

Zooplankton and Phytoplankton Time Series Analysis for the Belgian North Sea

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Introduction

In marine ecosystems, plankton compose the foundation of trophic webs. Factors that influence plankton can therefore have cascading effects across the ecosystem (Kim et al., 2024; Zeldis and Décima, 2020). In responding to changes in the environment, the plankton community may even amplify environmental signals. For instance, Taylor et al. (2002) used a model of the relationship between Gulf Stream latitude and plankton dynamics to demonstrate that the plankton community can respond to relatively subtle and diffuse meteorological changes. This sensitivity to environmental factors positions plankton in a crucial role for monitoring efforts. While plankton monitoring has previously been conducted using techniques such as microscopy, the more recent and expansive observation networks often take advantage of particle imaging techniques as well. Imaging serves as an important tool for generating interoperable, high-throughput plankton monitoring data. Furthermore, when used jointly, imagers such as the FlowCam and ZooScan offer coverage for much of the plankton size range (Lombard et al., 2019).

Plankton monitoring efforts could be vital for understanding the impacts of extreme climate events associated with climate change. Recent years have seen a 54% increase in annual marine heatwave (MHW) days from 1925 to 2016, with heatwaves becoming more frequent as well as longer in duration (Oliver et al., 2018). Temperature is already considered a key variable underlying plankton abundance trends (Deschutter et al., 2017; Luskow et al., 2022), but research should now also consider the effects of rapid-onset extreme temperatures. Laboratory-based experiments have demonstrated that steady temperature increases have different effects on phytoplankton compared to sudden temperature spikes and cooling phases (Wolf et al., 2024). Furthermore, higher MHW

intensity and longer MHW duration have more pronounced effects on plankton (Remy et al., 2017; Semmouri et al., 2019). Given that MHW effects often include changes in community composition (Arteaga and Rousseaux, 2023), the present research provides an initial assessment of existing FlowCam and ZooScan time series data from the Belgian part of the North Sea (BPNS), with particular focus on blooms and community composition shifts. The results from these time series are analyzed in the context of two more severe MHW events that were detected in 2018 and 2022.

Methods

Plankton samples were collected on the RV *Simon Stevin* at 9 coastal stations monthly, with an additional 8 offshore stations sampled seasonally. Zooplankton sampling began in 2014 while phytoplankton samples are available from 2017 onwards. Zooplankton were collected using vertical tows of a 200 μm Working Party 2 (WP2) net. To sample phytoplankton, 50-70 L of surface water were collected using a steel bucket and filtered through a 55 μm Apstein net (Amadei Martínez et al., 2020). These samples were imaged using the ZooScan and FlowCam for WP2 net samples and Apstein net samples, respectively. Images were classified using convoluted neural networks to recognize key image categories based on learning datasets. Images were then manually validated. Based on availability of validated FlowCam and ZooScan data, an initial analysis was conducted for plankton abundances from 2017-2023 and 2014-2023, respectively. Using classified and quantified imaging data, plankton abundances were analyzed for community composition and abundance trends over time, in particular with regard to MHWs. The *heatwaveR* package (Schlegel and Smit, 2018) was used to generate a 30-year climatology baseline using the National Oceanic and Atmospheric Administration Optimum Interpolation Sea Surface Temperature dataset (NOAA OI SST V2 High Resolution Dataset) (Huang et al., 2021). Events surpassing the 90th percentile of this climatology baseline for at least 5 days were considered MHWs (Hobday et al., 2018). MHW features and plankton community composition were compared by year to identify possible relationships between temperature shifts and biological shifts.

Results

Both FlowCam and ZooScan image datasets highlighted years of drastic community shifts (Fig. 1). In the FlowCam data, the years 2022 and 2023 had notably higher fractions of Hemiaulales diatoms (driven by *Bellerochea* spp.) than in previous years. For plankton detected by the ZooScan, shifts in community composition occur most prominently in 2014, 2018, and 2022. The 2014 community displayed a relatively even spread of taxa, while 2018 and 2022 were dominated by high abundance of *Bellerochea* spp. In years when the *Bellerochea* spp. colonies did not dominate the ZooScan images, *Noctiluca* spp. cells were dominant. Certain FlowCam-detected taxa, such as the Rhizosoleniales order, exhibited high cell densities as well as consistent seasonal dynamics. While ZooScan community compositions were categorized using all possible

groupings, FlowCam data was more taxonomically resolved and was therefore grouped at the order level (which was available for 72.9% of FlowCam observations).

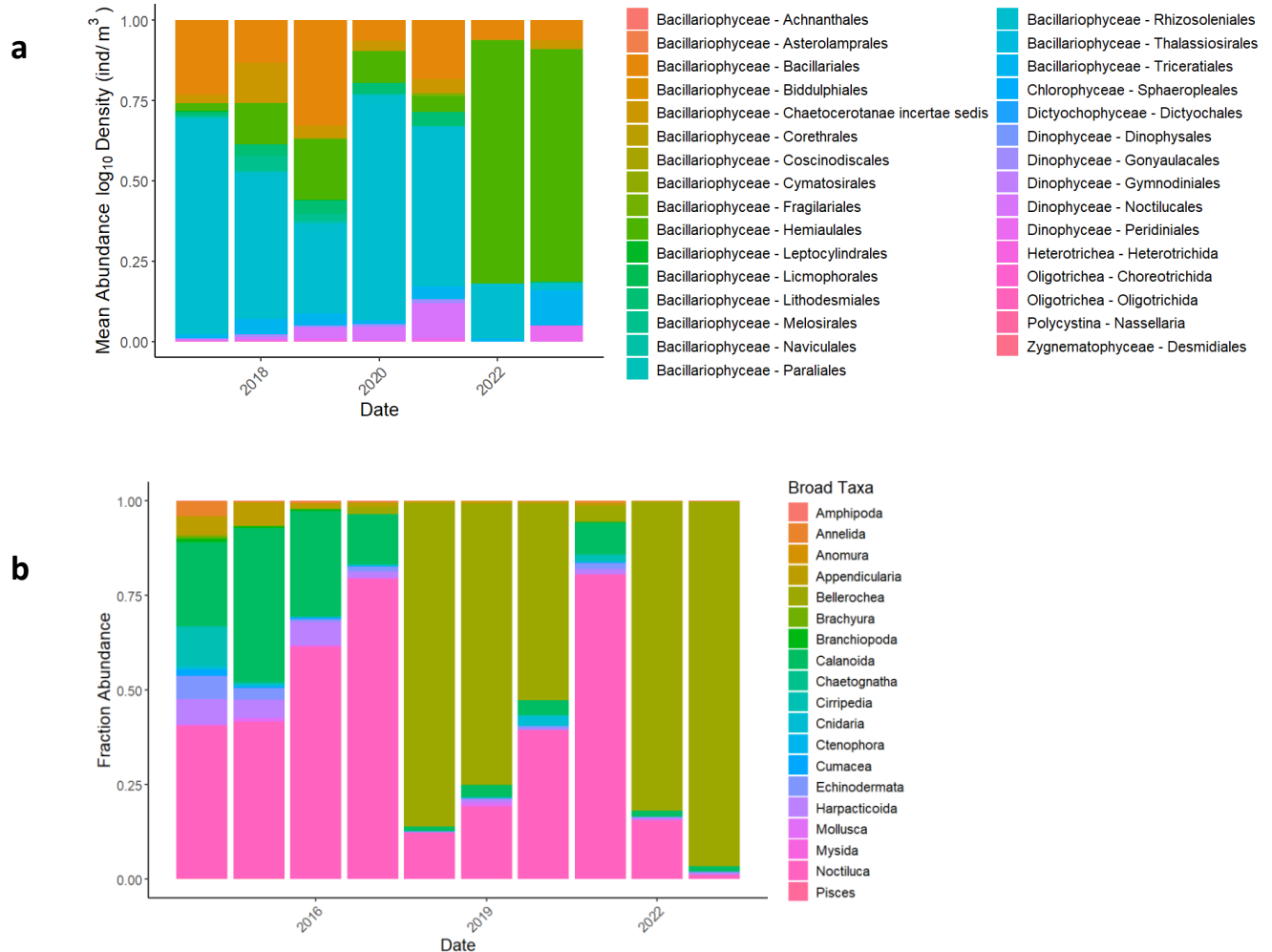


Figure 1. Fraction-based summer community composition for phytoplankton detected by the FlowCam at the order level (a) and for zooplankton and certain larger phytoplankton cells/colonies detected by the ZooScan (b). The community compositions are calculated using 9 coastal LifeWatch stations in the BPNS (see Mortelmans et al., 2019) in the months June-September. All years for which data was available and validated have been included.

Alongside the biological analysis, MHW detection and feature analysis in the heatwaveR package revealed that the years with maximum temperatures were 2018 (21.34°C) and 2022 (21.25°C). The year 2022 was also notable for having the greatest cumulative intensity (°C x days) of MHWs in the studied time frame (2014-2023).

Discussion

The data from the FlowCam and ZooScan revealed trends at the community level and suggest an association between MHW events and community composition shifts. Phytoplankton communities

exhibited couplet and triplet years wherein the communities were more closely related. This pattern seems to be visible for the groups 2017-2019, 2020-2021, and 2022-2023 in the FlowCam data and for groups 2015-2017, 2018-2020, and 2022-2023 in the ZooScan data. In agreement with the analysis of Mortelmans et al. (2024), the *Bellerochea* spp.-driven community shifts starting in 2018 and 2022 align with years exhibiting maximum MHW temperatures. The biological changes in 2022 may also have been influenced by the 91-day length of the summer heatwave that year. The strikingly long duration of the 2022 MHW meant that its cumulative intensity was the greatest of the last nine years. Although the FlowCam and ZooScan data agreed on some of these patterns, there are a few discrepancies that are likely unrelated to MHW effects. The lack of evidence of a 2018 *Bellerochea* spp. (Order Hemiaulales) bloom in the FlowCam data is likely due to the long chain-forming nature of these diatoms. Other organisms, such as *Phaeocystis globosa*, are also known for aggregating and causing clogs in the FlowCam (Aubert et al., 2022).

Despite their many advantages, automated imagers like the FlowCam and ZooScan can also lack taxonomic resolution, and each instrument covers only part of the plankton size range. A review by Lombard et al. (2019) noted that, because the concentration of plankton decreases with plankton size, it is not feasible to sample the full plankton system using one technique only. Hence, observations using only 1-2 methodologies provide an incomplete picture. Multifaceted plankton observation therefore offers the best insight into the status of a plankton community, and future studies would benefit from incorporating molecular observation techniques as well as classical microscopy (Aubert et al., 2022; Lombard et al., 2019). Using a variety of methods would also allow for more in-depth analysis of the relationship between MHW features and plankton densities. Next steps will therefore include the application of DNA metabarcoding on newly collected samples, which will complement the imaging data from the existing time series.

Conclusion

The FlowCam and ZooScan data from the Belgian contribution to LifeWatch capture several prominent trends in community composition and taxon-specific seasonal dynamics. There is some agreement in the data from the two imaging instruments, particularly driven by taxa that are present in both imaging datasets. Discrepancies between the FlowCam and ZooScan are likely due to technical differences such as phytoplankton inducing clogs in the FlowCam. Some key years highlighted by this preliminary assessment include 2016, 2018, and 2022 – these years showed marked shifts from adjacent years before (in the case of 2018 and 2022) or afterward (in the case of 2016). Unusually high temperatures reached during the summer MHWs of 2018 and 2022 may help explain the lasting plankton community shifts of those years. The cumulative intensity of the 2022 MHW may also have allowed it to affect the temporal dynamics of the summer plankton community that year, and such impacts of MHW features should be further investigated.

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