Hydrographic and nutrient measurements in the Daintree River plume and its vicinity

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Abstract

Hydrographic and nutrient measurements were conducted at four stations off Cape Tribulation - Port Douglas before and after cyclone Sadie. A significant decrease in salinity and an increase in nutrient concentration at the sea surface were observed at inshore to mid shelf stations a day after the peak rainfall. This low salinity and high nutrient sea surface water was quickly dissipated in the following two days. A series of hydrographic measurements after another heavy rainfall in late February revealed that the plume from Daintree River stretched along Cape Kimberley nearby and then away from the coast towards mid shelf reefs, suggesting the presence of a strong buoyant jet at the mouth of the river. The plume was only 2 - 3 m thick at most of the stations and was carrying ca. four to five times more dissolved inorganic nitrogen and twice the amount of dissolved organic nitrogen than the surrounding water. Chlorophyll concentration in the plume was relatively low, probably because of the short lapse after its formation and the limited light available to phytoplankton (high turbidity).

Introduction

Flood plumes introduce a large quantity of nutrients and sediments into Great Barrier Reef (hereafter GBR) shelf waters. There is, however, a degree of controversy over how far flood plumes extend offshore and the extent, to which they influence coral reef communities in the GBR. Davies and Hughes (1983) suggested the transport of terrestrial clays to mid-shelf coral reefs during cyclone Dominic, whereas Gagan et al. (1987) claimed that the transport of terrestrial carbon introduced during cyclone Winifred was confined to near-shore areas. King and Wolanski (1996) have shown, using numerical model simulations of flows in the GBR, that the mixing properties of the GBR are highly spatially variable; this may explain the discrepancy between the results of Davies and Hughes (1983) and Gagan et al. (1987).

The magnitude of flood plumes is one of the factors affecting their cross-shelf dispersion. Flood plumes usually stretch northward along the coast through the interaction of the Coriolis force with the pressure gradient across the shelf and do not reach the GBR (Wolanski 1981; Wolanski and Jones 1981). Wolanski and van Senden (1983), however, have suggested the possibility that very large flood plumes may extend over the width of the shelf.

Other factors that may have a significant consequence on the cross-shelf dispersion of flood plumes include the presence or absence of geographic features, such as headlands, islands and coral reefs (King and Wolanski 1992, 1996). Furthermore, the intensity of buoyant jets at the river mouth can vary depending on the size and morphology of rivers and catchment areas and the amount and continuity of rainfall. This paper presents the results of hydrographic and nutrient measurements in the Daintree River plume and its vicinity and urges the need for understanding the dispersion of flood plumes in the local/regional context.

Methods

Pre- and post-cyclone observation

Sampling was conduced at three stations located between Port Douglas and Undine Reef (Fig. 1, stations A - C) and at a station on the leeward side of Agincourt Reef (Stn D) twice before (January 11 and 18) and twice after cyclone Sadie (February 1 and 3). Water samples were collected with a water bottle from the sea surface and the near bottom at each of four stations. The salinity of water collected was immediately determined using a YSI conductivity meter. Duplicate 10 ml subsamples were collected from each bottle, filtered with disposable syringe filters and stored frozen for later analyses of nitrate and phosphate using a multichannel segmented flow autoanalyzer (Ryle et al. 1981).

Observation of the Daintree River plume

A series of hydrographic measurements were conducted at eleven stations off Cape Tribulation - Port Douglas on February 21 (stations 11) and 22 (stations 1-10). At stations 5-8, water samples were collected from two to four different depths using Niskin bottles. Duplicate 10 ml subsamples were obtained, processed as described above, and analysed for dissolved inorganic and organic nitrogens after the procedures of Strickland and Parsons (1972) and Ryle et al. (1981). A 100 ml sub-sample was also obtained from each bottle, filtered onto a Whatman GF/F glass fibre filter, stored frozen and analysed for chlorophyll by fluorometry (Strickland and Parsons 1972).

Results and discussion

Pre- and post-cyclone observation

Cyclone Sadie brought about 250 - 400 mm of rainfall during a three day period between January 29 and 31 in the north of Cairns (Fig. 2; Daily Rainfall Bulletin, Bureau of Meteorology).

Although the YSI conductivity meter used was not as reliable as initially expected, the data clearly show a significant decrease in sea surface salinity at stations B and C in response to the rainfall associated with the cyclone (Fig. 3). This low salinity sea surface water was quickly dissipated and was not observed on 3 February, only three days after the peak rainfall.

Fig. 4 shows the sea surface and near bottom concentrations of phosphate and nitrate at stations A - D. The concentrations of these nutrients were mostly below the detection limit before the cyclone. The sea surface concentration of phosphate at Stns. A and B reached > 0.19 μM a day after the cyclone-associated peak rainfall and droped to < 0.05 μM in the following two days. Nitrate showed a similar variation pattern to phosphate.

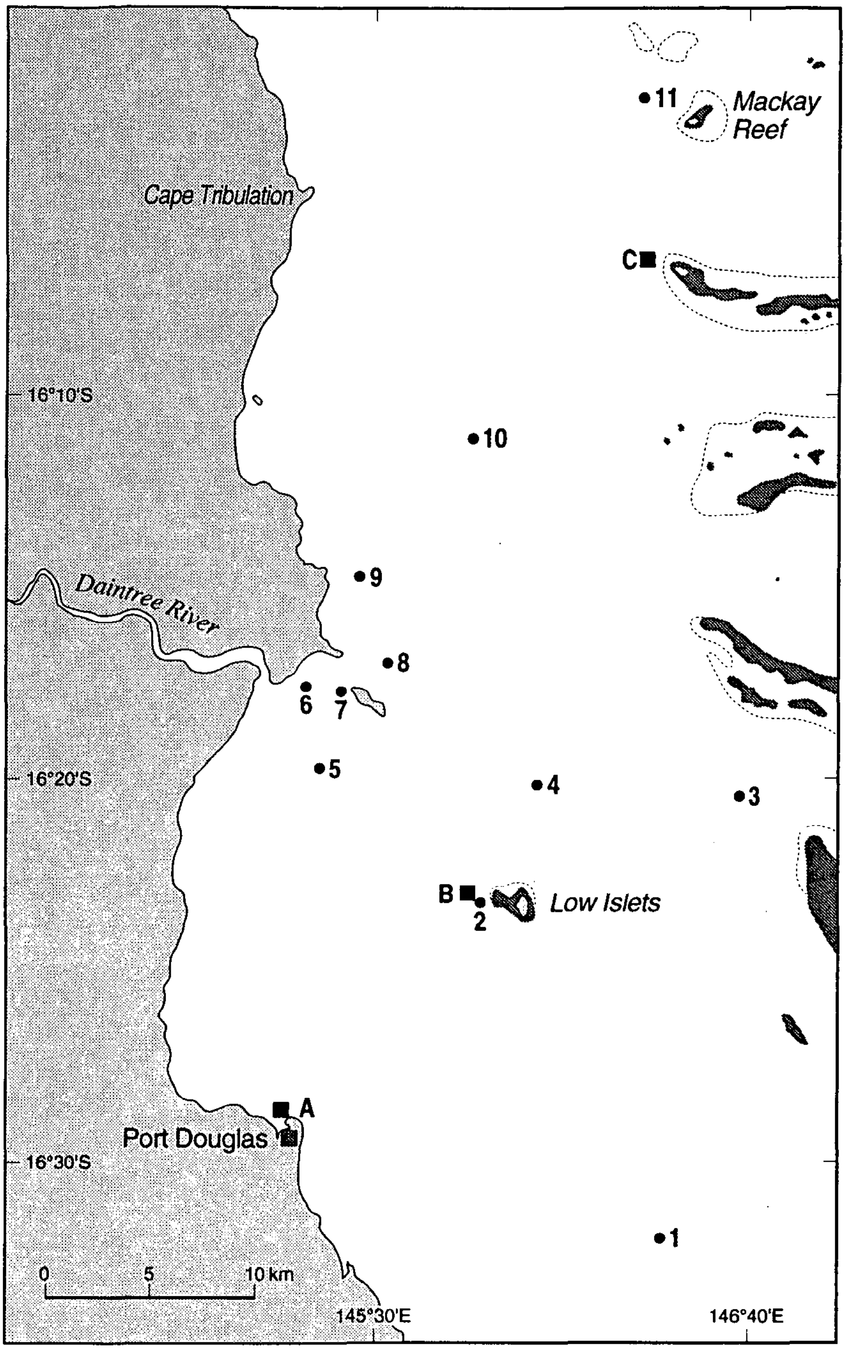

Fig. 1. Location of hydrographic stations sampled before and after cyclone Sadie (stations A-C) and after the heavy rainfall in late February, 1994 (stations 1-11)

The influence of the rainfall associated with cyclone Sadie on the sea surface salinity and nutrient concentration was significant, but rather short-lived. Unfortunately, however, the data are insufficient for answering the question of whether or not the observed changes in salinity and nutrient concentration were due to the flood plume caused by the cyclone. About a half of freshwater inputs into the GBR occurs through direct rainfall over the shelf (Wolanski 1981). Rain water itself may contain relatively high levels of nutrients (e.g. Furnas et al. 1995; Paerl and Fogel 1994). Furthermore, sampling stations were located relatively close to reefs and might be under some influence of water washed off reefs.

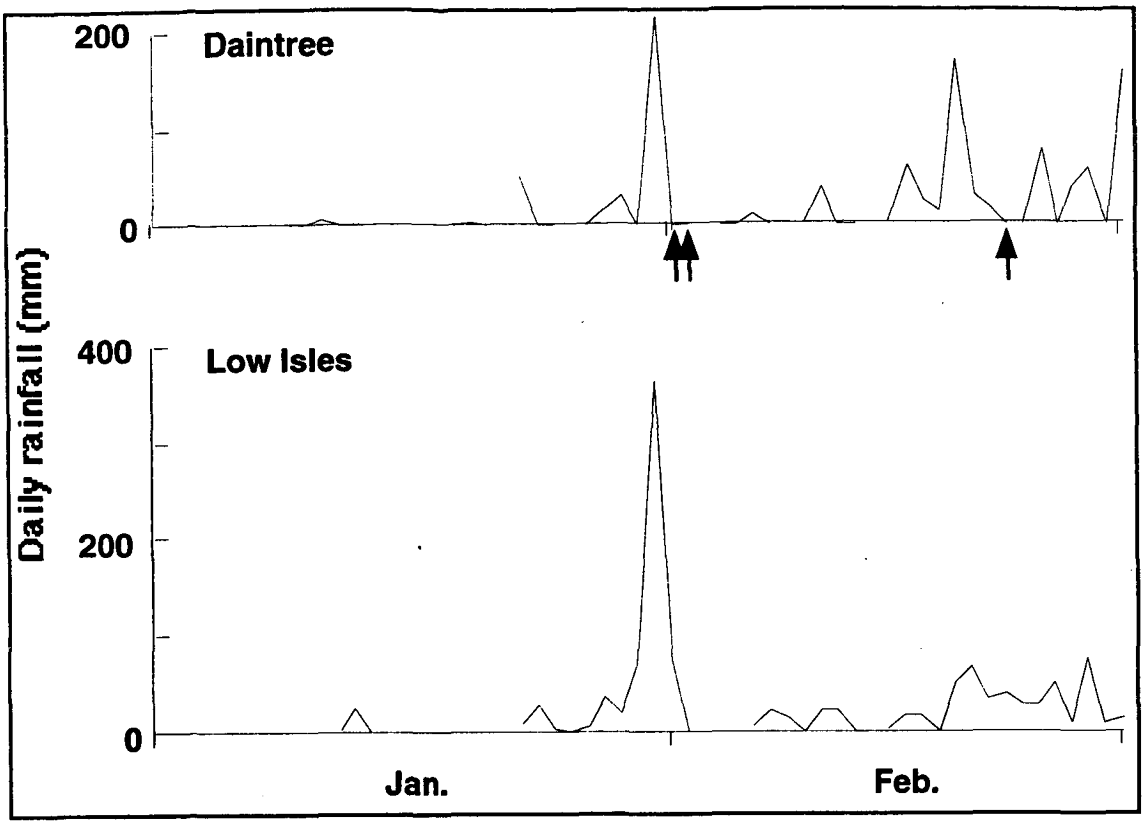

Fig. 2. Daily rainfalls in the Daintree and Low Isles areas between January and February, 1994 (from the Daily Rainfall Bulletin, Bureau of Meteorology)

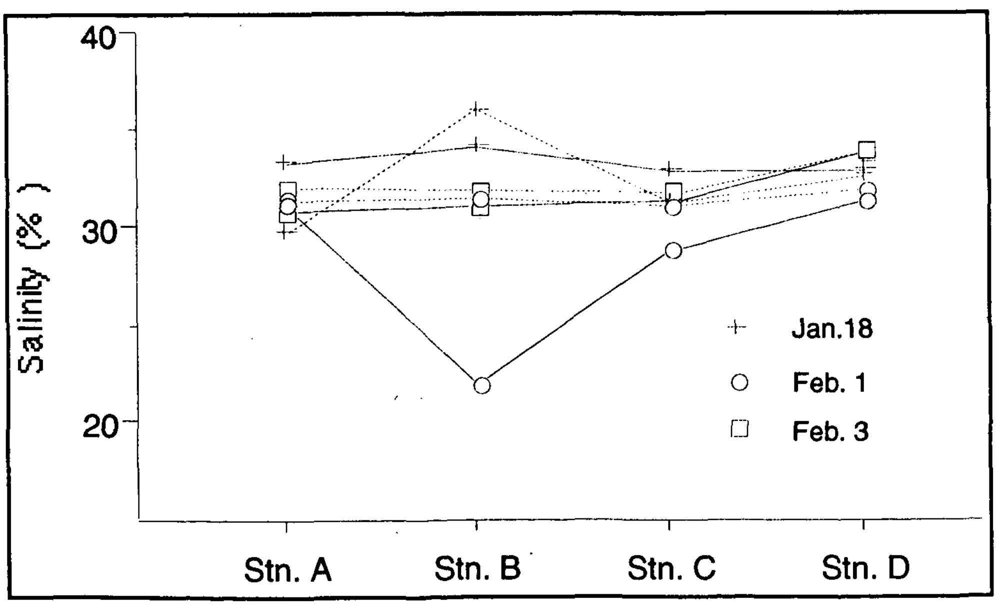

Fig. 3. Variation in salinity at the sea surface (solid line) and the bottom (broken line) at four stations off Cape Tribulation - Port Douglas before and after cyclone Sadie

Observation of the Daintree River plume

Observation of the Daintree River plume was conducted following the rainfall on 18-20 February (Fig. 3). Overall, this rainfall was not as wide-spread and not as intense as the one associated with cyclone Sadie. The Daintree area, however, received on February 18 about 170 mm of rainfall, similar to the peak rainfall during cyclone Sadie.

The sea surface salinity at the mouth of Daintree River was below 27‰ (Fig. 5). The plume stretched along Cape Kimberley and then away from the coast towards mid shelf reefs. A water mass of relatively high salinity (> 31‰) existed between the coast and the plume. The plume was only 2 - 3 m thick at most of stations and there was no significant sign of the plume at 5 m depth (Fig. 6).

There is a discrepancy between the general understanding of the behaviour of flood plumes and the observed features of the Daintree River plume. As mentioned earlier, flood plumes usually stretch northward along the coast through the interaction of the Coriolis force with the pressure gradient of plumes. A passive trajectory model also predicted that the plume would be adhered onto the coast under the tide and prevailing wind conditions during the time of the observation. The observed behaviour of the plume can be explained only by assuming a strong buoyant jet at the mouth of Daintree River: i.e. a buoyant jet is strong enough that its momentum in interaction with Cape Kimberley drives the plume offshore. It is interesting to note that the estimated speed of the vessel (from GPS) was about 7 knots from station 11 to station 9, whereas it increased to 10.5 to 11 knots during the run in the opposite direction. This gives an estimated current speed of approximately 2 knots (1 m s^{-1}), which is in good agreement with the current speed reported by Wolanski and Jones (1981) for the Burdekin River plume.

Fig. 7 shows the vertical profiles of dissolved organic and inorganic nitrogen (DON and DIN) and chlorophyll in the plume (station 6) and its vicinity (stations 3 - 5) for comparison. The plume was carrying about 4 - 5 times more DIN and twice the amount of DON than the surrounding water. Chlorophyll

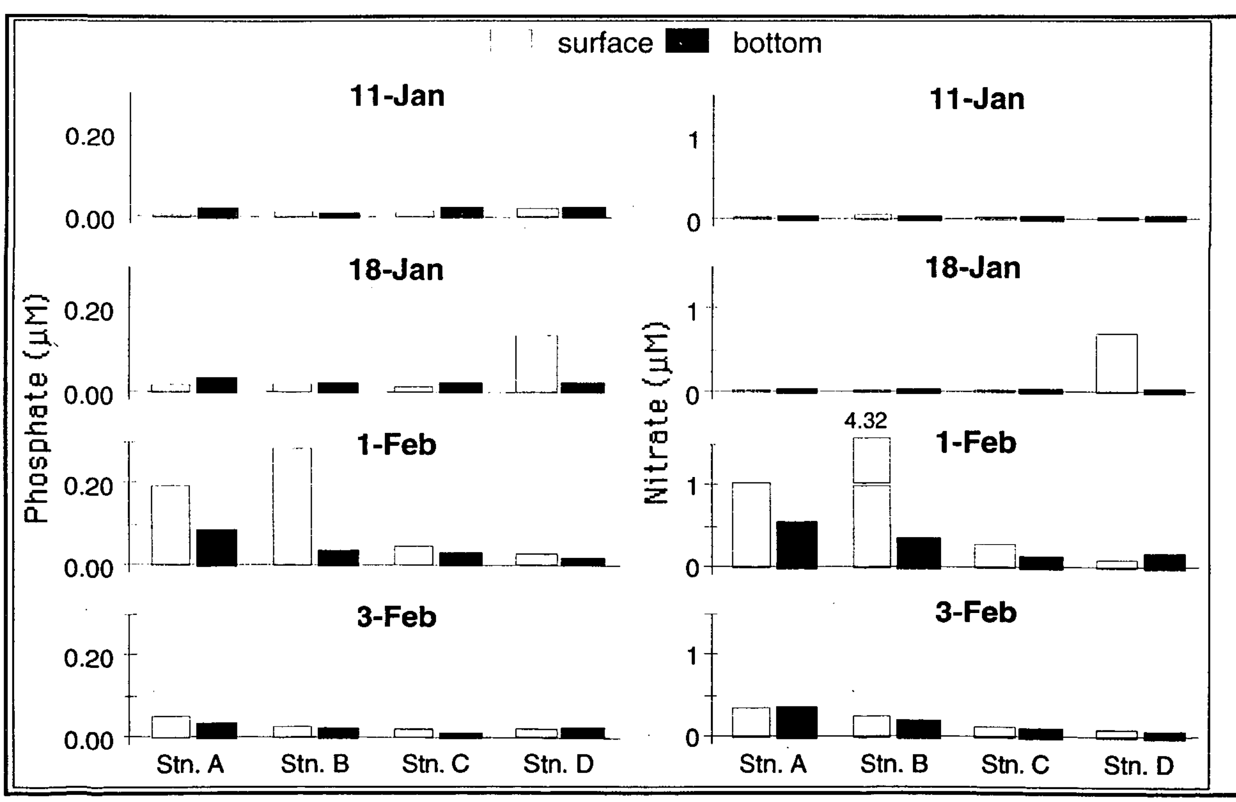

Fig. 4. Variations in phosphate and nitrate concentrations at the sea surface (open) and the bottom (filled) at four stations off Cape Tribulation - Port Douglas before and after cyclone Sadie

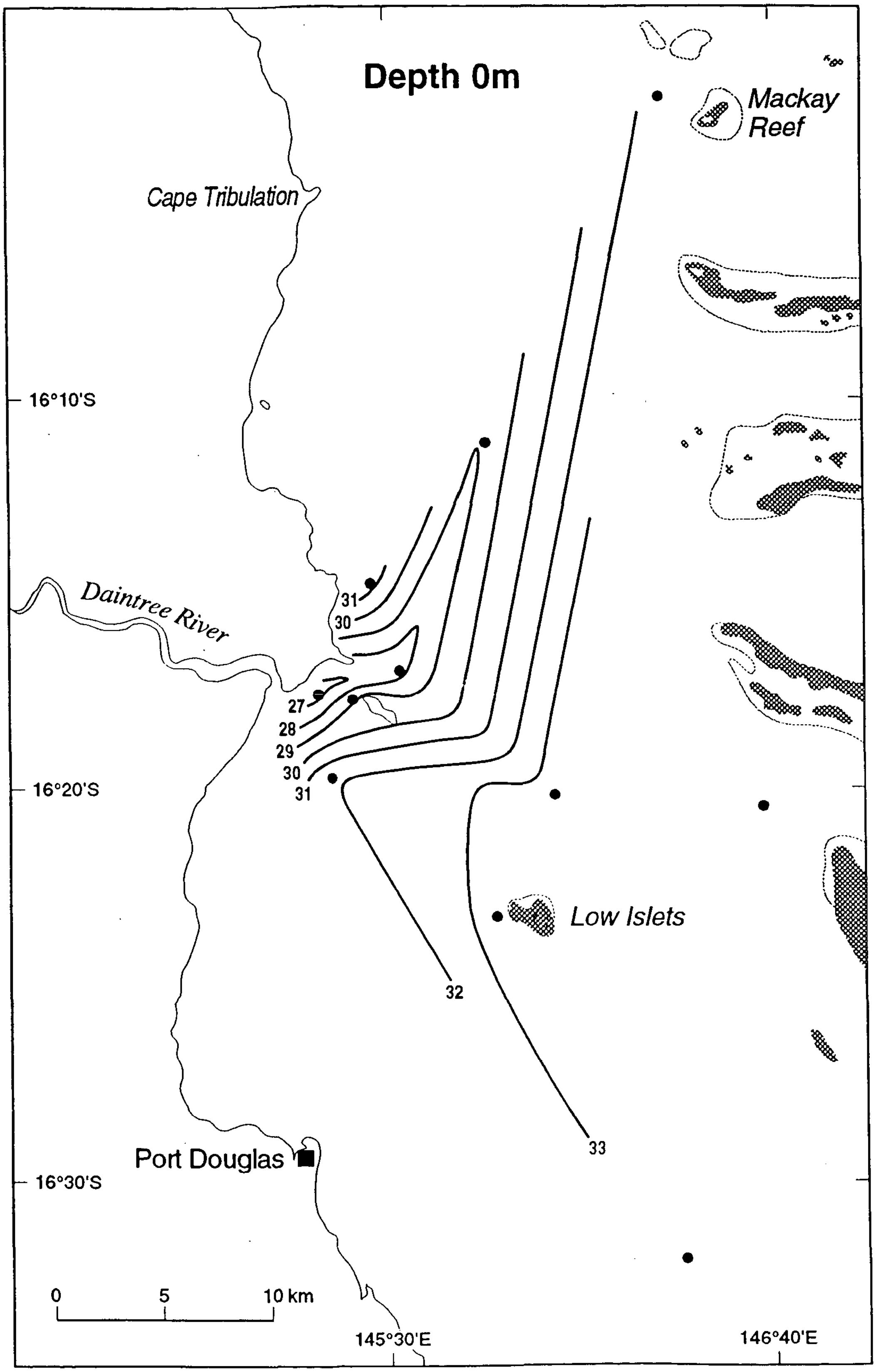

Fig. 5. Horizontal distribution of the sea surface salinity (‰) in the area between Cape Tribulation and Port Douglas after the heavy rainfall in late February, 1994.

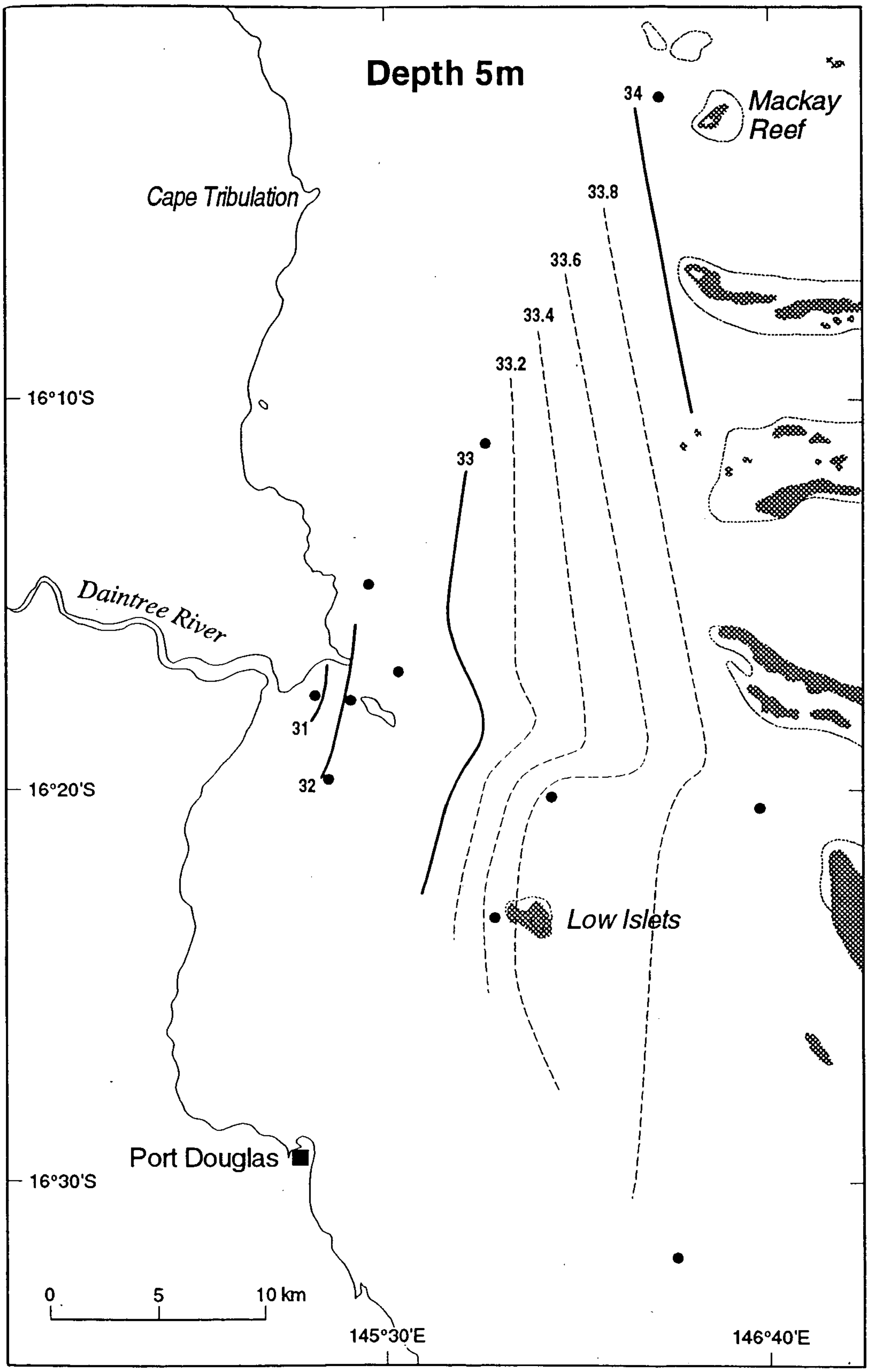

Fig. 6. Horizontal distribution of salinity (‰) at 5 m depth in the area between Cape Tribulation and Port Douglas after the heavy rainfall in late February, 1994.

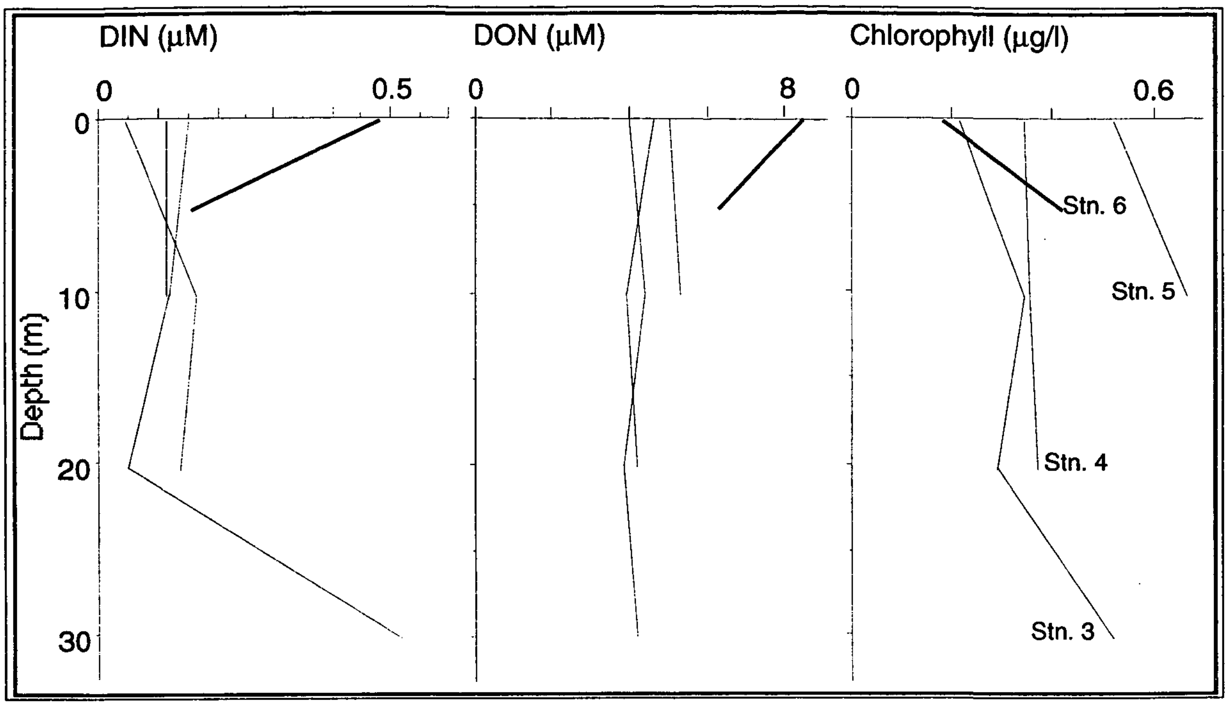

Fig. 7. Vertical distributions of dissolved inorganic (DIN) and organic nitrogens (DON) and chlorophyll in the Daintree River plume (station 6; bold) and its vicinity

concentration in the plume was relatively low, probably because of the short lapse after its formation and the limited light available to phytoplankton (high turbidity).

The observed river plume had a very thin vertical structure and might be dissipated fairly quickly through vertical mixing. The amount of nutrients and sediments carried offshore by the plume, because of its ephemeral nature, can not be estimated unless the plume is properly modelled and the model is verified against more field data. Yet, this study suggests a possibility that flood plumes can constitute an important mechanism for the cross shelf transport of nutrients and sediments in the study area.

Caveat

Riverine nutrient inputs into GBR shelf waters have significantly increased through decades of coastal development and a range of agricultural practices (Moss et al. 1992). This has raised concern over the effect of eutrophication on the health of GBR. Furthermore, it has been argued that eutrophication of GBR shelf waters may have a significant consequence on the growth and survival of the larvae of crown-of-thorns starfish and hence the dynamics of their adult populations (Bell 1992; Ayukai 1993). The results of field and modelling studies (Wolanski and van Senden 1983; King and Wolanski 1992; this study) suggest that there may be places, where the cross shelf transport of nutrients is locally enhanced through characteristic geographic features and urge the need for such concern being carefully dealt with in the local/regional context.

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