The extent of the river plumes associated with cyclone Sadie rainfall

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Abstract

Intense rainfall associated with cyclone Sadie, falling on catchments between Cooktown and Townsville, produced major flood flows in the coastal rivers of this area. Plumes from the rivers were able to be mapped, as they dispersed into the Great Barrier Reef lagoon, using aerial observation in the calm sea and high visibility atmospheric conditions. The plumes were observed to travel as far as the matrix of the outer reefs of the GBR but were of short duration with little evidence of plume water remaining in the lagoon one week after the flood peaks.

Introduction

Key objectives of water quality studies in the Great Barrier Reef (GBR) region are to quantify the amounts of sediment and nutrients entering the GBR from the major rivers and how these have changed as a result of human use of the catchments. A third objective is to understand the spatial distribution of river plumes and the fate and importance of the entrained material with respect to nutrient budgets and cycling on the GBR shelf. In association with river estuary and GBR-lagoon bed sediment studies, work on river discharges and plumes over the last 15 years has clarified the spatial and temporal extent of influence of river discharge. The content of the plumes, in comparison to water quality in non-plume conditions, is also considerably better understood.

Opinions as to the spatial extent of terrestrial runoff across the GBR continental shelf differ (Belperio 1983; Wolanski et al. 1986; Currie and Johns 1989; Johnson and Carter 1988; Gagan et al. 1987, 1990). King and Wolanski (1992) have shown by modelling how river plumes are normally constrained close to the coast by hydrodynamic conditions generated by the prevailing south-east wind regime and Coriolis effects. Under other wind conditions however, river plumes can reach the mid- and outer-shelf reefs. It is also now clear that rivers comprise a major source of new nutrients to the GBR system (Furnas et al. 1995) equal or greater than that provided from Coral Sea upwelling, rainfall and, in the case of nitrogen, atmospheric fixation.

Results from the Burdekin River in the early 1980s (Wolanski and Jones 1981; Wolanski and van Senden 1983) and the Fitzroy & Burdekin Rivers in 1991 (Brodie and Mitchell 1992) confirm that, during flood events, plumes from the larger rivers can travel hundreds of kilometres from the river mouth and persist as recognisably distinct water masses for several weeks.

Australian rivers are known to have unusually erratic flow patterns (Harris 1995). The larger dry-catchment coastal Queensland rivers such as the Burdekin and Fitzroy are extreme in this sense with average intervals between major flows of several years. The 'wet tropics' rivers, on the other hand,

although also displaying highly event driven discharge, display a more even discharge pattern with one or more major flows almost every year. This is a consequence of their location in the relatively reliable monsoon rainfall 'wet tropics' coastal region. Over the last decade, with regular wet season plumes, studies of these rivers (Endeavour, Daintree, Barron, Russel-Mulgrave, Johnstone, Tully and Herbert) have allowed preliminary conclusions as to the behaviour of the plumes to be made.

The Discharge Event

Cyclone Sadie originated in the Gulf of Carpentaria and after crossing the coast moved inland in a southerly direction parallel to the east coast (Fig. 1). Short, but intense, rainfall resulted on coastal catchments with the major flows between 30 January and 2 February 1994 (Table 1). Fig. 2 show discharge hydrographs for the most downstream gauging stations on the Daintree, Barron, Mulgrave, Russell, North Johnstone, South Johnstone, Tully and Herbert Rivers during the main event period.

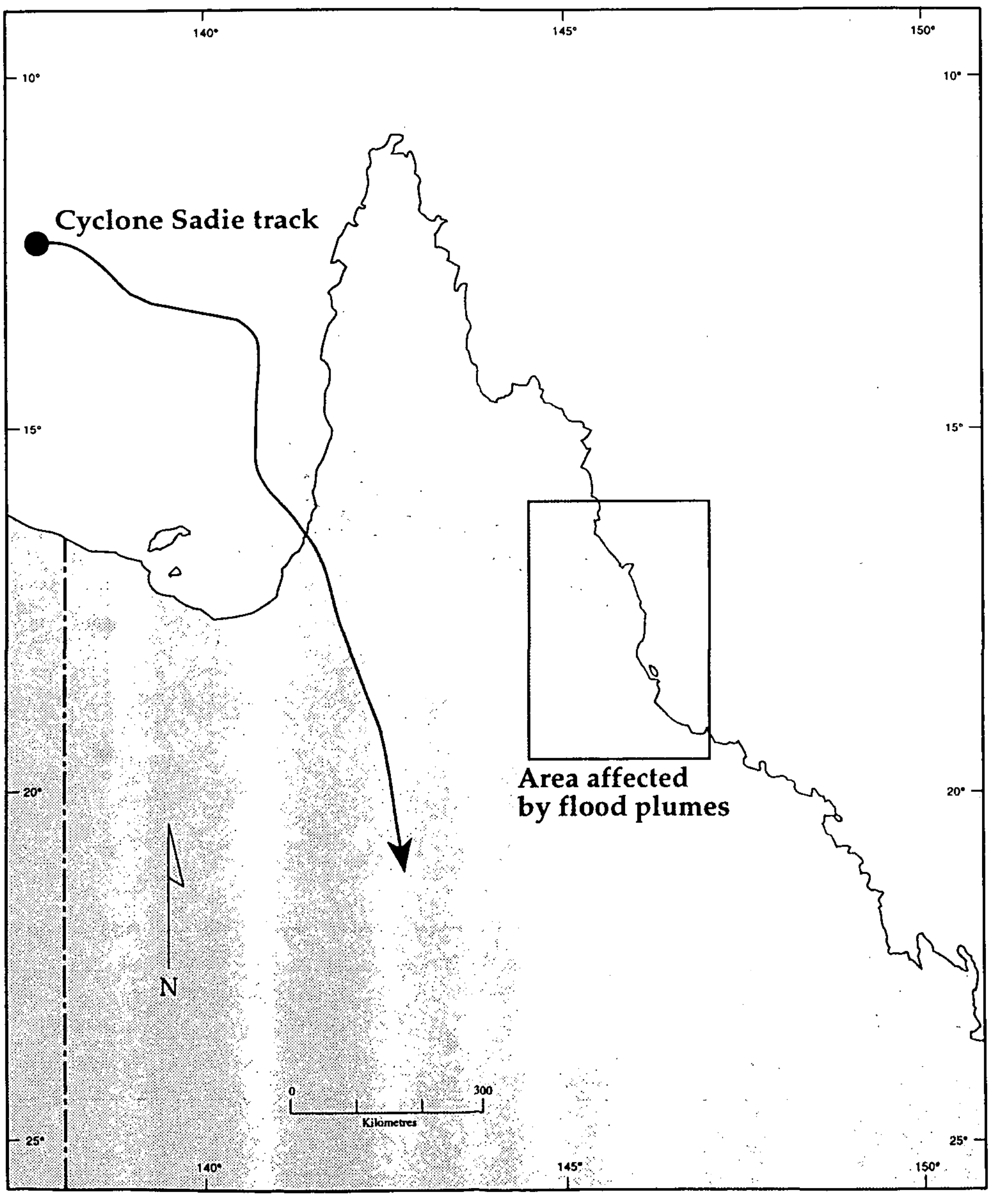

Fig. 1. Track of cyclone Sadie

The Plume

Winds offshore were slight and with no lagoonal resuspension turbidity river plumes in the period 31 January to 4 February were easily able to be mapped (Fig. 3). The plume was observed from the air on 2 and 3 February and the edge plotted using GPS positioning. Plumes originating from rivers from the Black River in the south to the Daintree in the north formed a continuous plume on 3 February (Fig. 3). The combined plume reached the outer-shelf near Noreaster Reef.

Table 1. Daily rainfall (mm) recorded at stations on coastal catchments during the passage of cyclone Sadie (26 Jan.-5 Feb. 1994). Superscripts denote the total rainfall over that number of days

Catchment & gauging stations	26/1	27/1	28/1	29/1	30/1	31/1	1/2	2/2	3/2	4/2	5/2
Mossman/Daintree											
Mossman	0.8	1.2	11	14.6	92.8	207	27	1.8	16.8	16.6	11.8
Daintree	0	23	34	67	226	73	0	0	0	0	21
Cape Tribulation	7	23	32	34	67	226	73	0	0	0	21
Barron											
Atherton	0	0.2	2	0	33	101	38	0	1	1	1
Mareeba	0	0	2	0		137	38	0	23	0	
Kuranda	0	2	9	6	57	291	90	0	1	0	26
Russell/Mulgrave											
Gordonvale		2^{2}	4			447^{3}	163	0	0	0	
Mount Sophia	0	8	49	15	99	381	209	0	0	0	0
Babinda		16^{2}	49	11	128	336	295	0	0	0	0
Johnstone											
Malanda	0	2	7	2		164^{2}	48	0	19	0	
Millaa Millaa	0	16	27	3	60	128	32	9		0	4
Crawford's lookout	1	40	7	12	123	472	41	0	2	0	23
Corsis	7	58	13	12	157	464	68	31	1	2	18
Mena Vale	1	26	26	36	161	323	74	37	5	2	5
Innisfail	4	8	19	28	158	264	226	0	2	1	2
Tully											
Kareeya		15^{2}	13			230^{3}	27	1	6	0	
Cardstone	4	7	21	4	85	193	37	1	3	0	6
Koombooloomba Dam	2	12	28	3	58	180	34	0	0	0	8
Tully	0	30	33	50	159	394	88	0	0	0	9
Herbert											
Mount Garnet	0	0	0	0	12	19	5	7	2	0	0
Gleneagle	0	0	0	0	13	60	4	0	0	2	0
Ravenshoe	0	0	8			103^{3}	17				29^{4}
Abergowrie	0	5	7	14	52	271	227	0	0	2	2
Ingham	3	8	9	33	21	309	216	1	15	2	1
Lucinda	0	0	2	0		149^{2}	176	17	2	2	

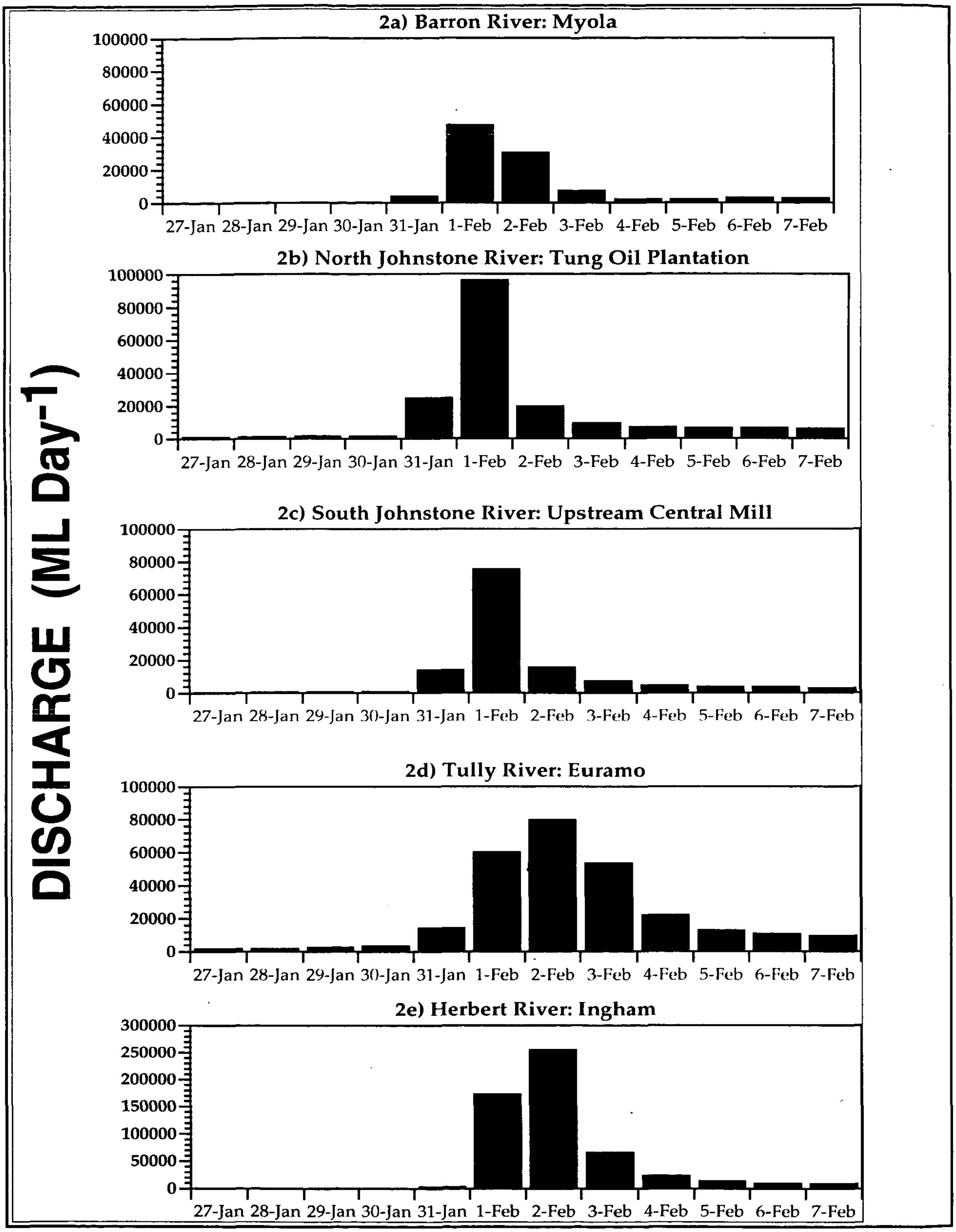

Fig. 2. Total river discharge (ML) per day from Jan 27 to Feb 7 1994 measured at the lowest gauging stations on the Barron River (a), North Johnstone R.(b), South Johnstone R. (c), Tully R. (d), and Herbert R. (e)

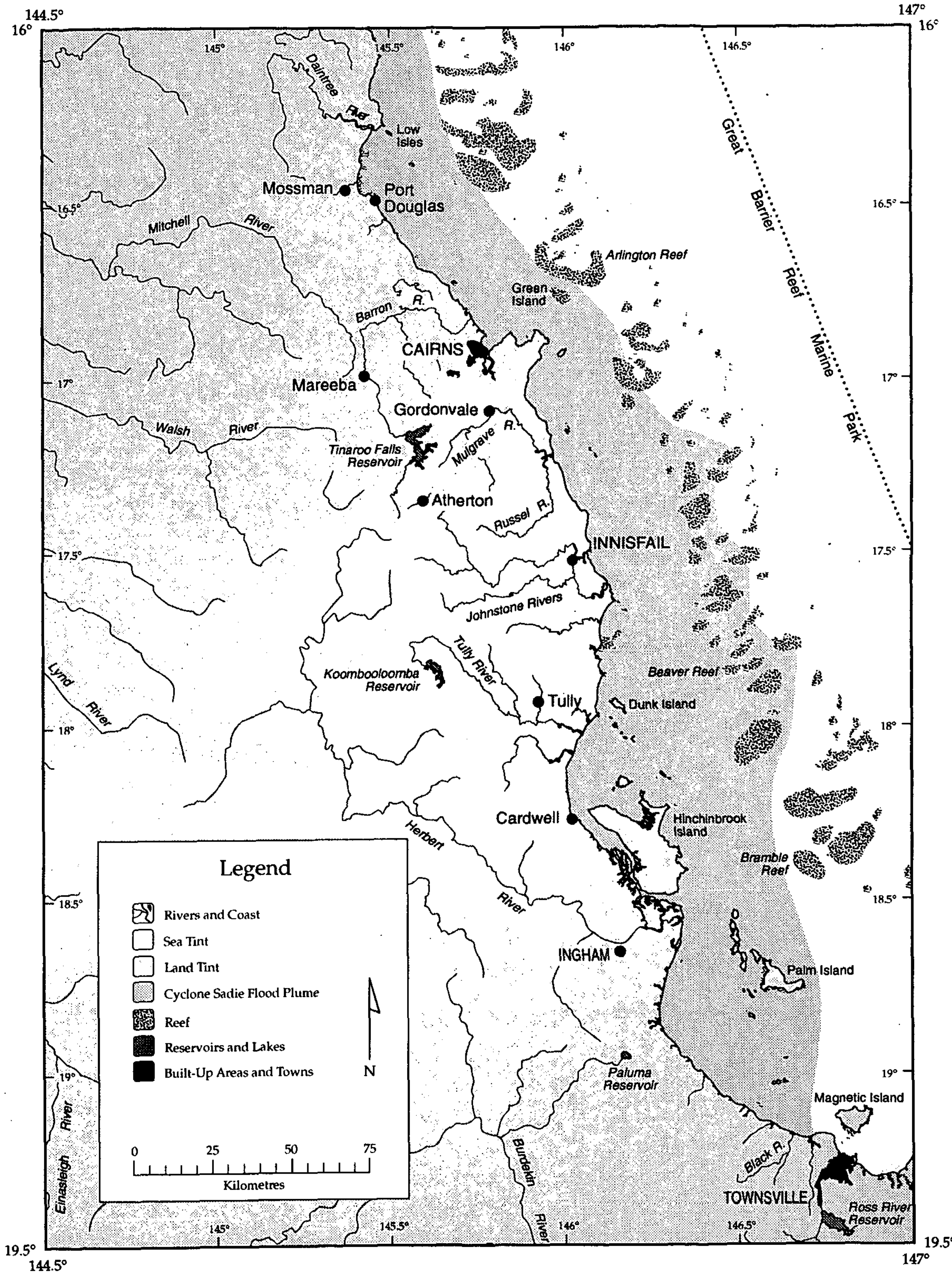

Fig. 3. Spatial extent of flood plumes recorded on 1 and 2 February 1994

Discussion

A comparison of the behaviour of coastal waters in the Townsville - Cooktown region during cyclones Winifred and Sadie reveals some of the complexities of the effects of cyclones on the water column. Cyclone Winifred originated in the Coral Sea and crossed the coast near Innisfail on 1 February 1986 (Dutton 1986). The category 3 cyclone caused substantial waves in the GBR lagoon and the resuspension of lagoon-floor sediments to a depth of 60 mm in waters up to 25 m deep (Gagan et al. 1990). It was concluded from this event that wave resuspension could be a major agent of terrestrial sediment movement across the GBR shelf, but that river plumes from the wet tropics rivers were unlikely to ever reach the mid- and outer-shelf reefs of the GBR in this region (Gagan et al. 1987). Large river flows resulted from the associated rain on the catchments, but the extent of the visible muddy river plumes was unable to be determined in the presence of wave-resuspended sediment in the lagoon. Lagoonal resuspension and river plume input of nutrients caused a phytoplankton bloom in the lagoon off the Johnstone River one to three days after the passage of the cyclone (Furnas 1989).

In contrast during cyclone Sadie, with a very light wind regime, no lagoon-floor resuspension occurred and the visible turbid water areas could be ascribed completely to river plumes. The combined plume was able to reach the outer shelf of the GBR under these conditions contradicting the conclusions drawn by Gagan et al. (1987) from the cyclone Winifred results. The plume was short-lived with little evidence of it in the water column by 6 February (Devlin 1996).

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