Relationship between zooplankton morphology and environmental conditions in a long term Mediterranean time series

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Biological background

→ Ecosystem biodiversity is linked with environmental heterogeneity[3,4]
→ Biodiversity can be quantified by various indices[2]
→ Functional diversity is directly linked to ecosystem functioning[5]
→ Among functional traits - that are any features measurable at the individual-level and affecting the fitness of the organism[6]- **morphological traits** can be affected by environmental conditions

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2. Beck, M., Cailleton, C., Guidi, L., Desnos, C., Jalabert, L., Elineau, A., ... & Irisson, J. O. (2023). Morphological diversity increases with decreasing resources along a zooplankton time series. Proceedings of the Royal Society B, 290(2011), 20232109.
3. Bell, G., et al. "The spatial structure of the physical environment." Oecologia (1993): 114-121.
4. Bell, Graham. "Fluctuating selection: the perpetual renewal of adaptation in variable environments. "Philosophical Transactions of the Royal Society B: Biological Sciences (2010): 76-911
5. Vallina, S. M., Cermeno, P., Dutkiewicz, S., Loreau, M., & Montoya, J. M. (2017). Phytoplankton functional diversity increases ecosystem productivity and stability. Ecological Modelling, 361, 184-196.
6. Violle, C., Navas, M. L., Vile, D., Kazakou, E., Fortunel, C., Hummel, I., & Garnier, E. (2007). Let the concept of trait be functional!. Oikos, 116(5), 882-892.

Initial objective: Relationship between environmental and phenotypic variances

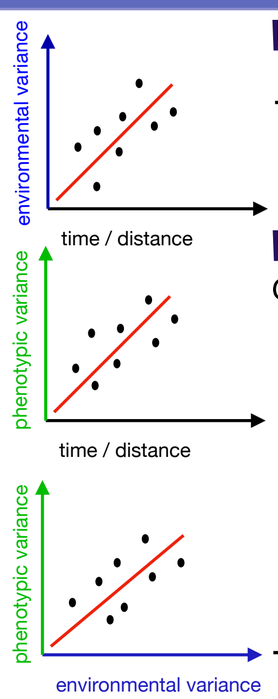
What should have been tested: Bell's hypothesis

1) Linearity of the relationship between variance and distance

Landscape heterogeneity influences ecosystem functioning and structure.
Environmental variance can be measured as the variance of key environmental characteristics.
This variance is expected to increase with spatial or temporal **distance.**

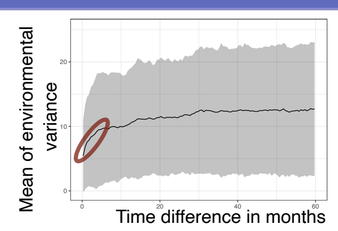
2) Linearity of the relationship between environmental and phenotypic variances

The ability of organisms to face environmental variance is positively linked to phenotypic diversity in functional traits.
Natural selection should drive an **increase** in **phenotypic variance** as **environmental variance increases.**



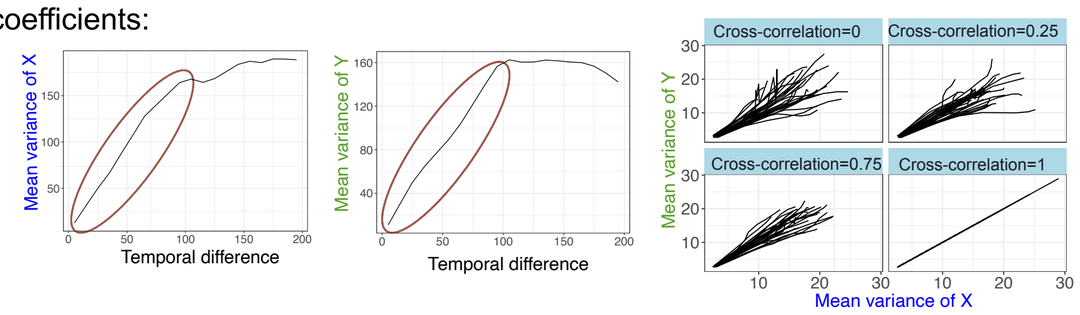
Why is this hypothesis not verified?

→ Increase and then saturation of environmental variance with time



Why is this hypothesis not falsifiable?

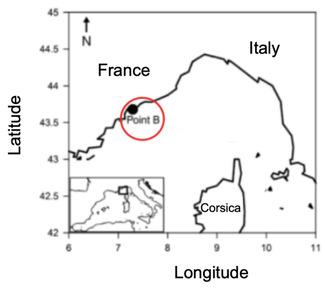
Generation of random time series with autocorrelation and different cross-correlation coefficients:



→ Linear relationship no matter the cross-correlation coefficient as long as there is **autocorrelation** in time series.

Material and methods

Sampling station in the Mediterranean Sea: global warming hot spot



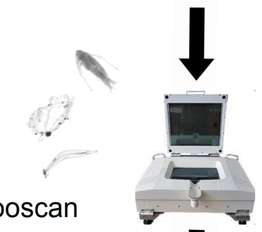
CTD environmental variables

Environmental variables treatment

Sampling

Juday Bogorov net
0 - 75 m depth
bimonthly sampled
since 1967

Image acquisition



Zooscan

Automatic classification with AI

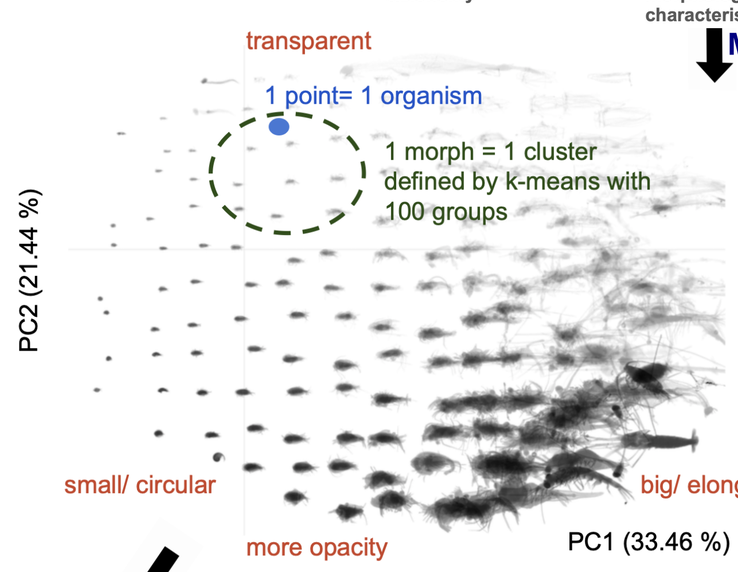
date	depth	latitude	longitude	temperature	qc_ temperature

date	id	lineage	sample volume	size	height	width	…	perimeter	acq_ sub_ part

taxonomy

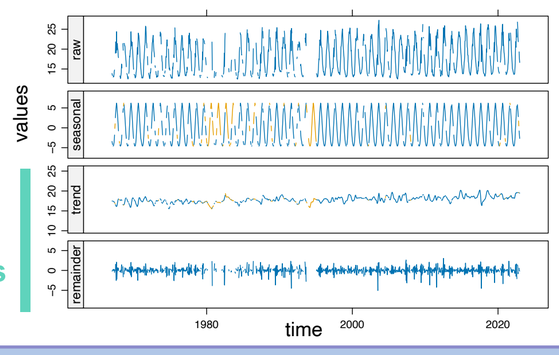
morphological characteristics

Morphological PCA



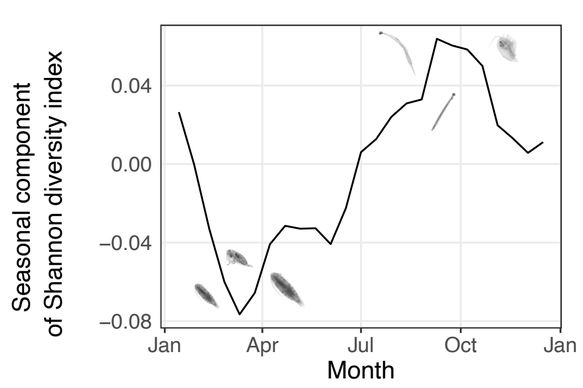
Shannon diversity index on morphs

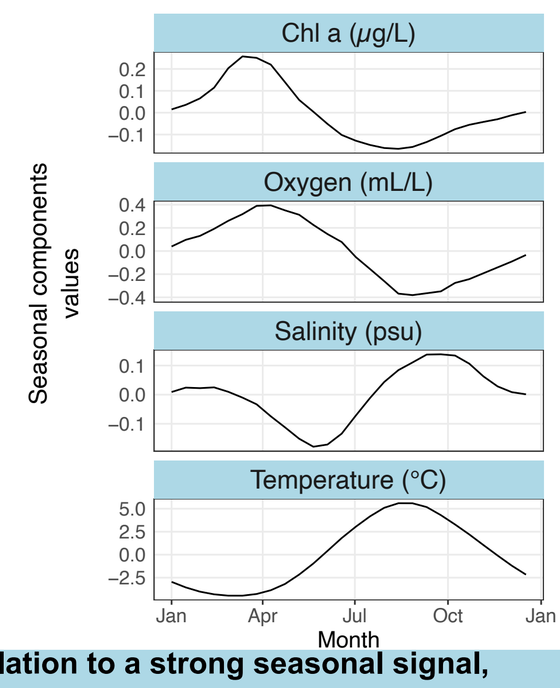
Time series analysis: Decomposition using STL



Time series analysis: Trend analysis on deseasonalised series using GLS regression with AR1

Seasonal variations



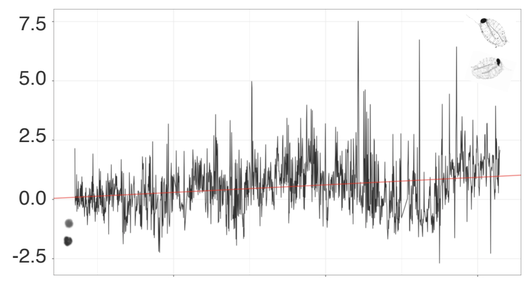


→ **Low morphological diversity in spring:** homogeneisation towards dominant species, mostly presence of lots of copepods
→ **Peak of diversity in the end of summer:** presence of gelatinous predators in the community in addition to other groups

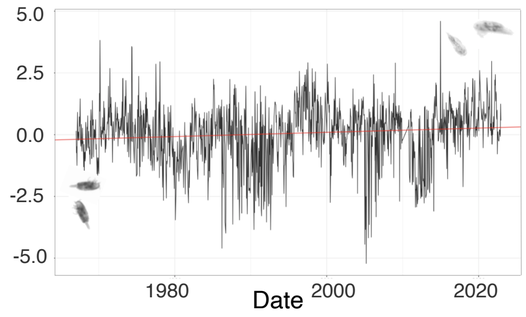
→Seasonal variations in morphology in relation to a strong seasonal signal, confirming what is observed in taxonomy

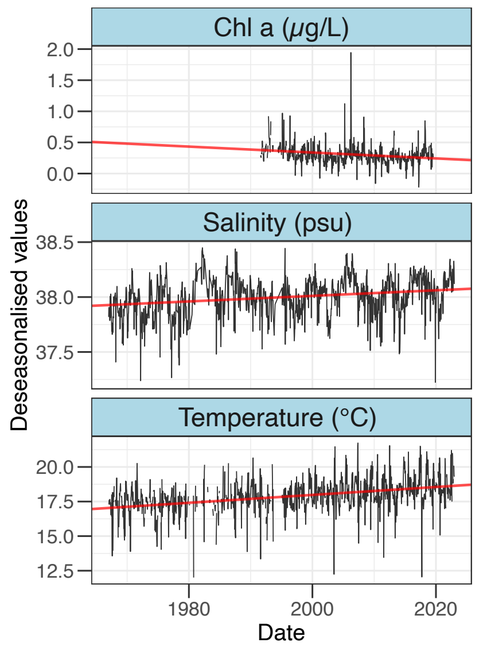
Long term trends

Long term trend in PC1 = size



Long term trend in PC2 = transparency





→Long term trends in morphology in response to environmental trends
→Surprising increase in size with an increase of temperatures, compared to what would be expected[1]
→This might be caused by shifts in taxonomy→ hypothesis to be tested