6. Zooplankton time-series analyses in the English Channel: potential for regional multimetric foodweb indices

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Introduction

We compare long-term plankton time-series from two coastal stations in the western and eastern English Channel and explore their potential to reveal regional differences in biodiversity patterns and ecosystem function. Through collaborations along the British and French coasts, within the framework of a regional, multidisciplinary ecosystem-based approach (CHannel integrated Approach for marine Resource Management = CHARM), these analyses will provide a resource for the development of a comprehensive plankton inventory of the English Channel (Figure 6.1).

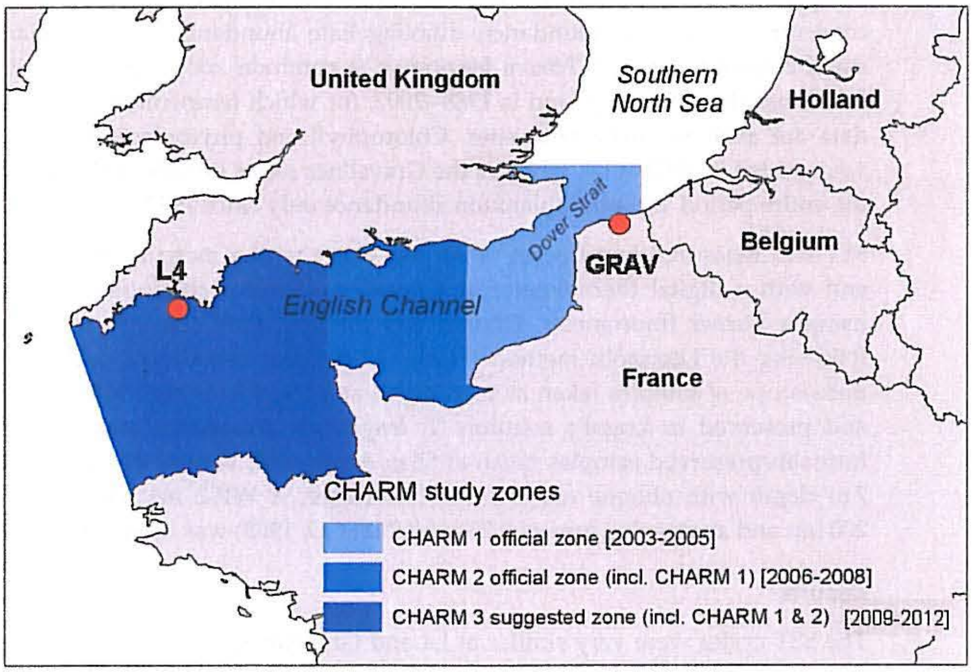

Figure 6.1. Map of the English Channel showing the western (L4) and eastern (Gravelines) sampling stations of the plankton time-series.

At Plymouth Marine Laboratory, a range of physical, chemical, and biological parameters has recently been placed in the context of an integrated Western Channel Observatory[1] (WCO). The WCO, which has a history of more than 100 years of *in situ* sampling and represents both oceanic and coastal environments, will feed data into ecosystem models (e.g. the European Regional Seas Ecosystem Model, ERSEM) to enable the assessment of changes in the marine environment (Southward *et al.*, 2005). One of the stations contributing to this database is L4.

Similarly, the French Research Institute for Exploitation of the Sea (Ifremer) has instituted a monthly time-series of zooplankton species, which has been in operation since 1975, at Gravelines, a coastal station on the French coast of Dover Strait. This survey comes within the framework of a research programme designed to monitor

[1] http://www.westernchannelobservatory.org

the effects of nuclear power plants on the environment and living resources, and includes the following parameters, measured on a weekly basis: temperature and salinity, ammonium, nitrate, Chlorophyll *a* (Chl *a*) and phaeopigment concentrations, as well as phytoplankton abundance. Ifremer archives these measurements in the database Quadrige[2], to which zooplankton species abundance will soon be added.

Combining and comparing the datasets from these two stations will allow the development of multimetric foodweb indices at the gateway between the North Sea and the open North Atlantic.

Material and methods

We selected a range of physico-chemical and biological parameters, which had been measured at both study sites (stations L4 and Gravelines), for a preliminary comparison. These parameters include sea surface temperature (SST), surface Chl *a* concentration, diatom abundance, dinoflagellate abundance, and abundance of the small calanoid copepod *Temora longicornis*, a common zooplankton species in both locations. The selected period is 1988–2007, for which temperature and zooplankton data are available from both sites. Chlorophyll and phytoplankton measurements were added in 1992 at L4, whereas the Gravelines series includes chlorophyll data for the entire period, but phytoplankton abundance only since 1997.

SST was measured in a bucket of surface water with a mercury thermometer at L4 and with a digital thermometer at Gravelines. Surface chlorophyll was measured using a Turner fluorometer. Diatom and dinoflagellate abundance was estimated following the Utermölh method (Hasle, 1978) from cell counts under an inverted microscope of samples taken at 10 m depth at L4 and from the surface at Gravelines and preserved in Lugol's solution. *T. longicornis* abundance was quantified from formalin-preserved samples taken at 55 m depth with vertical net tows at L4 and at 7 m depth with oblique net tows at Gravelines. A WP-2 net with a mesh size of 200 µm and an opening area of 0.25 m^2 (UNESCO, 1968) was used in both cases.

Results

The SST cycles were very similar at L4 and Gravelines, with no major differences in the average anomalies (not shown). However, Gravelines temperatures had much greater amplitudes, with more extreme values for both maximal and minimal temperatures than L4. Temperatures there often exceeded 20°C in summer and usually fell to 5°C in winter. Summer SSTs at L4 remained well below 20°C (except in 1997) and winter temperatures were more variable, ranging between 7 and 10°C (Figure 6.2a).

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[2] http://www.ifremer.fr/delao/francais/valorisation/quadrige/

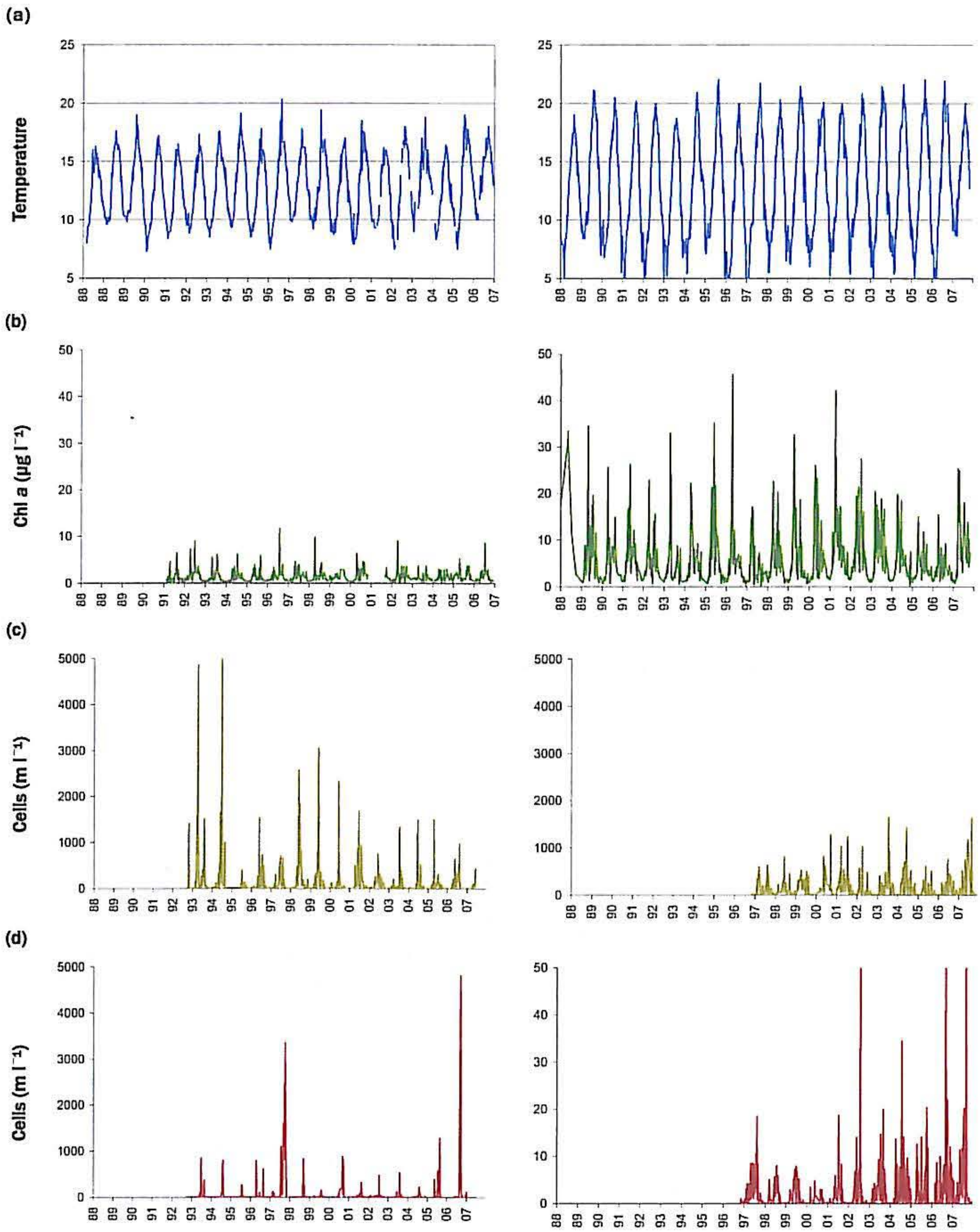

Figure 6.2. Physico-chemical and biological parameters for the period 1988–2007 at stations L4 and Gravelines: (a) temperature, (b) integrated chlorophyll *a*, (c) diatom abundance, and (d) dinoflagellate abundance. Note the difference in ordinate scale in (d).

Chlorophyll concentrations were significantly different at both sites (Figure 6.2b). Although both locations showed a peak in spring, Chl *a* levels at L4 were generally much lower, rarely exceeding 10 µg l^{-1}, whereas maxima at Gravelines ranged from 18 to 47 µg l^{-1}. This result is in striking contrast to the diatom and dinoflagellate abundance (Figure 6.2c and 6.2d). Both phytoplankton groups were more numerous at L4, with dinoflagellate numbers exceeding those at Gravelines by an order of magnitude. In addition, the highest diatom peaks at L4 occurred in spring, whereas some of the major diatom blooms at Gravelines occurred in autumn. Dinoflagellate abundance patterns seemed to follow a more regular seasonal cycle at Gravelines compared with the sudden and singular outbreaks at L4.

Abundance of *T. longicornis* was, on average, similar at both stations, but peaks were more extreme at Gravelines (Figure 6.3). When considering the entire data series at Gravelines, starting in 1978, a shift from higher to lower maximal *Temora* abundance becomes apparent in the mid-1980s. This trend is also reflected in the yearly average anomalies (Figure 6.4), where negative values dominate. Although this general pattern applies to both datasets, there are also some very dissimilar years, e.g. 1989, 1993–1995, and 2000–2002.

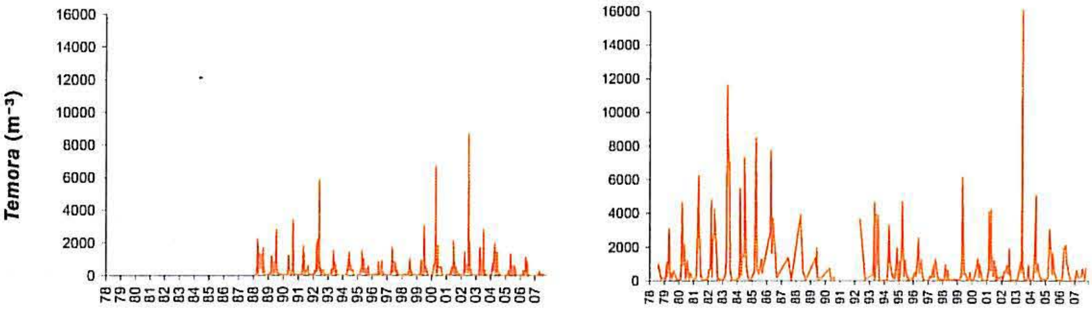

Figure 6.3. Abundance of the calanoid copepod *Temora longicornis* at stations L4 (left) and Gravelines (right) for the period 1978–2007.

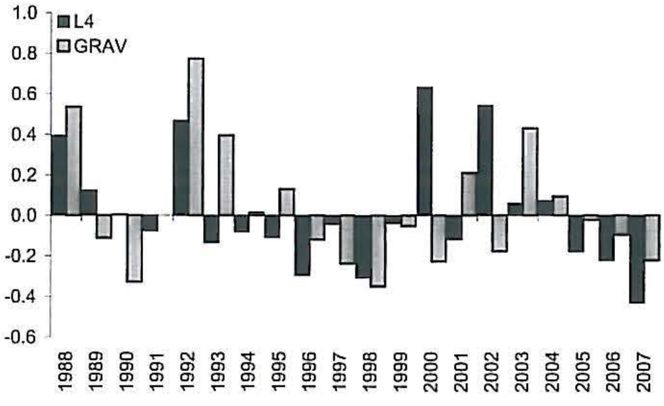

Figure 6.4. Abundance anomalies *of Temora longicornis* at stations L4 and Gravelines for the period 1988–2007.

Discussion

A first comparative analysis of the long-term datasets in the western Channel at L4 and in the eastern Channel at Gravelines reveals both similarities and site-specific differences. The difference in SST patterns clearly confirms that Gravelines is a much more coastal and shallow location that responds readily to fluctuations in atmospheric temperature (Woehrling *et al.*, 2005). This is also reflected in the higher levels of Chl *a*, associated with weak or absent summer stratification.

The striking differences and apparently contradictory results, in terms of phytoplankton concentrations, require further analysis. Although Chl *a* concentrations were generally lower at L4, the concentrations of diatoms, particularly dinoflagellates, were much higher at L4 than at Gravelines. These data need to be validated in order to exclude differences owing to methodology. If the differences are true, smaller flagellates and other pico- and nanophytoplankton may contribute to the high Chl *a* values in the more turbulent waters at Gravelines, rather than large diatoms and dinoflagellates. These latter taxa may have an advantage at L4, where waters are stratified in late spring and summer (Southward *et al.*, 2005). In contrast, the prymnesiophyte *Phaeocystis globosa* can reach very great abundance at Gravelines, to an order of magnitude higher than at L4, reflecting important differences in nutrient supply (not shown).

Nitrate and phosphate levels are significantly elevated at Gravelines and thus represent more eutrophic conditions than at L4. These dissimilarities provide the opportunity to study the impact of environmental factors on phytoplankton composition and community structure along a longitudinal gradient and the respective responses of the next trophic levels. Changes in phytoplankton dominance in diatom–*Phaeocystis* ecosystems are known to affect copepod diet and reproduction (Nejstgaard *et al.*, 2007; Daro *et al.*, 2008) and may explain some site-specific variability of zooplankton abundance.

The important grazer *T. longicornis* exhibited an overall decreasing trend in abundance over the last 20 years in both datasets. Although the patterns at the two stations were generally very similar, they showed signs of being opposite in some years, e.g. in the first half of the 1990s and in 2000 and 2002, indicating different environmental impacts in the eastern and western parts of the Channel. It would be interesting to explore further the differences in environmental pressures that lead to this site-specific variability. The negative trend of *T. longicornis*, a common cold–temperate species with thermal optima between 10°C and 15°C (Halsband-Lenk *et al.*, 2002, 2004), supports the hypothesis that the North Sea and the Channel are in a transition towards a warmer system with significant community changes, including impacts on commercially important fish (Beaugrand *et al.*, 2003; Beaugrand, 2009). Integrated trophodynamic models on both sides of the Channel that encompass the microbial and planktonic systems are needed in order to develop regional multimetric foodweb indices (Rodriguez *et al.*, 2000). A comparison of the variability of key species phenologies in both locations and resulting trophic interactions will help to assess how the plankton system in the Channel will respond to environmental change.

Acknowledgements

We acknowledge all contributors to the various datasets made available within the framework of the Western Channel Observatory, as well as the crews of RV "Quest" and RV "Sepia". The Gravelines data were collected within the framework of the research programme IGA (Impact des Grands Amenagements), conducted by Ifremer, and with financial support from the EDF (Electricité de France). Additional temperature records were supplied directly by the Institut Pasteur de Lille, which provided weekly measurements from 1986 onwards.

This work was funded in part by the EU under the INTERREG 4a scheme and ERDF (CHARM phase III project).

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