9.1 Blanes Bay (Site 55)

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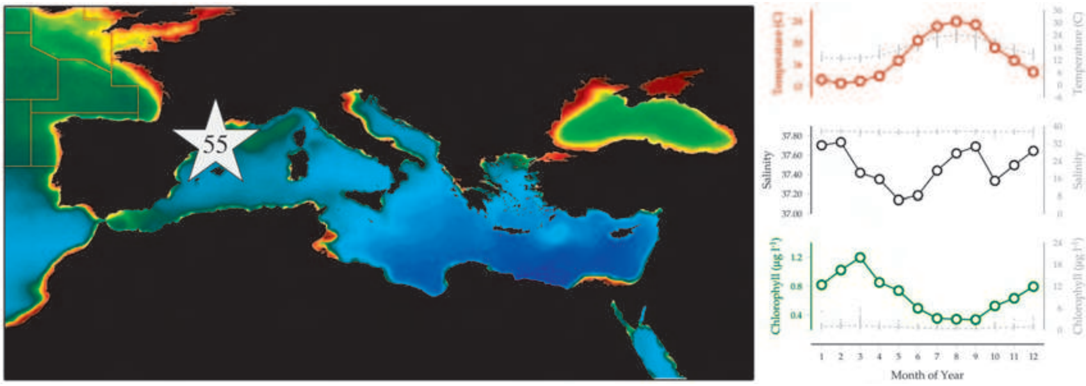

Figure 9.1.1
Location of the Blanes Bay plankton monitoring area (Site 55), plotted on a map of average chlorophyll concentration, and its corresponding environmental summary plot (see Section 2.2.1).

Blanes Bay is an open, east-facing bay in the northwest Mediterranean Catalan coast ca. 70 km north of the city of Barcelona. It was selected as a monitoring site because it is a good example of an oligotrophic (relatively nutrient-poor) coastal ecosystem that is relatively unaffected by human influence. It is also one of the sites for which more information exists on the ecology of the Mediterranean planktonic environment, with papers on phytoplankton dating back to the 1940s (Margalef, 1945).

The site is placed at ca. 0.5 miles offshore over a water depth of 20 m. An oceanographic, fully operated buoy is placed nearby (http://atlantis.ceab.csic.es/~oceans/index_en.html), and the station is close to an automatic meteorological station and a directional wave buoy. The station is just placed at the limit between the rocky coast of the "Costa Brava" and the sandy coast southwards, with very limited riverine influence. The dominant southwestern water circulation that characterizes this location drives away the water from Tordera River, which outflows south of the site, a river system than only brings substantial amounts of water in winter (Guadayol *et al.*, 2009). The site is near a submarine canyon, which facilitates the arrival of offshore seawater to this coastal site.

The phytoplankton of Blanes Bay was studied intensively in the 1950s for its phytoplankton (Margalef, 1945, 1948, 1964), and again later, during the 1990s, with a focus on phytoplankton and biogeochemistry (Cebrián *et al.*, 1996; Agawin *et al.*, 1998; Duarte *et al.*, 1999, 2004; Lucea *et al.*, 2005; Olsen *et al.*, 2006). Since 1998, there has been a continuous effort and focus on microbial biodiversity and biogeochemical function (Schauer *et al.*, 2003; Massana *et al.*, 2004; Alonso-Sáez *et al.*, 2007; Unrein *et al.*, 2007). Owing to these scopes, it is now known as the "Blanes Bay Microbial Observatory". DNA (and RNA) has been stored since 1998, and studies on archaeal, bacterial, and protist diversity are underway. Oceanographic data, nutrients, chlorophyll, bacterial and heterotrophic nanoflagellate abundance, picophytoplankton (by flow cytometry), and bacterial activity are some of the core variables monitored consistently over time. Variables for which a limited time-series exists include nano- and microphytoplankton species distribution, HPLC-determined pigments (Gutiérrez-Rodríguez *et al.*, 2011), primary production and respiration, organic sulphur (DMS, DMSP) concentrations and fluxes (Simó *et al.*, 2009), ectoenzymatic activities, CO2 system parameters, particulate and dissolved organic nutrient concentrations, viral abundance, and impact on microbial foodwebs (Boras *et al.*, 2009). Other variables have been introduced at specific times over the last years, and a few synthesis papers have been published (e.g. Alonso-Sáez *et al.*, 2008; Simó *et al.*, 2009).

Seasonal and interannual trends (Figure 9.1.2)

As at most other coastal sites, this site experiences a strong seasonal forcing, with warm and not very productive (CHL ca. 0.2–0.3 mg m^{-3}) summers and cold and richer winters (average CHL >0.7 mg m^{-3}). Though wind is much less forceful in summer, it does constrain water towards the coast, facilitating organic matter accumulation (Vila-Reixach *et al.*, 2012) simultaneously with nutrient deficiency and nutrient limitation (particularly P) of microbial growth (Pinhassi *et al.*, 2006).

Consequently, monthly average temperature correlates positively with Secchi disk depth, and negatively with chlorophyll *a* and with SiO_4, PO_4, NO_2, and NO_3 concentrations. Summer demonstrates clearer waters, with low chlorophyll and low nutrients. Salinity does not exhibit a clear seasonal cycle, but tends to be lower in spring and autumn, which are the typical rainy seasons in such a Mediterranean-climate area. Bacterial production is higher in summer (positively correlated with temperature and Secchi depth and negatively correlated with chlorophyll *a* and with most nutrient concentrations). Heterotrophic bacterial abundance also tends to be higher in summer, but is very much buffered by predators and viruses (Unrein *et al.*, 2007; Boras *et al.*, 2009) and stays fairly stable. Heterotrophic nanoflagellates are more abundant in summer, whereas autotrophic nanoflagellates are more abundant in winter. The ratio between the two types exaggerates this difference.

The picophytoplankton has been well characterized with a dominance of picoeukaryotes in winter vs. *Synechococcus* in summer. *Prochlorococcus* appears only at the end of summer and throughout early winter, probably supplied with advected oceanic water. The main phytoplankton groups have been characterized by HPLC and consist of diatoms in spring, prasinophytes and cryptophytes in winter, *Synechococcus* and dinofagellates in summer, and pelagophytes and *Prochlorococcus* in autumn, but with haptophytes appearing all year long (Gutiérrez-Rodríguez *et al*., 2011).

Some of the techniques have changed from one of the three main periods to the others, which may influence interpretation of the data. This is in particular the case for salinity, which displays a long-term shift that might be associated with a change in the sensor used.

Temperature and Secchi depth show a slight non-significant positive trend with time. Chlorophyll *a* exhibits no clear trend, and all inorganic nutrients (exemplified in PO_4 and NH_4) show negative trends albeit non-significant, all indicating a very slow tendency towards oligotrophication (see also Sarmento *et al.*, 2010), consistent with the implementation of wastewater treatment plants and P reduction policies over the last few decades.

The global temperature climatologies (HadISST) indicate a small temperature increase that agrees with the data measurements, and the ocean colour estimate of CHL (GlobColour Case-2) indicates a decrease that is barely observable. Winds are observed to increase over the sampled area according to the ICOADS, although with little changes during the period of observation.

Bacterial abundance is one of the variables that suffered from methodological inconsistencies. Measured by two sets of operators in two different periods by DAPI counts, it demonstrated dissimilar trends. The most consistent trend is that observed from 2002 to 2012 because it is observed in DAPI counts, but also in flow cytometry counts, including both fractions, the LNA and HNA bacteria. This trend goes towards bacteria being less abundant with time in this ecosystem.

Heterotrophic and phototrophic nanoflagellates show also the same declining trend. Bacterial production exhibits a similar trend.

Finally, the data show a somehow clear trend towards increased cyanobacteria and picoeukaryote concentrations and a decreased contribution of nanophytoplankton and cryptophytes, as determined by flow cytometry. *Synechococcus* enumerated by DAPI show the same trend.

All in all, this site shows a tendency towards oligotrophication, with decreased colour, chlorophyll, nutrients, increased transparency, decreased bacterial abundance and production, and increasing contribution of cyanobacteria and small eukaryotic algae to total chlorophyll. Most trends are consistent, although the still limited extension of the dataset precludes statistical confirmation of the observed tendencies.

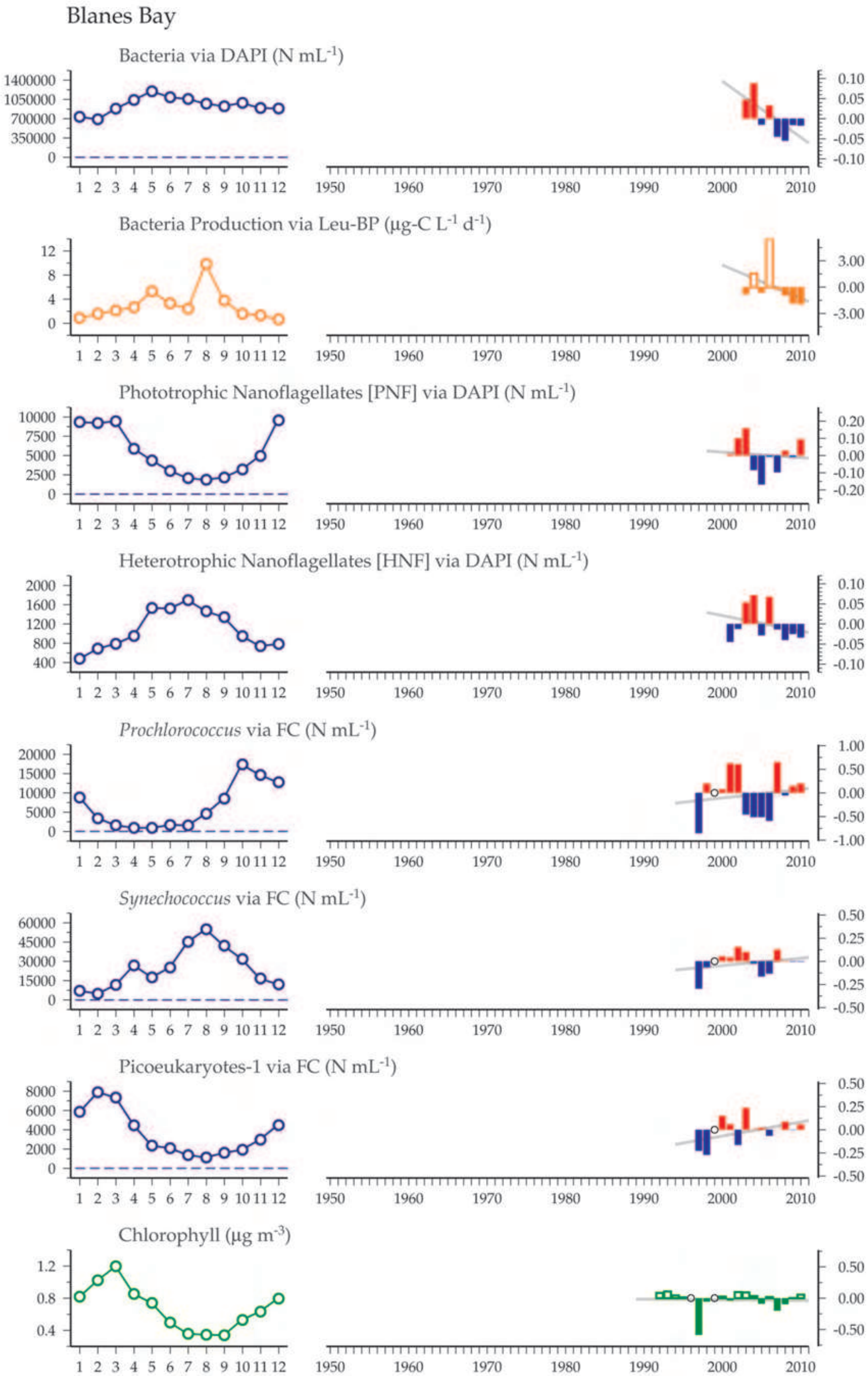

Figure 9.1.2 (continued on facing page)
Multiple-variable comparison plot (see Section 2.2.2) showing the seasonal and interannual properties of select cosampled variables at the Blanes Bay plankton monitoring site. Additional variables from this site are available online at http://wgpme.net/time-series.

Figure 9.1.2 continued.