Export of nutrients and suspended sediment from the Herbert river catchment during a flood event associated with cyclone Sadie

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Abstract

Intense rainfall associated with the passage of cyclone Sadie in January 1994, led to flooding of the Herbert River catchment. Dynamic changes in the nutrient and suspended sediment concentrations were monitored over the course of the flood via sampling in the Herbert River by two agencies, the Australian Institute of Marine Science and the Commonwealth Scientific and Industrial Research Organisation. Estimates of nitrogen, phosphorus and suspended sediment export during this event were made using the combined results.

Introduction

Tropical regions of north Queensland are subject to high intensity rainfall events during the wet season, often associated with cyclones (Sumner and Bonnel 1986), which may result in rapid flooding in river catchments. Leaching and runoff associated with these flood events leads to large fluxes of nutrient and sediment to the coastal zone.

Within the Herbert River catchment, rainfall from cyclone Sadie was concentrated in the coastal plain, with highest falls recorded at Dalrymple Creek and Stone River (Fig. 1). A large, though unresolved proportion of the Herbert catchment rainfall discharged through the Cattle Creek system to the south of the main Herbert River channel, due to overflow from the Stone River. In this paper, we summarise the work of two agencies, the Australian Institute of Marine Science (AIMS) and the Commonwealth Scientific and Industrial Research Organisation (CSIRO), to estimate the output flux from the Herbert River catchment following the passage of cyclone Sadie in January 1994. This study is reported in more detail in Mitchell et al. (in press).

Background to sampling program

Water-borne nutrients and sediments within the lower catchment of the Herbert River are presently being sampled by three research agencies, AIMS, CSIRO (Townsville) and the Bureau of Sugar Experimental Stations (BSES, Ingham). The collaborative sampling program of AIMS/BSES, is primarily concerned with assessing riverine export of nutrients and suspended sediment (Furnas et al. 1995), while the broader CSIRO program seeks to resolve the major source areas for nutrients and

sediments leaving the catchment (Bramley et al. 1994; Bramley and Johnson 1996). This paper refers to one of the sampling sites that is common to both programs, John Row Bridge at Ingham.

Flood sampling

Sampling opportunities throughout the catchment during the Sadie flood were restricted due to flooding of access roads. The John Row Bridge remained the only site accessible during peak flow. Time series sampling at this site commenced 13 hours after the initial rise in river discharge, 10 hours before the flood peak. Independent concurrent sampling was made by both AIMS and CSIRO personnel through the course of this flood event, resulting in two overlapping sample sets. Sampling at other catchment sites in the course of this flood and other temporal sampling, before this event and through a subsequent flood event, three weeks after the Sadie flood are described in Mitchell et al. (in press).

There were small differences in sampling and analytical methodologies between the two organisations (Furnas et al. 1995; USEPA 1984; Mitchell et al. in press). Water discharge in the Herbert River was monitored at a flow gauging station (116001E), located immediately upstream of the John Row Bridge (Department of Primary Industries, Water Resources, Mareeba).

Nutrient dynamics through the flood

At the time flood sampling commenced, concentrations of dissolved inorganic nitrogen (DIN = nitrate + nitrite + ammonia) were declining, and fell to a minimum (ca. 100 $\mu g\ L^{-1}$) around the flood peak, but thereafter recovered (ca. 350 $\mu g\ L^{-1}$) with falling discharge (Fig. 2a). Concentrations of orthophosphate (PO_4) similarly declined to a minimum near peak flow (12 $\mu g\ L^{-1}$), recovered slightly in the falling stages of the flood, then declined to very low (1 $\mu g\ L^{-1}$) levels (Fig. 2b). DON (dissolved organic nitrogen) concentrations were relatively constant through the flood, around 200-300 $\mu g\ L^{-1}$ (Fig. 2c). Measured DOP (dissolved organic phosphorus) concentrations differed considerably between the two agencies (Fig. 2d), with the AIMS results suggesting decline around the peak of discharge but CSIRO data suggesting an increase. Concentrations of both particulate nitrogen (PN) and phosphorus (PP) increased with rising discharge to maximum levels (1200 μg PN, 225 μg PP L^{-1}) at the flood peak, but declined rapidly thereafter to low levels (250 μg PN, 30 μg PP L^{-1}) with falling discharge.

Concentrations of suspended sediment exhibited a similar pattern to PN and PP, with a maximum at the flood peak (Mitchell et al. in press). Measures of silicate and potassium concentrations, pH and electrical conductivity, exhibited inverse relationships with discharge during the course of the Sadie flood. Good correlations were found between the sample determinations of AIMS and CSIRO for DIN, PO_4, PN and PP. Higher concentrations of DON and especially DOP were determined in the CSIRO analyses.

Discussion of dynamic behaviour

The cyclone Sadie flood event was the first major flush of the Herbert River catchment in the 1993/94 wet season. The first flush of the year is typically characterised by elevated concentrations of dissolved inorganic nutrients and to a lesser extent, particulate forms, a phenomenon well documented in both temperate rivers (e.g. Walling and Foster 1978; Webb and Walling 1985; Anon 1987) and tropical rivers (e.g. Lewis 1986; Mitchell and Furnas 1994; Mitchell et al. 1996). Soluble and readily erodable particulate material accumulated within the catchment over the dry season is transported to the river by leaching and surface runoff, raising river-water concentrations during early wet-season discharges. In the Herbert River, briefly elevated nutrient concentrations were observed two weeks prior to the Sadie flood, during a very small flow event (Mitchell et al. in press).

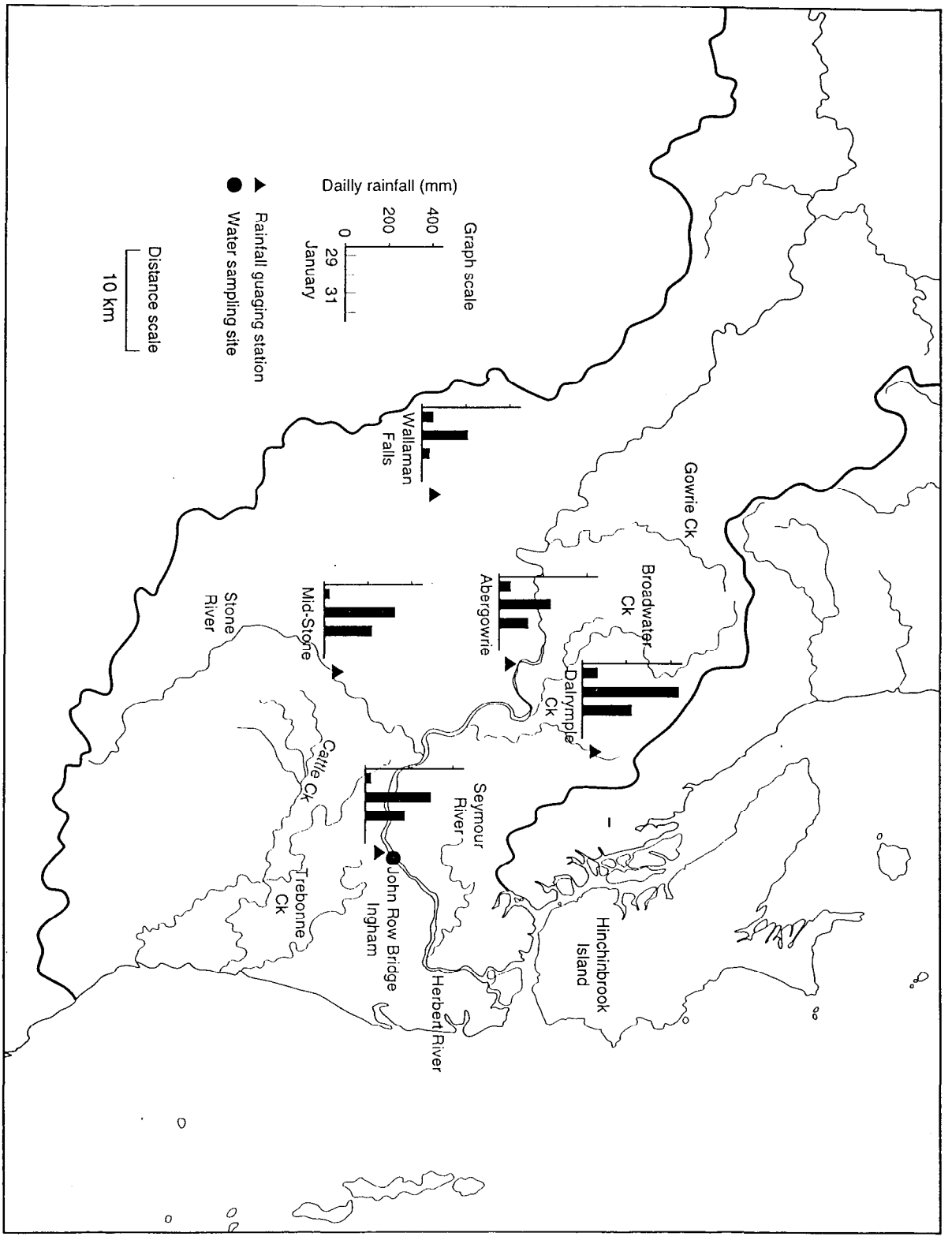

Fig. 1. Lower catchment of Herbert River. Sampling station at John Row Bridge, Ingham shown as filled circle. Rainfall measurement stations within catchment denoted by filled triangles. Daily rainfall over four days of flood shown by histograms.

Concentrations of DIN and orthophosphate were both falling at the commencement of sampling during the Sadie flood, 13 hours after the initial rise in river discharge (Fig. 2a, b). Based on high first flush concentrations previously observed in the Herbert River (Mitchell and Furnas 1996; Mitchell et al. in press), it is likely that concentrations of these dissolved nutrient forms peaked in the early stages of the flood, before sampling commenced. The decrease in concentrations of dissolved inorganic N and P to minima around the discharge peak and their subsequent recovery during falling discharge suggests dilution by the large volume of water entering the lower catchment. In contrast to DIN, orthophosphate concentrations only recovered briefly before falling off sharply, indicating that exhaustion of readily leachable stocks had occurred.

Concentrations of particulate forms (PN, PP or suspended sediments) rapidly increased with river flow (Fig. 2e, f), a result of higher levels of erosion and sediment mobilisation with increasing rainfall (Milliman and Meade 1983; Anon 1987). Particulate concentrations showed near-linear relationships with discharge, though at considerably higher concentrations in the rising stage than during the falling stage of the Sadie flood hydrograph (Mitchell et al. in press). This rapid fall-off in suspended material during the flow decline probably reflects some exhaustion of readily mobilised sediment and reduced hydraulic forces with decreasing rainfall. The dynamic behaviour of dissolved organic nutrients during flood events in tropical rivers is poorly reported, though the slight elevation observed through the Sadie flood peak suggests that in addition to leaching, a degree of mobilisation by runoff processes may be operating.

Research into sources of nutrients within the lower Herbert catchment (Bramley et al. 1994; Bramley and Johnson 1996) suggest that inputs of nutrients, in particular the dissolved inorganic forms, largely arise as a result of N and P fertiliser applications to land under sugar cane. However, the contribution of these inputs to nutrient export during rainfall events is unresolved.

Export estimates

Estimates of nutrient and suspended sediment exports from the Herbert River catchment during the Sadie flood were estimated by two methods using the combined data from both AIMS and CSIRO determinations. Estimations by these methods, one applying the arithmetic average of nutrient concentrations measured during the flood to the total discharge (flood averaged) and another, applying an interpolation technique (Anon 1987) using individual sample concentrations and the instantaneous discharge for each interval period (flow-weighted; see Mitchell et al. in press for details) are compared in Table 1.

Table 1. Exports of nutrients and suspended sediments from Herbert River through course of cyclone Sadie flood from samples taken at John Row Bridge. Period used = 10 am 30th January to midnight 5th February 1994; discharge = 538 100 ML; nutrient concentrations in μg L^{-1}; suspended sediment concentrations in mg L^{-1}; exports in tonnes.

Category	DIN	DON	PN	Tot N	PO_4	DOP	PP	Tot P	SS
Flood averaged[1]									
Average conc.	*203*	*242*	*576*	*1020*	*14.9*	*6.3*	*99.7*	*120.9*	*156*
Export (t)	109	130	310	549	8.0	3.4	53.7	65.1	84 152
Flow-weighted[2]									
Export (t)	153	132	309	595	8.9	3.6	52.1	64.6	101 408

[1] Exports calculated by applying the average flood concentrations, of the combined AIMS and CSIRO determinations, to the total flood discharge.

[2] Exports calculated by interpolating sample concentrations over each inter-sample period with the instantaneous discharge for each period.

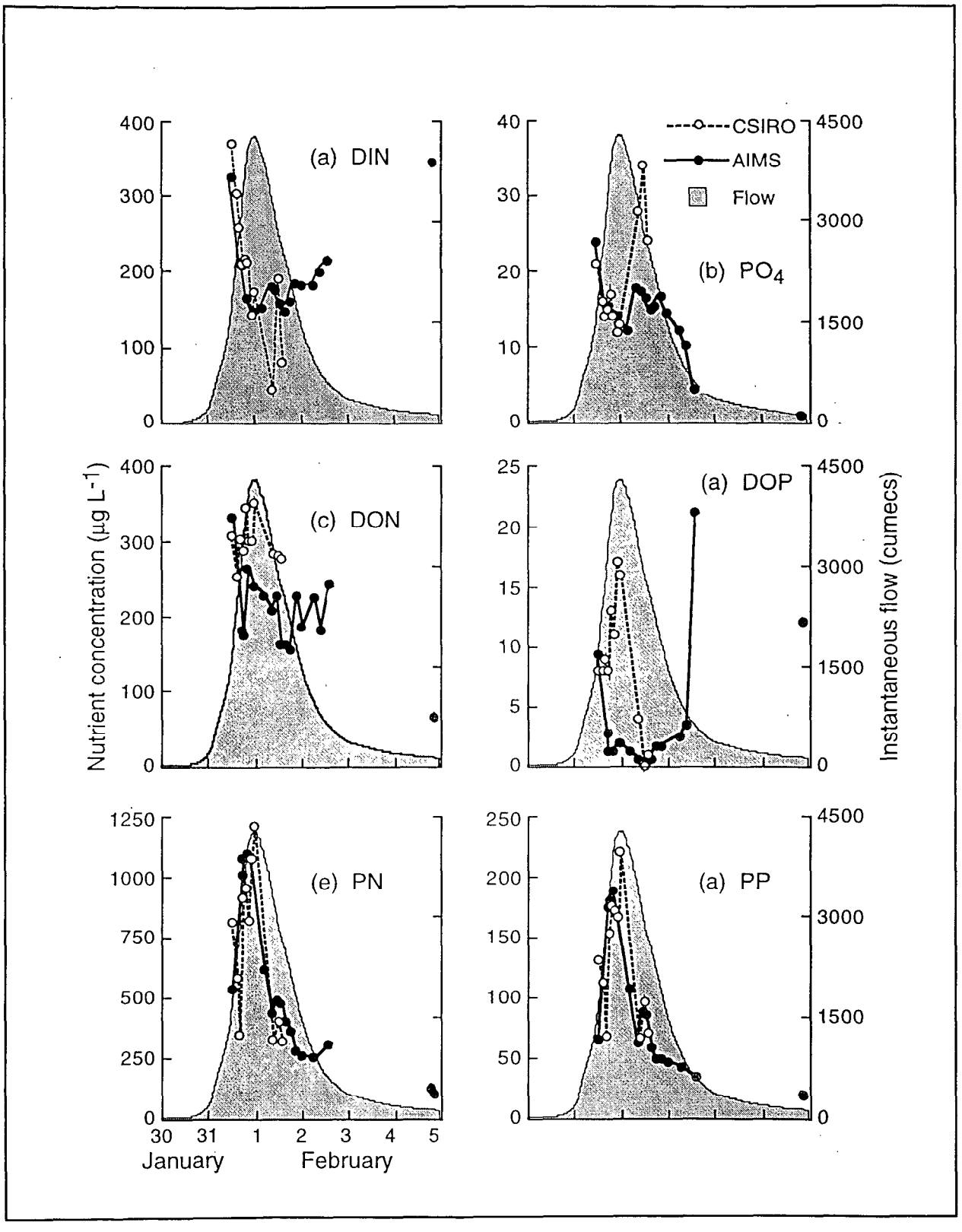

Fig. 2. Concentrations of N and P nutrient forms (µg l^{-1}) from samples taken by AIMS (closed circles) and CSIRO (open circles) at John Row Bridge on the Herbert River during the cyclone Sadie flood. Shaded area represents instantaneous flow (cumecs) measured at John Row Bridge. (a) DIN = dissolved inorganic nitrogen; (b) PO4 = orthophosphate; (c) DON = dissolved organic nitrogen; (d) DOP = dissolved organic phosphorus; (e) PON = particulate organic nitrogen; (f) POP = particulate organic phosphorus.

Similar estimates of export flux were obtained by the two procedures for most nutrient forms. The estimated export for DIN was 40% higher using the flow-weighted method, partially due to the assumption of high first-flush concentrations. Particulate forms dominated export flux, accounting for more than 50% of N and 80% of P. This finding is consistent with observations in other north Queensland rivers that suspended sediment is primarily transported during stormflow events, and that the proportion of particle-bound nutrients increases with the intensity of the flood event (Mitchell et al. 1996).

It was estimated that approximately 600 t of N and 65 t of P were discharged past the John Row Bridge site during the Sadie flood (Table 1). An estimated flux of 100 000 t of suspended sediment during this event (Mitchell et al. in press) was similar to an independent estimate using whole water-column sampling during the falling stages of this flood and a subsequent discharge event in the Herbert River (Wong 1996). A number of unresolved factors, detailed in Mitchell et al. (in press), chiefly those concerning ungauged discharge, suggest that these estimates understate the true magnitude of exports from the Herbert catchment during the Sadie flood.

Conclusions

It is estimated that flooding in the Herbert River associated with cyclone Sadie resulted in the export of at least 600 t N, 65 t P and 100 000 t suspended sediments from the catchment over a six and a half day period, with most of this (85%) occurring over just two days. Particulate fractions of N (50%) and P (80%) constituted the bulk of the nutrient flux from the Herbert River, consistent with findings in other North Queensland rivers. Combined with the simultaneous flux of neighbouring flood-affected rivers, from the Mulgrave River south to Crystal Creek, the Sadie flood event would have represented a large proportion of the annual wet season output from this region. It dramatically illustrates the episodic nature of riverine export to the GBR Marine Park.

While the contribution of agricultural fertiliser to nutrient loadings in the Herbert River is still unresolved, it is clear that the potential exists in tropical catchments for high levels of nutrient export from areas of intensive agriculture during wet season storm events such as cyclone Sadie. There is a need to better resolve the input sources of nutrients, and also to improve our understanding of the ecological impact of such large intermittent deliveries of nutrients and sediments to the coastal shelf.

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