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Observations of a thin near surface layer in an estuarine environment: An exceptional bloom of the dinoflagellate *Akashiwo sanguinea* in the Lee estuary (Lough Mahon), Co. Cork, in September 2010

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ABSTRACT

Observations on the occurrence of an exceptional phytoplankton bloom in the Lee estuary, Co. Cork, in September 2010 are reported. A thin layer of phytoplankton dominated by the dinoflagellate *Akashiwo sanguinea* (Dinophyceae), with a cell concentration of 16,900 cells ml^{-1} and chlorophyll *a* concentration of 680 $\mu g\, l^{-1}$, was observed at a depth of 1 m. The layer extended over a horizontal distance of 3 km and was located in the estuarine pycnocline. Levels of dissolved oxygen supersaturation were elevated at 190 (%) saturation (15.9 mg $O_2\, l^{-1}$) and the highest biochemical oxygen demand associated with the bloom was greater than 25 mg $O_2\, l^{-1}$. Using biovolume data to calculate carbon content, and a water exchange rate of 0.06 d^{-1} and dilution factor of 0.1, the potential oxygen demand following bloom collapse was estimated to be 7.22 mg $O_2\, l^{-1}$. The potential impact of this thin layer on the water quality of the estuary is discussed.

1. Introduction

In recent years the occurrence of thin layers of phytoplankton in stratified marine waters has received greater attention, in part due to the development of technologies capable of resolving fine scale biological and physical features. The improved spatial characterisation of these features in stratified environments has contributed toward a better understanding of how these thin layers influence ecosystem dynamics and in particular primary productivity and the biogeochemical cycling of nutrients and other substances (Durham and Stocker, 2012). Furthermore, knowledge about the presence of thin layers of potential toxin-producing species has also improved the detection of harmful algal events (Gentien et al., 1995).

Here, we provide a short communication on the occurrence of an exceptional thin layer of phytoplankton dominated by the dinoflagellate *Akashiwo sanguinea* (Hirsake) G. Hansen et Moestrup in the Lee estuary (Lough Mahon), Co. Cork in September 2010. The potential impact of this thin layer on water quality in the estuary is discussed.

2. Materials and methods

Observations at eight stations in the Lee estuary (Lough Mahon) and Cork Harbour (Fig. 1) were carried out as part of the Irish Environmental Protection Agency's national estuarine and coastal waters monitoring programme. Percentage dissolved oxygen (DO) saturation measurements together with temperature, salinity and depth were recorded using a Hydrolab Datasonde CTD. Fluorescence measurements were taken using a Cyclops (Turner Designs) fluorometer integrated to the CTD. Samples for the analysis of chlorophyll *a*, nutrients and BOD were collected using 2-litre Hydrobios Ruttner bottles. DO saturation measurements and water samples were taken at the surface and 0.5 m above the bottom. Composite phytoplankton samples containing equal volumes of surface and bottom sample, mixed together, were collected from the upper Lee estuary (LE150, LE160, LE170), Lough Mahon (LE 180, LE330, LE340) and Cork Harbour (LE380 and LE610). Discrete samples were also collected from a depth of 1 m at station LE180 and at the surface at station LE330 in response to elevated fluorescence readings. Samples for plankton analysis were preserved in Lugol's iodine and stored in Sterilin tubes. Samples were counted using a Sedgewick Rafter cell and specific phytoplankton dimensions were taken on 20 randomly selected individual cells.

DO measurements were calibrated on a daily basis using the water-saturated air method. Salinity measurements were calibrated against KCl standards of known conductivity. Samples for

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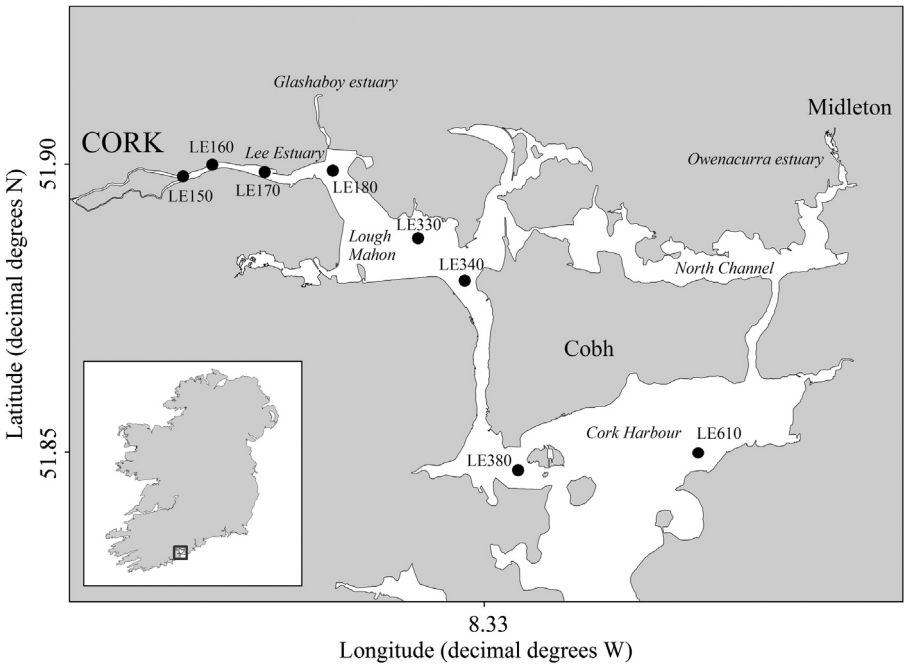

Fig. 1. Location of sampling stations in the Lee estuary, Lough Mahon and Cork Harbour.

Table 1
Calculated carbon cell content based on biovolume.

Parameter	Method	Calculation	Result
Cell volume (V_c)	$V_c=(\pi/6)$*L1*D1*D2 μm^3 [a]	$V_c=(3.1416/6)$*59.7*47.0*28.4[b]	$V_c=41650\ \mu m^3$
Cell carbon (C_c)	$C_c=0.216 * V_c^{0.939}$ pg C cell^{-1}[c]	$C_c=0.216*41650^{0.939}$	$C_c=4702$ pg C cell^{-1}

[a] From Olenina et al. (2006): Flattened ellipsoid.
[b] Measurements of L1, D1 and D2 averaged from 20 specimens.
[c] From Menden-Deuer and Lessard (2000).

the measurement of chlorophyll *a*, a proxy for phytoplankton biomass, were filtered using Whatman GF/C glass fibre filters and stored overnight and in the dark to prevent photodegradation. Pigments were extracted using hot methanol and absorbance (not corrected for the presence of phaeopigments) was measured at 665 nm using a spectrophotometer (Standing Committee of Analysts, 1980). Nutrients (total ammonia, total oxidised nitrogen and molybdate reactive phosphorus) and BOD_5 were measured according to Standard Methods for the Examination of Water and Wastewater (2005).

Residence time for the Lough Mahon area of the Lee estuary, was calculated using the method developed by Hartnett et al. (2011). This method uses the physical characteristics of the estuary such as width, length, width of mouth, mean volume and river discharge to calculate residence time. Applying this method gave a residence time for Lough Mahon of 15.9 days, which in turn gives a water exchange coefficient of 0.06 d^{-1}.

Cell biovolumes to *A. sanguinea* were calculated using the equation for a flattened ellipsoid, the best fitting geometric shape assigned to it, in Olenina et al. (2006). Using this calculated biovolume, the cellular carbon content was then estimated using the carbon to volume relationship for dinoflagellates as determined by Menden-Deuer and Lessard (2000) (Table 1).

3. Results

An exceptional bloom of the dinoflagellate *A. sanguinea* with a maximum cell density of 16,900 cells ml^{-1} and chlorophyll concentration of 680 $\mu g\ l^{-1}$, was observed in the Lee Estuary Lough Mahon area of Cork Harbour (Fig. 2). The bloom consisted of a thin layer located at a depth of 1 m in the estuarine pynocline and extended over a distance of 3 km (Fig. 2). Water discolouration on the surface was not apparent but a sample taken from 1 m at station LE180 was noticeably reddish brown in colour.

Chlorophyll fluorescence levels at a depth of 1 m exceeded the fluorometer's upper limit of detection for the instrument (range: 0.0–4.6 relative units), but were close to zero at the surface and below the pycnocline (Fig. 3). Chlorophyll levels were also elevated (>50.0 µg/l) at the surface at station LE330 and LE340. A surface sample taken at station LE330 had an elevated cell concentration of 1180 cells ml^{-1}. Biochemical oxygen demand (BOD) at the subsurface chlorophyll maximum at LE180 was >25 mg $O_2\ l^{-1}$, BOD was also elevated at the surface at station LE330. *A. sanguinea* was also detected in the upper Lee estuary (composite of LE150, LE160 and LE170) and in the Harbour (composite of LE380 and LE610), but at much lower concentrations of 18 and 34 cells ml^{-1}, respectively. Cells were also detected in the North Channel and Owenacurra estuary (Table 2).

DO supersaturation of 190% was associated with the subsurface chlorophyll maximum indicating that the bloom was actively photosynthesising (Fig. 2). Saturation levels were much lower below the pycnocline in the upper estuary and close to fully saturated in the lower part of Lough Mahon and Cork Harbour. DO levels in the upper part of the Lee estuary have historically been undersaturated due to the presence of organically enriched sediments that have accumulated in the absence of waste water