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Seasonal and interannual relationships in the zooplankton dynamics of the Northeast Atlantic Shelves in relation to latitude and trophic status

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INTRODUCTION

Latitudinal variations of environmental factors influence the distribution and organization of zooplankton communities at different temporal scales. So the comparative analysis of the seasonal and interannual dynamics of the main zooplankton taxa along a latitudinal gradient gives valuable information about the response of the zooplankton community to latitude-related changes at different time scales. However, local anthropogenic nutrient enrichment of plankton ecosystems may interfere in the response of zooplankton to latitude-related environmental variability.

AIM

The aim of this study was to determine the patterns of variation of the seasonal and interannual dynamics of the main mesozooplankton taxa with latitude along the Northeast Atlantic Shelves Province, and to assess how anthropogenic changes in trophic state may alter such seasonal and interannual dynamics.

STUDY AREA

The **study sites** are: Bilbao 35 (**B35**) and Urdaibai 35 (**U35**), both located in the Bay of Biscay near the southern limit of the Northeast Atlantic Shelves Province, Plymouth L4 (**L4**), located in the English Channel, in the middle of that province, and Stonehaven (**SH**), located in the North Sea at the northern limit. The **B35** site is mesotrophic while the **U35** is oligotrophic.

METHODS

Zooplankton series were obtained by monthly (**B35** and **U35**) or weekly (**L4** and **SH**) samplings. Interannual and seasonal components of mesozooplankton abundance variability were extracted for the main holoplankton groups, (6), meroplankton groups (9), and genera of copepods and cladocerans (11), using the method described by **Cloern and Jassby** (2010). Group-average clustering based on the Bray-Curtis similarity index were performed using PRIMER v6 software to group zooplankton taxa with similar spatial-temporal patterns. Contour plots were created using SURFER 10 to show the spatial-temporal patterns.

Figure 1. General map and detail view (sampling points marked with **yellow stars**) of the 4 sites.

RESULTS AND CONCLUSIONS

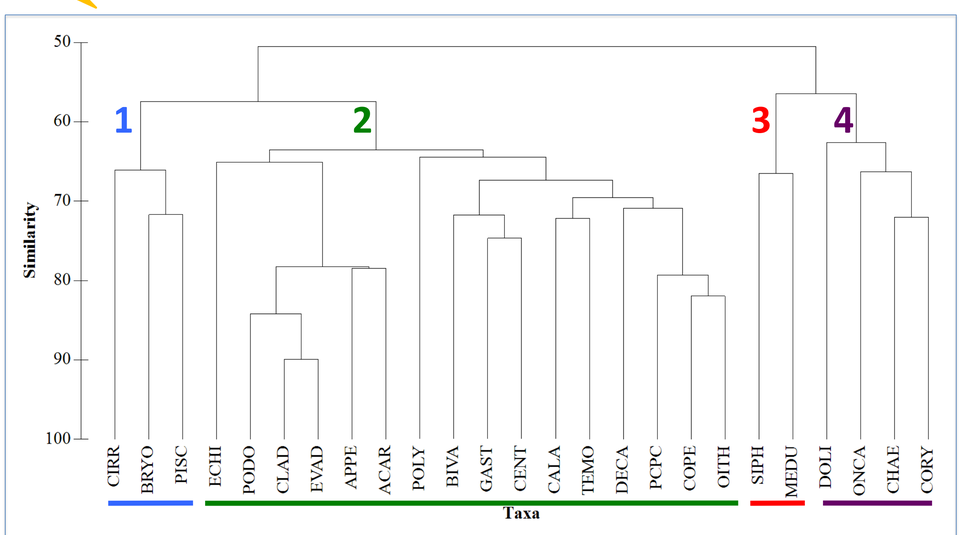

Figure 2. Group-average clustering from Bray-Curtis similarities of taxa for seasonal variability at the four sites.

Seasonal patterns

Four main assemblages were distinguished (Fig. 2): **1** Earliest peaking taxa (e.g. **Cirripede larvae**, CIRR), **2** Spring-summer taxa (e.g. **Appendicularians**, APPE), **3** Spring-autumn taxa (e.g. Siphonophores, SIPH) and **4** Latest peaking taxa (e.g. **Chaetognath**s, CHAE. See Fig. 3. Different groupings show the following:

Seasonal patterns differing with latitude

1. **Delay of the annual maxima** from early spring at U35 to late summer at SH: Cladocerans and their genera *Podon* and ***Evadne***, the copepod genus ***Acartia*** and **Appendicularians** (see Fig. 3).
2. **Early annual peak delayed** and **late peak moved forward** from U35 to SH in taxa with a bimodal distribution, which become unimodal at SH in some cases: Decapod larvae, **Copepods** and their genera *Temora*, *Calanus*, *PCPCalanus* and ***Oithona*** (see Fig. 3)**.**

Seasonal pattern without latitudinal effect

1. **Annual maxima occurs almost simultaneously at different latitudes. Cirripede larvae** with peaks in early spring in U35, L4 and SH. **Chaetognaths** and **Doliolids** with peaks in late summer-early autumn at the four sites (Fig. 3).

Seasonal patterns differing with the trophic state

1. **Change of unimodal or bimodal cycles to trimodal cycles** from U35 to B35 in Bryozoan larvae, **Copepods**, *PCPCalanus* and ***Oithona*** (see Fig. 3)**.**
2. **Delay of the annual maxima** from early spring or spring at U35 to late spring-summer at B35 in **Cirripede larvae**, Cladocerans and ***Evadne,*** **Appendicularians**, *Calanus*, ***Oithona***, Bivalve and Decapod larvae (Fig. 3).

Interannual variations

The stair-step shape of the dendrogram of interannual variations of mesozooplankton taxa reveals the lack of clearly defined groupings by patterns along the time series in any of the four sites (see Fig. 5).

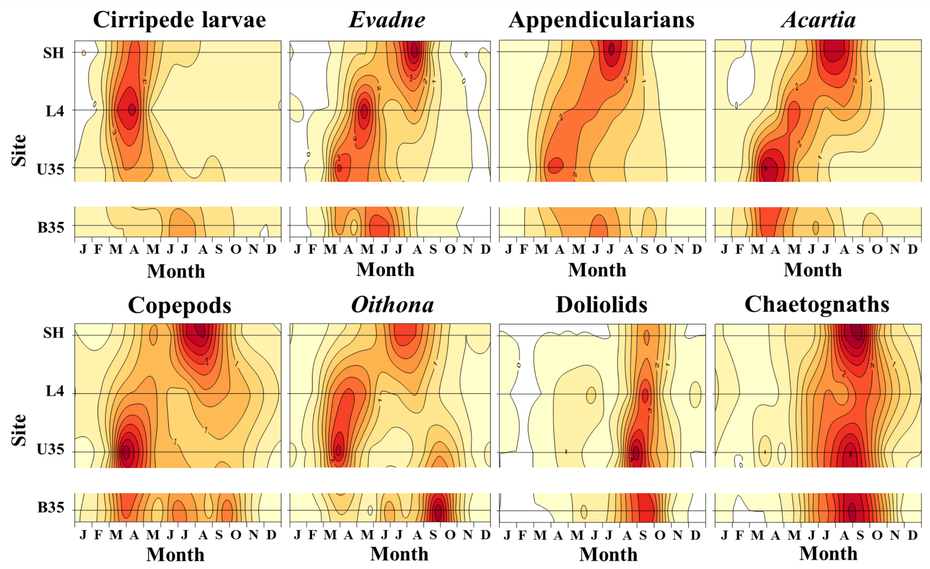

Figure 3. Spatial variations of the seasonal component of variability (dimensionless) for Cirripede larvae, *Evadne*, Appendicularians, *Acartia*, Copepods, *Oithona*, Doliolids and Chaetognaths at SH, L4, U35 and B35.

Annual maxima and peaking period

Annual maxima: Most taxa peaked earlier (early spring) in U35, and successively later in L4 and SH (summer). In the mesotrophic B35 most taxa peaked later than in U35, despite being located at the same latitude (Fig. 4).

Peaking period: Only the peaking period of holoplankton groups showed a clear reduction and delay from U35 (March-August) to SH (July-September) as latitude increases (Fig. 4).

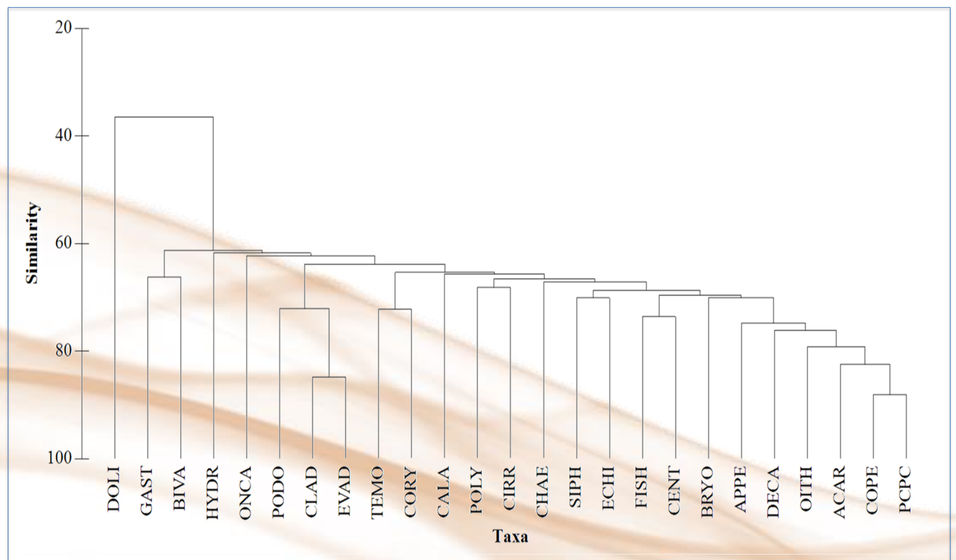

Figure 5. Group-average clustering from Bray-Curtis similarities of taxa for interannual variability at the four sites.

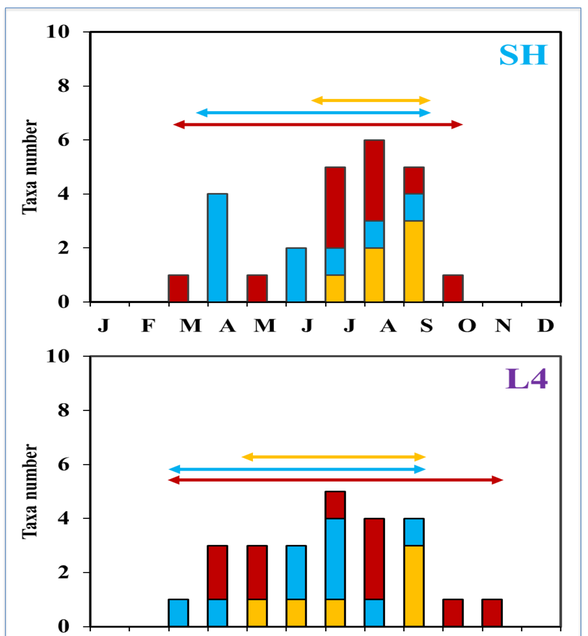

Figure 4. Number of taxa belonging to the categories of copepod and cladoceran genera (GEN), and meroplankton (MERO) and holoplankton (HOLO) groups that showed the annual maximum in each month of the year. Two-headed arrows represent the year period within which each taxa showed its annual maxima.

Conclusions

1. **The latitudinal effect on mesozooplankton seasonality was mainly illustrated by the delay of the annual maximum in several taxa, and the reduction of the peaking period for holoplanktonic taxa as latitude increases.**
2. **Seasonal variability of most mesozooplankton taxa in the anthropogenically enriched site (B35) did not fit into the latitudinal pattern observed for the other sites, mainly due to the delay of the annual maxima and the extension of the peaking period.**
3. **Neither latitude nor man-made changes in trophic status accounted for interannual differences in mesozooplankton between sites.**

Acknowledgements

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