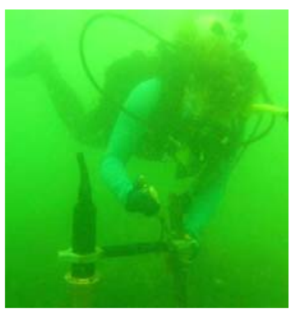
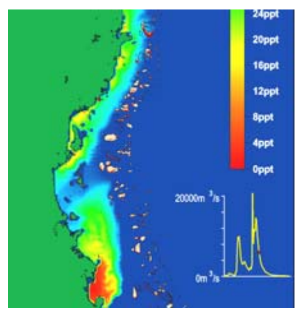
Water Quality and Ecosystem Monitoring Programme
Reef Water Quality Protection Plan

3.7.2 Ext b: Marine flood plume monitoring

Final Report 2007/08



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Contents

List of Figures and Tables

Executive Summary

This final report summarises results of monitoring activities carried out by AIMS under the joint AIMS/ACTFR Marine flood plume monitoring project under the Reef plan Marine Monitoring Program. This project is the first year of a planned longer term project to study the exposure of reef ecosystems to land-sourced pollutants and had limited aims in 2007/08 given the late start date (Mid-January, 2008).

Overall, 2007/08 was a wetter year compared to the 3 years before and to available historical total catchment discharge values. The Barron, Pioneer and especially the Burdekin and Fitzroy rivers exceeded their long-term discharge averages, whereas the Normanby, Tully and Herbert Rivers were close to average. The Russell, S-Johnstone and O'Connell rivers were below average and the Burnett River again much below its long-term average, similar to the last three dry years in this catchment. The Burdekin flood in 2007/08 was ranked 3rd largest in the river discharge record going back to 1951, while the Fitzroy flood was the 5th largest since 1964 and the most significant event since the 1990/91 flood, which is still the largest on record.

The fine sediment discharge of the Burdekin River, measured by AIMS river loggers, showed a clear 'first flush' signal in late December to early January with very high suspended solids concentrations at the first minor discharge event (Figure 3). The water discharge during the 2007/08 wet season was ~ 3 x the long-term average while the fine sediment discharge was ~ 11 x the long-term average sediment export. The discharge-weighted fine sediment export in 2007/08 was comparable to the estimate from 2004/05, while the area-weighted export was significantly larger than the estimates since beginning of Reef Plan MMP, as well as the long-term average (which does not include the 1991 flood). This indicates that major erosion has occurred during this major event in the Burdekin catchment, which led to substantial fine sediment export per area of catchment.

The application of the AIMS "King" model produced computer simulations that gave a comprehensive 3-dimensional spatial model of the fate and mixing of plume waters during the flood events in 2007/08. While the prediction of the distribution of the flood plumes of the Northern GBR rivers gave a realistic picture, the spatial patterns could not be validated because suitable geo-referenced remote sensing imagery of the flood plumes was not available at time of reporting.

As part of this project, a flood-specific analysis of chlorophyll and turbidity data from 14 existing FLNTUSB instruments deployed at inshore reefs was carried out; the instruments were deployed and maintained under the Lagoon WQ monitoring component of the Reef Plan MMP (as part of a contract between AIMS and GBRMPA). The times series obtained using FLNTU loggers delivered high-frequency, location-specific data records during the wet season, including periods where the inshore reefs were exposed to flood plumes. To bring the time series data into context, they were compared to seasonally adjusted chlorophyll Guideline Trigger Values (GBRMPA 2008) and a suggested turbidity 'threshold' of 5 NTU, beyond which corals may be severely light-limited (based on experiments with the coral species *Pocillopora damicornis* and field assessments; Cooper *et al.* 2007 and 2008).

The flood-specific analysis of the logger data indicates that chlorophyll and turbidity values at several sites exceeded the proposed thresholds. For example, chlorophyll values at Pandora Reef, Double Cone, Pine and Pelican islands were above the GBRMPA chlorophyll trigger values for more than 50% of days during the wet season (01 December 2007 to 31 March 2008). Sites with low average chlorophyll values were Russell Is., High and Pelorus Is. (<0.4 µg L^{-1}), which had values above the GBRMPA Chlorophyll trigger value on only 0-7% of the days during the wet season.

The suggested turbidity threshold was only significantly exceeded at Pelican Island in the Fitzroy Region (> 60% of the time), whereas other sites exceeded this value between 0 and 25%. Sites further away from river influence, such as Fitzroy Is., Russell Is., High Is., Pelorus Is., Pandora Reef, Double Cone Is. Barren Is. and Humpy Is. had relatively clear waters outside the periods they were directly subjected to river flood plumes, and exceeded the turbidity threshold at less than 5% of the days during the wet season. Very high values of turbidity were only reached intermittently at all sites apart from Pelican Island.

The data collected in this part of the project, together with the results of the direct flood plume sampling carried out by ACTFR under this project, will be useful for estimating exposure times and concentrations for areas of the coastal GBR or individual reefs.

If the deployment of the autonomous loggers receives continued funding under the inshore water quality monitoring of Reef Plan MMP in 2008/09 and beyond, these high-frequency, location-specific records of chlorophyll and turbidity will be available to inform future models of exposure to flood plume constituents.

Introduction

Riverine flood plumes are of significant ecological importance to the Great Barrier Reef (GBR) as river runoff is the principal carrier of eroded soil (sediment), nutrients (e.g., N, P, Si, Fe) and contaminants from the land into the coastal and inshore lagoon waters (Furnas 2003). On average, approximately 70 km^3 of freshwater is discharged each year by rivers and streams into the GBR lagoon, carrying between 10 and 15 x 10^6 tonnes of fine sediment (Furnas 2003). On a year-to-year basis, runoff volumes typically ranges within 3-fold of the long-term mean. Most of the runoff to the GBR lagoon is delivered in discrete, short-lived flood events during the 5-month summer wet season. Floodwater entering the GBR lagoon forms distinct plumes which contain diluted freshwater and enhanced concentrations of suspended sediment, nutrients and pollutant materials. The quantity of sediment and nutrients delivered to the coast by individual rivers is correlated with the annual volume of freshwater runoff (Furnas 2003), and depends on catchment size, geography, annual rainfall, rainfall intensity and land cover. The magnitude and duration of flood plumes are inherently unpredictable in space, time and frequency. The distribution of flood waters within the GBR lagoon is driven by the volume of freshwater runoff, along-shore transport and physical mixing processes (e.g. King *et al.* 2002; Devlin & Brodie 2005) which are primarily influenced by buoyancy, tidal currents and wind stress (strength and direction).

This final report summarises results of monitoring activities carried out by AIMS under the joint AIMS/ACTFR Marine flood plume monitoring project under the Reef plan Marine Monitoring Program. This project is the first year of a planned longer term project to study the exposure of reef ecosystems to land-sourced pollutants and had limited aims in 2007/08 given the late start date (Mid-January, 2008).

Key Objectives of the AIMS component of the flood plume monitoring project:

a. Quantify freshwater exports from 10 priority river into the GBR and fine sediment from two rivers, to maintain long-term series using a consistent methodology (AIMS River loggers);
b. Characterize maximum exposure levels and times of inshore coral reefs by instrumental methods, measuring short-term temporal changes of key water quality parameters at strategic locations that are influenced by flood plumes from priority rivers draining wet (Barron, Johnstone, Tully, Herbert rivers) and dry (Burdekin, Pioneer, Fitzroy rivers) catchments.

Milestones 2008/09[responsible agency identified in brackets]	
Final Report submission: Analyse and report on results of work carried out over the previous Contract period (2007/08), including: ▪ Freshwater exports from 10 priority rivers and quantification fine sediment exports from 2 priority rivers (AIMS) ▪ Flood-specific analyses of data outputs from 14 inshore reef water quality loggers from 2007-08 (AIMS) ▪ The implementation of the AIMS hydrodynamic flood plume model • Supply of DVD with MS Access database files containing all the data collected, on which reporting is derived. Available metadata and QA/QC data will be provided as documentation (MS Word, MS Excel or Adobe PDF format) or as part of the database export.	20 Sep 2008

Freshwater exports from 10 priority rivers

River discharge rate and volume data from DNRW gauging stations were provided by the regional DNRW offices in Mareeba, Tully, Ayr and Mackay. Partial time-series to March/April have been received for the Wet Tropics rivers; full time series (to early June 2008) have been received for all other rivers. These data will be used for calculating of sediment exports (Burdekin River only) and reporting of freshwater discharges for all 10 priority rivers under Reef Plan.

The river flow data was also be used as input parameters for the assessment and visual representation of flood plume distribution and transport using the King et al. (2002) hydrodynamic model (model domain covers the lagoon adjacent to the Burdekin River in the south to the Normanby River in the North) and to aid interpretation of water quality logger data from selected inshore reefs.

The rivers for which flow data were received show similar patterns of flood flows during the wet season 2008. The Wet Tropics rivers had two distinct flood peaks, from mid to end of January and from mid February to mid March (Figure 1a). The central Queensland rivers also showed two distinct peaks, from mid to end of January and from mid to end of February (Figure 1b). The Burdekin River had major flooding in 2008, while the Burnett River had only minor flows. Flow data will reported as monthly and annual discharge volumes for the 10 Reef plan priority rivers.

Overall, 2007/08 was a wetter year than the 3 years before and compared to the total long-term catchment discharge (see Table 1). In the wet season 2007/08, the Barron, Pioneer and especially the Burdekin and Fitzroy rivers exceeded their long-term discharge averages, whereas the Normanby, Tully and Herbert Rivers were close to average. The Russell, S-Johnstone and O'Connell rivers were below average, and the Burnett River again much below its long-term average, similar to the last three dry years in this catchment. The Burdekin flood in 2007/08 was ranked 3rd largest in the river discharge record going back to 1951, while the Fitzroy flood was the 5th largest since 1964 and the most significant event since the 1990/91 flood, which is still the largest on record (information from www.nrw.qld.gov.au/watershed/precomp; accessed 23/06/2008 .

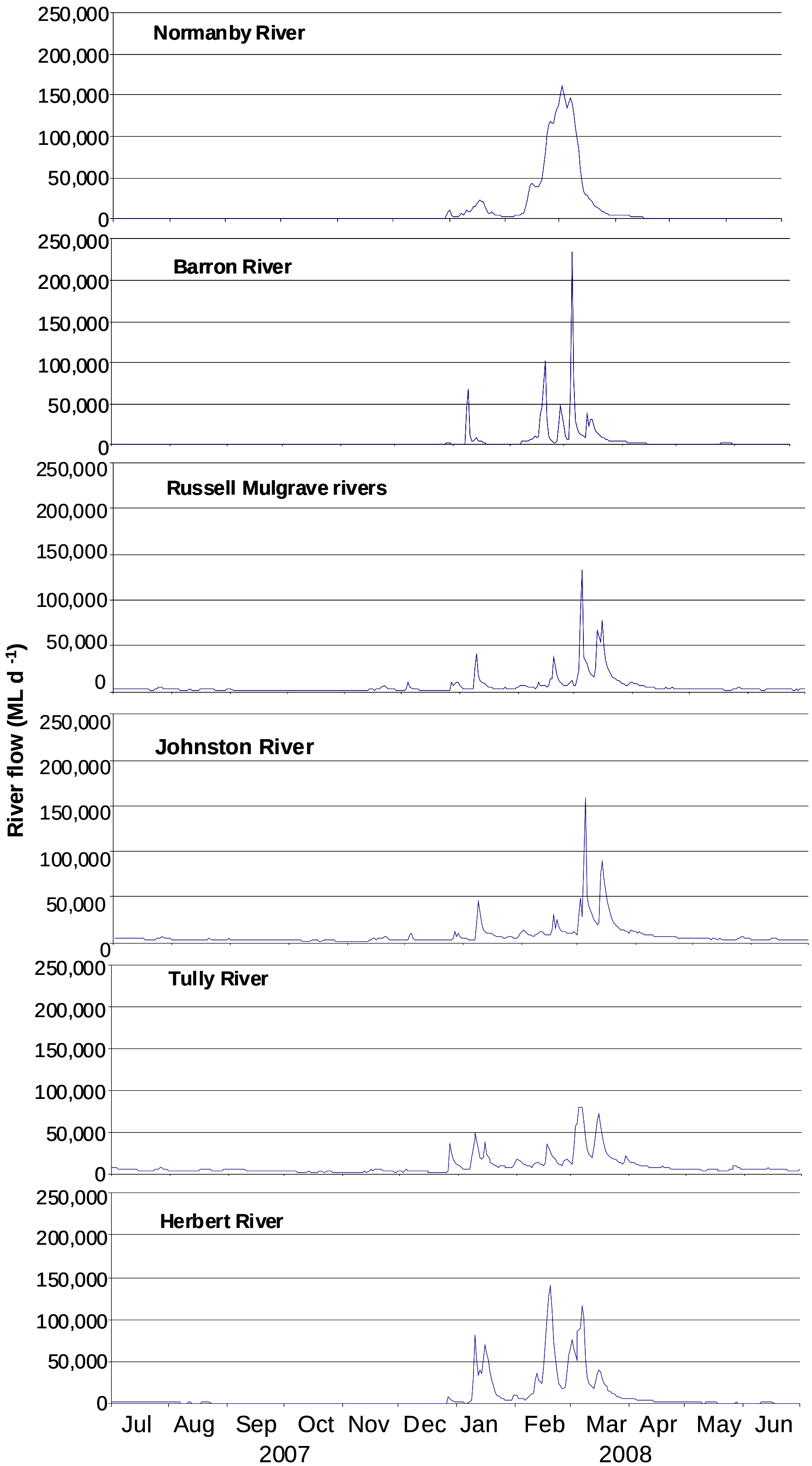

Figure 1a Daily river flows for Wet Tropics rivers in 2007/08. Data are property and copyright of the State of Queensland (Department of Natural resources and Water, 2008). Note that some data in the latter part of 2008 are interim values.

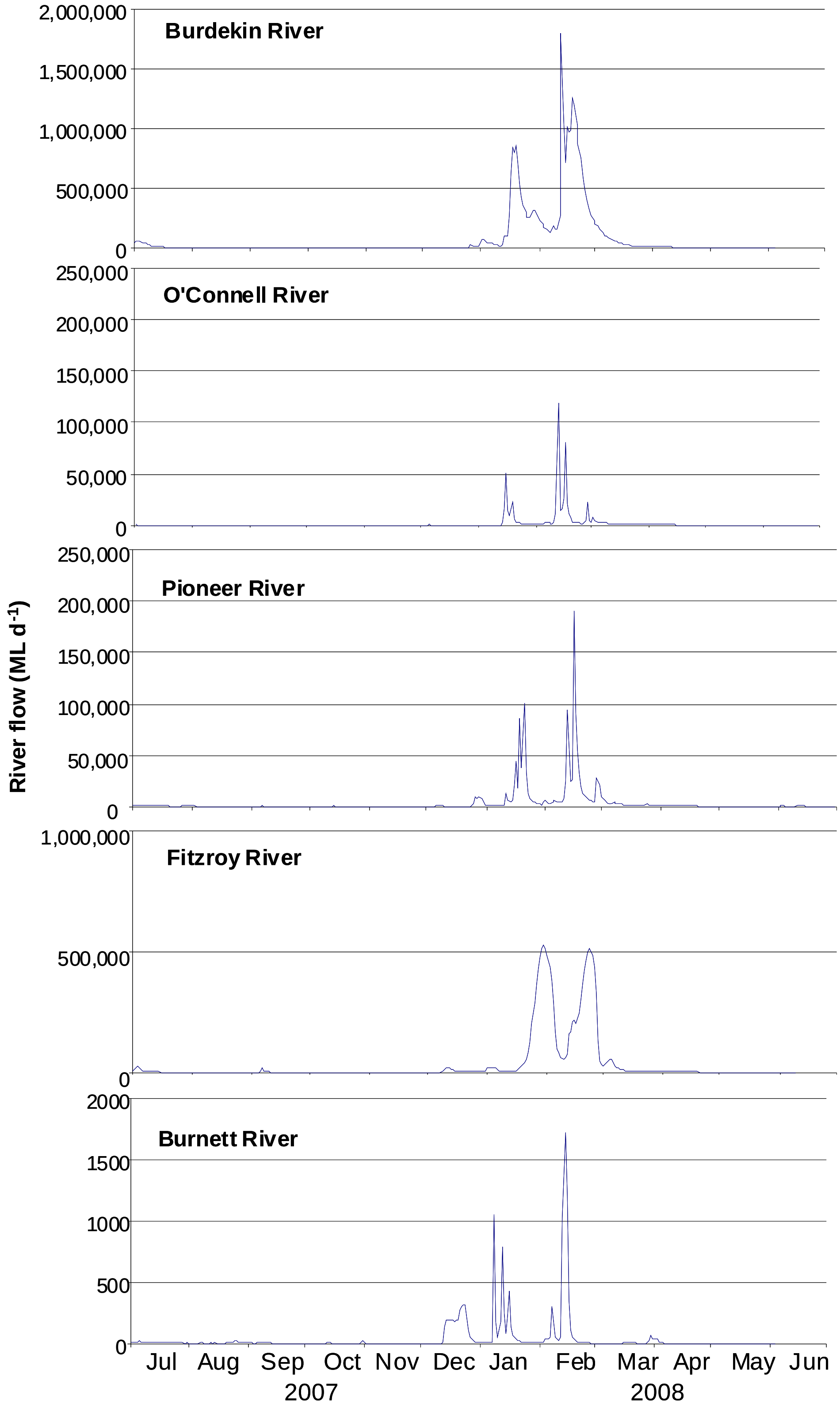

Figure 1b Daily river flows for central Queensland rivers in 2007/08. Data are property and copyright of the State of Queensland (Department of Natural resources and Water, 2008). Note different axis scales to accommodate vastly different flows and that some data in the latter part of 2008 are interim values.

Table 1. Monthly freshwater discharge volume (ML) from priority GBR catchment rivers in 2007-08. Bold print indicates rivers and months where AIMS river loggers were deployed for monitoring of suspended sediment concentrations. 1969-94: Estimated long-term discharge average for the respective DNR drainage basin for comparison. Discharge data are property and copyright of the State of Queensland (Department of Natural resources and Water, 2008).

River	Normanby	Barron	Mulgrave	Russell	N-Johnstone	S-Johnstone	Tully	Herbert	Burdekin	O'Connell	Pioneer	Fitzroy	Burnett	Total
DNRW Site	105107A	110001D	111007A	111101D	112004A	112101B	113006A	116001E	120006B	124001A	125016A	130005A	136007A	
2007/08														
July	4,319	26,377	30,906	49,385	90,347	43,397	159,921	72,867	587,806	5,130	19,151	128,339	359	1,218,305
August	920	10,447	22,829	37,086	67,276	32,096	127,269	50,963	58,274	2,232	3,330	502	353	413,577
September	96	6,088	15,401	24,506	46,637	23,176	122,415	34,526	51,715	1,447	3,628	41,231	205	371,074
October	0	6,963	12,578	19,421	35,795	20,878	72,463	23,773	73,345	545	2,992	307	131	269,191
November	0	7,141	18,549	43,441	56,991	28,273	90,826	19,630	103,449	649	2,151	0	118	371,217
December	13,183	19,159	19,108	76,611	77,858	42,634	169,518	43,073	209,139	3,856	50,335	192,017	3,120	919,611
January	283,224	180,006	85,226	123,419	190,486	84,241	447,235	641,647	8,460,320	140,010	438,359	3,846,302	3,887	14,924,361
February	1,387,291	428,933	129,913	127,873	247,560	100,684	427,185	1,087,184	16,351,655	366,348	717,575	7,407,356	5,538	28,785,094
March	1,859,567	746,195	493,930	411,854	791,164	295,025	1,059,212	1,124,127	1,817,752	51,982	74,744	433,642	325	9,159,520
April	75,998	65,848	55,817	80,226	136,587	67,524	243,362	117,403	171,589	10,828	15,058	53,810	211	1,094,262
May	14,507	45,146	29,628	46,605	81,832	42,644	164,607	53,562	79,149	8,259	3,851	14,380	51	584,221
June	6,675	40,188	24,238	40,917	63,890	30,881	148,653	43,809	7,804*	5,068	7,880	8,722*	14*	428,737
Total	3,645,780	1,582,492	938,122	1,081,343	1,886,423	811,454	3,232,667	3,312,564	27,971,996	596,356	1,339,054	12,126,608	14,312	58,539,170
1969-94	4,950,000	810,000		3,640,000		4,670,000	3,290,000	4,010,000	10,290,000	1,540,000	1,190,000	6,080,000	1,150,000	41,620,000

*Flow records only available to 04/06/08 (Burdekin River), 10/06/08 (Fitzroy River) and 03/06/08 (Burnett River).

Quantification of fine sediment exports

AIMS river loggers were deployed in two priority GBR catchment rivers (Tully and Burdekin rivers) to estimate wet season fine sediment exports and to maintain long-term time series of exports, using a consistent methodology. The Tully River logger was deployed at the Bruce Highway Bridge at Euramo; the Burdekin River logger at Clare, immediately downstream of the QNRM&W gauging station at the Clare weir (Table 1 for deployment periods).

The AIMS river loggers contain dual LED-based transmissometers (15mm and 85mm pathlengths) to measure in situ turbidity associated with suspended sediment over a 0-5 g L-1 concentration range (Mitchell and Furnas, 2001). The transmissometer light beams are largely attenuated by sediment and other particles in the light path through absorption and scattering. Test measurements indicate that absorption of the red light from the LEDs by coloured dissolved organic matter (CDOM) in river waters is small compared to absorption and scattering by particles. The turbidity readings are primarily affected by the concentration of very fine (<10 μm) silt and clay particles. Most of the particulate-phase nutrients carried by rivers are attached to these small particles. The degree of light attenuation is then used to calculate the fine sediment concentration. The loggers concurrently record pressure (water depth) and internal temperature. Readings are taken at 30 minute intervals. Automatic wiper brushes clean the optical surfaces of the transmissometers on an hourly basis, allowing the river loggers to run unattended over the course of a full wet season. The electronic and mechanical components of the river loggers are contained within a pressure housing that allows the river loggers to run fully submerged. Internal batteries provide sufficient power for deployments exceeding 6 months. At the deployment sites, the loggers are locked in a galvanised steel mesh cage for protection against floating debris and vandalism. The cages are mounted on structures in the river (e.g. bridge support, water intake tower) which provide further protection from floating debris.

The Tully River logger was damaged, flooded and the electronics corroded; no data were retrieved. The Burdekin River logger was retrieved in good working order.

Table 2. Details of AIMS Mudlogger deployments over the 2006-7 wet season.

NRM Region	River	Deployed	Retrieved
Wet Tropics	Tully	18 Dec 2007	20 May 2008
Burdekin	Burdekin	21 Nov 2007	19 May 2008

The fine sediment discharge of the Burdekin River showed a clear 'first flush' signal in late December to early January with very high suspended solids concentrations at the first minor discharge event (Figure 3). During the major flood peaks the suspended solids concentrations were equally high (~3 g L^{-1}), however, the total fine sediment export was obviously larger with the higher discharge volume during the two major flood peaks in January and February 2008. The water discharge during the 2007/08 wet season was ~ 3 x the long-term average while the fine sediment discharge was ~ 11 x the long-term average sediment export (Table 3; Furnas 2003). This mismatch is likely to be due to the long-term sediment average not covering the 1991 flood event, which was the second largest on record since 1950/51.

The discharge-weighted fine sediment export in 2007/08 was comparable to the estimate from 2004/05 (Table 3), while the area-weighted export was significantly larger than the estimates since beginning of Reef Plan MMP as well as the long-term average (which does not include the 1991 flood; data from Furnas 2003). This indicates that major erosion has occurred during this event in the Burdekin catchment, which led to substantial fine sediment export per area of catchment.

Table 3. Estimates of fine sediment export from the Burdekin Rivers during the 2004/05, 2005/06, 2006/07 and 2007/08 wet seasons. Long-term averages are given for comparison (annual river discharge: 1969-94, sediment export: 1989-2000, but missed 1991 flood). Discharge data are property and copyright of the State of Queensland (Department of Natural resources and Water, 2008).

Deployed	Retrieved	Freshwater discharge Km^3*	Sediment export 10^6 tonnes	Discharge-weighted sediment export (10^3 tonnes km^{-3})	Area-weighted sediment export (tonnes km^{-2}) (from gauged catchment area)
30 Nov 04	8 Jul 05	4.09	7.1	1745	55
15 Dec 05	6 Jun 06	1.93	0.565	295	4
6 Dec 06	2 May 07	8.52	**	**	**
21 Nov 07	26 May 08	27.05	42.68	1578	329
Long-term average		10.29	3.77	366	29

* Measured freshwater discharge during the period of logger data collection (1 $Km^3 = 10^9 m^3 = 10^6$ megalitres)

** No useful data recorded due to failure of the logger mounting structure under flood conditions

Figure 2 Fitting river logger (in protective cage) to structure on river bridge.

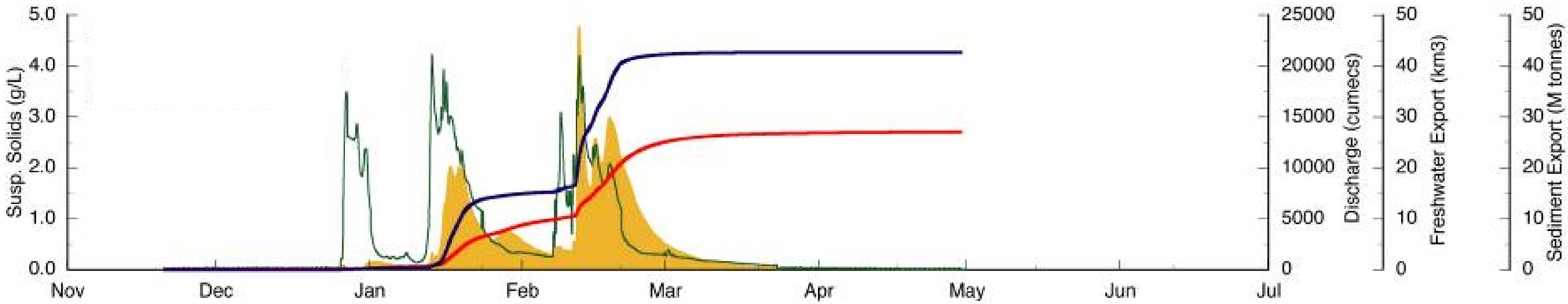

Figure 3 Time series of fine suspended solids concentrations (solid line) in the Burdekin River at Clare measured by AIMS river loggers over the 2007-08 wet season in relation to concurrent river flow (brown area, in cumecs) and integrations of cumulative freshwater discharge (red line, in km³) and fine sediment export (blue line, in mega tonnes). River discharge data are property and copyright of the State of Queensland (Department of Natural resources and Water, 2008).

Modelling of flood plume distribution in the northern GBR regions

To simulate flood plume dynamics, a verified 3-dimensional hydrodynamic model (King et al. 2002, based on the MECCA model, Hess 1989), was applied to create computer simulations of the fate and mixing of discharges of freshwater from the Burdekin, Herbert, Tully, Johnstone, Russel, Barron, Daintree, Endeavour and Normanby rivers.

King et al. (1998, 2001 and 2002) verified the model for the 1981 flood, by comparing the model results with the field salinities recorded by Wolanski and Van Senden (1983). Input variables into the model were measured daily variability in river discharge (provided by Department of Natural Resources and Water, 2008) and actual wind data (source AIMS weather station data for Davies Reef). In this project, the model was used to simulate the distribution of river flood waters during the 2007/08 wet season. The modelling period was from the 24th December 2007 until the 17th April 2008 a total of 116 days, with output being written to file every six hours.

The purpose of applying this model was to test its value to predict flood plume dispersal and actual salinity. After development of the model, it has not been widely applied or validated.

The computer simulations produced a comprehensive 3-dimensional spatial model of the fate and mixing of plume waters during the flood events. Since direct rainfall inputs were not modelled, salinity fluctuations in this model reflected only the presence of freshwater runoff from one or more of the rivers. Thus modelled salinities were direct measures of the runoff dilutions with ambient coastal waters in time and space. It is important to note that plume trajectories are complex and event-driven. This complexity is better appreciated from viewing the animated model simulations (available on request, could be made available on the RRRC website). A selection of model outputs for specific days are presented and described in Figures 4a and 4b.

While the prediction of the distribution of the flood plumes of the Northern GBR rivers gave a realistic picture, the spatial patterns could not be validated because suitable geo-referenced remote sensing imagery of the flood plumes was not available at time of reporting.

The salinity predictions of the model were matched against measured salinity at 16 locations (data from the lagoon monitoring under Reef Plan MMP, see 2007/08 Final Report, Schaffelke et al. 2008). This validation shows a moderate fit and generally underestimated the salinity in waters less affected by flood plumes (e.g. around and above 30 PSU, Figure 5). More measured salinity data from the Burdekin flood sampling in February 2008 by ACTFR should be included before making a final judgement of the value of the model.

Limitation of the King model have long been recognised because it does not include tidal forcing and, hence, may underestimate the dilution of flood waters in the coastal zone by physical forcing (e.g., wind, tides, currents).

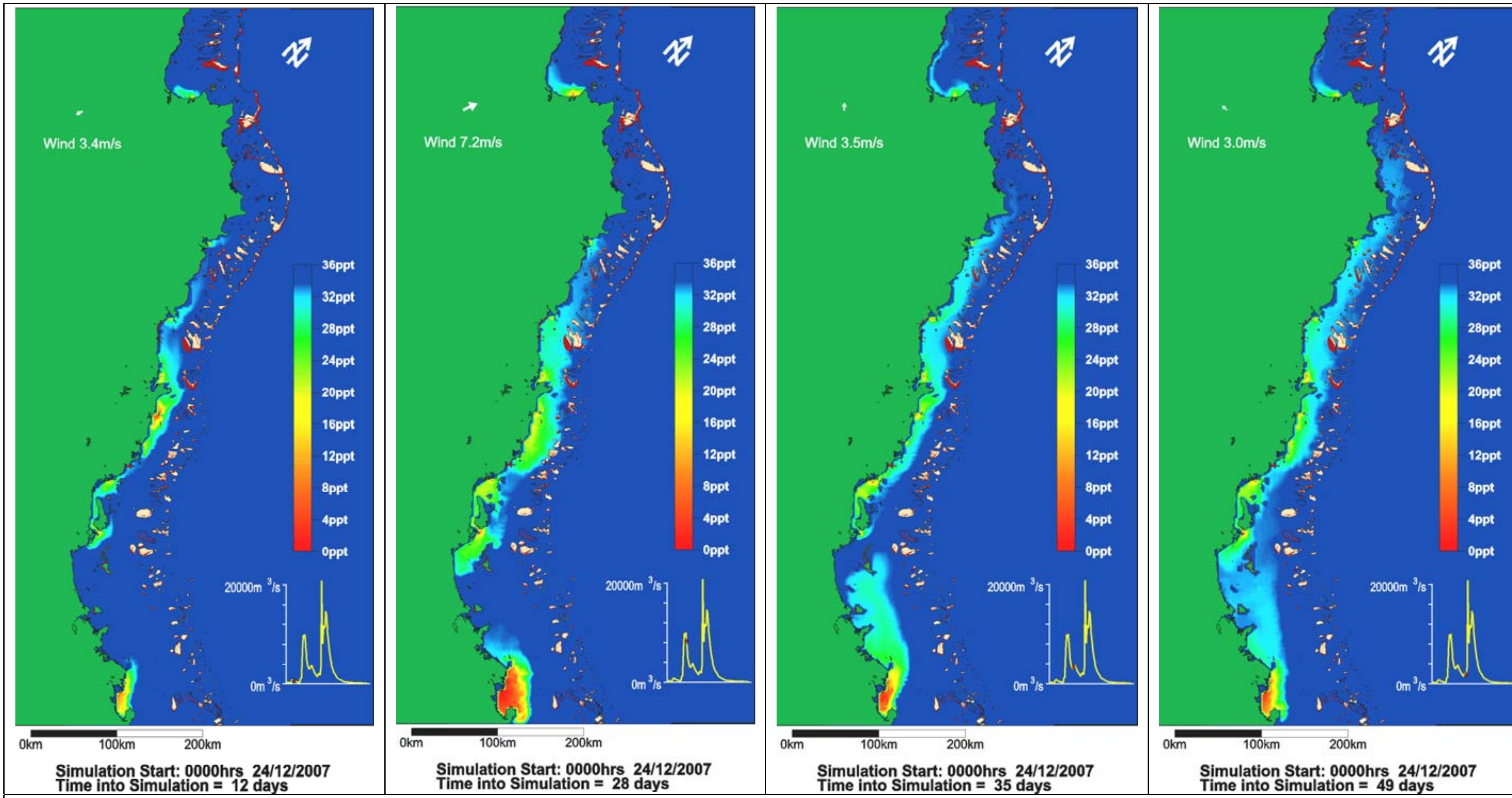

Figure 4a: Model output of the AIMS river plume distribution model (King et al. 2002).

4 January 08: minor flooding of Burdekin River and several Wet Tropics rivers.	19 January 08: just after first major Burdekin flood peak, minor floods of several Wet Tropics rivers.	26 January 08: Burdekin flood plume reached the Palm Islands, dispersed flood plumes along the Wet tropics coast.	09 February 08: Diluted plume from the Burdekin and Herbert rivers merge between Hinchinbrook Is. And the Palm Islands.

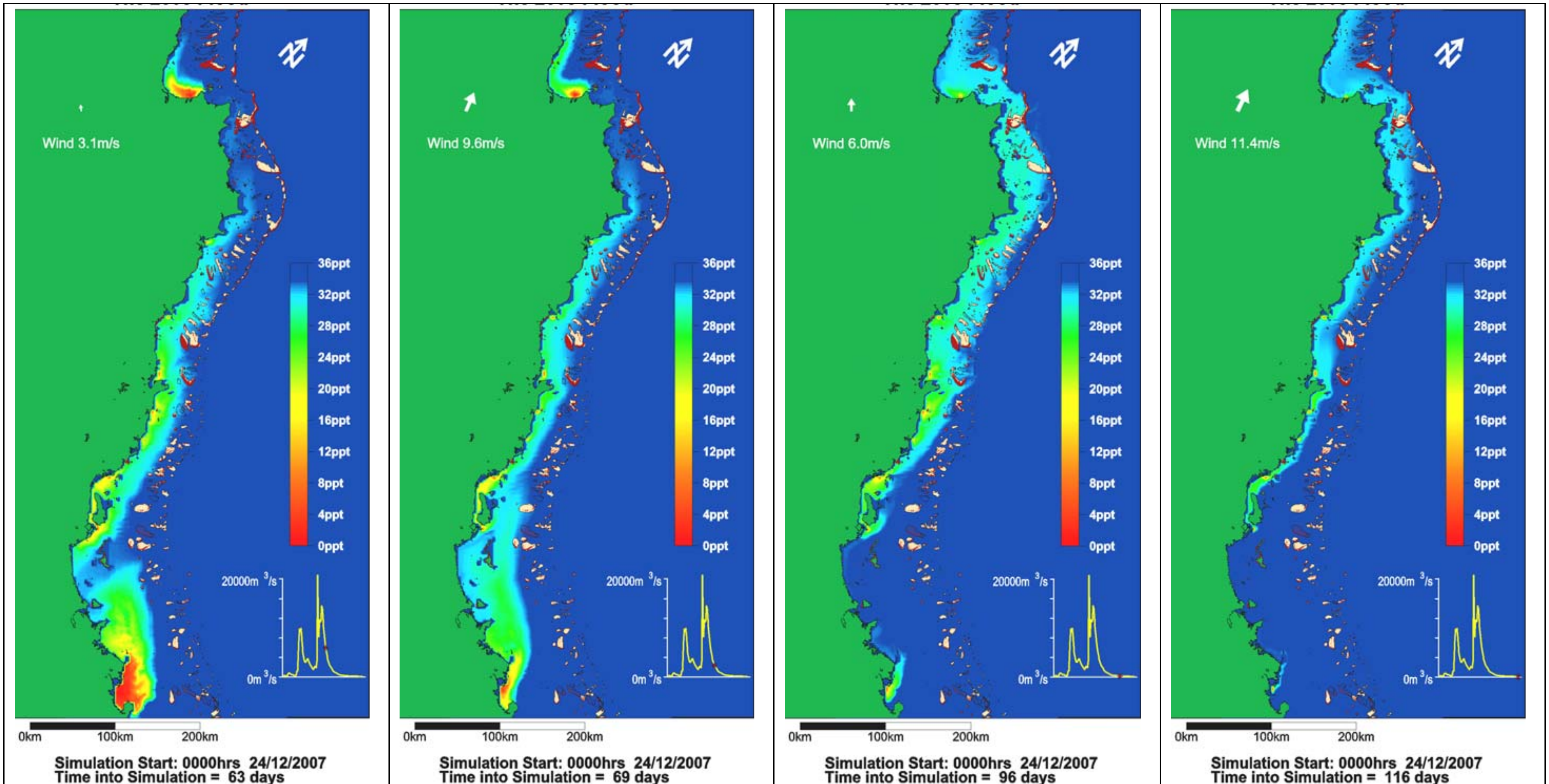

Figure 4b: Model output of the AIMS river plume distribution model (King et al. 2002).

23 February 08: after 2nd major flood peak of Burdekin river and moderate to major flooding of several Wet Tropics rivers.	29 February 08: Burdekin flood plume reached the Palm Islands, dispersed flood plumes along the Wet tropics coast.	27 March 08: Burdekin flood plume dispersed Wet tropics flood plumes reach their maximum extension after main flood peak mid March.	17 April 08: End of simulation, full salinity to Hinchinbrook Island, diluted flood signal still visible along the Wet Tropics coast.

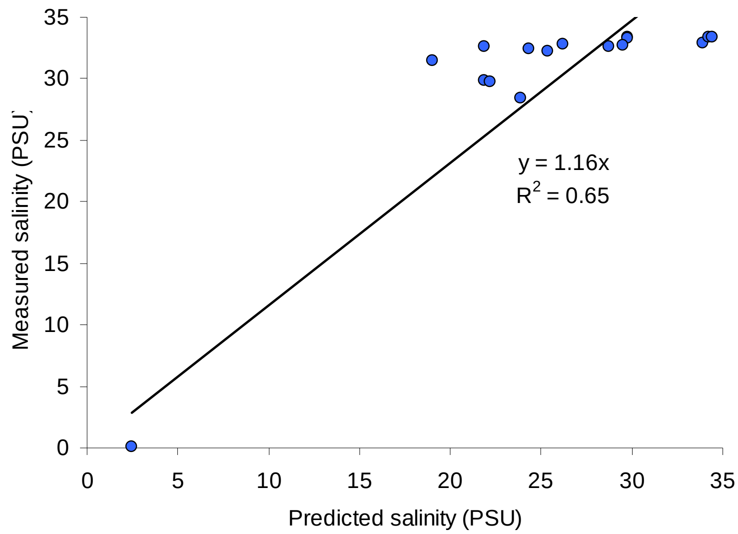

Figure 5 Match-up of salinity values predicted by the King and salinity values from collected water samples.

Autonomous environmental water quality loggers

As part of this project, a flood-specific analysis of chlorophyll and turbidity data from 14 existing FLNTUSB instruments deployed at inshore reefs was carried out; the instruments were deployed and maintained under the Lagoon WQ monitoring component of the Reef Plan MMP (as part of a contract between AIMS and GBRMPA). The instruments were deployed in October 2007 at all 14 selected sites (Table 4) and are changed-over ca. every 4 months.

The Eco FLNTU Combination instruments perform simultaneous *in situ* measurements of chlorophyll fluorescence, turbidity and temperature. The fluorometer monitors chlorophyll concentration by directly measuring the amount of chlorophyll *a* fluorescence emission, using blue LEDs (centred at 455 nm and modulated at 1 kHz) as the excitation source. A blue interference filter is used to reject the small amount of red light emitted by the LEDs. The blue light from the sources enters the water at an angle of approximately 55–60 degrees with respect to the end face of the unit. Fluoresced red light (683 nm) is received by a detector positioned where the acceptance angle forms a 140-degree intersection with the source beam. A red interference filter discriminates against the scattered blue excitation light. The red fluorescence emitted is detected by a silicon photodiode. Turbidity is measured simultaneously by detecting the scattered light from a red (700 nm) LED at 140 degrees to the same detector used for fluorescence. The instruments were used in 'logging' mode and recorded a data point every 10 minutes for each of the three parameters, which was a mean of 50 instantaneous readings.

Table 4 Locations selected for inshore water quality monitoring by autonomous instruments (Wetlabs FLNTUSB) under Reef Plan MMP and deployment and change-over times.

NRM Region	Water quality monitoring locations
Wet Tropics	Snapper Island North
	Fitzroy Island West
	High Island West
	Frankland Group W-est
	Dunk Island North
Burdekin	Pelorus & Orpheus Is West
	Pandora Reef
	Geoffrey Bay
Mackay Whitsunday	Double Cone Island
	Daydream Island
	Pine Island
Fitzroy	Barren Island
	Pelican Island
	Humpy & Halfway Island

The times series obtained using FLNTU loggers delivered high-frequency, location-specific data records during the wet season, including periods where the inshore reefs were exposed to flood plumes. Time-series for the period of the 1 December 2007 to 31 March 2008 are presented as daily means (Figures 5 to 9), calculated from the readings obtained every 10 minutes. In addition to the instrument readings, the graphs include relevant environmental data (daily discharge volume of the closest river (provided by QDNRW) and averaged daily wind speed data from the nearest weather station of the Bureau of Meteorology (calculated from twice-daily readings available at URL <http://www.bom.gov.au/climate/dwo>).

To bring the time series data into context, we included the seasonally adjusted chlorophyll Guideline Trigger Values (Table 5, GBRMPA 2008). For turbidity we applied a suggested turbidity 'threshold' of 5 NTU, beyond which corals may be severely light-limited (based on experiments with the coral species *Pocillopora damicornis* and field assessments; Cooper *et al.* 2007 and 2008). This threshold was deduced from turbidity and light measurements at 2 m depth (LAT), hence, applying it to our logger data from 5m depth (LAT) gives a conservative estimate of turbidity-related stress because the light reduction would be more pronounced at this deeper depth.

Table 5 Chlorophyll trigger values from the GBRMPA Draft Water Quality Guideline for the Great Barrier Reef Marine Park (GBRMPA 2008). Trigger values used for comparison in this report are highlighted.

	Water body			
Parameter	Enclosed coastal	Coastal	Inshore	Offshore
Chlorophyll (µg L^{-1})	2.0	0.32 / 0.63*	0.28 / 0.56*	0.28 / 0.56*

*Seasonal adjustment: Summer/winter
**Geographical adjustment: Wet Tropics/Central Coast

Five reef locations in the Wet Tropics NRM Region had instruments deployed.
Snapper Island, the northernmost location of the Reef Plan MMP inshore water quality network, had an extremely spiky record, especially for turbidity (Figure 5). The overall mean chlorophyll concentration during the wet season was 0.59 µg L^{-1}. Mean turbidity was ~2 NTU, but frequent spikes were above this mean with a highest daily value of 18 NTU. 30% of the daily means in the record exceeded the wet season GBRMPA chlorophyll trigger values (Table 6) and 12% of values exceeded the suggested 5 NTU limit for coral photo-physiological stress. A 10 d period of high turbidity readings during March 2008 coincided with a flood event of the Daintree River; high chlorophyll values follow the turbidity readings with a lag of a few days.

Table 6 Summary of chlorophyll (µg L^{-1}) and turbidity (NTU) data from wet season 2007/08 deployments of WET Labs Eco FLNTU Combination Fluorometer and Turbidity Sensors at 14 inshore reef sites (01 Dec 07 to 31 Mar 08). N= number of daily means in the reported time series, SE= standard error. "Above trigger value" and shading refers to the percentage of days with mean values above the chlorophyll trigger values from the GBRMPA Draft Water Quality Guideline for the Great Barrier Reef Marine Park (GBRMPA 2008) or the suggested turbidity threshold of 5 NTU (Cooper *et al.* 2008).

			Chlorophyll				Turbidity			
NRM Region	Location	N (d)	Max	Mean	SE	% >trigger	Max	Mean	SE	% >trigger
Wet Tropics	Snapper Island	121	2.13	0.59	0.03	30	18.4	2.14	0.28	10
	Fitzroy Island	103	1.12	0.45	0.02	14	8.12	0.91	0.1	2
	Russell Island**	118	0.68	0.3	0.01	3	1.88	0.41	0.03	0
	High Island	118	0.87	0.39	0.02	7	6.66	0.92	0.09	2
	Dunk Island	100	1.12	0.53	0.02	14	17.83	2.19	0.32	15
Burdekin	Pelorus Island**	15*	0.55	0.32	0.02	0	0.87	0.44	0.03	0
	Pandora Reef**	116	1.16	0.57	0.02	52	3.77	0.89	0.06	0
	Geoffrey Bay	102	1.28	0.58	0.03	30	23.86	2.9	0.41	16
Mackay Whitsunday	Double Cone Island	77	5.49	0.92	0.09	71	6.37	1.58	0.17	5
	Daydream Island	120	0.76	0.76	0.01	14	11.05	2.63	0.24	18
	Pine Island	122	1.08	0.72	0.01	81	19.9	3.8	0.37	25
Fitzroy	Barren Island**	122	1.1	0.52	0.02	28	3.43	0.54	0.04	0
	Humpy Island	122	1.8	0.6	0.02	20	6.55	1.5	0.12	2
	Pelican Island	122	3.36	0.9	0.05	75	36.99	9.59	0.81	61

*logger failure

The mean chlorophyll concentration at Fitzroy Island was 0.45 µg L^{-1} (Table 6). Mean turbidity was ~0.9 NTU, with two spikes in February reaching a maximum value of 8 NTU and elevated turbidity during the March flood of the Russell-Mulgrave River (Figure 5). 14% of the daily means in the record exceeded the GBRMPA chlorophyll trigger values and only 2% of values exceeded the suggested 5 NTU limit for coral photo-physiological stress (Table 6).

Russell Island, in the Frankland Islands Group had the lowest chlorophyll and turbidity levels in the Wet Tropics Region (Figure 6) during the wet season 2007/08. The mean chlorophyll concentration was 0.30 µg L^{-1} (Table 6). Mean turbidity was ~0.4 NTU, with slightly elevated turbidity during the March flood of the Johnstone River but a maximum value of only ~2 NTU (Figure 6). Only 3% of the daily means in the record exceeded the GBRMPA chlorophyll trigger values and none exceeded the suggested 5 NTU limit for coral photo-physiological stress (Table 6).

High Island had a mean chlorophyll concentration of 0.39 µg L^{-1} and a mean turbidity of 0.9 NTU (Table 6). Maximum turbidity was ~7 NTU, reached during a period of elevated turbidity during the March flood of the Johnstone River (Figure 6). 7% of the daily means in the record exceeded the GBRMPA chlorophyll trigger values and only 2% exceeded the suggested 5 NTU limit for coral photo-physiological stress (Table 6).

Dunk Island chlorophyll and turbidity levels and variability over time were comparable to Snapper Island. Dunk Island had a mean chlorophyll concentration of 0.53 µg L^{-1}, and a mean turbidity of 2.2 NTU (Table 6). Maximum turbidity was 18 NTU, reached during a period of elevated turbidity during the March flood of the Tully River (Figure 6). 14% of the daily means in the record exceeded the GBRMPA chlorophyll trigger values and 15% exceeded the suggested 5 NTU limit for coral photo-physiological stress (Table 6).

In the Burdekin NRM Region, three reef locations had instruments deployed.
Due to instrument problems, data for Pelorus Island were only retrieved for a period of 15 days during the wet season and are not further discussed.

Pandora Reef had a mean chlorophyll concentration of 0.57 µg L^{-1}, and a mean turbidity of ~0.9 NTU (Table 6). Maximum turbidity was ~4 NTU, reached during the February flood. Turbidity was more variable and slightly elevated from late December to end of March. Chlorophyll was above the GBRMPA chlorophyll trigger value from late January to late March, coinciding with major flooding of the Burdekin River (Figure 7). 52% of the daily means in the record exceeded the GBRMPA chlorophyll trigger values but none exceeded the suggested 5 NTU limit for coral photo-physiological stress (Table 6).

Geoffrey Bay Reef had a mean chlorophyll concentration of 0.58 µg L^{-1} and a mean turbidity of ~3 NTU, the highest in the Burdekin Region (Table 6). Turbidity was more variable and elevated from late December to late March with a maximum value of ~24 NTU (Figure 7). Chlorophyll was above the GBRMPA chlorophyll trigger value from early February to mid March, coinciding with the second major flood peak of the Burdekin River (Figure 7). 30% of the daily means in the record exceeded the GBRMPA chlorophyll trigger values and 16% exceeded the suggested 5 NTU limit for coral photo-physiological stress (Table 6).

Three reef locations in the Mackay Whitsunday NRM Region had instruments deployed. Double Cone Island had a mean chlorophyll concentration of 0.92 µg L^{-1}, which was above the GBRMPA threshold, and a mean turbidity of ~1.6 NTU (Table 6). Turbidity and chlorophyll concentrations were elevated from mid December to early January (Figure 8), for no obvious reason. Maximum turbidity was ~6 NTU, reached in December 2007 before the main floods and, hence, more likely to be caused by resuspension. Chlorophyll was above the GBRMPA chlorophyll trigger value from mid January to mid February, coinciding with the two major flood peak of the Pioneer River (Figure 7). 71% of the daily means in the record exceeded the GBRMPA chlorophyll trigger values and only 5% exceeded the suggested 5 NTU limit for coral photo-physiological stress (Table 6).

Daydream Island had a mean chlorophyll concentration of 0.76 µg L^{-1}, which was just above the GBRMPA threshold and the lowest value in the Region, and a mean turbidity of ~2.6 NTU (Table 6). Maximum turbidity was ~11 NTU in March, after second major flood peak of the Pioneer River (Figure 8). Chlorophyll values showed very little response to the flood. 14% of the daily means in the record exceeded the GBRMPA chlorophyll trigger values and 18% exceeded the suggested 5 NTU limit for coral photo-physiological stress (Table 6).

Pine Island had a mean chlorophyll concentration of 0.72 µg L^{-1}, which was above the GBRMPA threshold, and a mean turbidity of ~4 NTU, the highest mean value in this Region (Table 6). Chlorophyll was above the GBRMPA chlorophyll trigger value for most of the record with 81% of the daily means exceeding this value. Maximum turbidity was ~20 NTU in early March. Turbidity values were variable and slightly elevated from late December to mid February, the latter part coinciding with the flood of the Pioneer River (Figure 8) and 25% of daily means exceeded the suggested 5 NTU limit for coral photo-physiological stress (Table 6).

Three reef locations in the Fitzroy NRM Region had instruments deployed.
Barren Island had a mean chlorophyll concentration of 0.52 µg L^{-1}, and a mean turbidity of ~0.5 NTU, both the lowest values in this Region (Table 6). Turbidity was slightly elevated and more variable from late December to late February with a maximum of ~3 NTU (Figure 9). Chlorophyll was highest after the second flood peak of the Fitzroy River mid to late February (Figure 9). 28% of the daily means in the record exceeded the GBRMPA chlorophyll trigger values but none exceeded the suggested 5 NTU limit for coral photo-physiological stress (Table 6).

Humpy Island had a mean chlorophyll concentration of 0.6 µg L^{-1}, and a mean turbidity of 1.5 NTU (Table 6). Chlorophyll was above the GBRMPA chlorophyll trigger value in mid February, coinciding with the second major flood peak of the Fitzroy River, during which also the maximum turbidity of ~6.5 NTU was briefly reached (Figure 9). 20% of the daily means in the record exceeded the GBRMPA chlorophyll trigger values and only 2% exceeded the suggested 5 NTU limit for coral photo-physiological stress (Table 2.13).

Pelican Island had a mean chlorophyll concentration of 0.9 µg L^{-1}, which was above the GBRMPA threshold, and a mean turbidity of ~10 NTU, both the highest values in this Region and, for turbidity, of all 14 locations (Table 6). Daily means of chlorophyll were above the GBRMPA chlorophyll trigger value on 75% of the days, during the flood event for 77 days in a row. Maximum turbidity was ~37 NTU and values were very variable for most of the record with more elevated values from late December to late March, encompassing the major flood of the Fitzroy River (Figure 9). 61% of daily means exceeded the suggested 5 NTU limit for coral photo-physiological stress, with 30 days above this threshold during the flood event (Table 6).

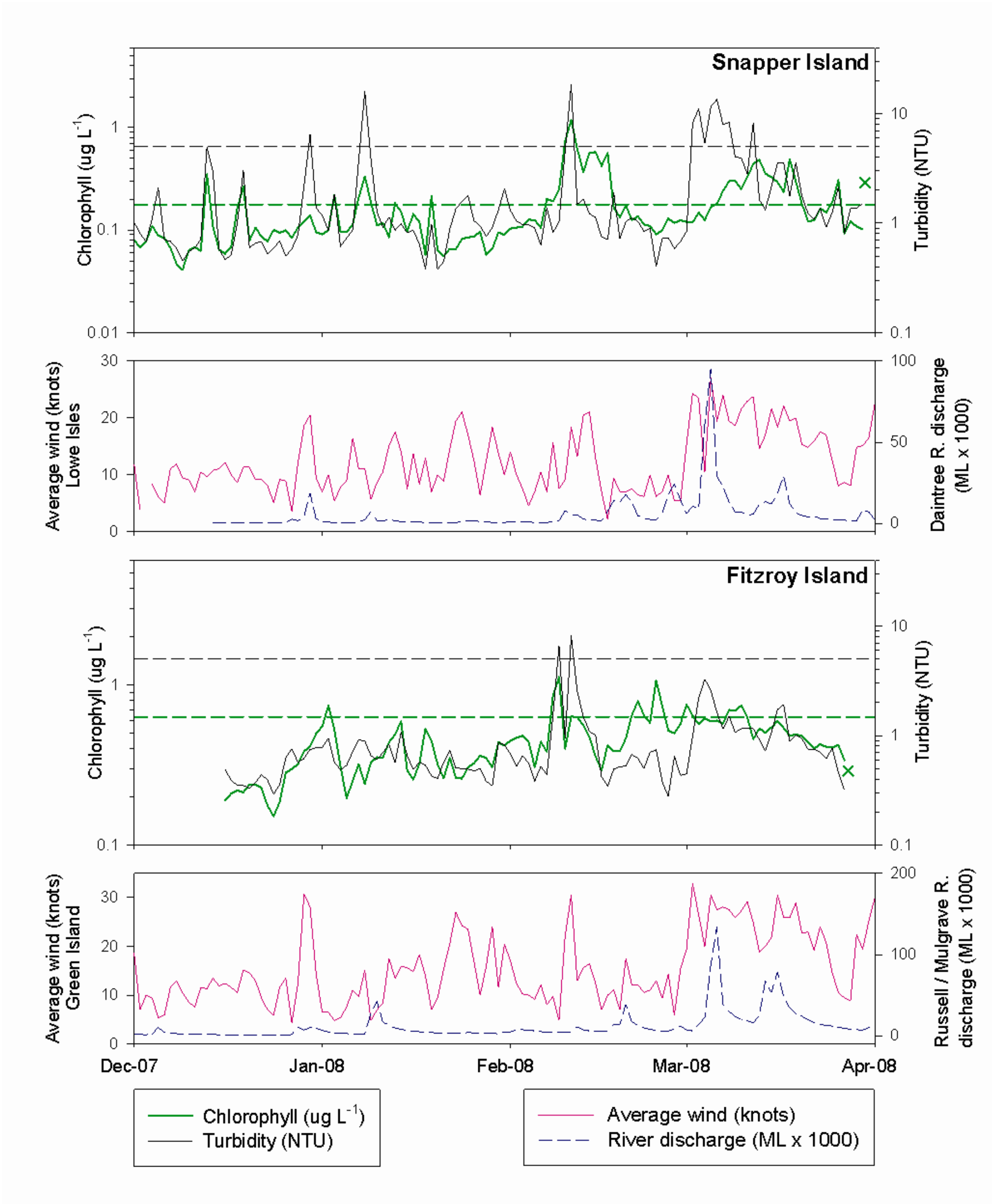

Figure 5 Time series of chlorophyll (µg L-1, green line) and turbidity (NTU, black line) from field deployments of WET Labs Eco FLNTU Combination Fluorometer and Turbidity Sensors at Snapper and Fitzroy islands in the Wet Tropics NRM Region. Additional panels represent daily mean wind speeds from weather stations closest to the deployment locations (knots, pink solid line) and discharge volumes from the closest river (ML x 1000, blue dashed line). Green horizontal dashed lines represent the chlorophyll trigger values in the GBRMPA Draft Water Quality Guideline for the Great Barrier Reef Marine Park (GBRMPA 2008), black dashed lines represent the suggested turbidity 'threshold' of 5 NTU, beyond which corals may be severely light-limited (Cooper *et al.* 2008).

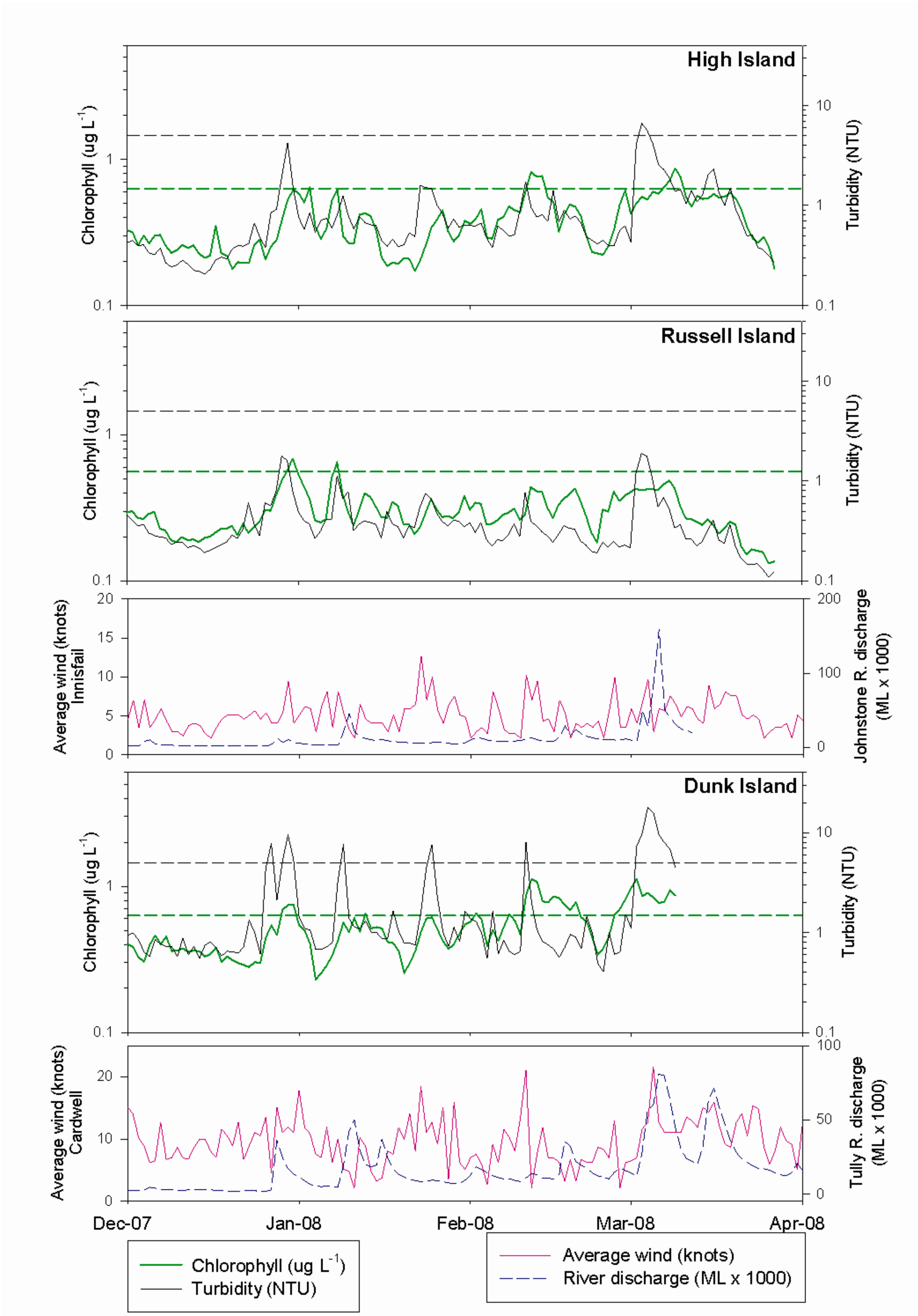

Figure 6 Time series of chlorophyll (µg L^{-1}, green line) and turbidity (NTU, black line) from field deployments of WET Labs Eco FLNTU Combination Fluorometer and Turbidity Sensors at High, Russell and Dunk islands in the Wet Tropics NRM Region. All other details as in Figure 5.

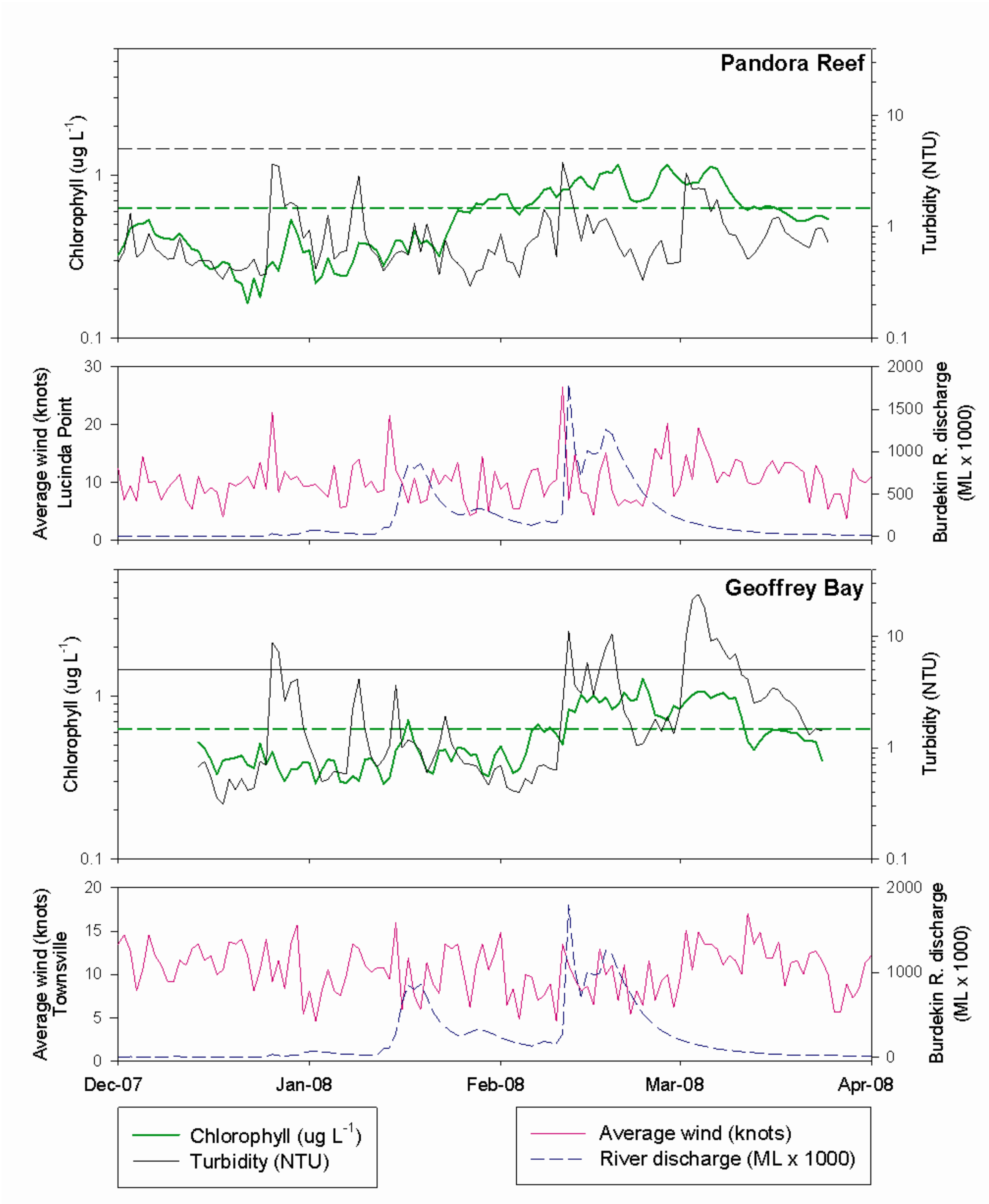

Figure 7 Time series of chlorophyll (µg L-1, green line) and turbidity (NTU, black line) from field deployments of WET Labs Eco FLNTU Combination Fluorometer and Turbidity Sensors at Pandora Reef and Geoffrey Bay Reef in the Burdekin NRM Region. All other details as in Figure 5.

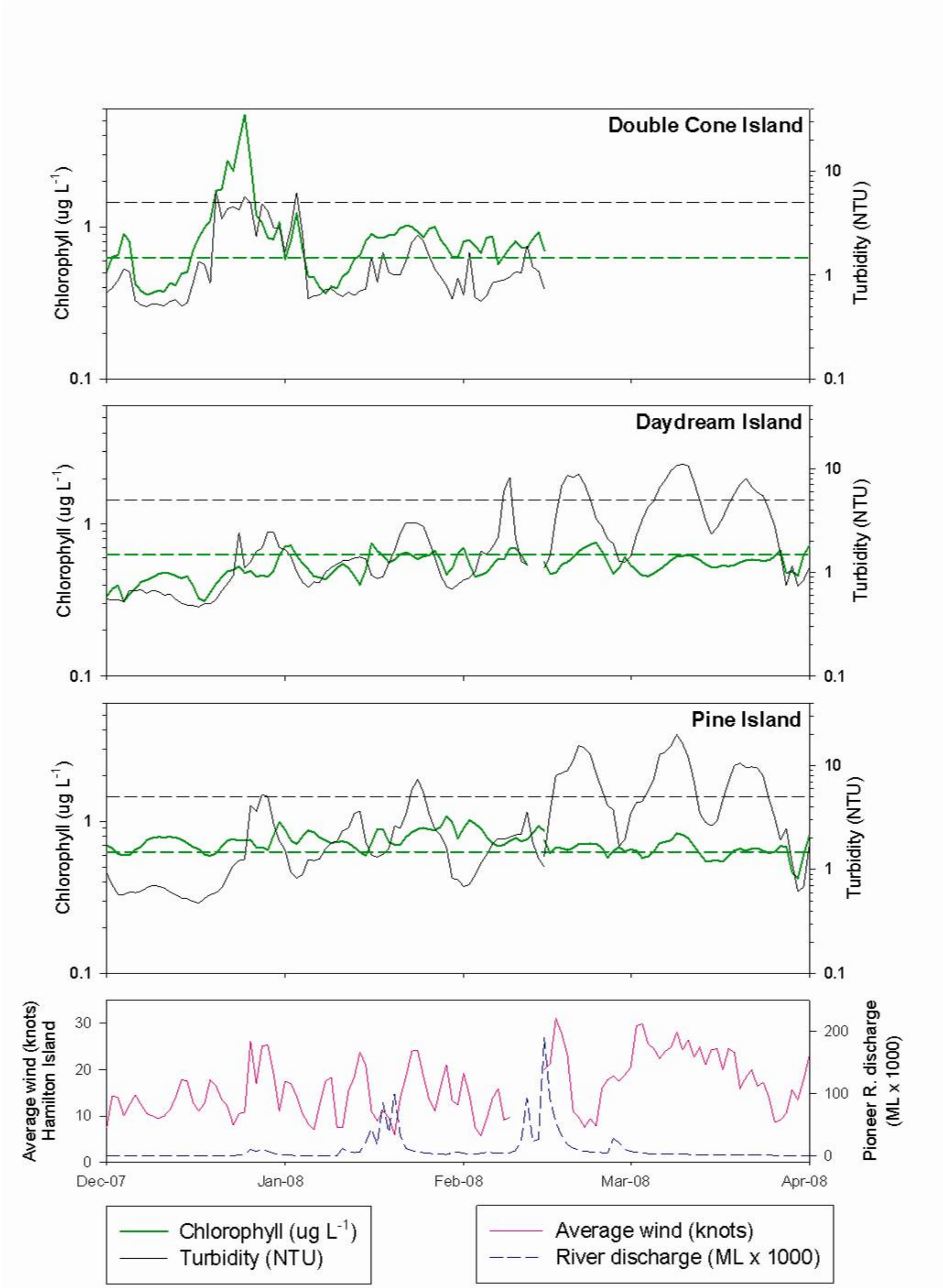

Figure 8 Time series of chlorophyll (µg L^{-1}, green line) and turbidity (NTU, black line) from field deployments of WET Labs Eco FLNTU Combination Fluorometer and Turbidity Sensors at Double Cone, Daydream and Pine islands in the Mackay Whitsunday NRM Region. All other details as in Figure 5.

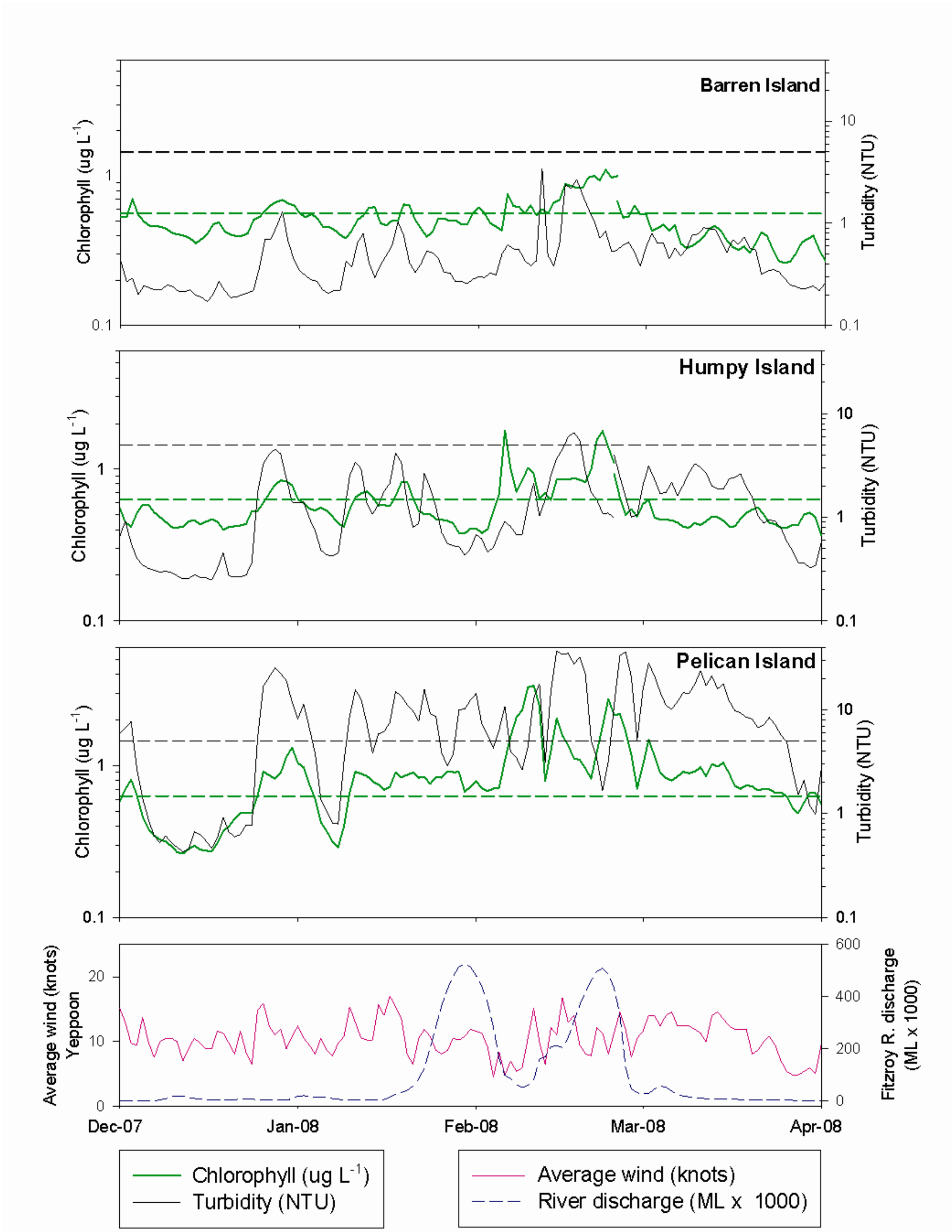

Figure 9 Time series of chlorophyll (µg L-1, green line) and turbidity (NTU, black line) from field deployments of WET Labs Eco FLNTU Combination Fluorometer and Turbidity Sensors at Barren, Humpy and Pelican islands in the Fitzroy NRM Region. All other details as in Figure 5.

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