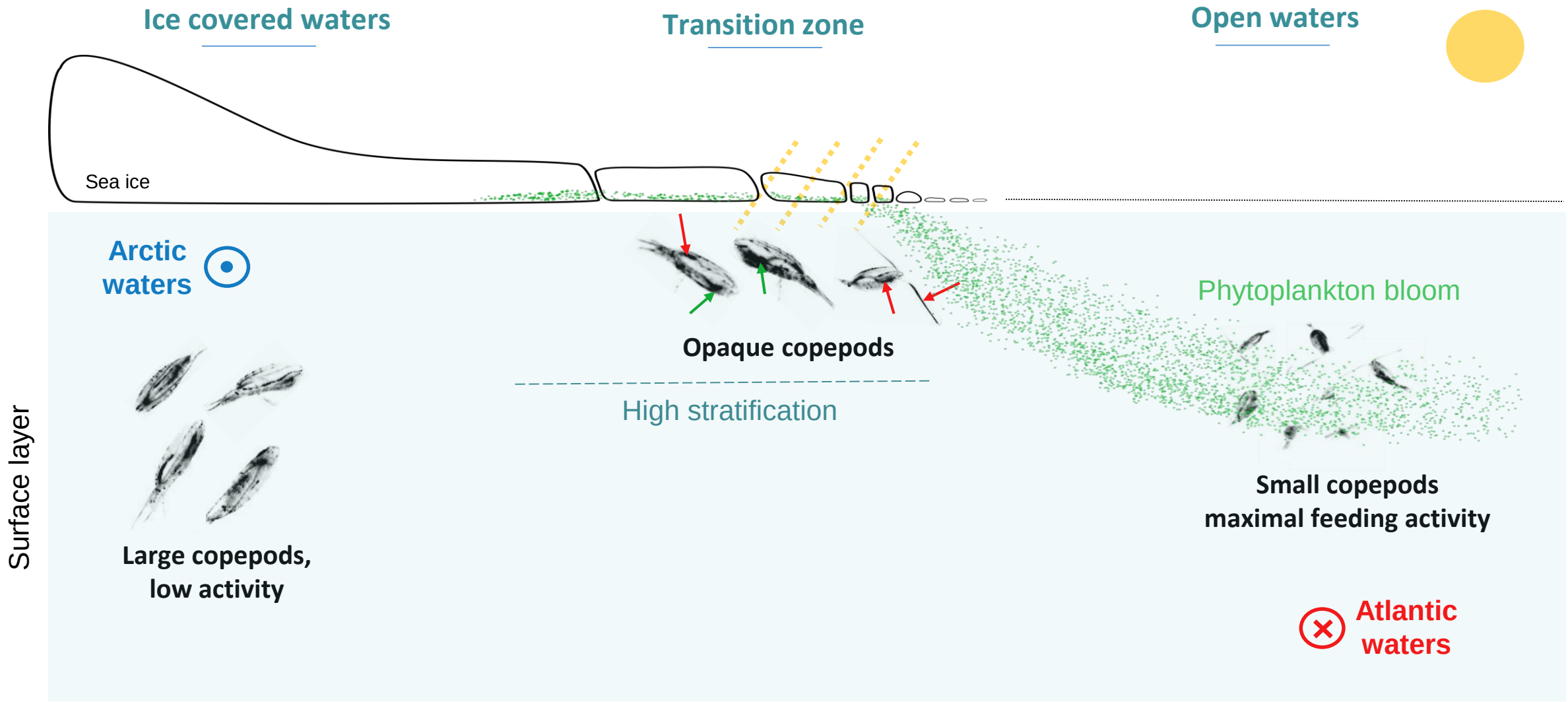
Bottom-up control

- Atlantic communities
- Good development conditions



- Arctic communities
- Resting posture (overwintering?)

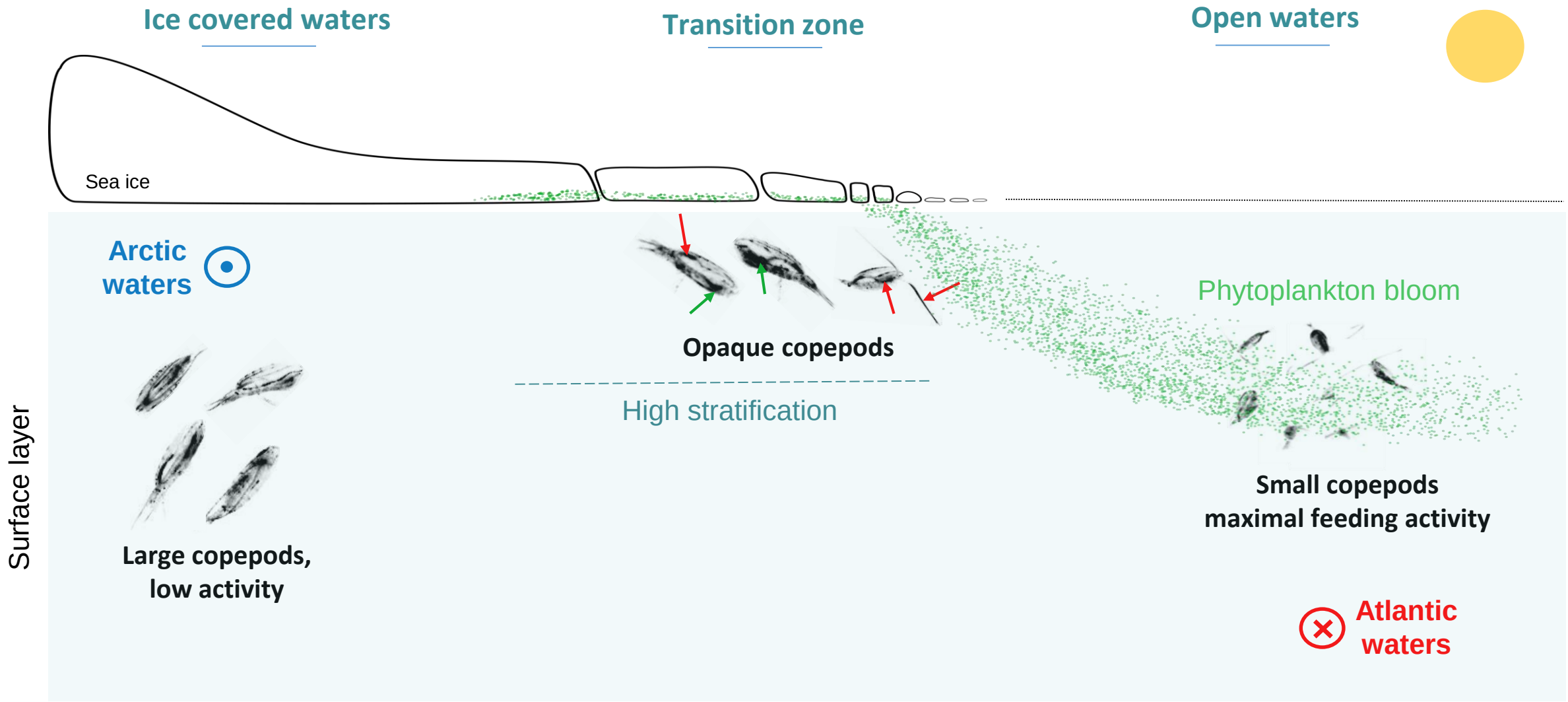
- Atlantic communities
- Good development conditions



- Arctic communities
- Resting posture (overwintering?)

Shallow bloom + Photo-oxydative stress?

- Atlantic communities
- Good development conditions



- Arctic communities
- Resting posture (overwintering?)

- Response to shallow bloom and solar radiations

- Atlantic communities
- Good development conditions

Conclusions

- Copepods respond to environment in term of size distribution, **feeding activity, pigment synthesis**
- **Individual traits** reveal ecological patterns at **community** level
- Morphological trait-based approach can be **generalized to other organisms** if quantitive imagery is available

Conclusions

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M-H. Forget


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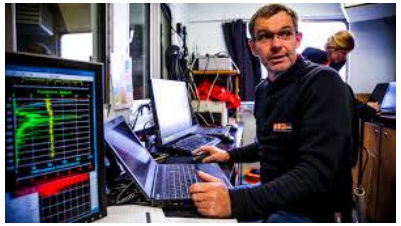
J. Ferland

GreenEdge campaign organization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M. Picheral
UVP conception and processing, image sorting


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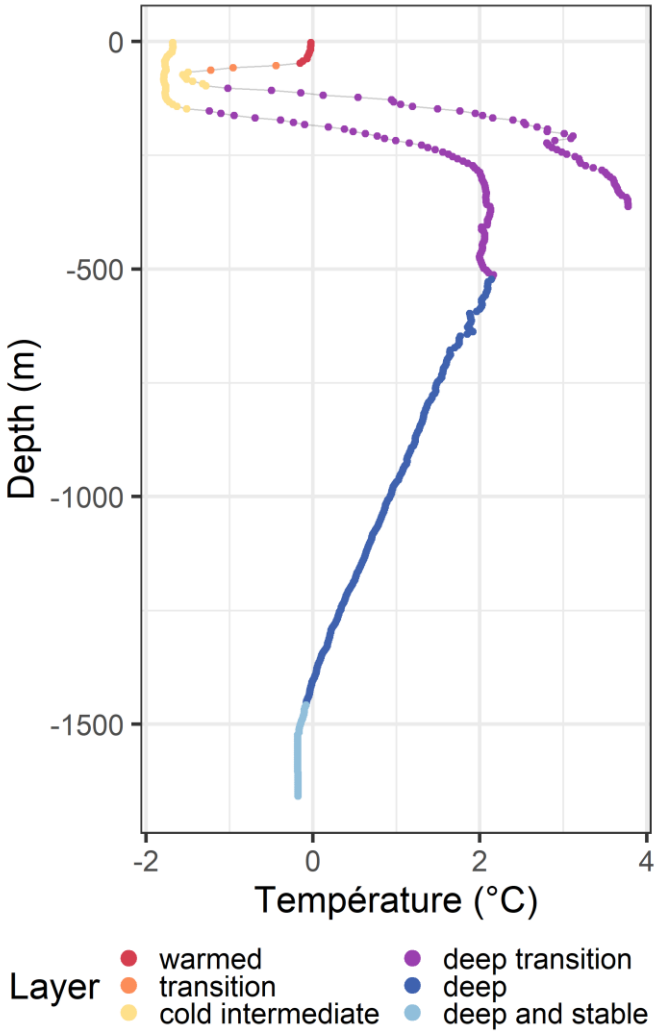
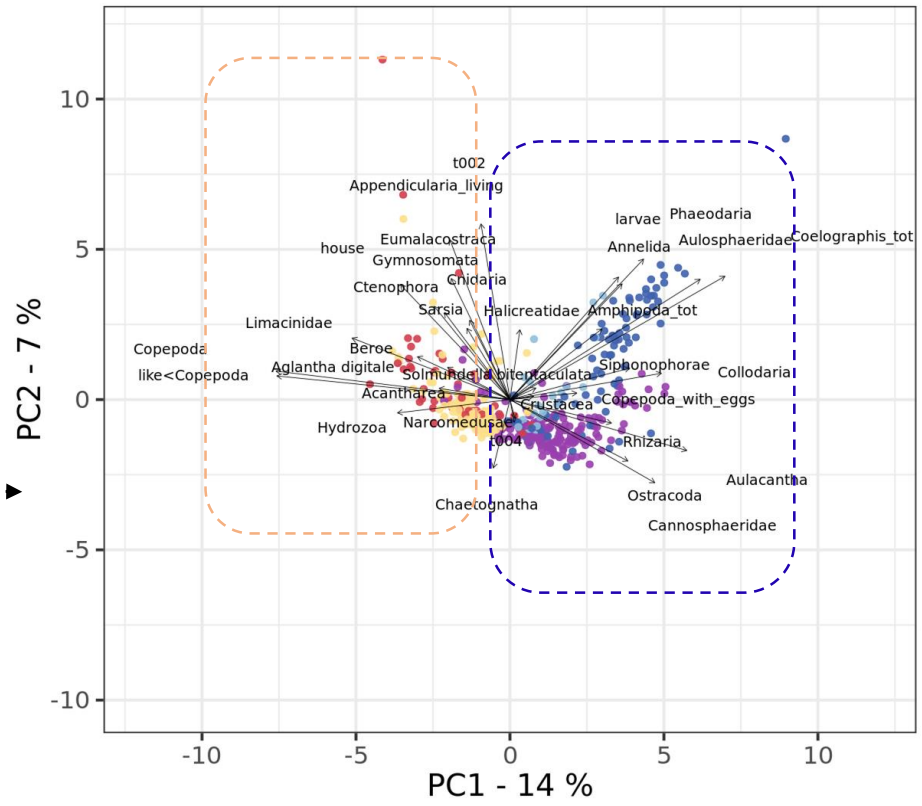
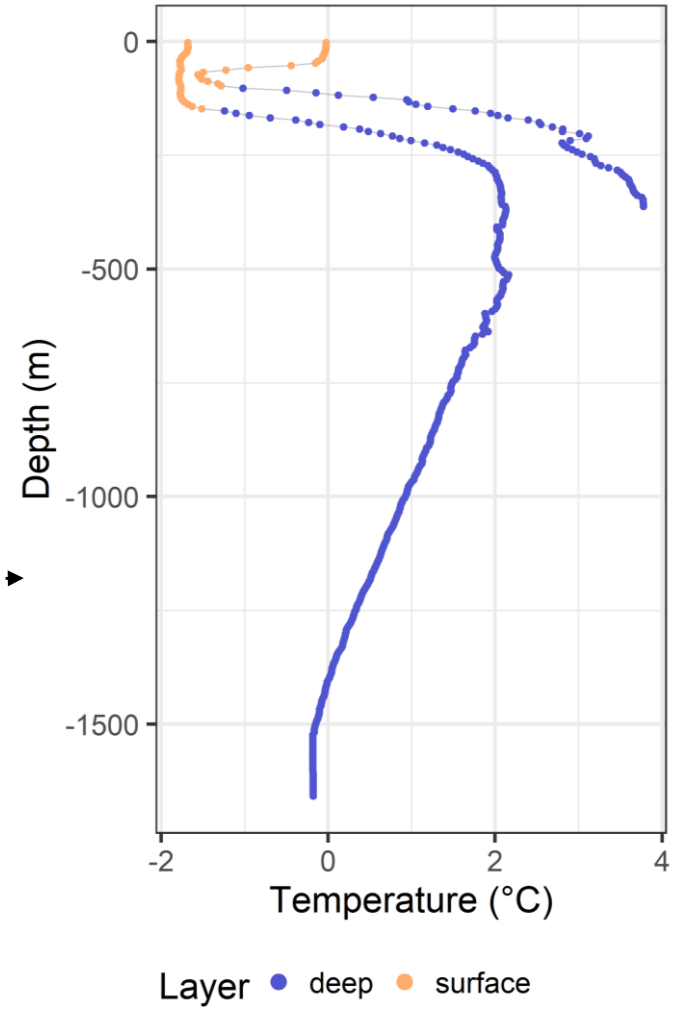
P. Guillot
CTD data processing and quality control

Annexes

Zonation according to depth



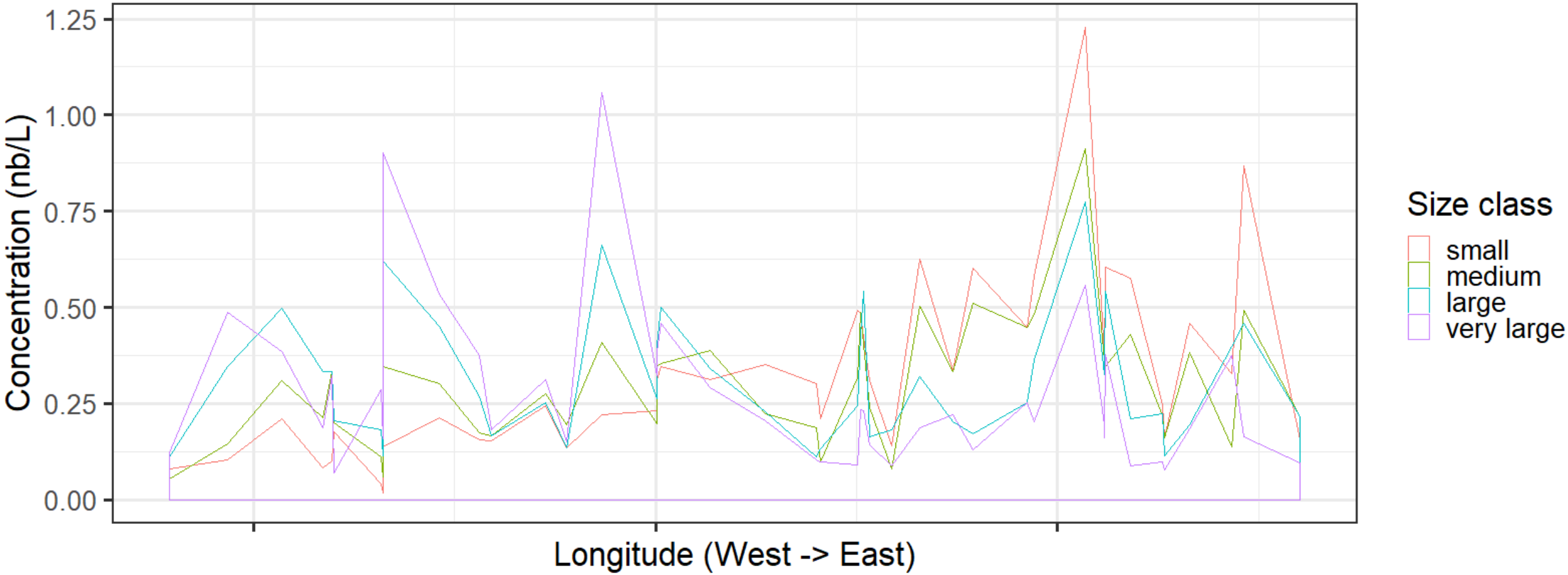


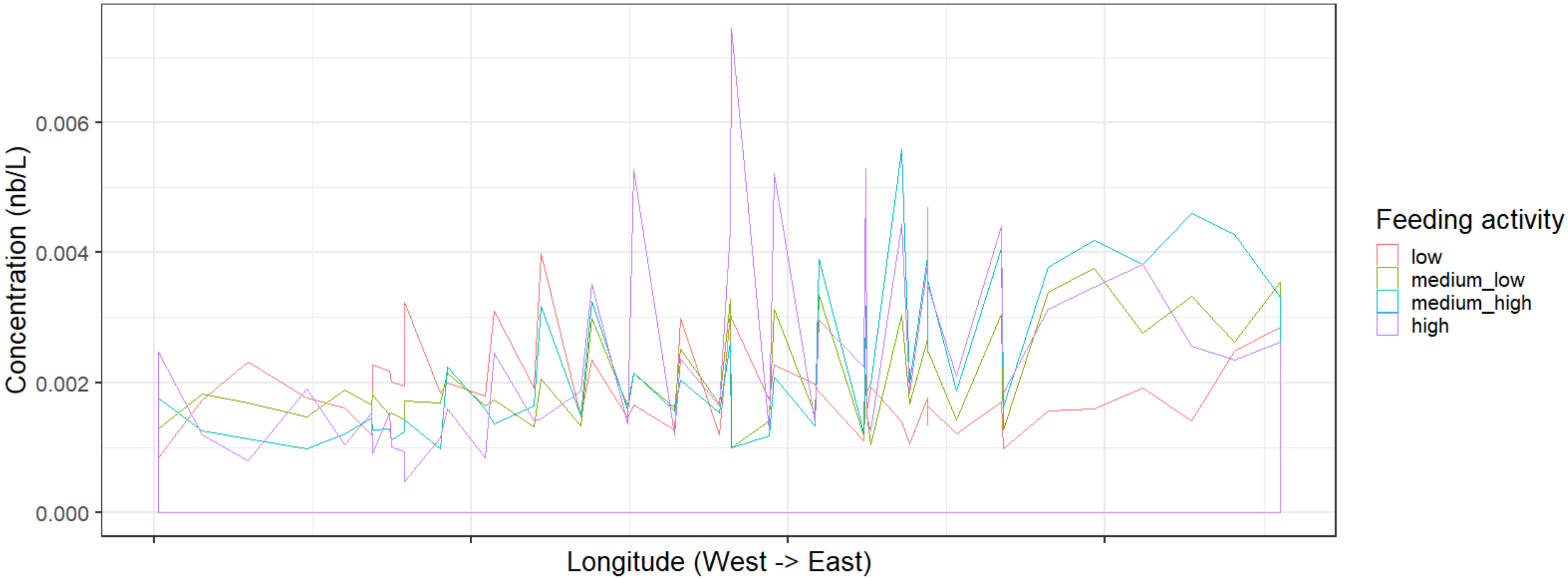


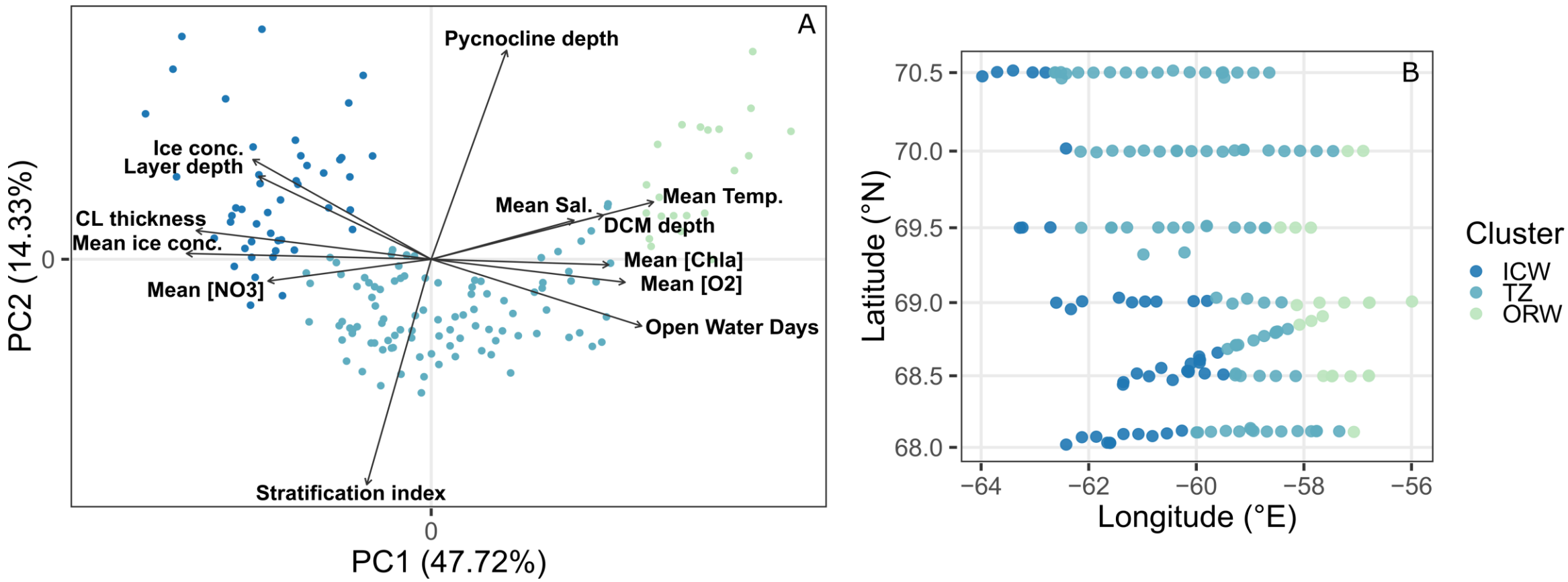
1 Detailled zonation of the water column according to temperature profiles

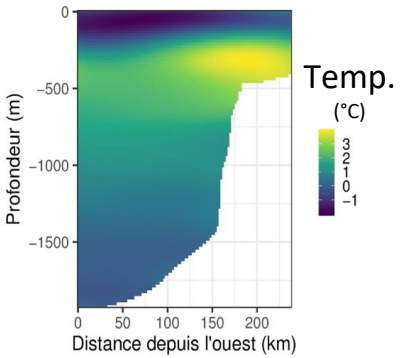
2 Verification of taxa distribution between layers

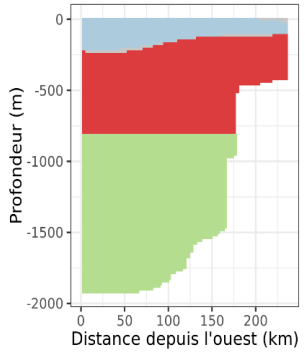
3 Simple definition of a surface and a deep layer


1.25
1.00
0.75
0.50
0.25
0.00
Concentration (nb/L)
Longitude (West -> East)
Size class
small
medium
large
very large


Concentration (nb/L)
0.006
0.004
0.002
0.000
Longitude (West -> East)
Feeding activity
low
medium_low
medium_high
high


A
Pycnocline depth
Ice conc.
Layer depth
CL thickness
Mean ice conc.
Mean [NO3]
Mean Sal.
Mean Temp.
DCM depth
Mean [Chla]
Mean [O2]
Open Water Days
Stratification index
PC2 (14.33%)
PC1 (47.72%)
0
0
B
70.5
70.0
69.5
69.0
68.5
68.0
−64
−62
−60
−58
−56
Latitude (°N)
Longitude (°E)
Cluster
ICW
TZ
ORW



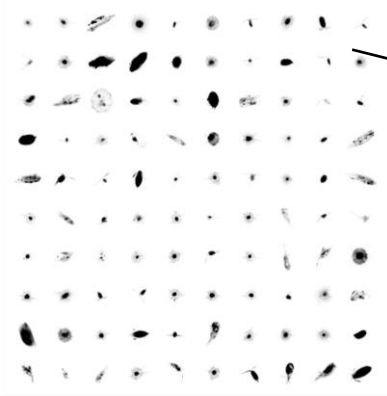


Arctic Waters
Atlantic Waters
Bottom Waters

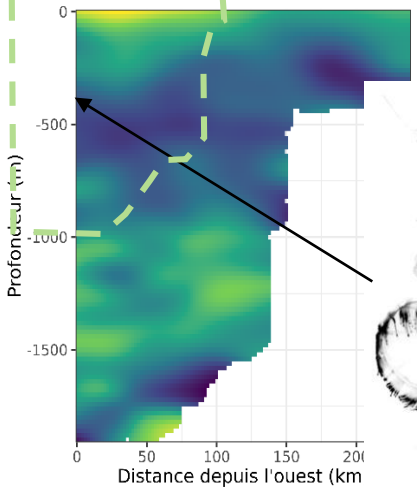
Tang *et al*, 2004

To go further, for all zooplankton community on the water colomun:

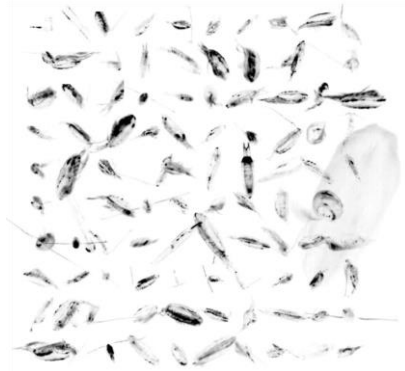
Atlantic waters



Size



Arctic waters

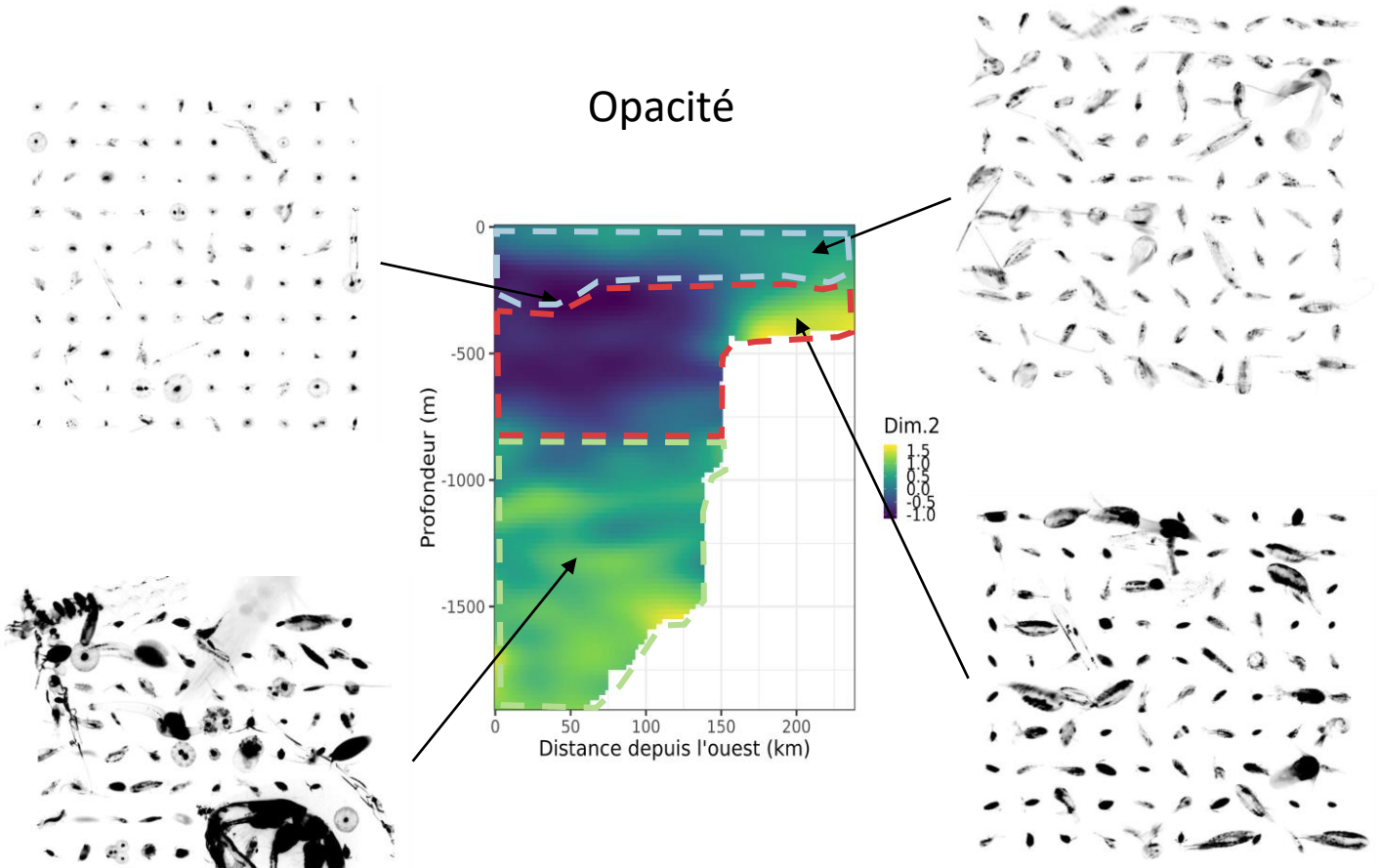


Bottom waters

Descripteurs morphologiques calculés par ZooProcess et leurs significations.

Taille	**Majeur** = axe primaire de l'ellipse ajustée à l'image **Mineur** = axe secondaire de l'ellipse ajustée à l'image **Aire** = Surface de l'objet (i.e. nombre de pixels appartenant à l'objet) **Diam.Féret** = Distance entre les 2 point les plus éloignés du contour de l'objet **Périm.** = Longueur du périmètre de l'objet
Forme	**Circ.** = Mesure de circularité = (4*π*area)/perim., 1 = rond, 0 = trait. **Élongation** = majeur/mineur, 1 = rond, >1 = plus allongé **Ratio épaiss.** = Thickness ratio, relation entre l'épaisseur maximale d'un objet et l'épaisseur moyenne de l'objet en enlevant le maximum (Romagnan et al., 2016) **Sym.ver.** = indice de symétrie bilatérale (Romagnan et al., 2016) **Sym.ver.2** = indice de symétrie bilatérale en ne tenant compte que des 75% des pixels les plus sombres de l'objet)
Transparence	**Gris moyen** = moyenne des niveaux de gris de l'objet (faible = objets foncés, fort = objets clairs) **Gris médian** = médiane des niveaux gris **Hist. gris 75%** = valeur à 75% de l'histogramme normalisé des niveaux de gris **Dev. gris** = déviation standard de la valeur du niveau de gris (par rapport à la moyenne) **Asym. gris** = asymétrie de l'histogramme des niveaux de gris
Complexité	**Périm./Majeur** = Périm/majeur, reflète à la fois la complexité (valeurs hautes si le périmètre est particulièrement complexe pour un objet d'une taille donnée) et la circularité (les objets ronds ont un ratio périmètre sur diamètre élevé). **Périm./Féret** = Périm./Diam. Féret, même interprétation **Fractale** = dimension fractale (i.e. complexité) du contour (Bérubé and Jébrak, 1999)

Opacité


0
-500
-1000
-1500
Profondeur (m)
0
50
100
150
200
Distance depuis l'ouest (km)
Dim.2
1.5
1.0
0.5
0.0
-0.5
-1.0