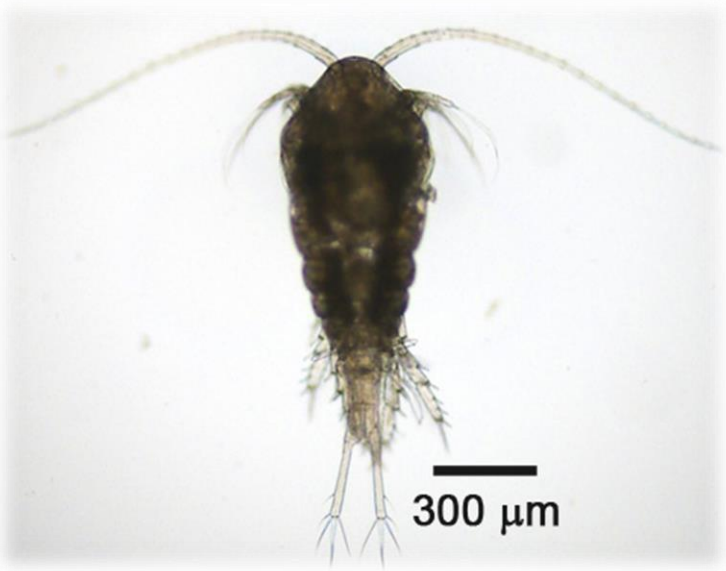
Temora longicornis and *T. stylifera* in a changing ocean climate: A macroecological perspective



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Aim of the study

Evidence that environmental changes affect species biogeography and abundance of many marine species (e.g. Beaugrand et al 2002).

Investigate changes in the seasonal and spatial abundance of two congeneric species, *Temora longicornis* and *T. stylifera,* in the North Atlantic over the past 60 years.

Focus on the Eastern North Atlantic (Bay of Biscay)

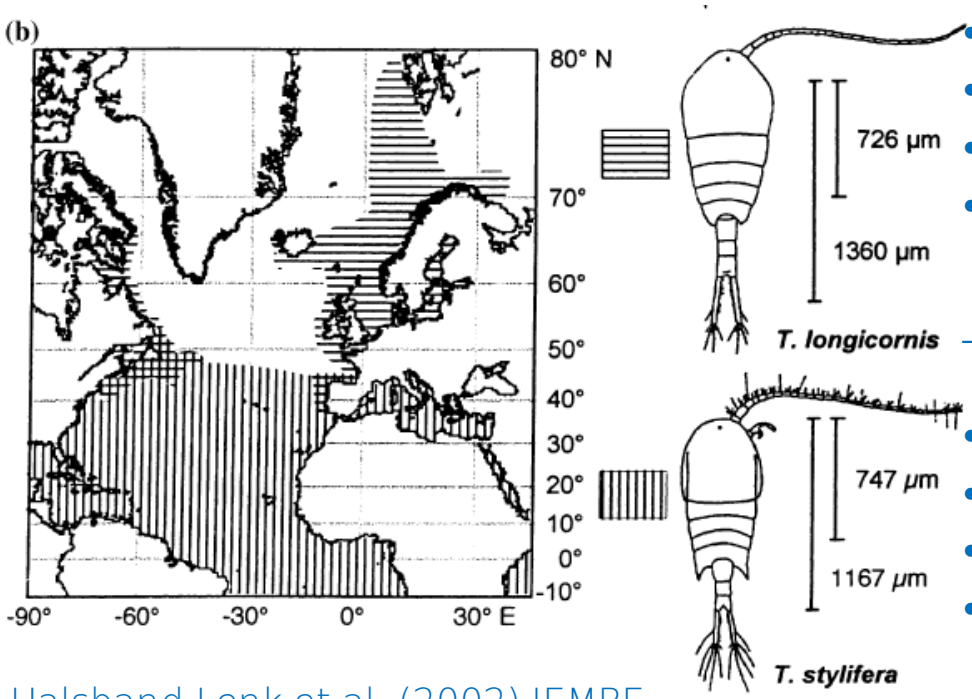
Explore biogeographical changes in relation to environmental variables

Compare two different periods of the time series:
Cold period: 1960-1980
Warm period: 1990-2014

Determine environmental preferences for the two species

T. longicornis vs *T. stylifera*

Biogeography (Literature source)



Halsband-Lenk et al. (2002) JEMBE

T. longicornis

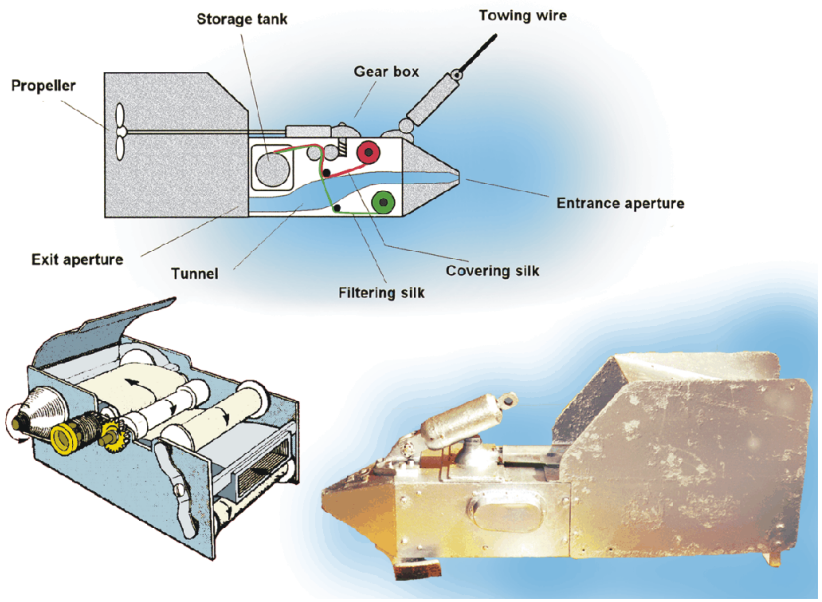
- Cold-temperate
- Neritic, epipelagic
- Peak in spring-summer
- 40 N – 72 N

T. stylifera

- Warm-temperate
- Peak autumn-winter
- Neritic, epipelagic
- Bay of Biscay since 1980 (Valdes et al. 2007)
- English Channel since 1990 (Lindley & Dykin 2005)

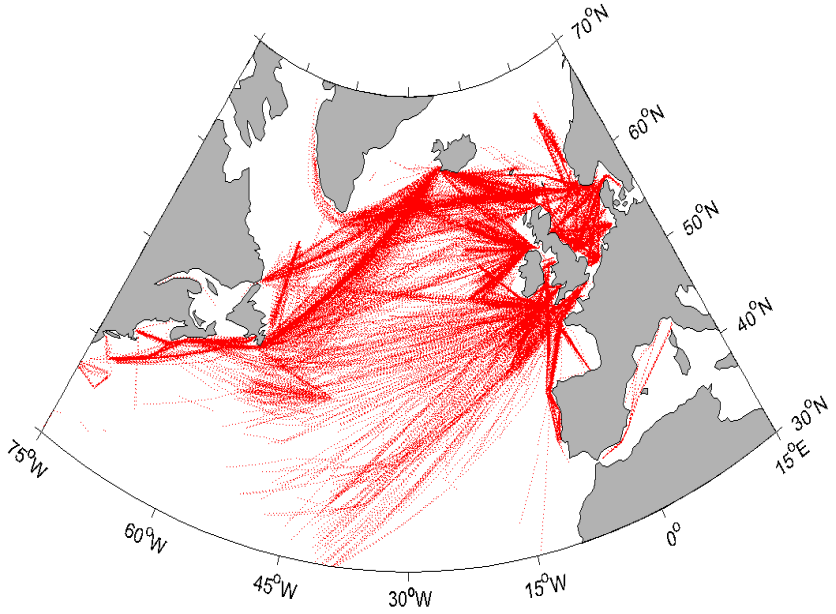
Method and Data

Continuous plankton Recorder



- Towed by ships of opportunity
- Between 7 and 10 metres depth
- Plankton caught on silk mesh (~270µm) and fixed in formalin.
- 6.5 million nautical miles towed since 1931

CPR-Survey in the North Atlantic



Data analysed consistently since 1958

~ 60 years time series

Data Analysis

Variables:

- *T. longicornis* and *T. stylifera* (abundance)
- Phytoplankton colour Index (PCI): annual mean, max and min
- Sea Surface Temperature (SST): annual mean, max and min
- Salinity, Oxygen
- Bathymetry

Data spatially interpolated with inverse squared distance (grid 1° lat x 1° long).

Interpolation carried for each month and year (with min 5 month observations) over the period 1958-2014.

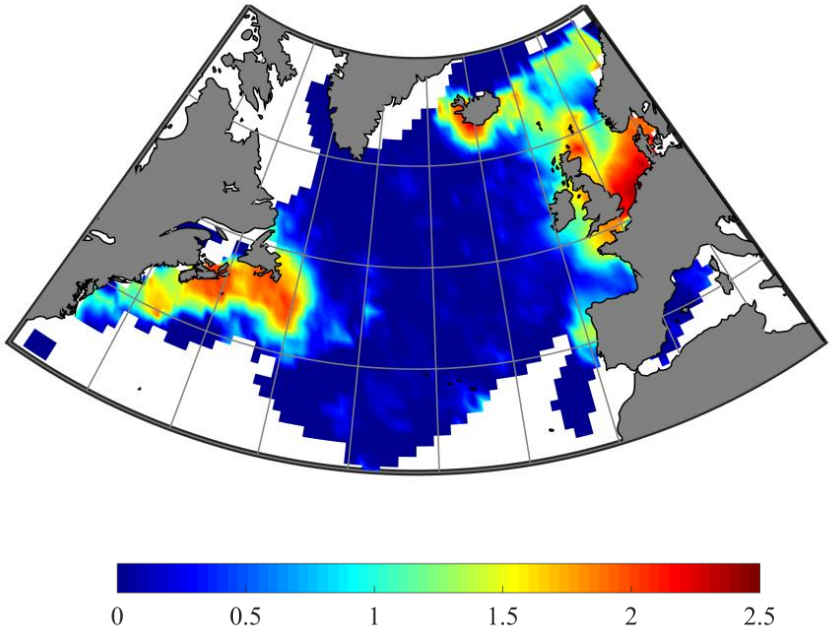
Spearman correlation and bootstrap (abundance vs environmental variables).

Spatialised PCI to compare seasonal and long term variability in the two species

Analysis of environmental preference for the species

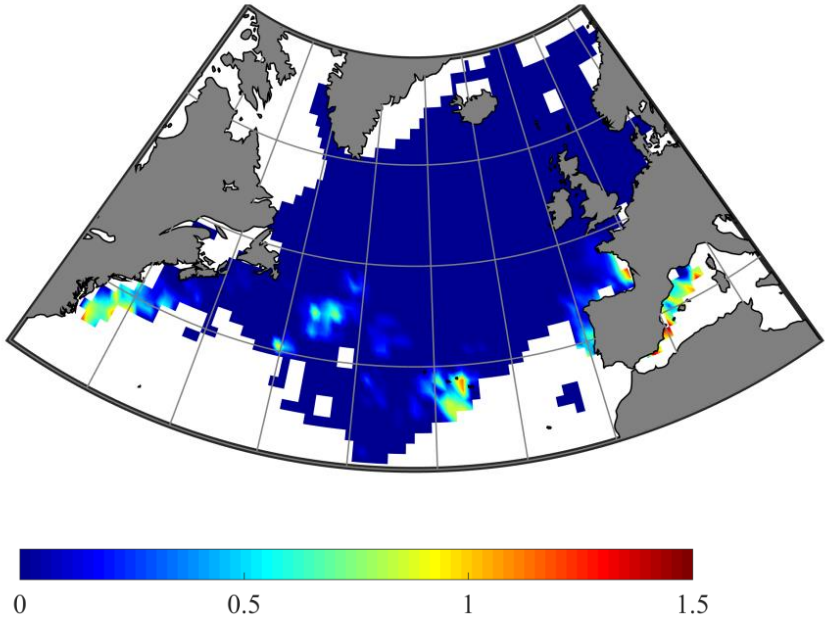
Spatial distribution and abundance

T. longicornis
(1958-2014)



abundance
(log10+1)

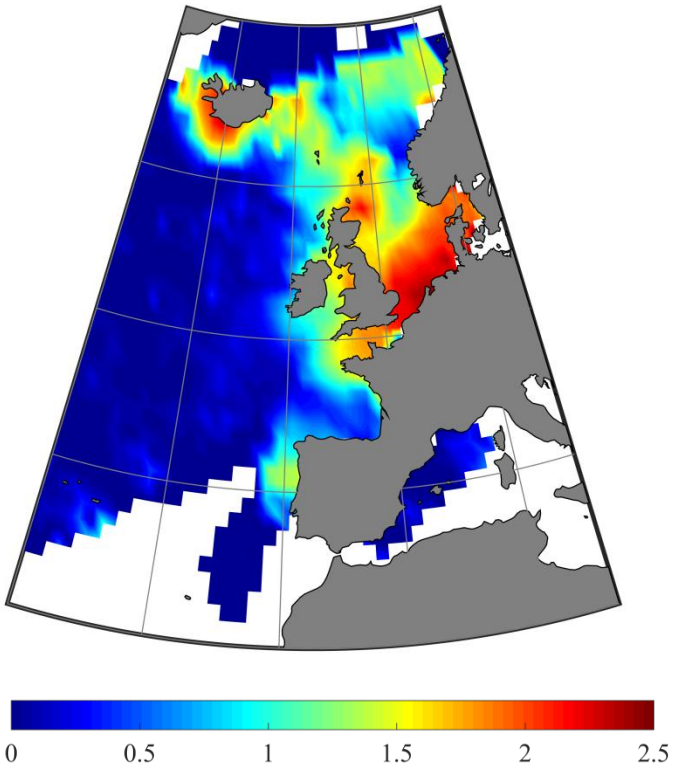
T. stylifera
(1958-2014)



abundance
(log10+1)

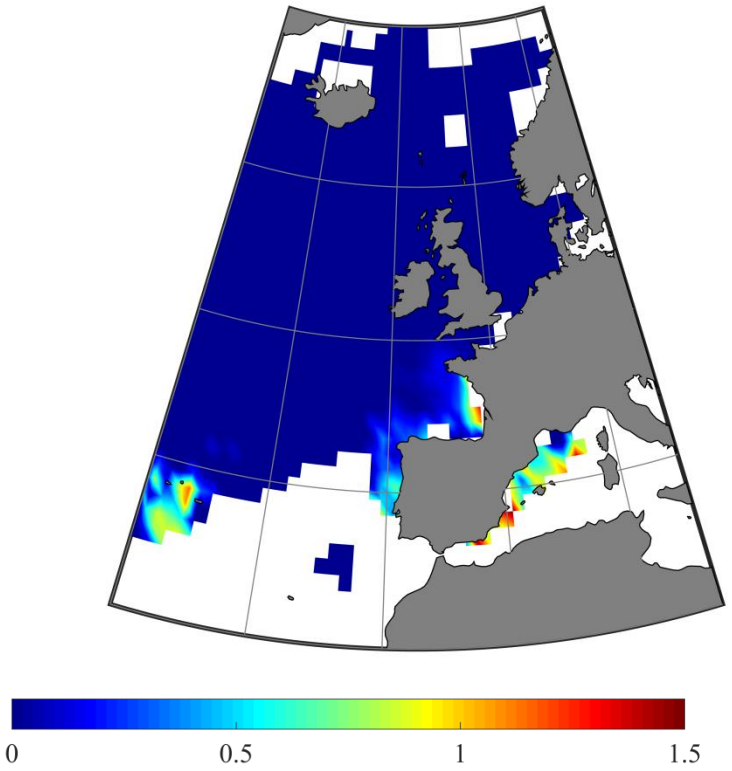
Spatial distribution and abundance

T. longicornis
(1958-2014)



abundance (log10+1)

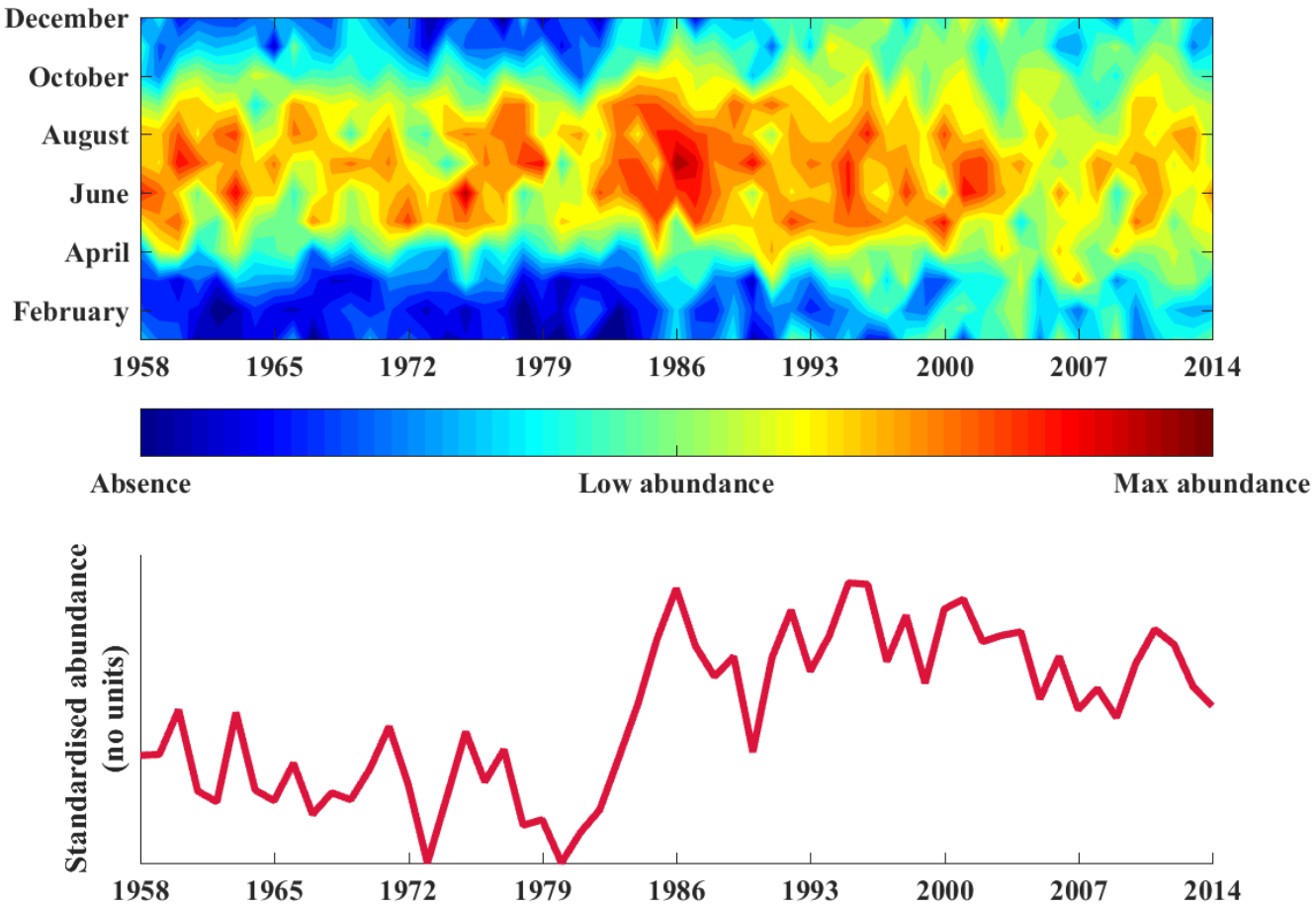
T. stylifera
(1958-2014)



abundance (log10+1)

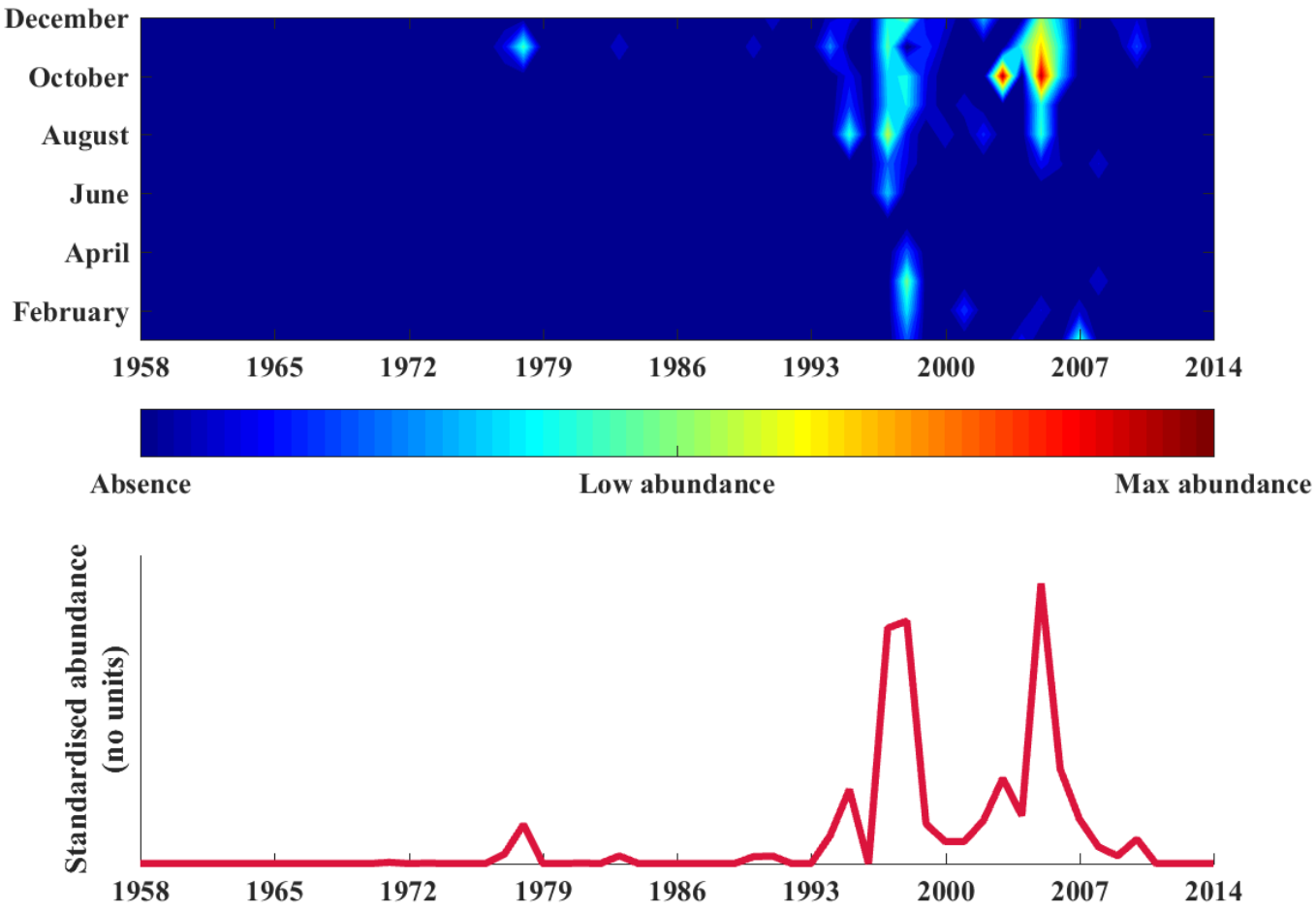
Long-term changes in abundance

T. longicornis (1958-2014)

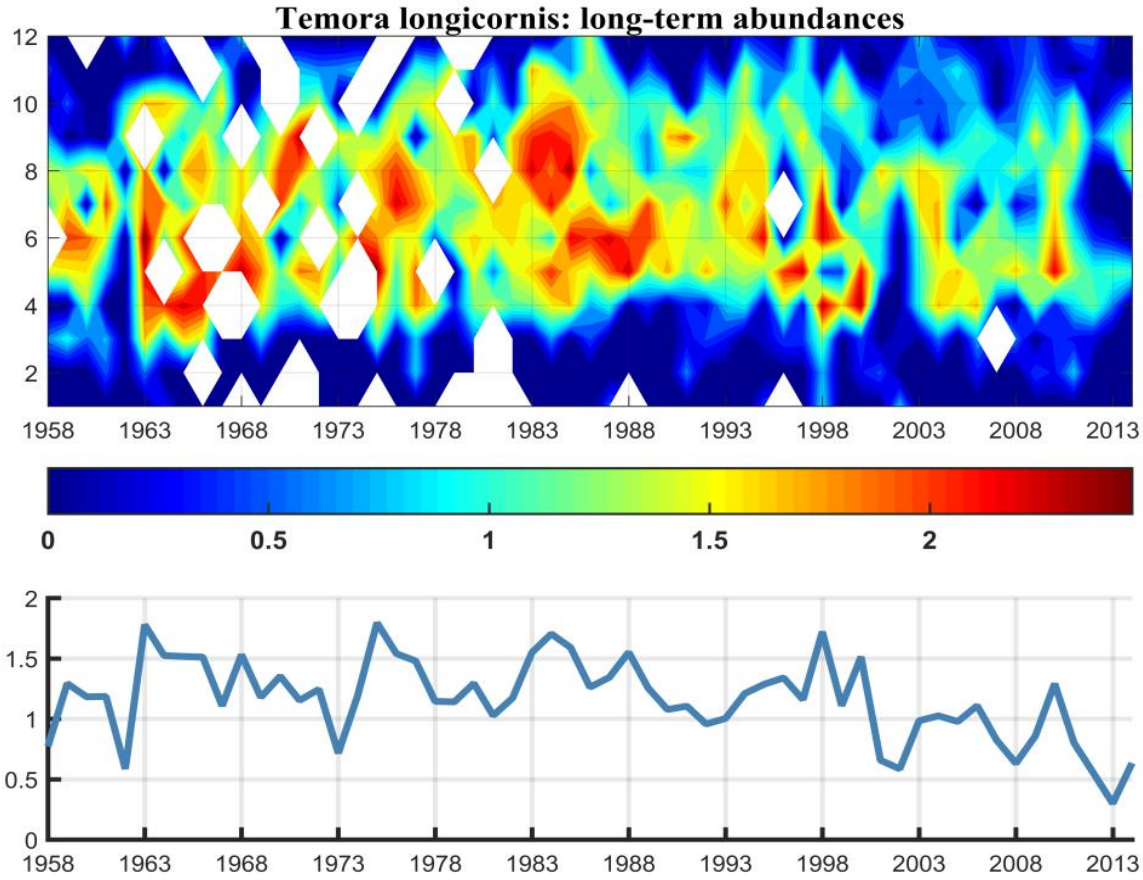


Long-term changes in abundance

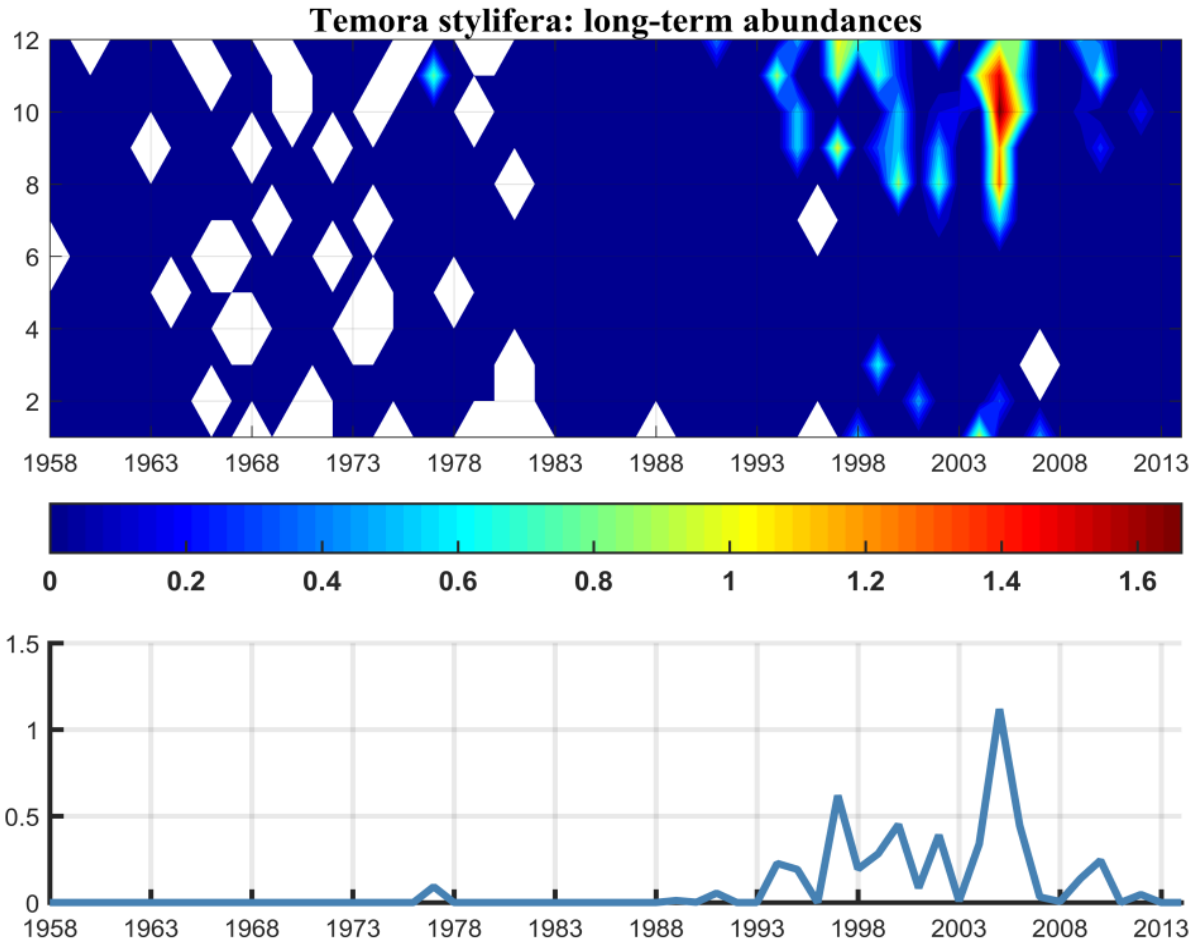
T. stylifera (1958-2014)



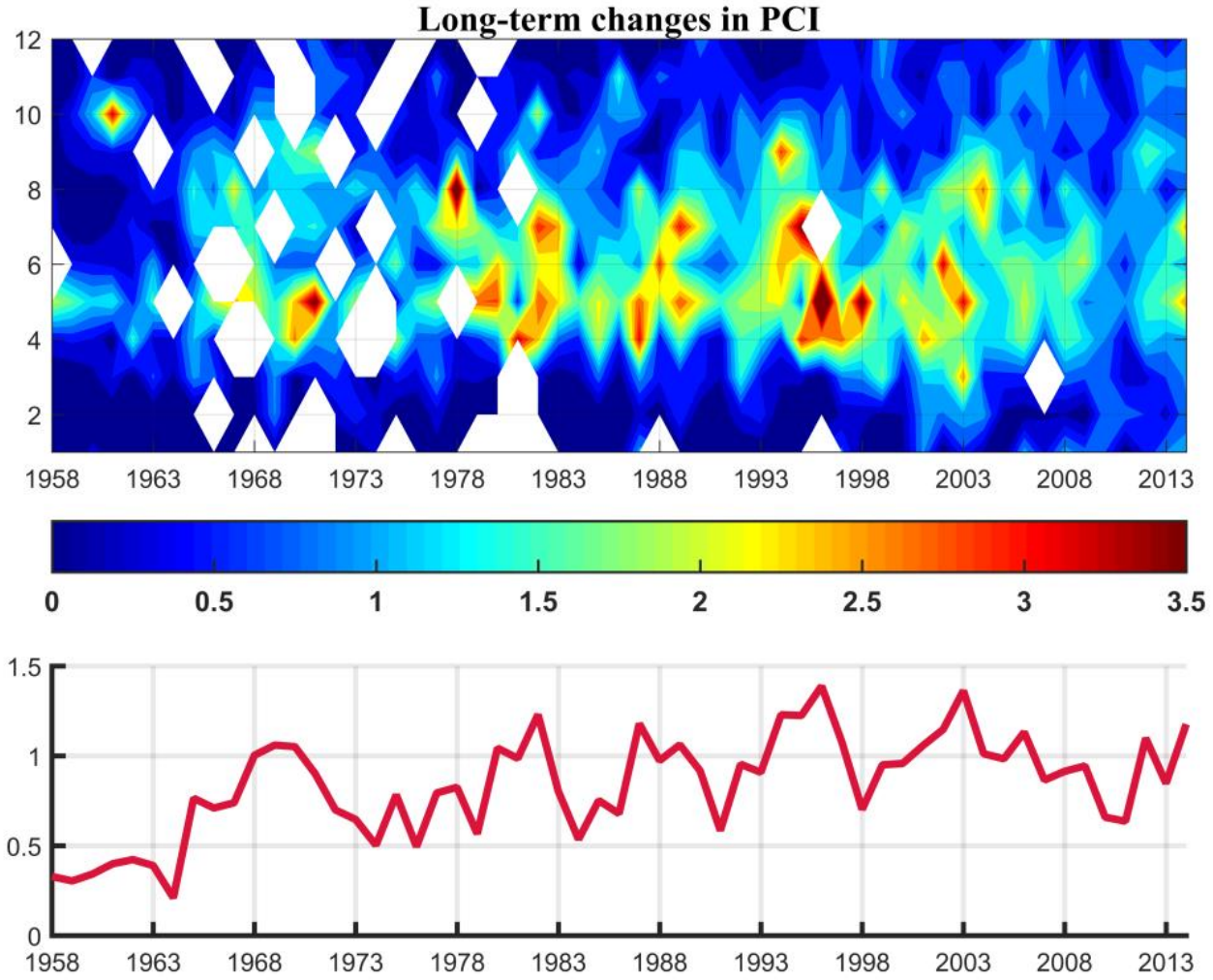
T. longicornis (Bay of Biscay)



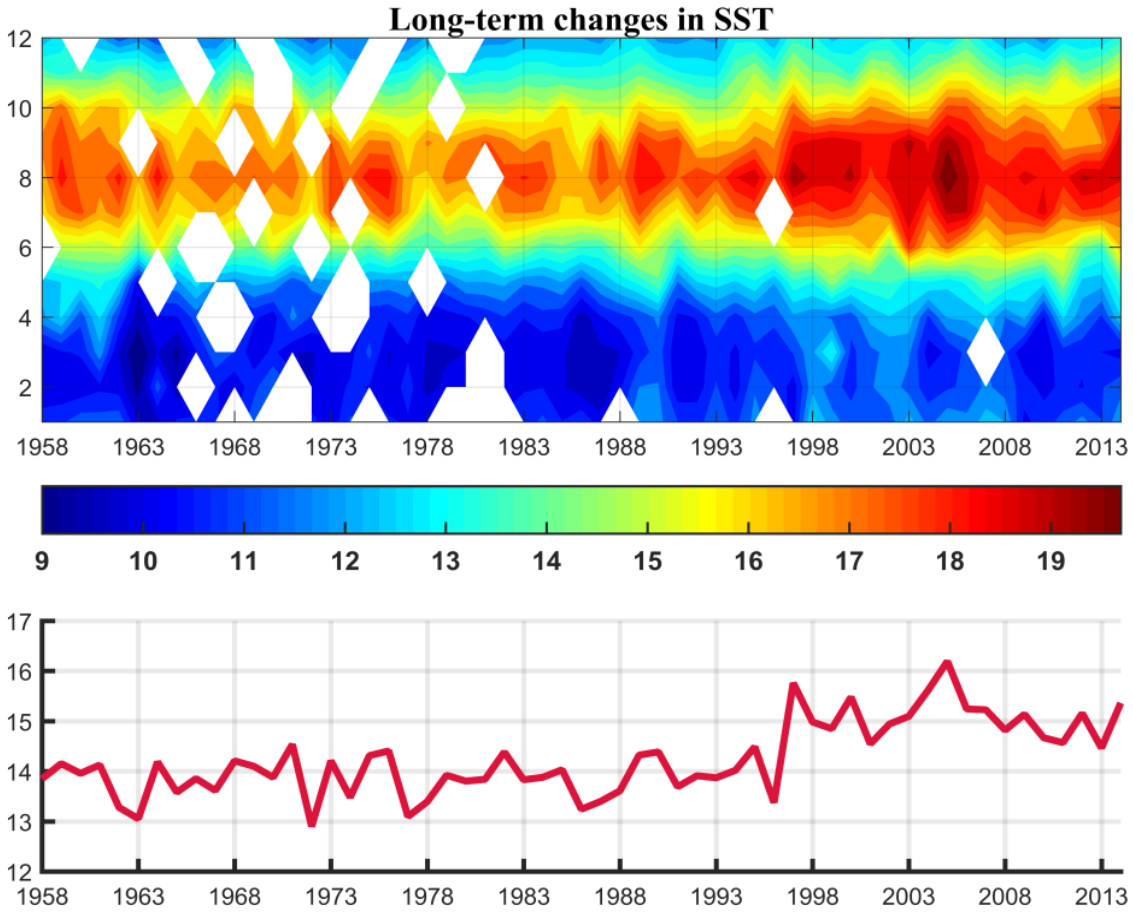
T. stylifera (Bay of Biscay)



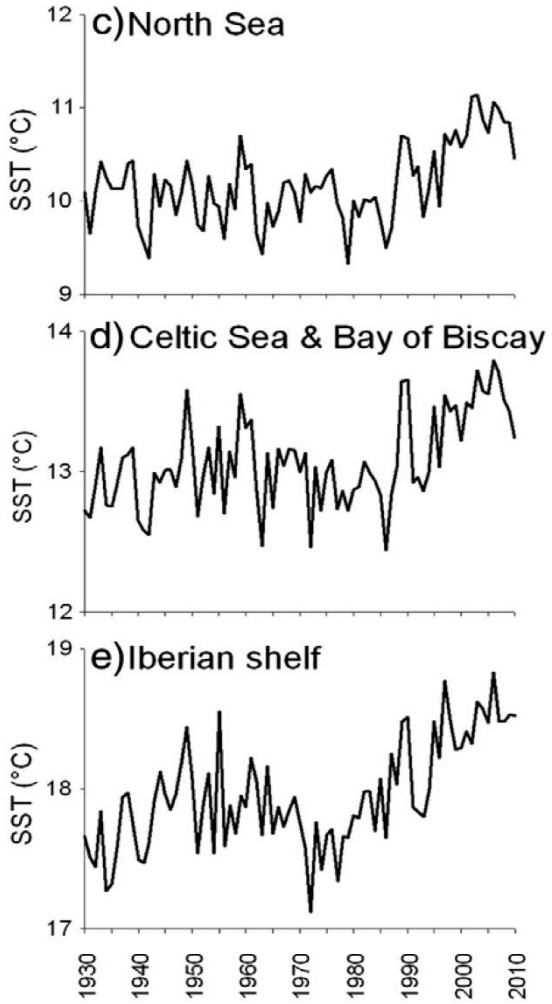
Phytoplankton Colour Index (Bay of Biscay)



SST (Bay of Biscay)



Changes in SST



Modified from Alheit, et al., (2014)

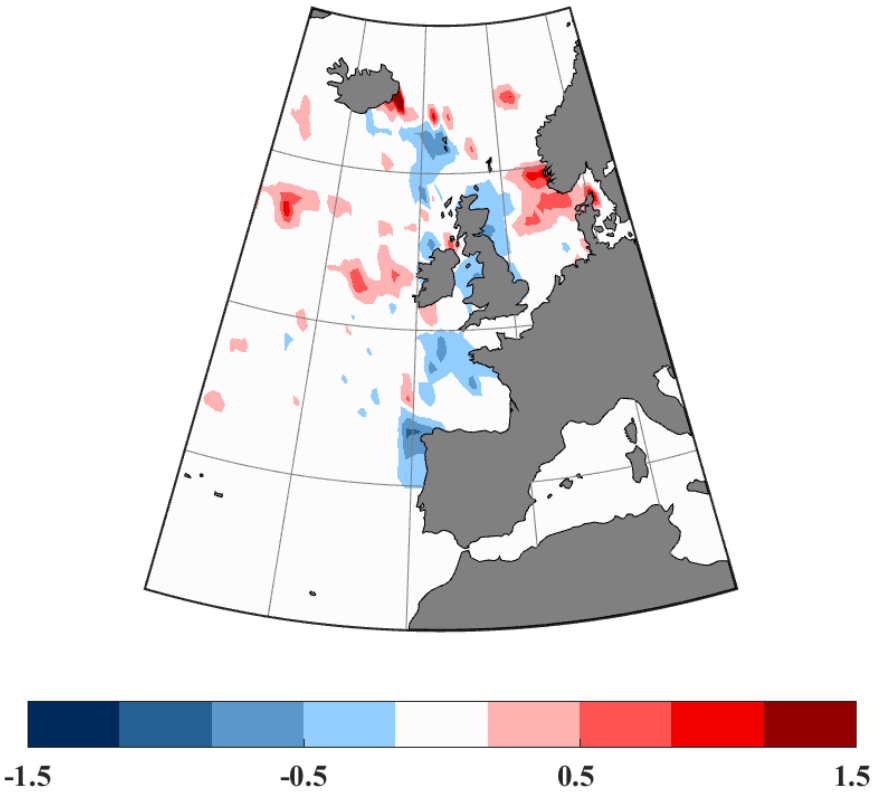
SST increase from the 1980s:

"Cold period (1960-1980)"

"Warm period (1990-2014)"

Biogeographic change in abundance

T. longicornis



Changes in abundance (log10+1)

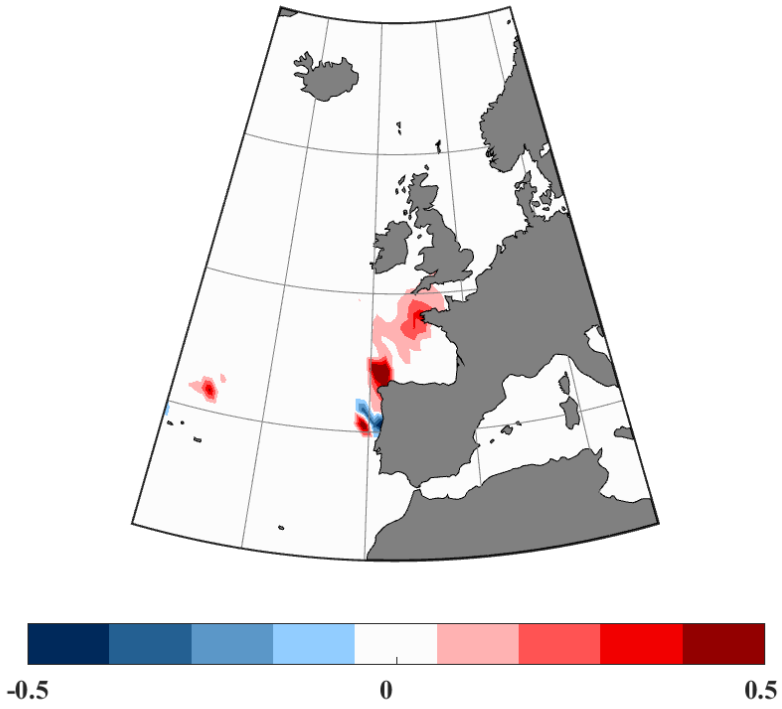
Changes in the abundance between the cold (1960-1980) and a warm (1990-2014) period:

- Increase in the north;
- Decrease in the south

Particularly along the Iberian coast, the Celtic Sea and south of Iceland.

Biogeographic change in abundance

T. stylifera

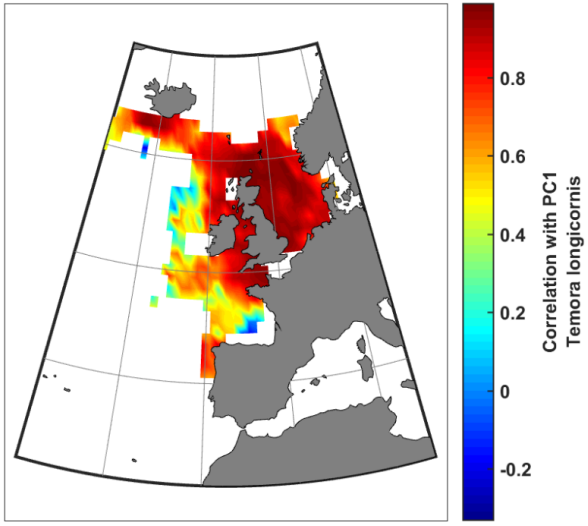


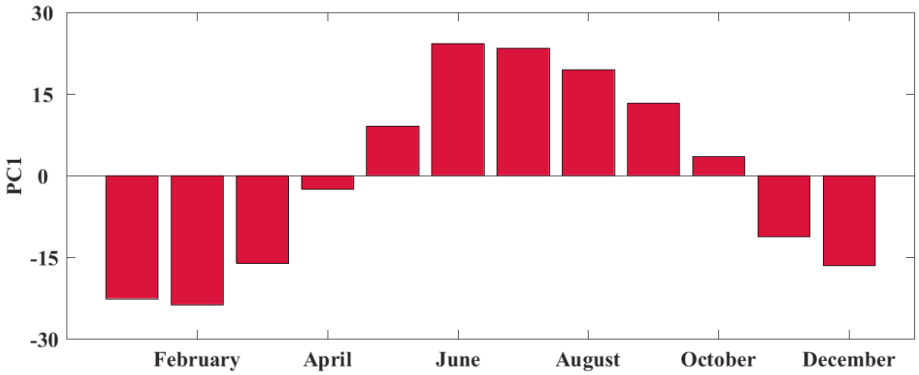
Changes in abundance (log10+1)

Changes in the abundance between the cold (1960-1980) and a warm (1990-2014) period:

- Increase in the Bay of Biscay and the Celtic Sea during the warm period (1990-2014)

Seasonal change in abundance





T. longicornis
(1958-2014)

First principal component
(~50% of the variability)

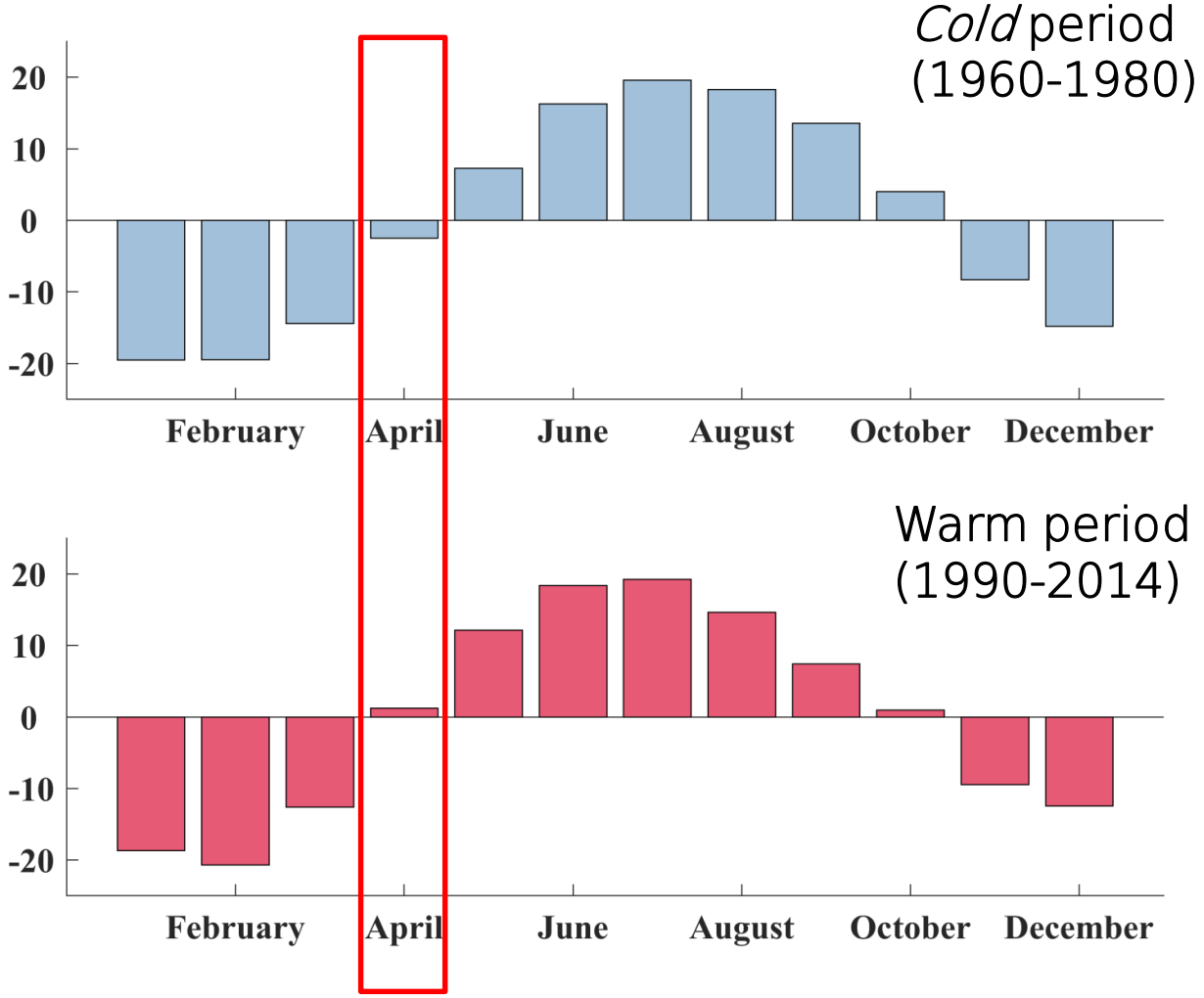
- Increases from March-April
- Peak during summer (June/July)
- Minimum from October

Phenology

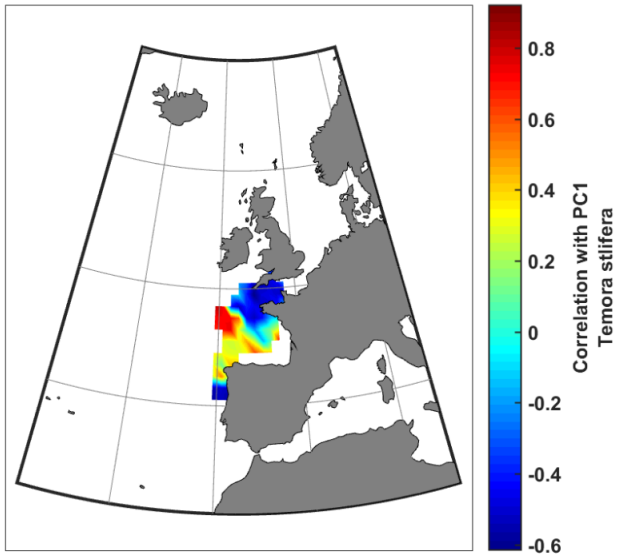
T. longicornis

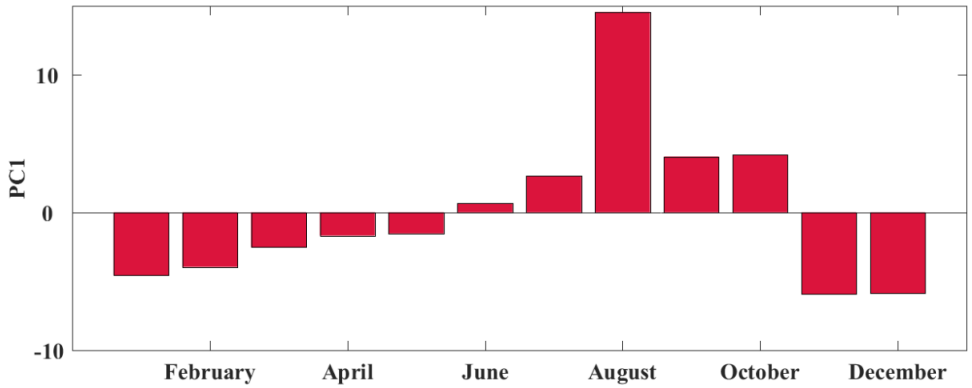
The seasonal cycle has anticipated

(first positive values of the PC1 in April during the warm period)



Seasonal change in abundance





T. stylifera
(1958-2014)

First principal component
(~31% of the variability)

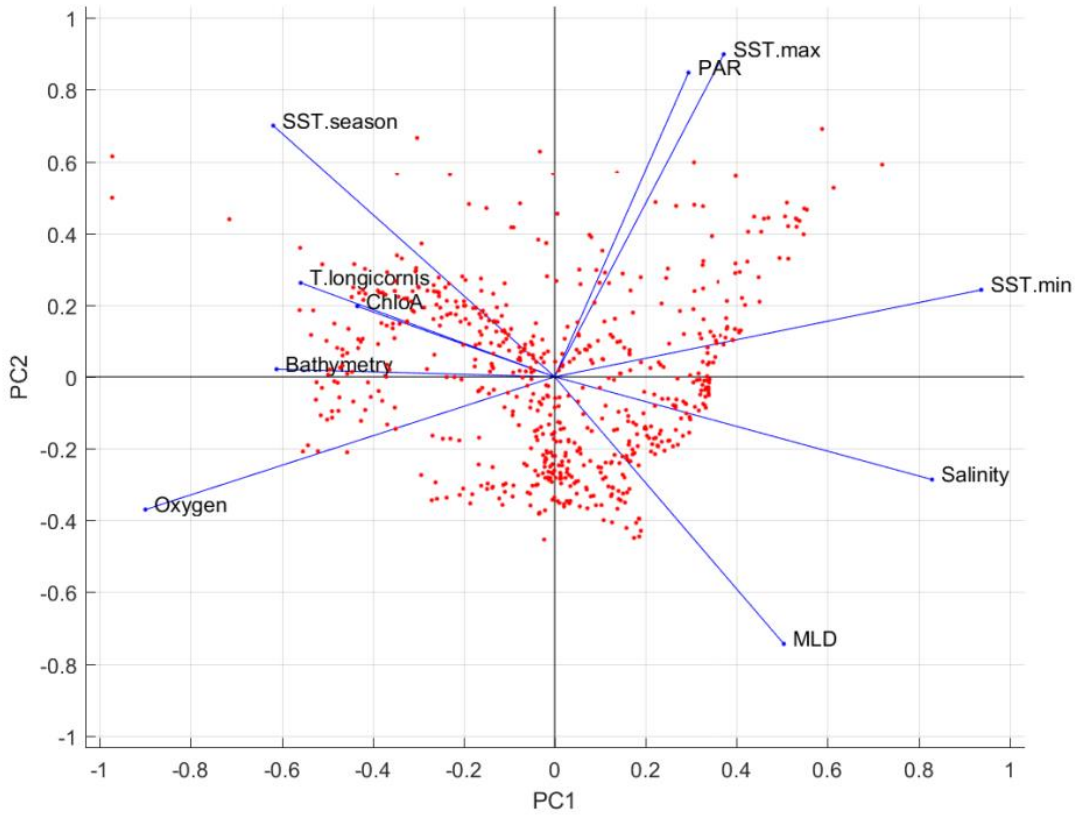
Bay of Biscay

- Peaks in August
- Decline after October

Celtic Sea

- Peaks in winter probably as a result of advection in this area

Environmental preferences



T. longicornis
(1958-2014)

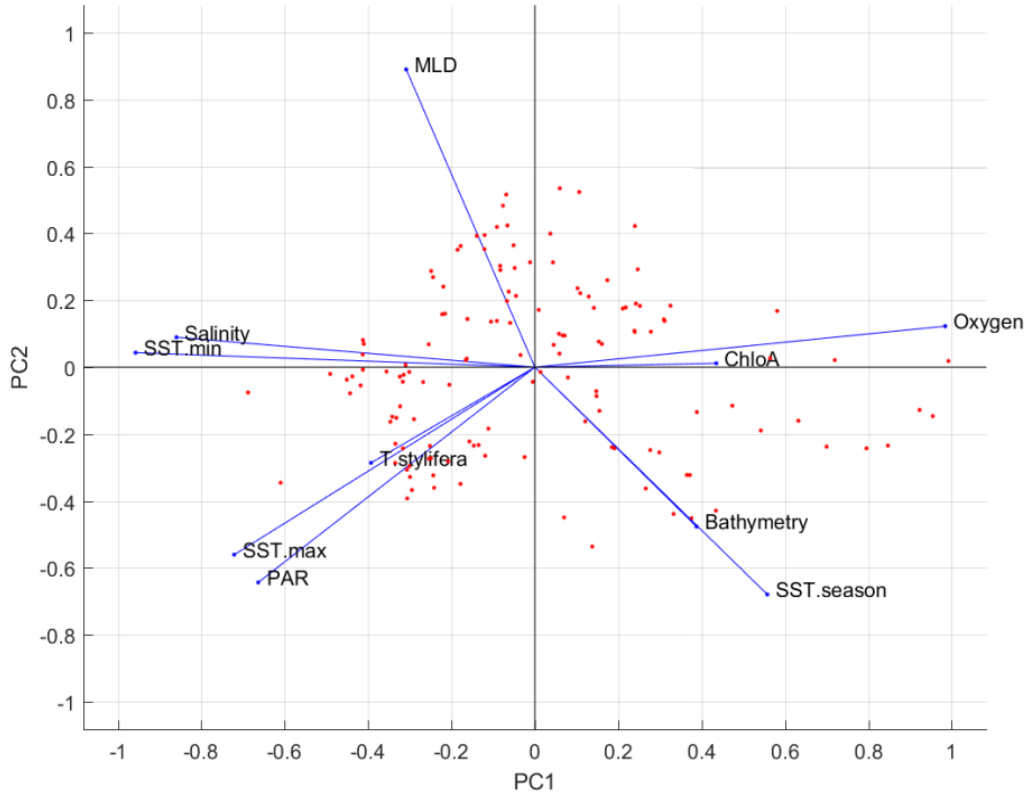
Correlation PC2 vs PC1:

Abundance

- +ve correlated with Chl-a, bathymetry and seasonal changes in SST
- -ve correlated with min SST

Coastal species highly dependent on prey supply

Environmental preferences



T. stylifera
(1958-2014)

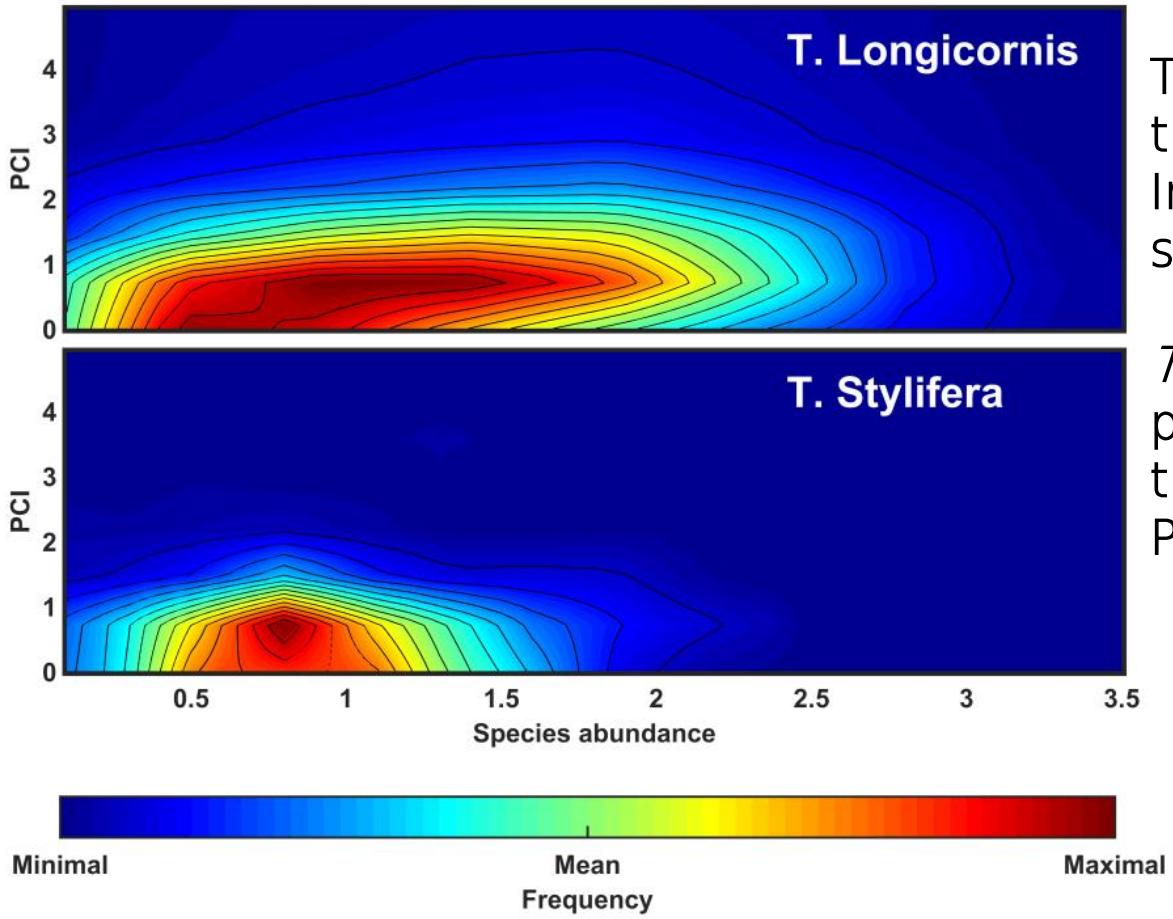
Correlation analysis PC2 vs PC1:

Abundance

- +ve correlated with **SST max** and PAR

High affinity for warm water environment

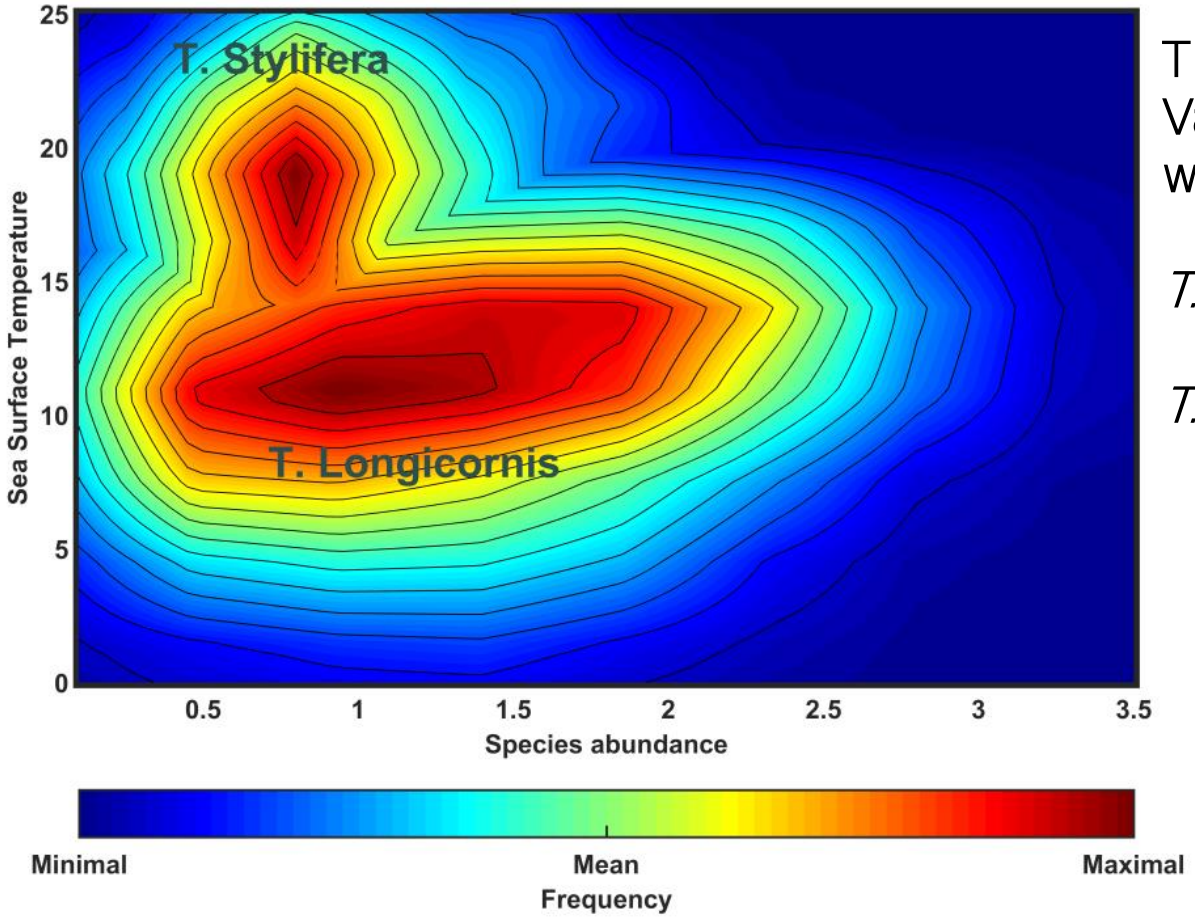
PCI *preferendum*



The *preferendum* for the Phytoplankton Colour Index is similar for the two species

T. longicornis has higher population abundance than *T. stylifera* at similar PCI values

SST *Preferendum*



The *preferendum* for SST Varies for the two species with optimum:

T. longicornis ~ 12 C

T. stylifera ~ 18 C

Summary and Conclusions

The biogeographical distribution of the two congeneric species in the NE-Atlantic has shifted northwards over the past 20 years

The main changes have occurred in the Bay of Biscay where *T. stylifera* has increased and *T. longicornis* has slightly decreased:

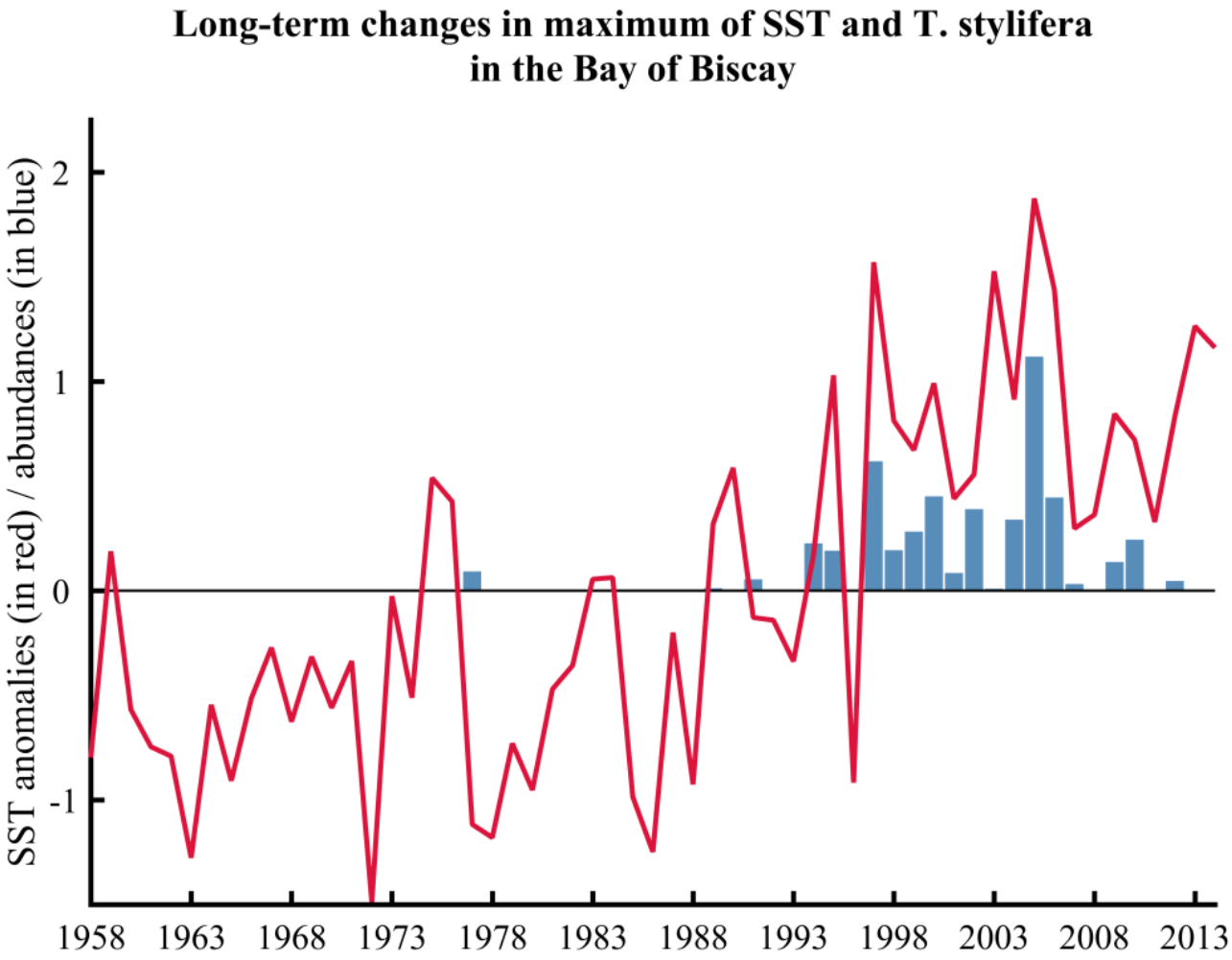
T. stylifera increase is linked to a higher SST (max) after summer which corresponds to the start of its seasonal cycle.

T. longicornis decrease also seem related to higher SST. Increase in SST min. in spring appears to have anticipated the seasonal cycle of *T. longicornis*.

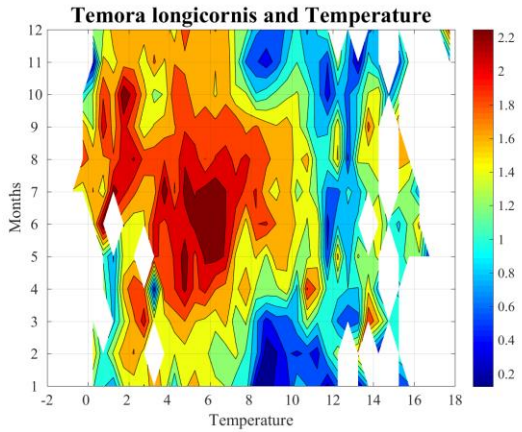
T. longicornis appears more dependent on food availability than *T. stylifera.*

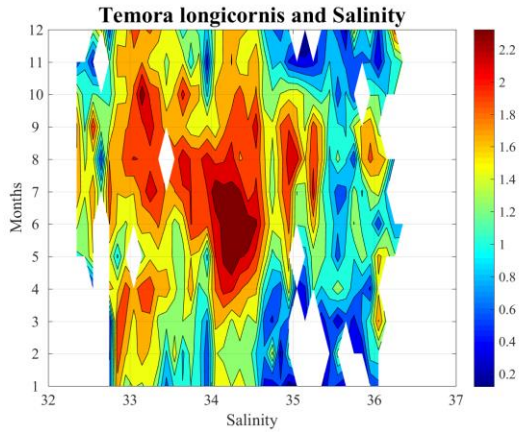
The two species have distinct environmental preferences leading to specific adaptation of their life cycles

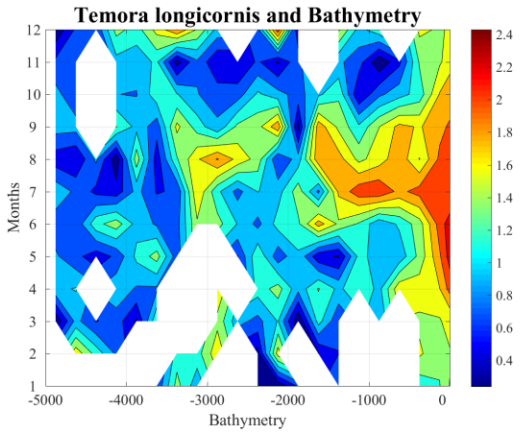
Temora species in the Bay of Biscay

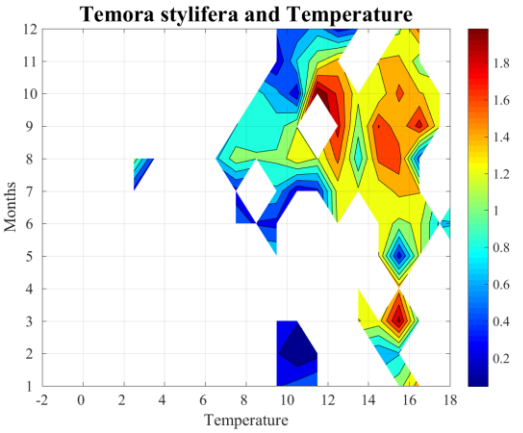


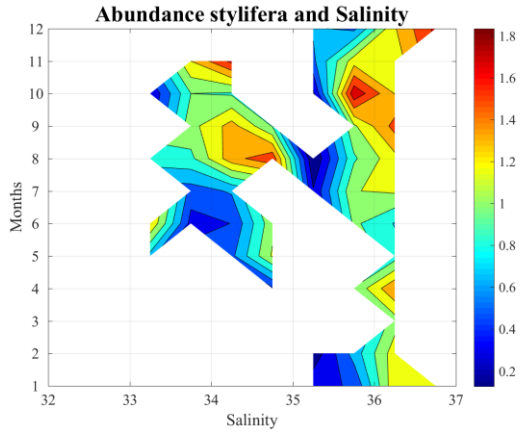
Environmental affinity of the two species of the genus Temora

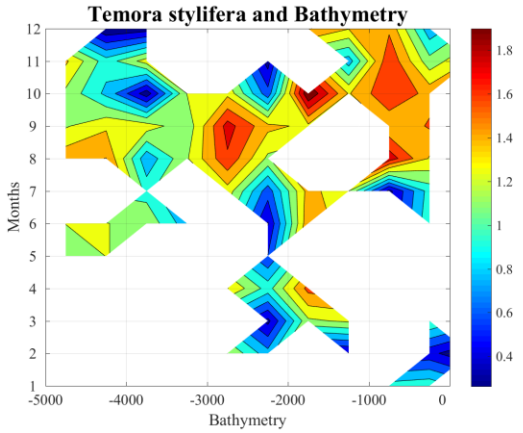








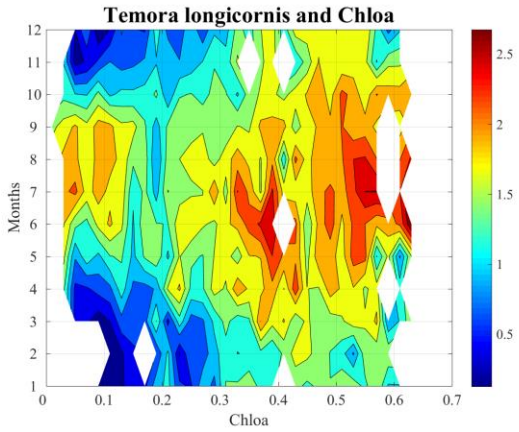


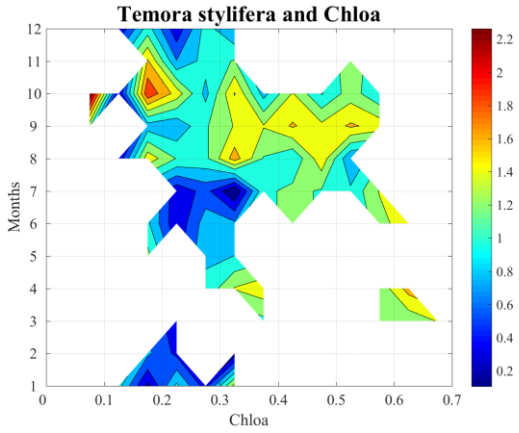


Difference in the optimum of SST. T. stylifera is a warm adapted species compared to its congener

T. longicornis appears more coastal in comparison to T. stylifera

Environmental affinity of the two species of the genus Temora





The highest abundance of T. longicornis are found for the highest concentration in chloa: relation with the coastal environment