Nutrient distribution in the Barron River and offshore during cyclone Sadie

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Abstract

Following intensive rainfall associated with ex-tropical cyclone Sadie runoff from the Barron River catchment produced flooding in the lower reaches and an extensive plume offshore. Rainfall recorded at Cairns between 30 January and 1 February, 1994 was 627 mm. Significant fluvial discharge assisted by light northerly winds enabled the plume to extend to the mid-shelf reefs. Water quality was monitored throughout the flood event in the Barron River and offshore to the plume edge. Data display a rapid change for all parameters collected (Conductivity, suspended solids, temperature and total nutrients) along the lower reaches of the River. Elevated levels of particulate nutrients were evident within 5 km of the coast with an increased dissolved organic component further offshore. Timing of sampling is important as the plume had moved 15-20 km prior to sampling. Data show a significant decrease in concentration between sampling periods of 2 and 4 February.

Introduction

Coastal water quality in the Cairns region is inferred to have altered from 'natural' levels due to mainland runoff from the anthropogenically altered coastal catchments (Moss et al. 1992; Rasmussen 1994). In this region the continental shelf is relatively narrow (ca. 40 km), which influences the proximity of coral reefs to the mainland (ca. 25 km) and hence serves as an important location for study due to the influence of terrigenous runoff following flood events (Hopley 1982).

There are many references to show that the major proportion of the annual fluvial sediment and nutrient load can be transported during flood events (Schubel 1971; Cullen et al. 1978; Hart et al. 1988; Cosser 1989; Furnas 1995). Hart also noted that the situation may be 'more pronounced in tropical regions' due to the distinct wet season that is characterised by a predominance of rainfall over short periods of time. Recent research (Brodie and Mitchell 1992) has confirmed that increased nutrient levels may be apparent in coastal waters following the first flush after an extended dry period. Therefore, to facilitate reasonable estimates of fluvial sediment and nutrient input to the Great Barrier Reef Lagoon, sampling has focussed on these flood events.

Data collection during periods of high fluvial discharge in this region are made difficult by the adverse conditions associated with such events, and by the relatively unpredictable spatial and temporal nature of individual events. Inability to plan a research program around such events has meant that data collection and results have often been patchy. The establishment of a core group of researchers in the area, and the coordination of sampling programs at a number of locations on various rivers, has lead to a significant increase in the amount of data now available.

A rain depression following cyclone Sadie produced significant rainfall along the northern wet tropical coast and provided the opportunity for the research group to simultaneously sample various rivers. This paper presents data collected in the Barron River and offshore area before and after the rain event associated with cyclone Sadie (28 January to 5 February 1994) and provides an assessment of the nutrient dynamics that occur during a flood event.

Study Details

Cairns is located in the wet tropics. The region is characterised by marked seasonality in the rainfall with 75% falling in the monsoon period between December and April (Hausler, 1990). Cyclone Sadie, after crossing the Carpenteria Gulf coast, weakened into a rain depression and produced extensive rainfall on the east coast between Townsville and Cooktown. This was accompanied by light north-east winds which assisted in the development of expansive river plumes. Rainfall was most intense on the coastal fringe, with Cairns receiving 627mm between 30 January and 1 February (Fig. 1). This represents almost one third of the average annual Cairns rainfall in three days. The extent of the plume was mapped on 1 February by aerial surveillance in order to establish suitable offshore sampling sites. Sampling was conducted on 2 and 4 February. The extent of the plume and sample locations are shown in Fig. 2.

Water samples (suspended solids, total and dissolved nutrients) and physico-chemical measurements (salinity/conductivity and temperature) were collected in the Barron River and up to 5 km offshore from the mouth prior to the flood event. Physico-chemical parameters were measured in situ at approximately 30 cm below the water surface using a calibrated TPS 90 FL fieldmeter attached to a weighted tripod. Water samples were also collected at this depth by pumping samples using a diaphragm pump. Samples were filtered in the field or stored in 1 L polyethylene bottles on ice and in the dark if sample integrity was likely to be compromised by filtering on site. Water samples for dissolved nutrient analyses were vacuum filtered through 0.45 μm cellulose acetate filter papers and stored frozen in polypropylene tubes prior to analysis. A known volume of water was vacuum filtered through pre-weighed GF/F glass fibre filters for suspended solid concentration.

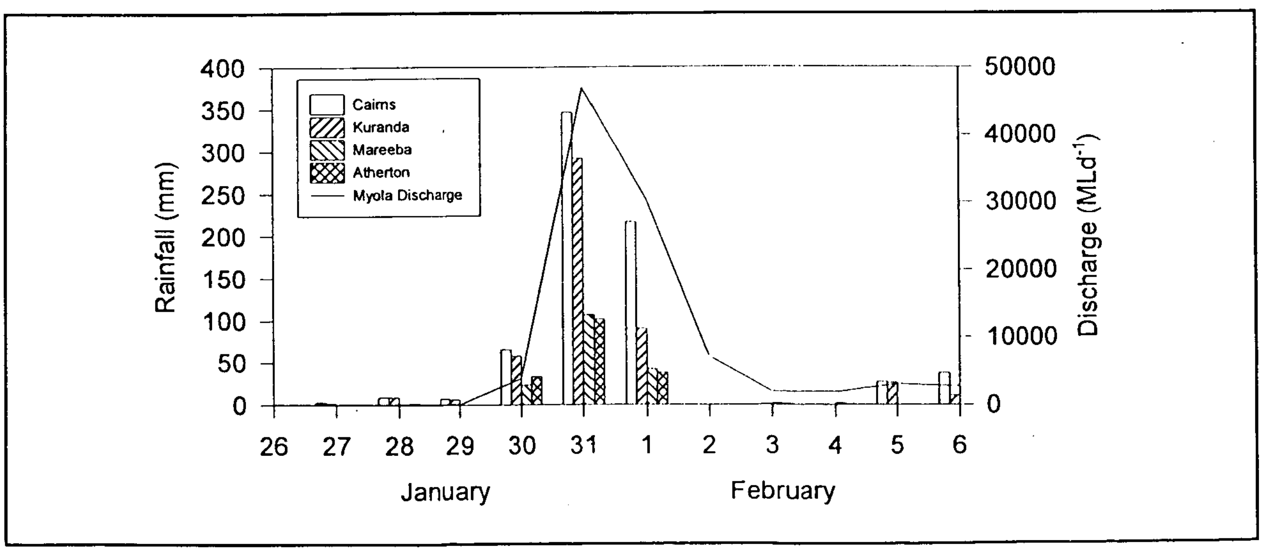

Fig. 1. Rainfall and river discharge in the Barron River catchment.

Water samples from the plume were collected at six sites on 2 and 4 February from 30 cm, 2 m and 10 m below the water surface (if site depth was < 10 m the sample was collected from 1 m above the substrate). An additional site was sampled on the first day on either side of the estimated plume front. A further six sites within 5 km of the mouths of the Barron River and Thomatis Creek were sampled at the surface and near bottom for the same parameters. Filtering of all samples for the

plume monitoring study was completed after returning to port and accomplished within 10 hours of sampling.

Results

Prior to the onset of rain, water samples were collected in the river and offshore from the mouth of the Barron River at sites A, B, C and BR 4-1,2 & 3 (Fig. 2). Site A represents a freshwater section of the Barron River while B is a mid estuary site, and C lower estuary. Sampling continued at these locations throughout the rain event and summary time series plots of the data collected is presented in Fig. 3.

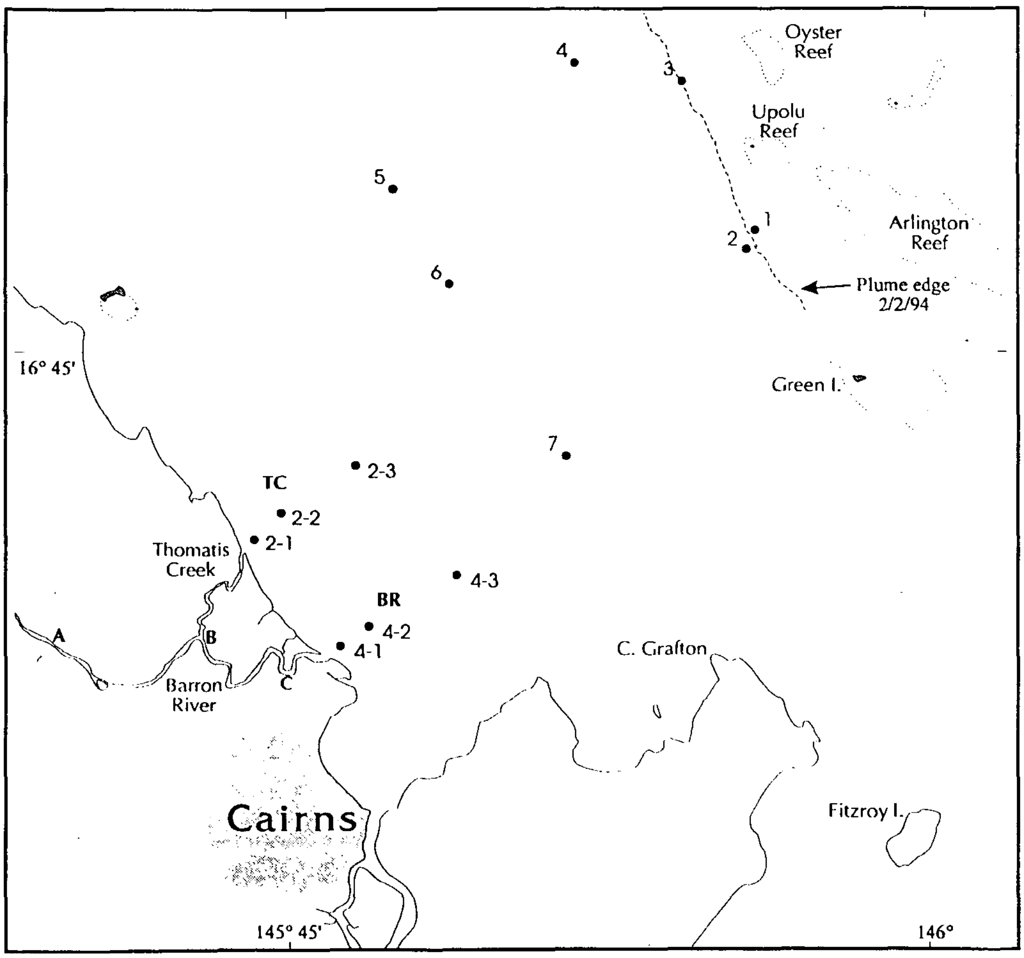

Fig. 2. Plume extent (2 February) and sampling locations

Mapping the extent of the plume was conducted by aerial surveillance to establish sampling locations. On 1 February the plume had reached 15-20 km from the mouth of the Barron River and was moving in a north easterly direction. While the rainfall was intense on the coastal fringe there was no official flooding recorded (Bureau of Meteorology pers. comm.) and the light winds and neap tides allowed the water discharged from the Barron to extend to the mid shelf reefs within a few days.

Summary graphs (Figs. 4-7) are provided to demonstrate the spatial and temporal variability of nutrient partitioning that was experienced during this seasonal runoff event.

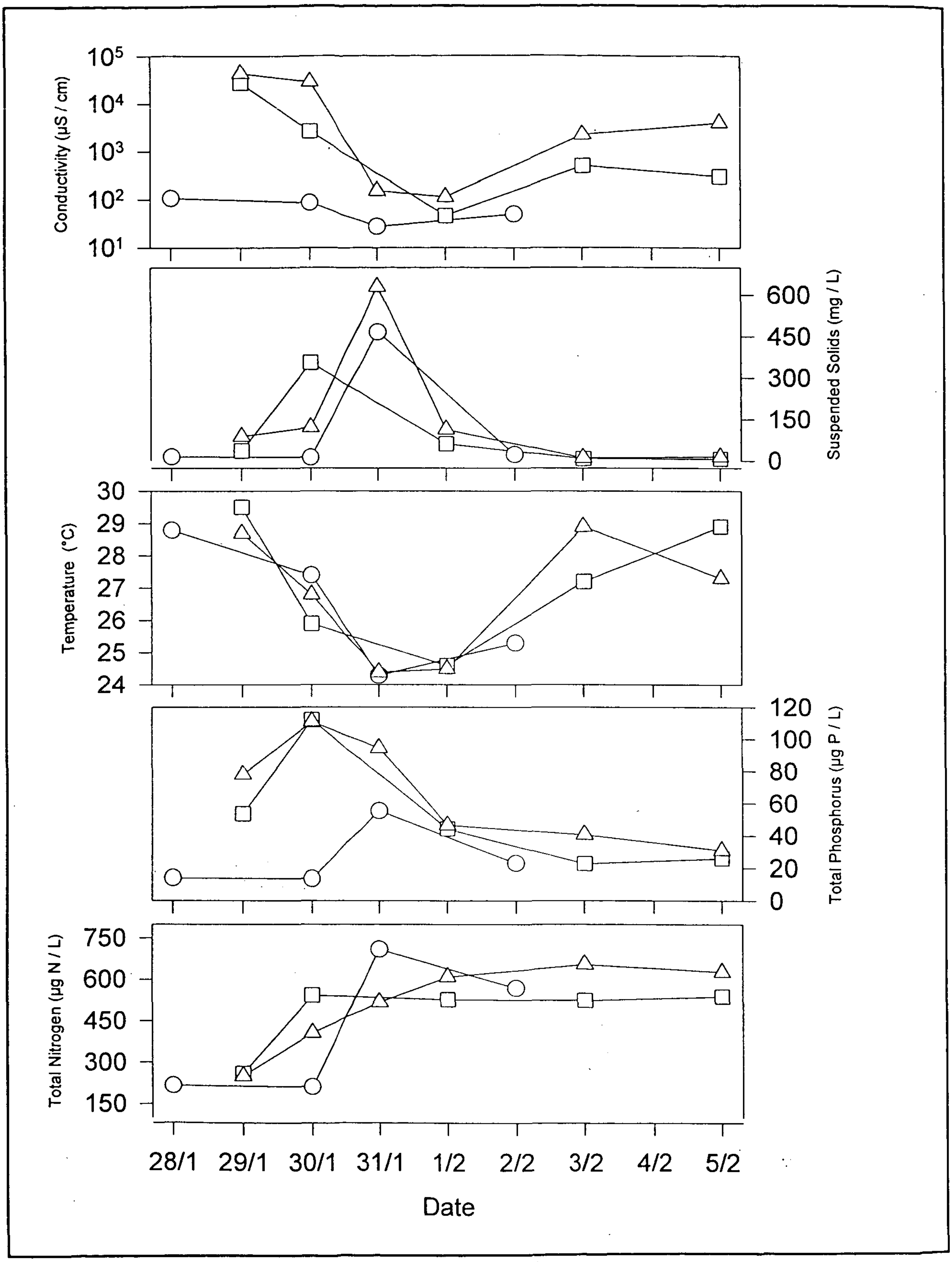

Fig. 3. Time series plots of conductivity, suspended solids, temperature, total phosphorus and total nitrogen at 3 river sample locations (Site A = O; B = □; C =Δ)

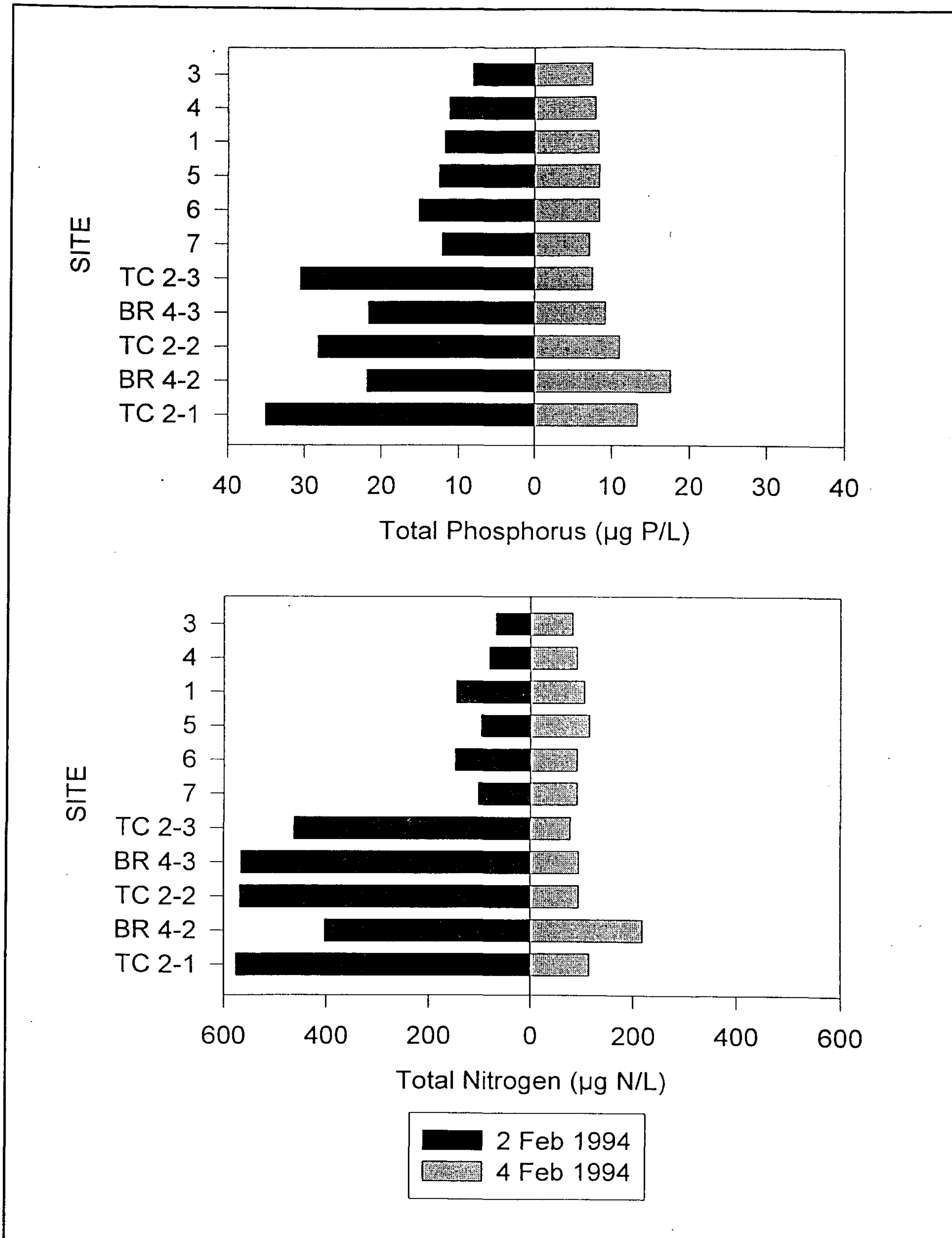

Fig. 4. Surface total phosphorus and total nitrogen concentrations

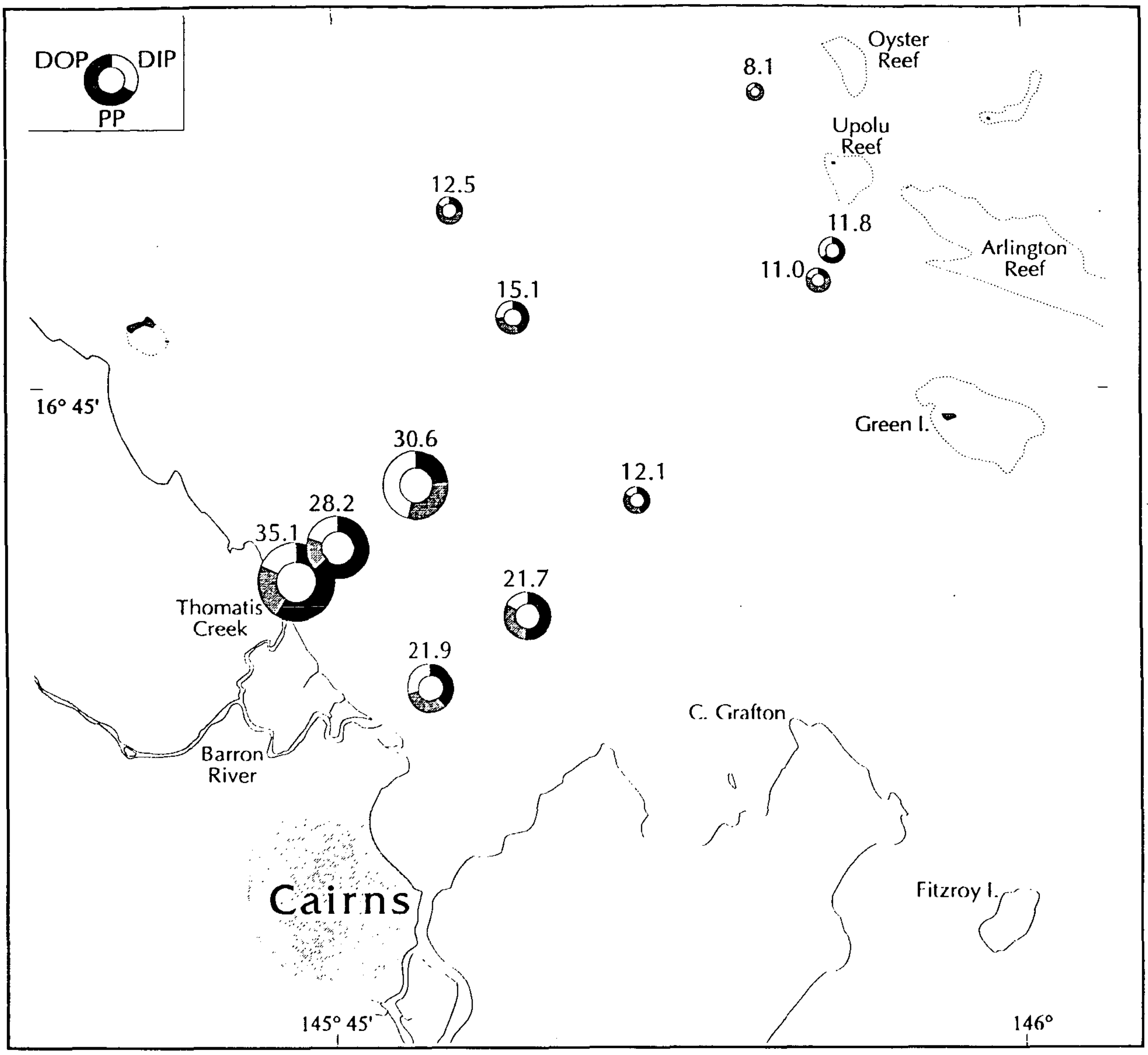

Fig. 5. Phosphorus partitioning of surface samples on 2 February. Values indicate total phosphorus concentration (μg P/L)

Discussion

There are clear spatial and temporal differences along the Barron River due to the freshwater runoff. It can be clearly seen that for site A there is a slight drop in conductivity, but 3 orders of magnitude difference at the mid estuary site, B. Suspended solids peak with the highest rainfall and subsequent runoff, with B peaking on the 30 January while A and C have maximum concentrations on 31 January. This is an artefact of the sampling times and lack of a sample for B on 31 January. Data collected by a current meter suggests that the flood may have peaked during the night and the highest concentrations were not sampled due to the timing of sampling. Temperature further demonstrates that the river along the entire estuary became relatively homogeneous with a fall of 4 - 5 °C during the flood peak. Total phosphorus peaks prior to maximum river discharge at sites B and C with the peak for the upstream site C occurring the next day. This can be attributed to the upstream sample being collected early in the day while the other sites were sampled later with the hydrograph still rising. Total nitrogen shows a different pattern to total phosphorus with its concentration remaining reasonably constant even after the peak discharge has passed. While dilution can be attributed to suspended solid and total phosphorus concentrations decreasing this is not the case for nitrogen and

therefore the fluvial nitrogen load will be proportionally higher than phosphorus for this event. Due to the dynamic nature of flood events and especially the rapidity of change, caution needs to be given to interpreting results. Many factors need to be considered, for example, timing of sampling is critical but often has to be compromised because of financial and logistical constraints.

The highest concentrations of suspended sediment and nutrients are located near the mouth of the Barron River and Thomatis Creek. Depth-weighted mean water values for the Cairns area have been estimated as TP ca. 10 µg P/L; TN ca. 115 µg N/L (Furnas 1990; Furnas et al. 1995). Data collected shows that the total phosphorus and nitrogen concentrations are elevated in the area up to 5 km offshore on 2 February with values returning to mean background levels two days later. Total phosphorus displays some evidence of slightly elevated concentrations at the other sampling locations, closer to the reef also on the first sampling day.

The distribution of the plume over a much wider area may act to dilute the nutrients and suspended sediment rather than concentrate them if the plume was more constrained in area. This data demonstrates the need to understand the timing of sampling with respect to the plume's life as elevated concentrations may be short lived in the water column.

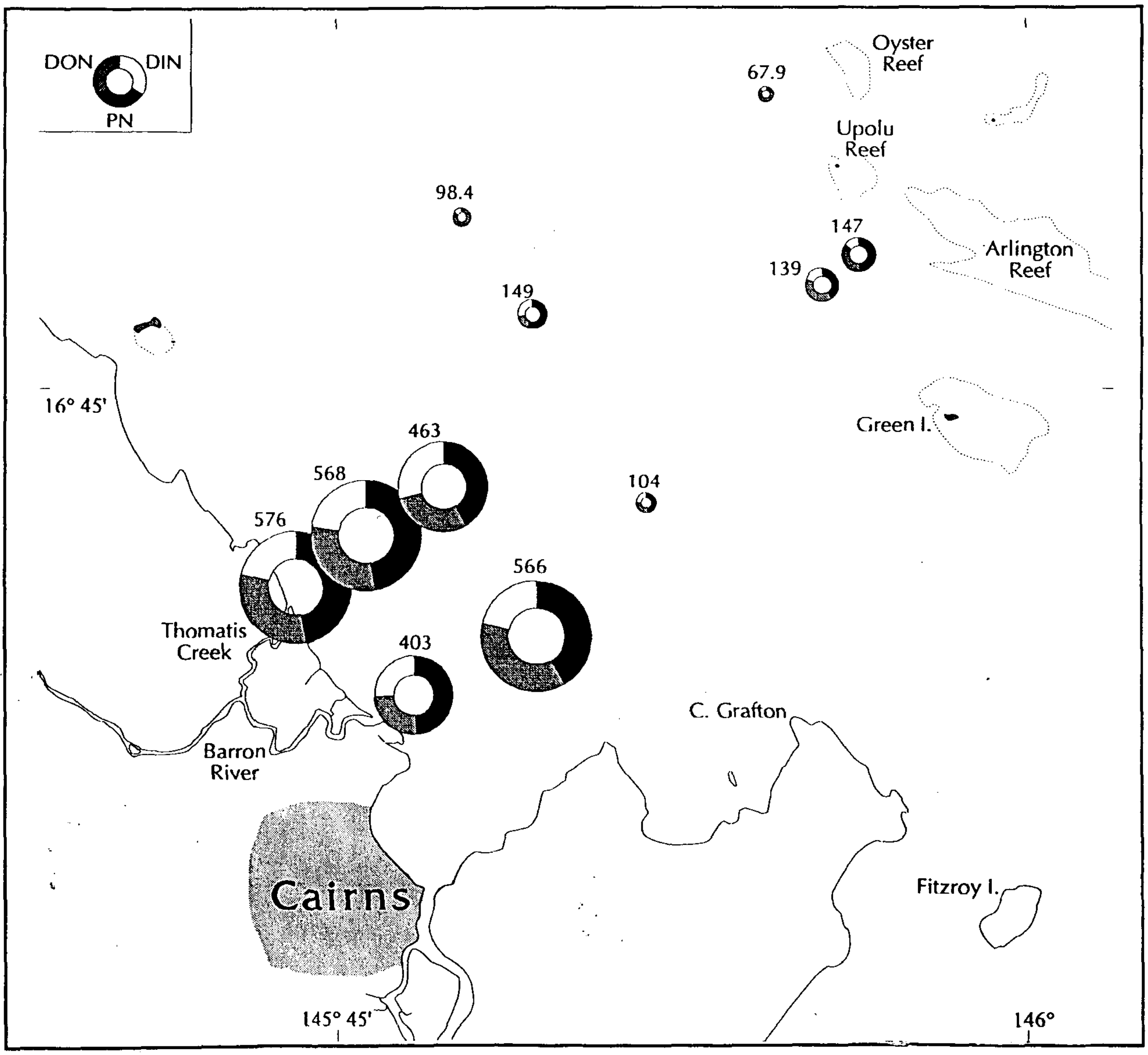

Fig. 6. Nitrogen partitioning of surface samples on 2 February. Values indicate total nitrogen concentration (µg N/L)

The partitioning of nutrients is generally dominated by particulate and dissolved organic forms for both nitrogen and phosphorus. The particulate material is slightly higher in proportion within 5 km of the coast, with the material further offshore generally having an increased dissolved organic component. The timing of sampling should be noted as the plume front had moved 15 - 20 km offshore on 1 February when the plume was mapped.

However, this data agrees with other observations which display dissolved organic and particulate nutrients as the dominant fractions after a cyclonic event (Furnas 1990). The Barron River has not had a major flood since 1979 so extrapolation needs to be conducted with some caution as each event can be unique.

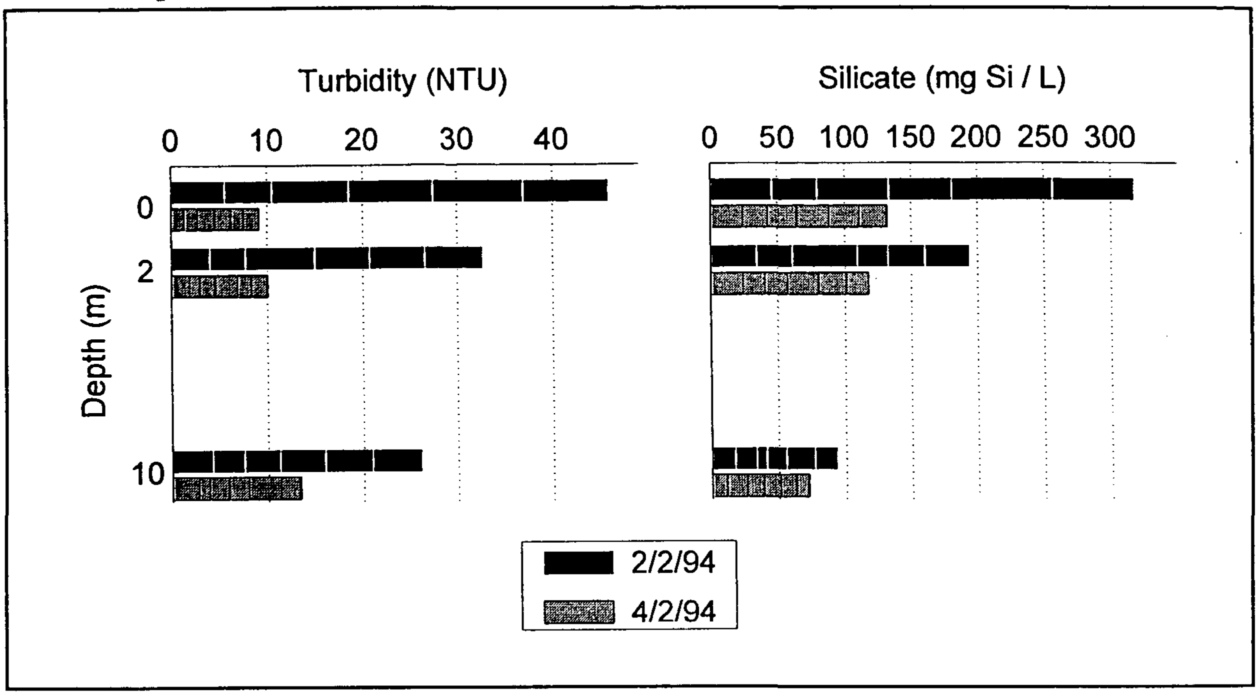

Fig. 7. Turbidity and silica temporal variability with depth. Bars are cumulative for Sites 1, 3-7.

Due to the unpredictable timing and location of these seasonal flushing events it is difficult to plan sampling strategies, and sampling is often opportunistic in nature. Timing of sampling is critical to understanding the dynamics of nutrient and suspended material movement during flood events. Also as important is the depth to which these concentrations persist as this will provide a volume estimate as to the amount of material transported. Grouping all the plume study sites that were collected on 2 and 4 February shows a marked change both temporally, as has been seen for nitrogen and phosphorus, but also spatially. The general water mass has elevated turbidities and silicate concentrations on 2 February compared to 4 Febraury for all depths sampled. However, there is a different relationship with depth that is observed between turbidity and silicate on the second day of sampling. While silicate is reduced at all depths there is an increase in turbidity with depth. While there could be a number of explanations for this, the most likely would be material settling from the water column.

A more concerted effort to understand the dynamics of nutrients associated with these events has meant that a greater wealth of information is now becoming available. Future work on these events should concentrate on understanding the partitioning of nutrients and their transformation on a more intensive time scale. Data is needed before, during and after the peak of the plume discharge period for these runoff events to fully understand the processes operating.

Despite time limitations, this small study has led to some interesting conclusions about the fate of dissolved nutrients in a freshwater plume. Generally the concentrations of dissolved nutrients (Table 2) and phytoplankton (Table 3) in the cyclone Sadie plume were higher than non-flood periods with

high variability between sites and position in the water column. The variability between sites may be related to catchment characteristics and the specific upstream activities connected with each catchment. The low concentrations of some dissolved species in the plume indicates that the uptake of the dissolved nutrients by the phytoplankton may have occurred within a relatively short time.

Clearer resolution of flood waters effects in the GBR lagoon would involve increased sampling of all dissolved and particulate nutrient species and the initiation of sampling as close as possible to the start of the flood event. The successful monitoring of any large flood event could only be improved by rapid and intensive sampling techniques and greater awareness of the individual characteristics of each catchment.

Acknowledgments

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