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

Claudia Castellani ¹ and Eric Goberville¹,²

¹ Sir Alister Hardy Foundation for Ocean Science (SAHFOS), Plymouth, UK
² CNRS, Univ. Lille, Univ. Laboratoire d'Océanologie et de Géosciences, Wimereux, France
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)

**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)

Halsband-Lenk et al. (2002) JEMBE
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
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)

**T. stylifera** (1958-2014)

abundance (log10+1)
Spatial distribution and abundance

*T. longicornis* (1958-2014)

*T. stylifera* (1958-2014)
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)

Long-term changes in SST

12 10 8 6 4 2

9 10 11 12 13 14 15 16 17 18 19

12 13 14 15 16 17
Changes in SST

SST increase from the 1980s:

“Cold period (1960-1980)”

“Warm period (1990-2014)”

Modified from Alheit, et al., (2014)
Changes in 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

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)

Changes in abundance (log10+1)

T. stylifera
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
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.
The *preferendum* for SST varies for the two species with optimum:

- *T. longicornis* ~ 12°C
- *T. stylifera* ~ 18°C
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

Long-term changes in maximum of SST and T. stylifera
in the Bay of Biscay
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.