

Research paper

Dinoflagellate cysts from two sediment traps east of New Zealand

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ABSTRACT

Two discontinuous sediment trap records of organic-walled dinoflagellate cyst (dinocyst) flux, each sampling > 300 days within the years 2005–2009, were derived from two time-incremental traps deployed at 1500 m water depth east of New Zealand. The traps sampled flux from beneath two distinct surface water masses on either side of the Subtropical Front: (i) warm, seasonally macronutrient-depleted Subtropical and (ii) cold, micronutrient-limited Subantarctic waters. Nineteen dinocyst taxa or taxonomic groups were identified from the trap samples. Trap assemblages at both sites were dominated by cysts of Protoperidiniaceae, notably *Brigantedinium* spp., which comprised almost ~98% of the dinocyst flux. The seasonality of the dinocyst flux differed between the traps, with a pronounced spring flux in the Subtropical trap, while seasonal variation in the Subantarctic trap was relatively muted. In Subtropical waters, moderate correlation was observed between Protoperidiniaceae cyst flux and chlorophyll *a* concentrations in surface waters in the 3–4 weeks prior to sampling. In Subantarctic waters, there was a weak correlation between Protoperidiniaceae cyst flux and reduced intensity of storm-induced turbulence during the preceding 2–3 weeks. There was a large discrepancy between dinocyst assemblages in the traps and those observed in nearby sea-floor sediments. Protoperidiniaceae dinocysts, particularly *Echinidinium* and *Brigantedinium*, were highly under-represented in the sea-floor assemblages. These forms are more susceptible to degradation in oxygenated sediments than other dinocysts, but inter-annual variability in cyst flux, or short-term variation not covered by sampling discontinuities in the current study could also have contributed to this discrepancy. The major differences in the seasonality of dinocyst fluxes between the two water masses examined in this initial study, suggest that mean-annual rather than seasonal climatologies are more appropriate for dinocyst-based quantitative palaeoenvironmental reconstructions in the New Zealand region.

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1. Introduction

Dinoflagellates make a significant contribution to primary productivity and grazing in modern oceans, at times forming blooms that dominate carbon fixation and carbon cycling in surface waters (Chang, 1988; Verity et al., 1993; Sherr and Sherr, 2007; Wasmund et al., 2011). About 10–20% of modern dinoflagellates form organic-walled cysts (Dale, 1996; de Vernal and Marret, 2007), resulting in approximately 80 fossilisable taxa in modern sea-floor samples (Marret and Zonneveld, 2003; Zonneveld et al., 2013). The organic-walled dinoflagellate cyst (dinocyst) represents a resting stage in the dinoflagellate life cycle, and is generally formed after sexual reproduction (Pfiester and Anderson, 1987; Figueroa et al., 2007; Kremp et al., 2009).

Quaternary fossil dinocyst assemblages extracted from marine sediments are frequently interpreted in terms of varying environmental conditions. These studies are based on observations of cyst assemblages

in modern sediments (e.g., Marret and Zonneveld, 2003; Radi et al., 2007; Pospelova et al., 2008; Crouch et al., 2010; Limoges et al., 2010; Zonneveld et al., 2013), either by semi-quantitative interpretation of trends (e.g., Esper et al., 2004; Verleye and Louwye, 2010) or by mathematical transfer functions that quantify environmental gradients, such as sea-surface temperature, salinity, sea-ice cover or marine productivity (e.g., Marret et al., 2001, 2008; Peyron and deVernal, 2001; Bonnet et al., 2010). Although the distribution of dinocysts in modern sediments is the primary archive used to interpret palaeo-assemblages, additional information on dinoflagellate ecology is desirable. Such information allows exploration of the implicit assumptions required for reconstructions based on correlations to selected abiotic gradients, particularly the ecological relevance of the target environmental variable to the dinoflagellate (e.g., Birks et al., 2010). Observations of modern dinocyst flux from time-series sediment trap samples are one way to gain insights into the ecology of cyst-forming dinoflagellates.

Previous multi-year observations of seasonal-scale variations in dinocyst flux have been mainly from near-shore and continental margin environments (e.g., Montresor et al., 1998; Fuji and Matsuoka, 2006; Ribeiro and Amorim, 2008; Pitcher and Joyce, 2009; Pospelova et al.,

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2010; Price and Pospelova, 2011; Bringué et al., 2013), although there are a few records from open-ocean settings (e.g., Dale, 1992; Harland and Pudsey, 1999; Zonneveld and Brummer, 2000; Zonneveld et al., 2010). A common theme of these studies is the observation of marked seasonal and inter-annual variability of cyst fluxes, occasionally accompanied by large differences between the observed trap assemblages and nearby sea-floor samples in deep-water oceanic settings (e.g., Dale, 1992; Harland and Pudsey, 1999; Zonneveld et al., 2010). In addition to improving the understanding of near-surface marine conditions that correspond to cyst formation, trap experiments have provided information on a range of factors relevant to regional palaeoenvironmental interpretations using dinocysts: for example nutritional modes (Fuji and Matsuoka, 2006; Pitcher and Joyce, 2009; Pospelova et al., 2010; Zonneveld et al., 2010; Price and Pospelova, 2011; Bringué et al., 2013), the possible effects of long distance transport (Dale, 1992), and the effects of degradation on dinocyst assemblages (e.g., Zonneveld and Brummer, 2000; Zonneveld et al., 2008).

Here, we present discontinuous dinocyst flux observations from two time-incremental sediment traps moored in the ocean to the east of New Zealand. The traps were moored at 1500 m water depth beneath Subtropical and Subantarctic surface water masses (STW and SAW, respectively, Fig. 1) in a water depth of >2700 m. Approximately every third sample of the available trap material between May 2005 and March 2009 was examined, although there were additional time gaps due to mooring and sample losses, meaning that >300 days of flux was sampled from each trap during this three year period. These are the first sediment trap observations of dinocyst flux from oceanic waters in the mid-latitudes of the Southern Hemisphere, and this study provides an initial investigation into the contrasting modes of dinocyst flux between STW and SAW east of New Zealand.

2. Oceanographic setting

A significant surface oceanographic feature to the east of New Zealand is the Subtropical Front (STF), formed by the convergence of STW transported by the East Cape Current and SAW carried by local flows associated with the zonal westerly wind system (e.g., Chiswell, 1996; Sutton, 2003).

Around New Zealand, the STF (Fig. 1) follows the outer continental shelf up the east coast of the South Island (locally called the Southland Front), then strikes eastwards along the crest of the Chatham Rise at ~45°S (Heath, 1985; Carter et al., 1998; Uddstrom and Oien, 1999; Sutton and Roemmich, 2001). Maximum productivity is typically observed in the frontal zone, where STW and SAW converge and mix (e.g., Bradford-Grieve et al., 1997; Murphy et al., 2001). East of the North Island, surface currents to the north of the STF flow in a southerly direction as the East Cape Current (ECC) (Roemmich and Sutton, 1998). The ECC turns east along the northern flank of the Chatham Rise (Heath, 1985; Roemmich and Sutton, 1998). A feature of the ECC is the formation of the semi-permanent, cyclonic Wairarapa Eddy (Chiswell and Roemmich, 1998; Chiswell, 2003, 2005).

Compared to SAW, STW is warmer, saltier, relatively poorer in macronutrients, such as nitrate and phosphate, but is relatively enriched in micronutrients, such as iron (Boyd et al., 1999, 2004). This results in higher primary productivity in the STW, particularly during spring months, compared to the lower production and muted seasonal variation observed in SAW (Murphy et al., 2001).

Annual productivity in STW in the New Zealand region appears to follow a classic spring bloom cycle, with the introduction of nutrients to surface waters by mixing during winter storms. This is followed by a spring bloom dominated by diatoms initiated in thermally-stratified near-surface waters. Surface productivity is then reduced by early summer, due to the depletion of macronutrients (Bradford-Grieve et al., 1997, 1999; Chang and Gall, 1998; James and Hall, 1998; Boyd et al., 1999; Murphy et al., 2001; Hall et al., 2004; Chiswell, 2011). A close coupling between the spring bloom and export of biogenic material to the deep ocean has been observed in the Wairarapa Eddy, with rapidly-sinking diatoms observed in deep-ocean traps during spring (Nodder and Northcote, 2001; Nodder et al., 2005; Sikes et al., 2005).

In contrast, primary productivity in SAW is limited by iron and dissolved silicate, and is dominated by picophytoplankton (organisms < 2 µm) (Bradford-Grieve et al., 1997, 1999; Chang and Gall, 1998; Boyd et al., 1999, 2004). A consequence of the small size of the dominant phytoplankton is generally a reduced export flux from surface waters due to low settling rates, although they too may aggregate into more rapidly sinking particles (Waite et al., 2000). Thus, although the peak flux to the deep ocean (dominated by organic carbon and biogenic silica) in

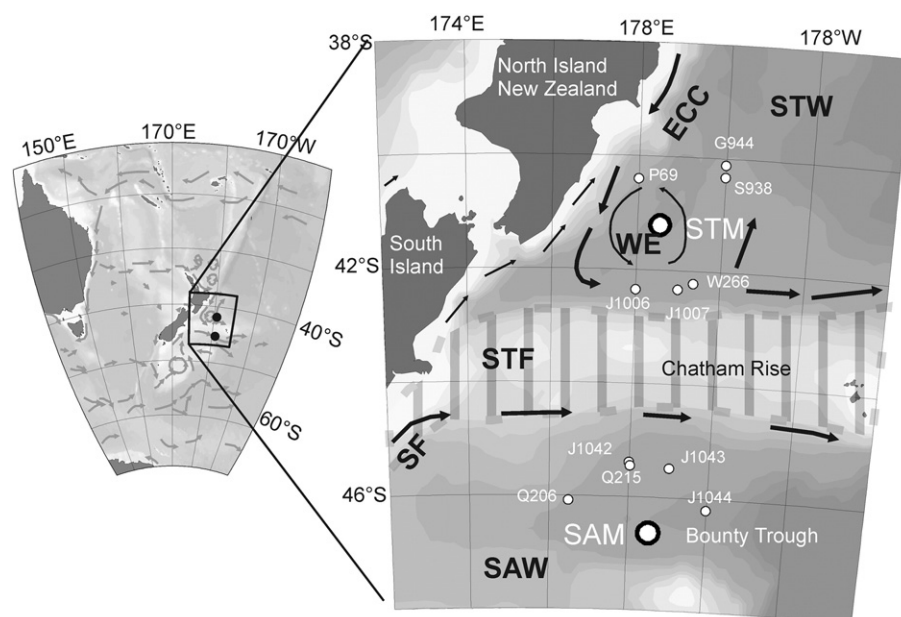


Fig. 1. Location map, showing the position of the Subtropical (STM) and Subantarctic (SAM) sediment trap moorings, and sea-floor sediment samples discussed in the text shown in white. ECC = East Cape Current, WE = Wairarapa Eddy, SF, Southland Front, STW = Subtropical surface water, SAW = Subantarctic surface water, STF = Subtropical Front.

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