Evolution of Coccolithophores bloom dynamics in the North Sea: observations from Remote Sensing, Continuous Plankton Recorder and FerryBoxes

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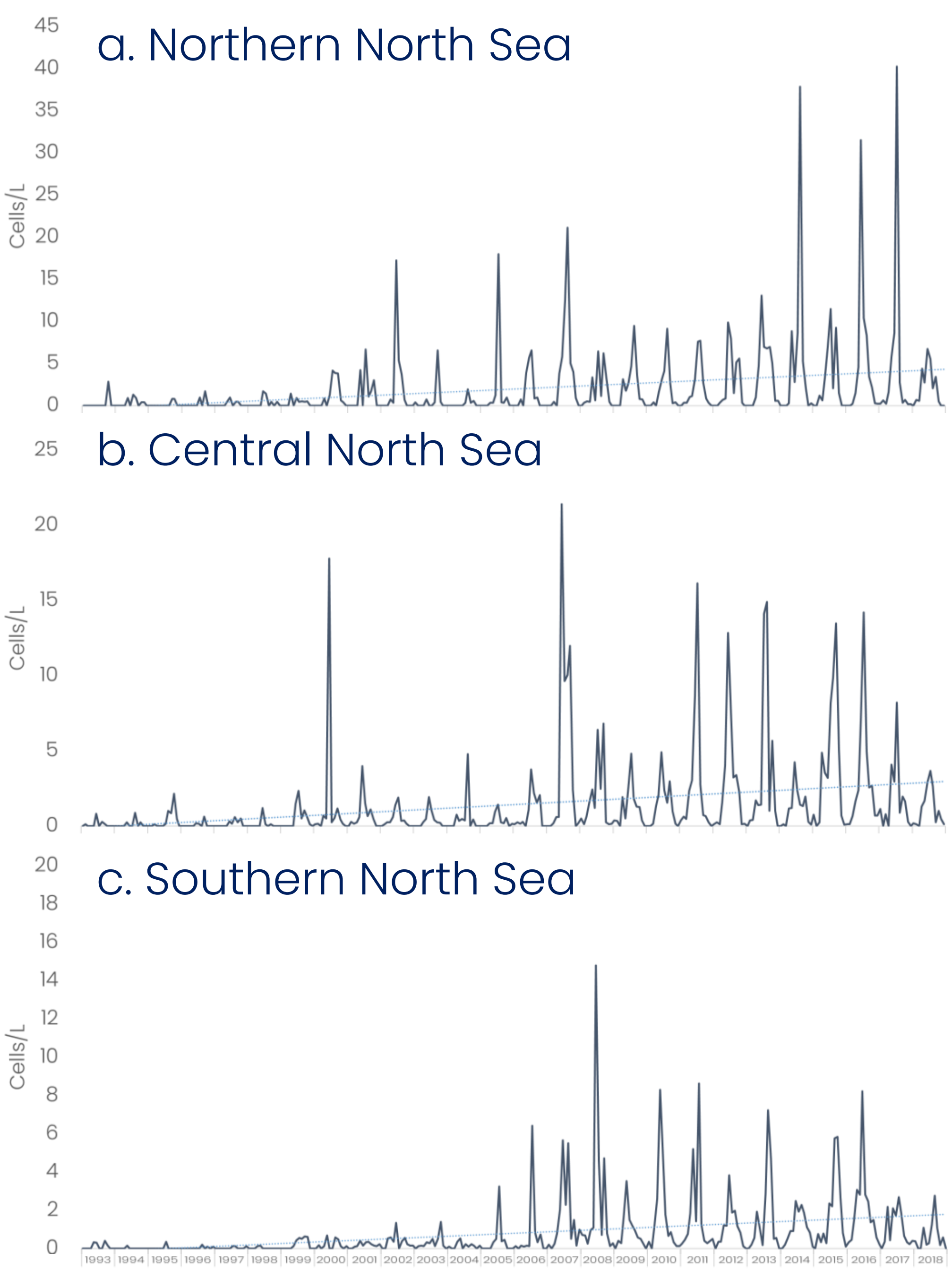
Introduction

Coccolithophores occupy a major role in the marine carbon cycle through production and export of calcite plates, contributing to particulate inorganic carbon (PIC) cycling in the open ocean[1]. When shed, they cause strong light scattering[2]. Coccolithophores can form massive blooms covering thousands of square kilometers, which appear bright turquoise in contrast to the ocean and are therefore reasonably well detectable with ocean color imagery[3]. The most abundant Coccolithophore species globally and in the North Sea, is *Emiliana huxleyi*, with three different morphotypes of varying calcite production rates[4]. Even though *E. huxleyi* is a tolerant species, models predict a general decrease in occurrence under future climate change conditions[5], including increased temperatures and ocean acidification. The aim of this study is to **understand recent dynamics** of Coccolithophores in the North Sea, to **identify bloom drivers** and to **assess the impact on the carbon cycle**.

Methodology

Analysis and correlation of:

- Continuous Plankton Recorder time-series (1993-2018)
- Satellite images (Sentinel-3 OLCI)
- FerryBox data (temperature, salinity, pCO_2)



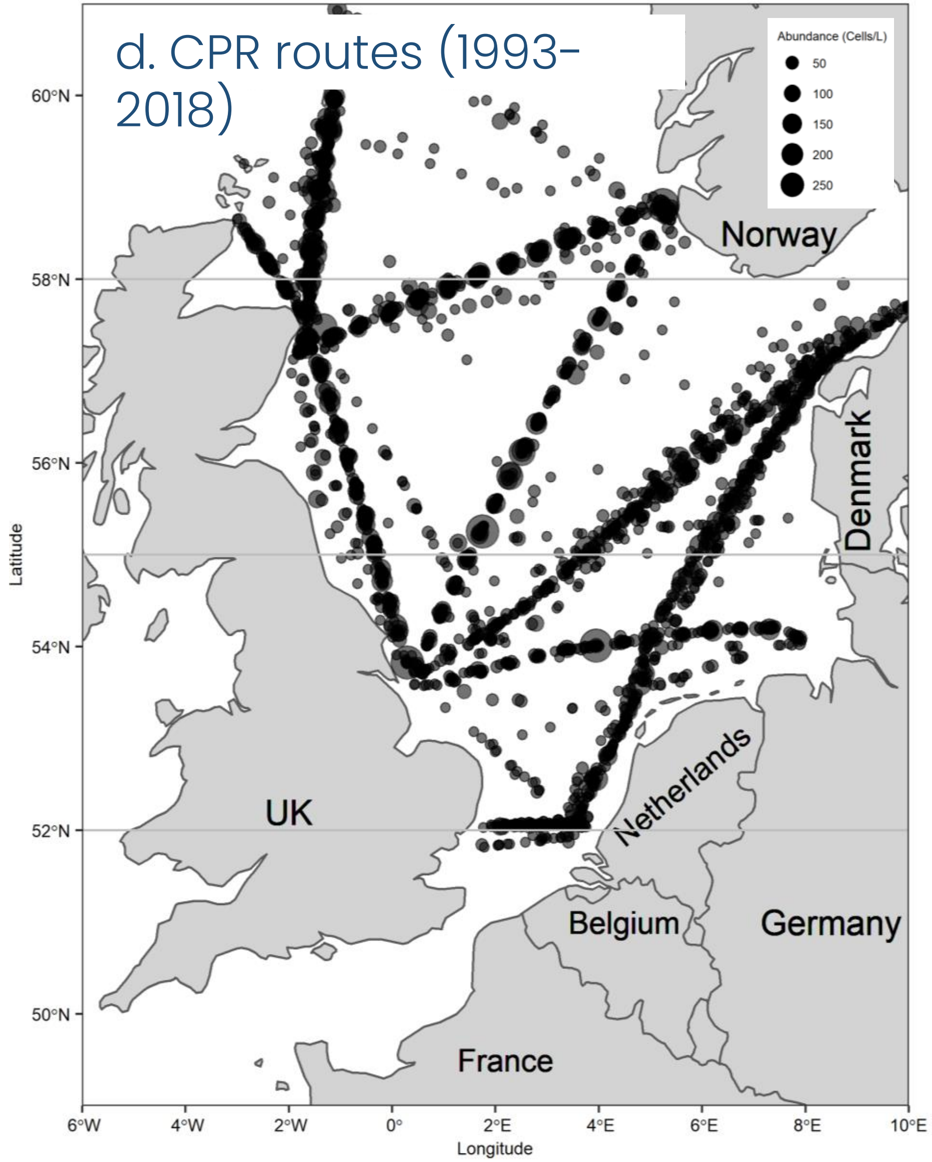


Figure 1: a.-c. Monthly mean abundances of Coccolithophores in different regions of the North Sea (1993-2018) d. CPR sampling routes (1993-2018) and abundances of Coccolithophores

Results

Abundance

Significant increase in Coccolithophore abundance in the entire North Sea, particularly in the northern regions

20-fold increase in abundance between the 1990s and 2010s

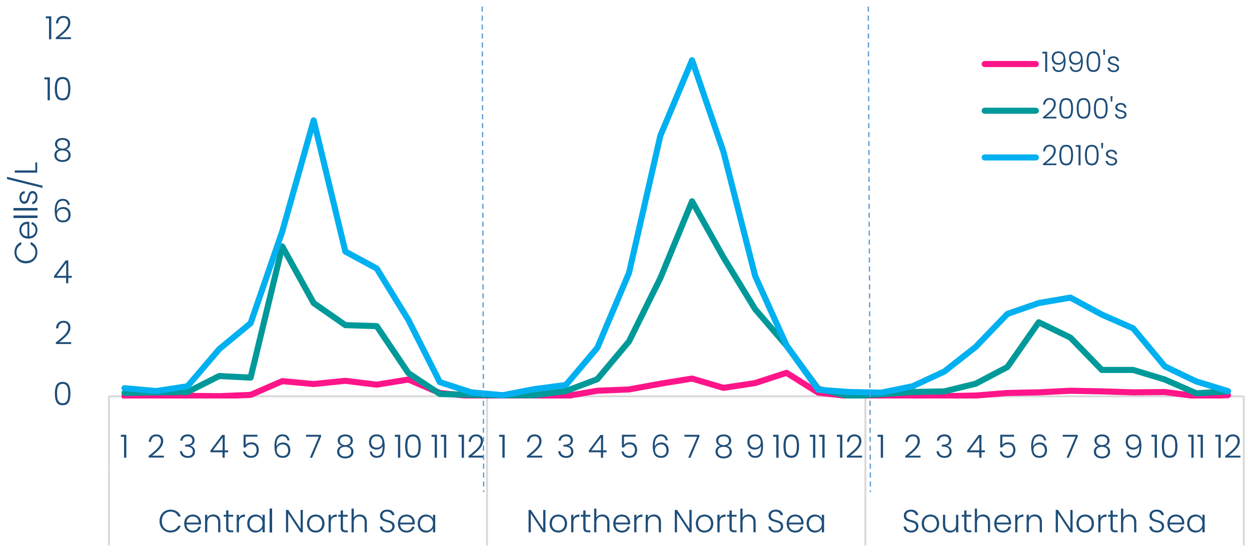


Figure 2: Monthly mean abundances of Coccolithophores in the different regions of the North Sea (1993-2018)

Bloom timing

Coccolithophores bloom every year in the North Sea with highest abundance between June and July

Bloom peak shifted from June to July since the 2010s in the central and southern North Sea

Longer bloom period especially in the southern North Sea

Detection through Remote Sensing

Significantly different Rrs spectrum in comparison to diatoms (Fig. 3)

Different spectra obtained for different bloom stages: live cells (Coccolithophores) and deteriorated cells (Coccoliths) (Fig. 3)

Clear difference in scattering and attenuation when compared to other phytoplankton groups (Fig. 4)

Detection through Remote Sensing possible

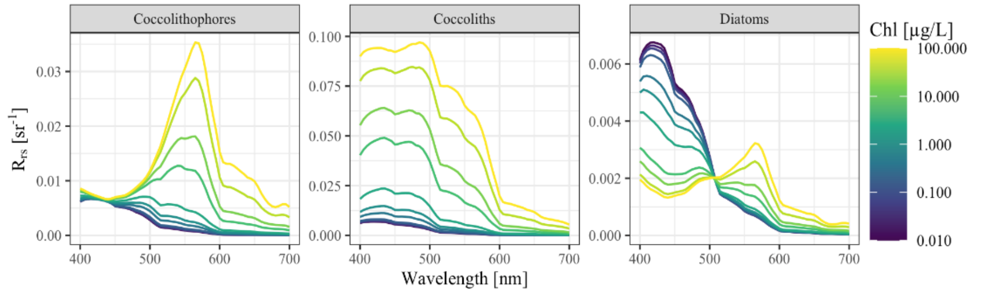


Figure 3: Remote Sensing Reflectances (Rrs) of Coccolithophores, Coccoliths and Diatoms

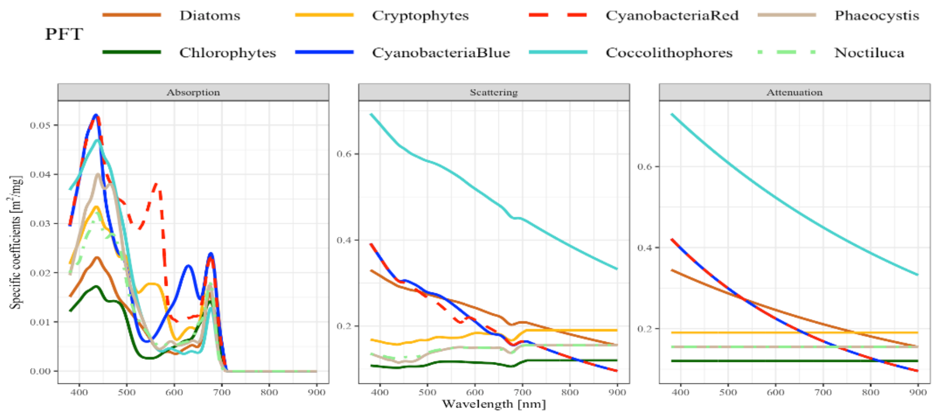


Figure 4: Inherent optical properties of Phytoplankton Functional Types (PFTs)

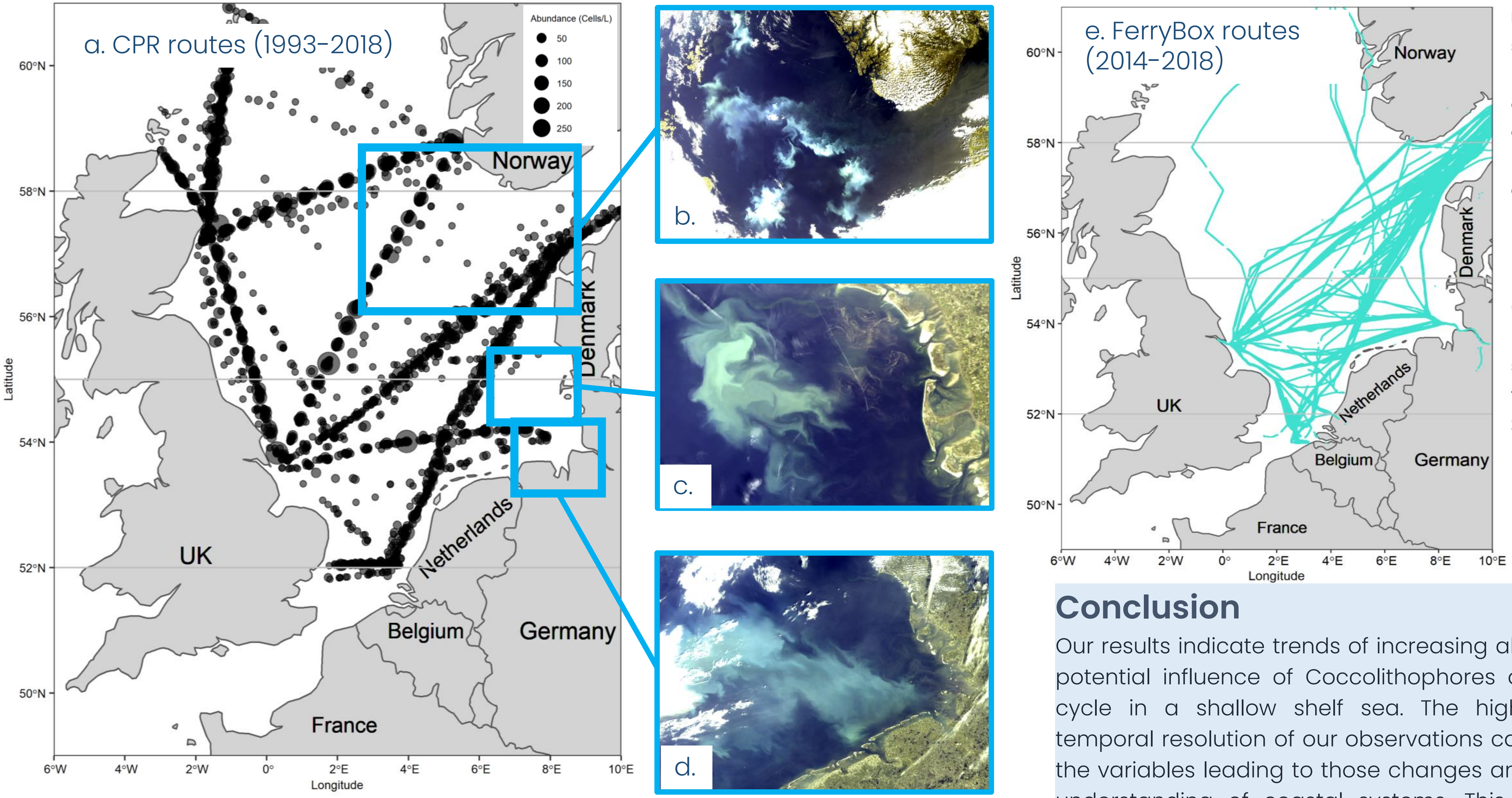


Figure 5: a. CPR sampling routes (1993-2018) and abundances of Coccolithophores, b.-d. Coccolithophore blooms recorded by Sentinel-3 OLCI (06.2016, 06.2017, 05.2018), e. FerryBox measurements : salinity, pCO_2 and temperature (2014-2018)

Compatibilty of data

High abundances (CPR data) correspond to intense bloom events (Sentinel-3 OLCI)

Good geographical and temporal overlap among datasets (CPR data, FerryBox data, satellite images)

Conclusion

Our results indicate trends of increasing abundance and potential influence of Coccolithophores on the carbon cycle in a shallow shelf sea. The high spatial and temporal resolution of our observations can help identify the variables leading to those changes and improve the understanding of coastal systems. This can enhance predictions of the impact that Coccolithophore blooms will have on the carbon cycle and ecosystem dynamics.

Knowledge gaps

Drivers

- What lead to this significant increase in Coccolithophore abundance in the North Sea?
- Which environmental variables may have contributed to this change especially between the 1990s and 2000s?

Impact

- How is this increase in abundance affecting the Carbon cycle and productivity today and in the future?

Adaptability

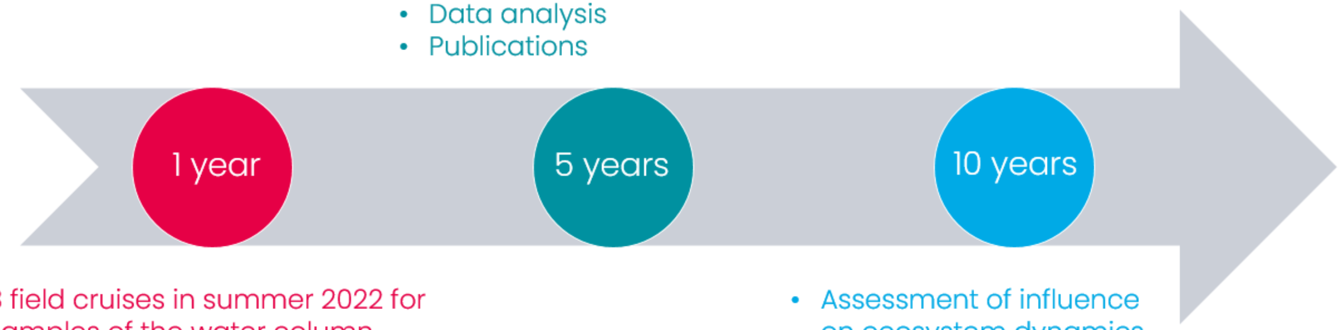
- Has there been a change of *E. huxleyi* morphotype over time in the North Sea?
- Has there been a shift of Coccolithophore species in the North Sea?

Sampling

- Combination of localized *in situ* data collection with autonomous large-scale data collection (FerryBox, Sentinel-3 OLCI)
- Further collaboration with CPR work

Next steps

- Field cruises (further assessment of Coccolithophore dynamics)
- Data analysis
- Publications



- 3 field cruises in summer 2022 for samples of the water column (pCO_2, pH, temperature, nutrients and total alkalinity) and phytoplankton
- Analysis of samples with electron microscopy
- Combination of collected *in situ* data with Remote Sensing data and autonomous FerryBoxes
- Assessment of localized and large-scale influence on the carbon cycle

- Assessment of influence on ecosystem dynamics
- Assessment of changes with coastal ocean acidification
- Publications

References

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