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The relationship between river discharges and water clarity in the Great Barrier Reef

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Australian Institute of Marine Science, University of Queensland, and James Cook University

BACKGROUND: WATER CLARITY IS A FUNDAMENTAL MEASURE OF REEF HEALTH

- Water clarity of less than 10 m Secchi depth -> significant increase in macroalgae, declining coral diversity (GBRMPA WQ Guidelines 2010)
- Cloudy water absorbs light -> communities shift from photosynthesis to filter feeding
- Suspended particles are food for algae, but are also a deterrent for herbivorous fishes (-> bottom-up and top down control of algae)
- Water clarity also important for tourism experience

OBJECTIVE

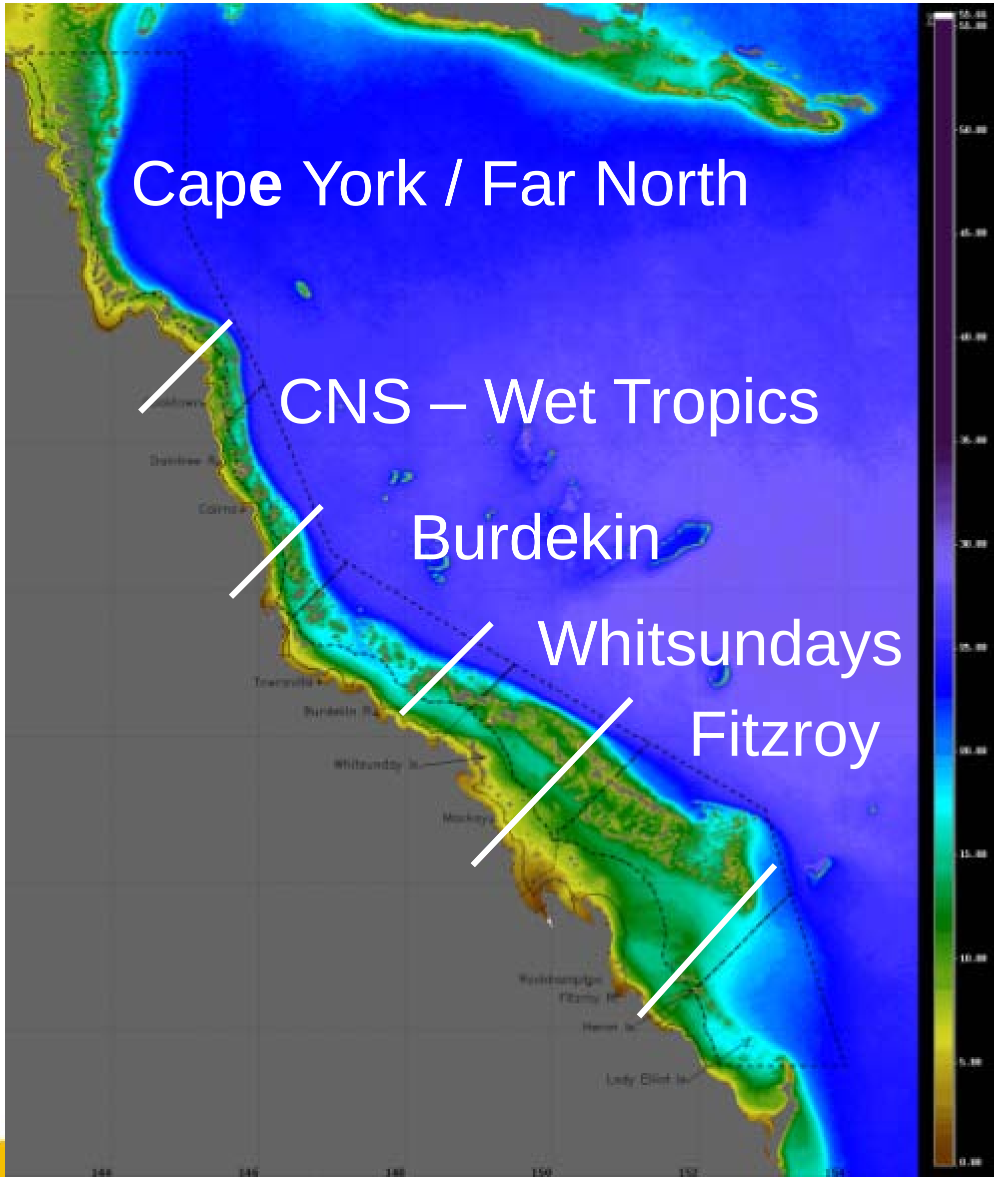
To investigate the relationship between GBR water clarity and river discharges.

1) Develop and test methods on Burdekin Region

   Logan et al. 2013 (NERP Report)
   Fabricius et al. 2014 (Marine Pollution Bulletin)

2) Apply to all NRM Regions

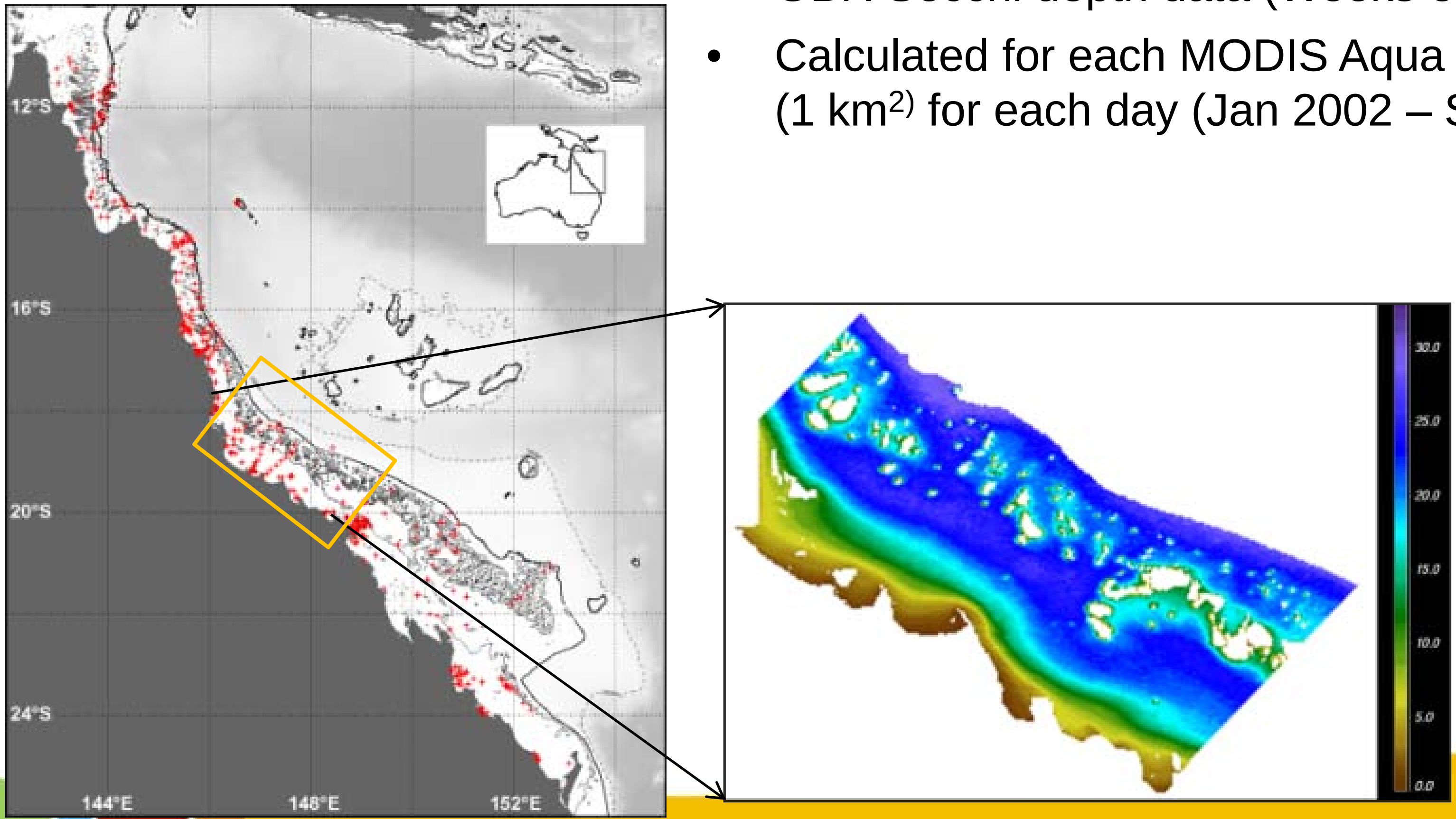
   Logan et al. 2014 (NERP Report)



METHODS: DEVELOP AND CALCULATE 'PHOTIC DEPTH' - A MEASURE OF WATER CLARITY

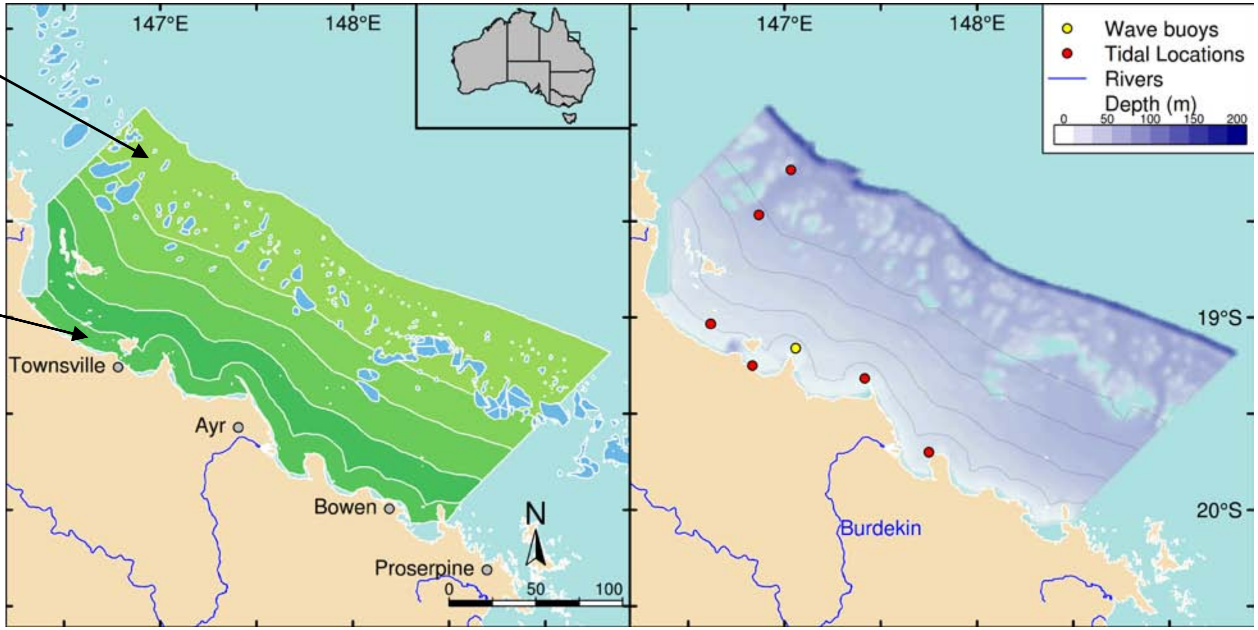
Photic depth:

- defined as water clarity measure equivalent to Secchi depth (same unit)
- Based on regression of MODIS Aqua vs GBR Secchi depth data (Weeks et al., 2012).
- Calculated for each MODIS Aqua pixel (1 km^{2}) for each day (Jan 2002 – Sept 2013)



METHODS: COMPILE ENVIRONMENTAL DATA

Outer shelf
Mid shelf
Lagoon
Inshore
Coastal



- Define zones of interest (eg Burdekin: Across: <0.1, 0.25, 0.45, 0.65, 1.0)
- Average ‘Photic depth’ across all pixels within each zone
- Compile **daily** environmental data: waves, tides, river freshwater volume
- Estimate **annual** river loads of sediments, nutrients

METHODS: COMPILE DAILY ENVIRONMENTAL DATA

Photic depth

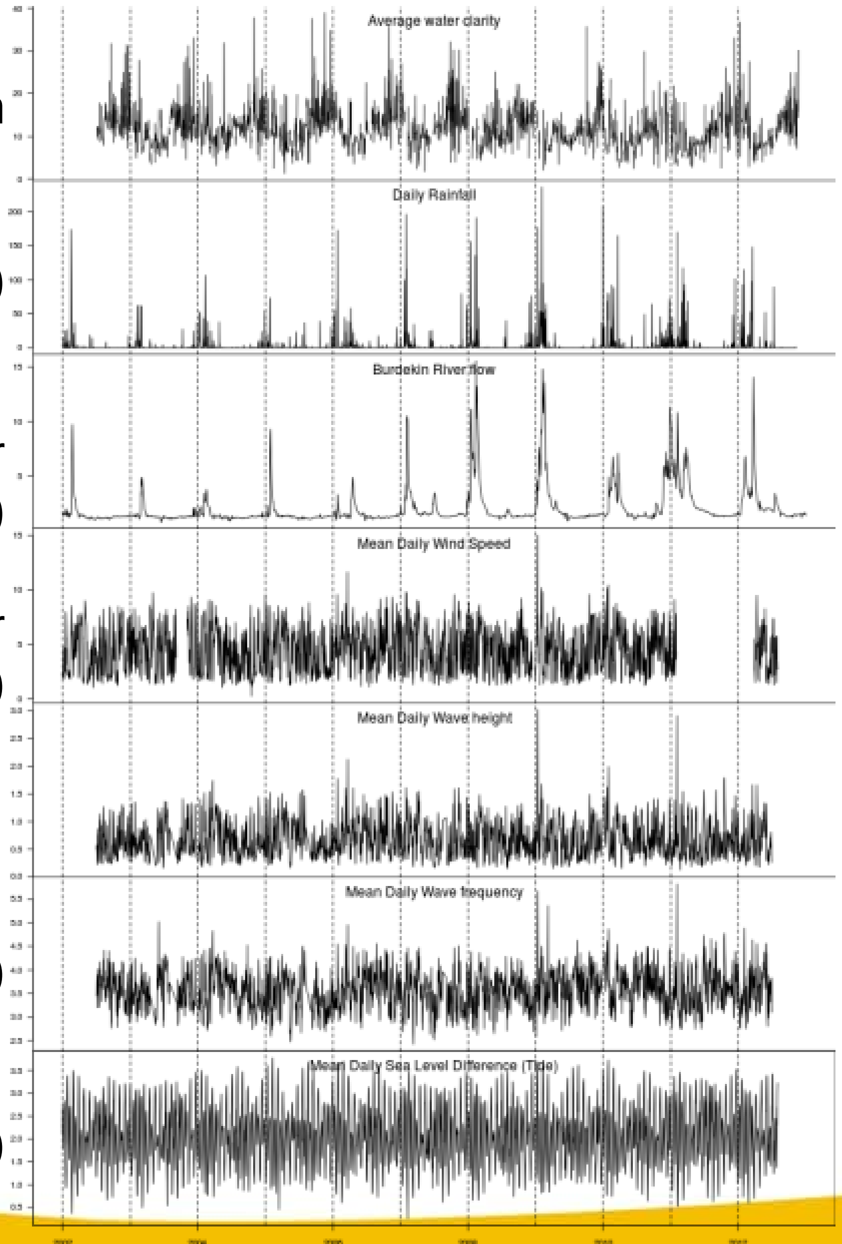
Rainfall (BOM)

Burdekin River (DERM)

Wind (AIMS Weather Station C. Cleveland)

Waves (DERM Wave Rider Buoy Cape Cleveland)

Tidal Range (DERM)



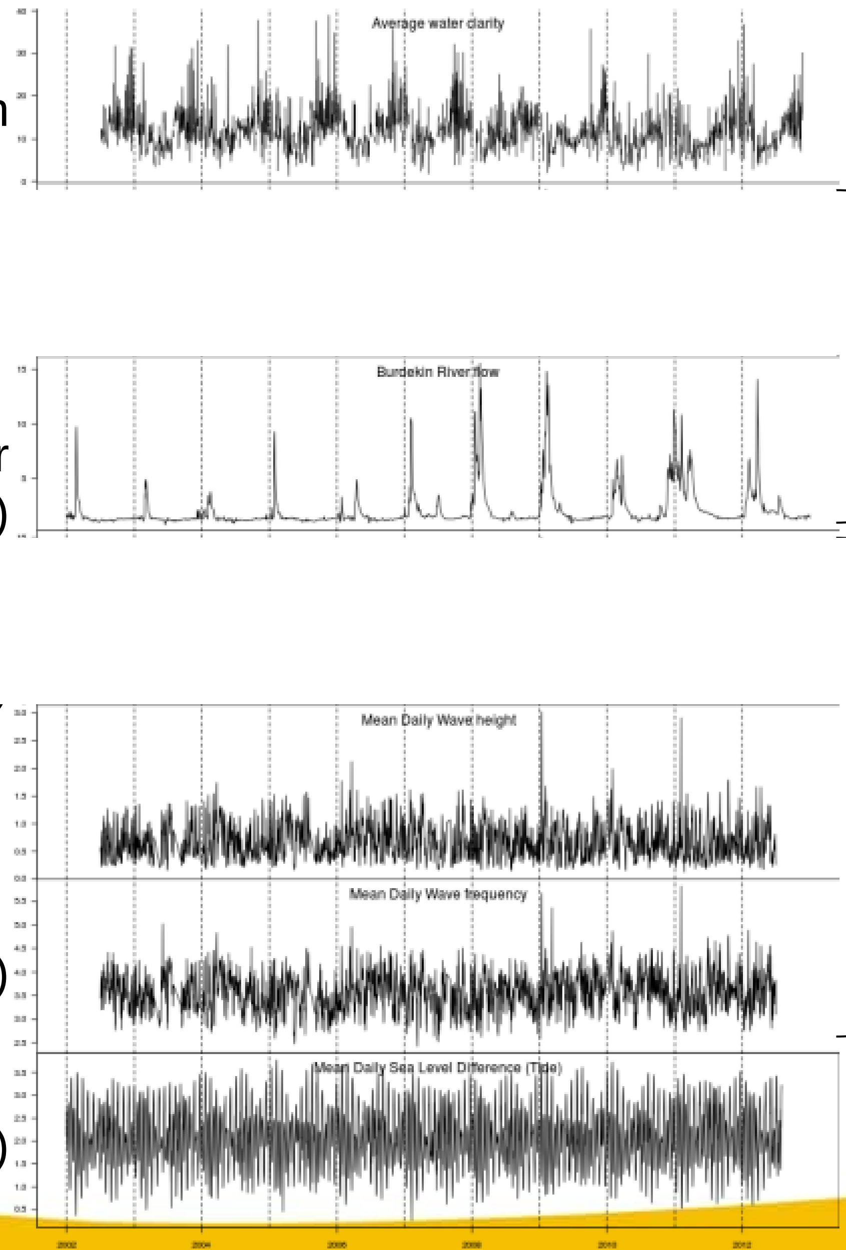
METHODS: COMPILE DAILY ENVIRONMENTAL DATA

Photic depth

Burdekin River (DERM)

Waves (DERM Wave Rider Buoy Cape Cleveland)

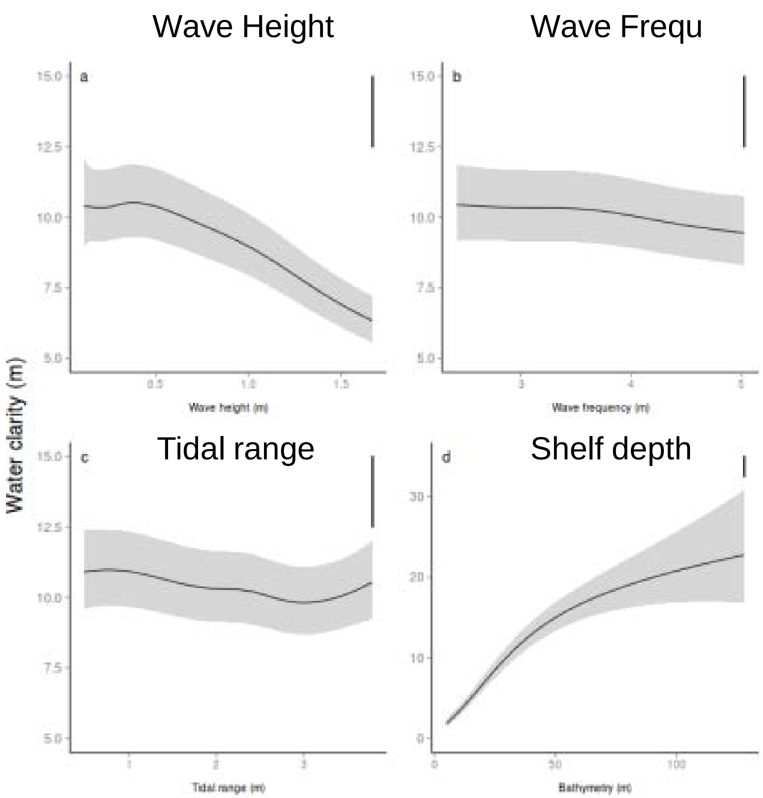
Tidal Range (DERM)



Use Burdekin River flow only

Use Wave data only

METHODS: REMOVE EFFECTS OF WAVES, TIDES, DEPTH



Water clarity is strongly related to wave height, wave frequency, tidal range and depth.

No significant time lags

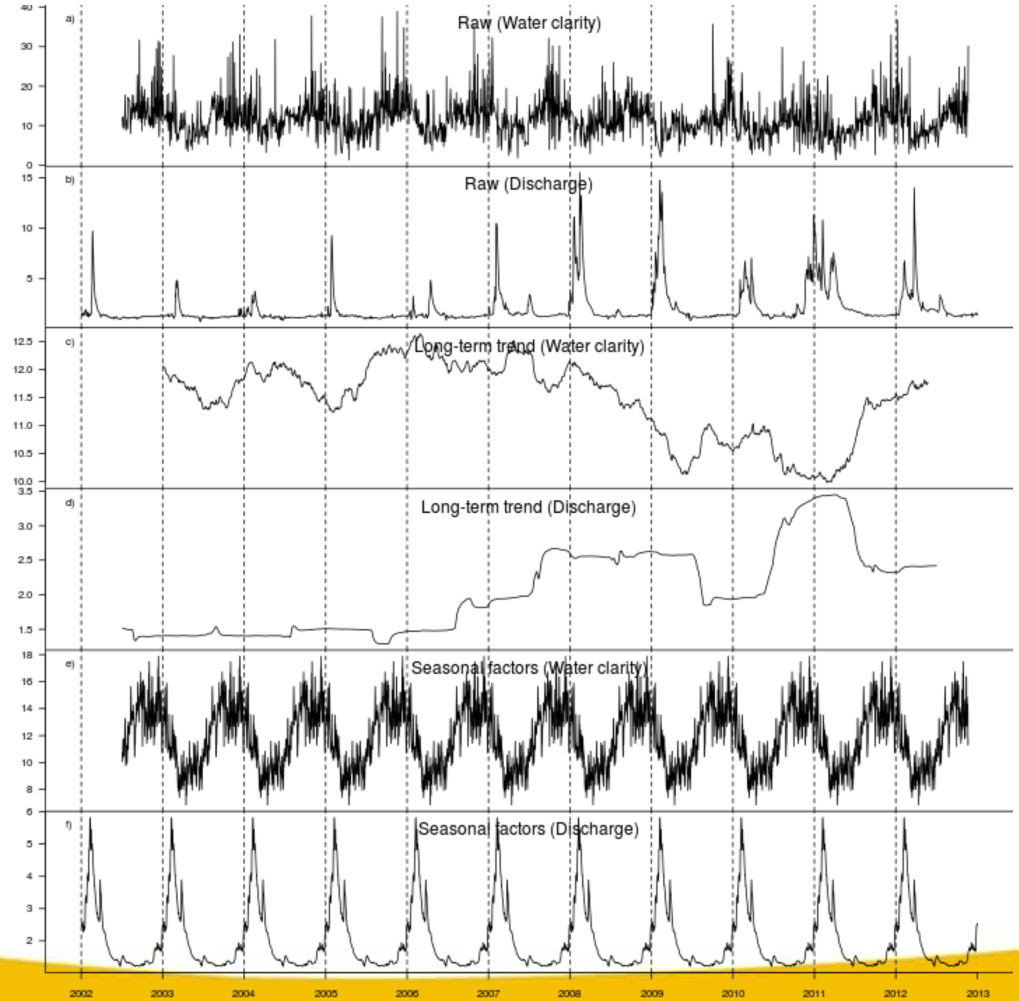
→ Statistically control for waves and tides in further analyses.

Photic depth:

	df	Ref.df	F	p-value	
Wave Height	4.24	4.24	51.62	<0.0001	***
Wave Frequ.	1.51	1.51	7.23	0.0022	**
Tidal Range	1.00	1.00	40.98	<0.0001	***
Shelf Depth	3.90	3.90	2231.47	<0.0001	***

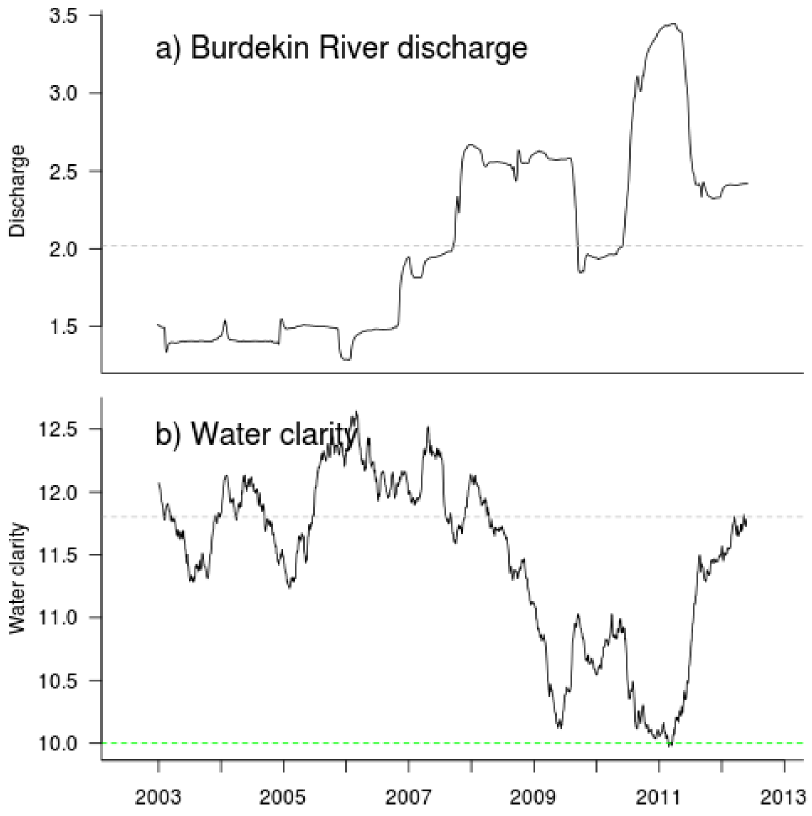
RESULTS 1: INTER-ANNUAL CHANGES IN WATER CLARITY: BURDEKIN REGION

Water clarity: Values corrected for differences due to waves, tides. Water clarity, river discharges: detrended to accommodate seasonal cycles.



RESULTS 1: INTER-ANNUAL CHANGES IN WATER CLARITY: BURDEKIN REGION

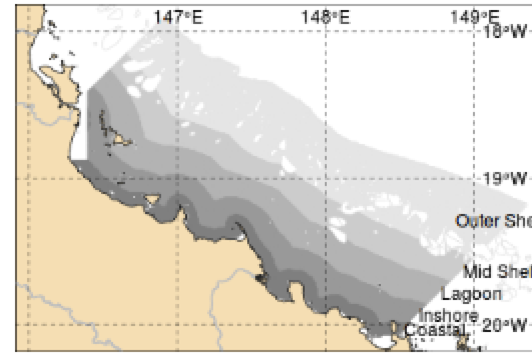
Mean water clarity is strongly related to Burdekin discharges ($R^2 = 0.65$)

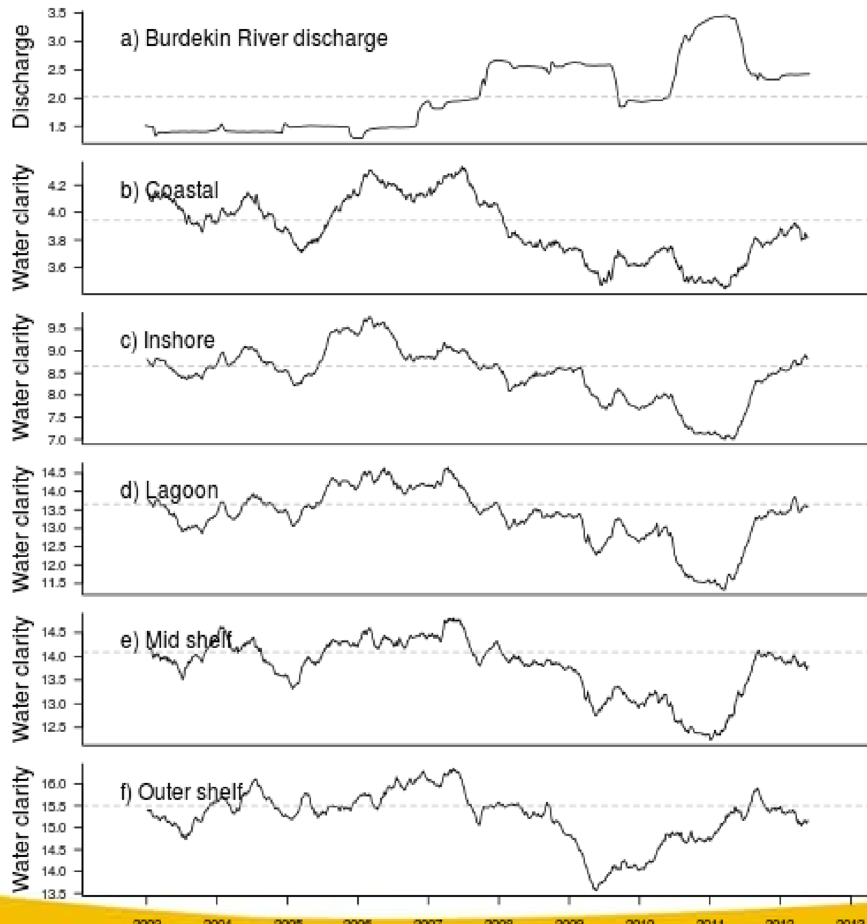


RESULTS 1: INTER-ANNUAL CHANGES IN WATER CLARITY

Strength of relationship water clarity – Burdekin runoff:

- ➢ Strong for inshore, lagoon and mid-shelf bands
- ➢ Weaker within the coastal strip that is always turbid
- ➢ Very weak for outer shelf waters.





Coast: $R^2 = 0.44$

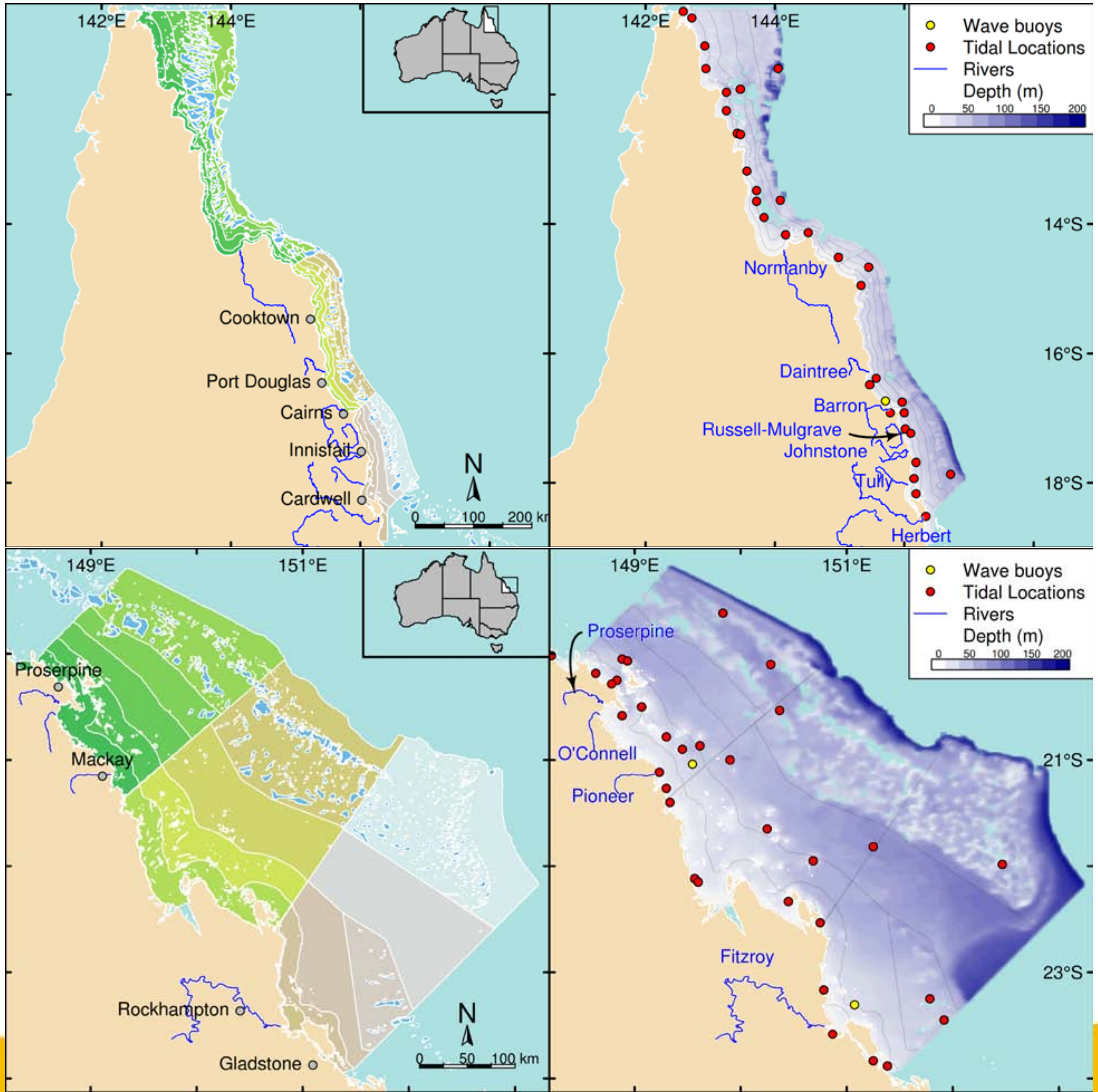
Inshore: $R^2 = 0.60$

Lagoon: $R^2 = 0.64$

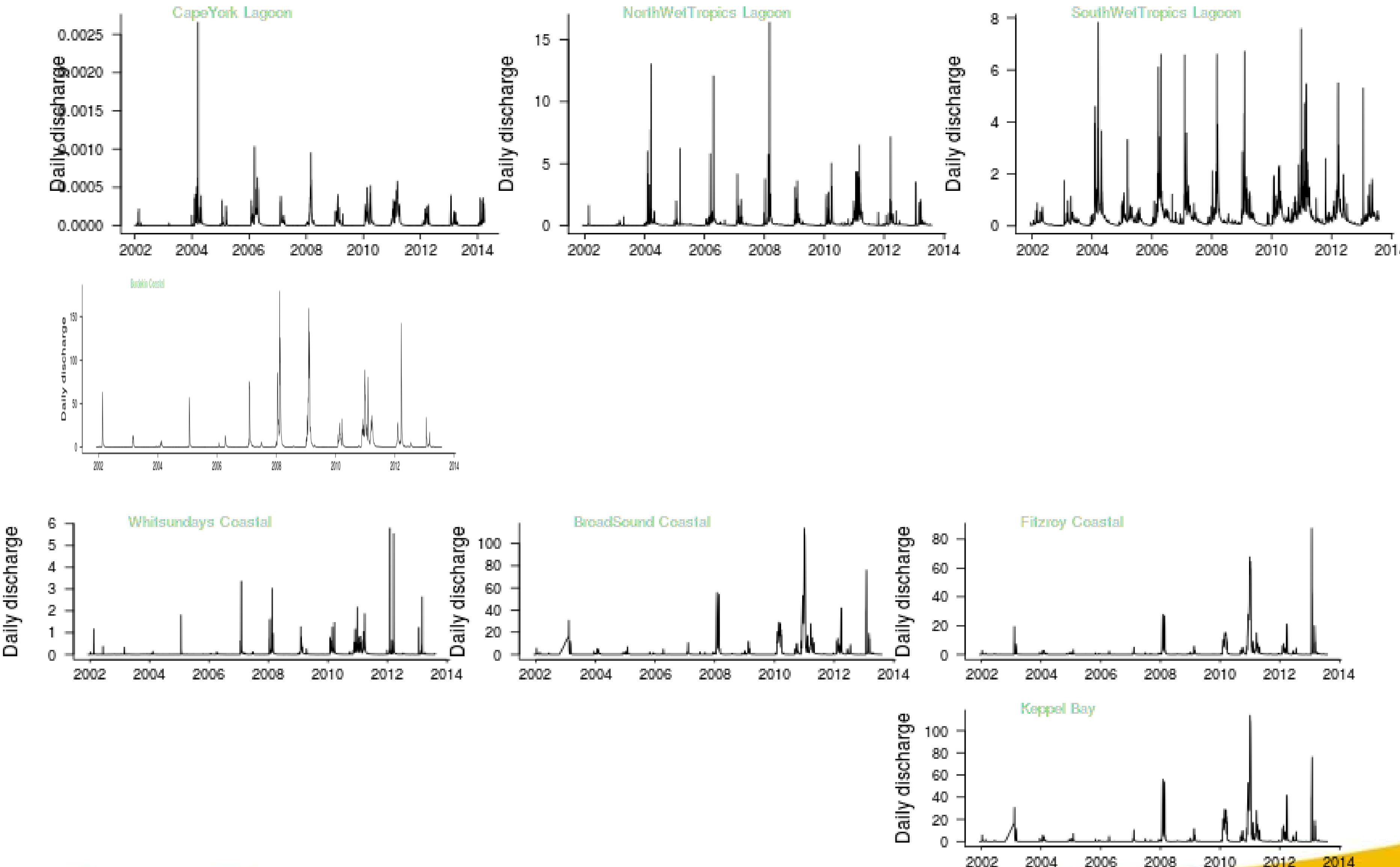
Mid-shelf: $R^2 = 0.55$

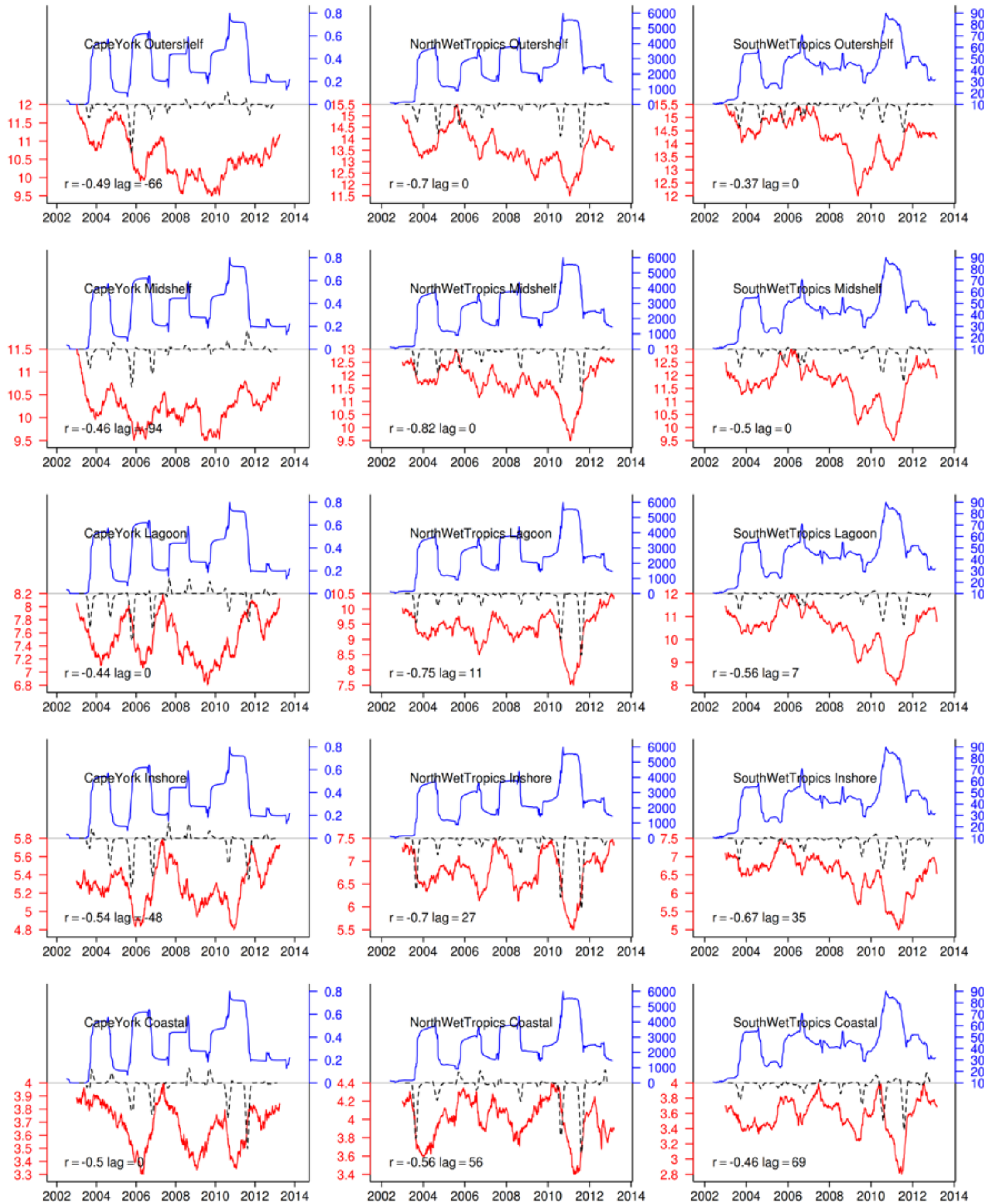
Outer shelf: $R^2 = 0.24$

PART 2: WHOLE GBR

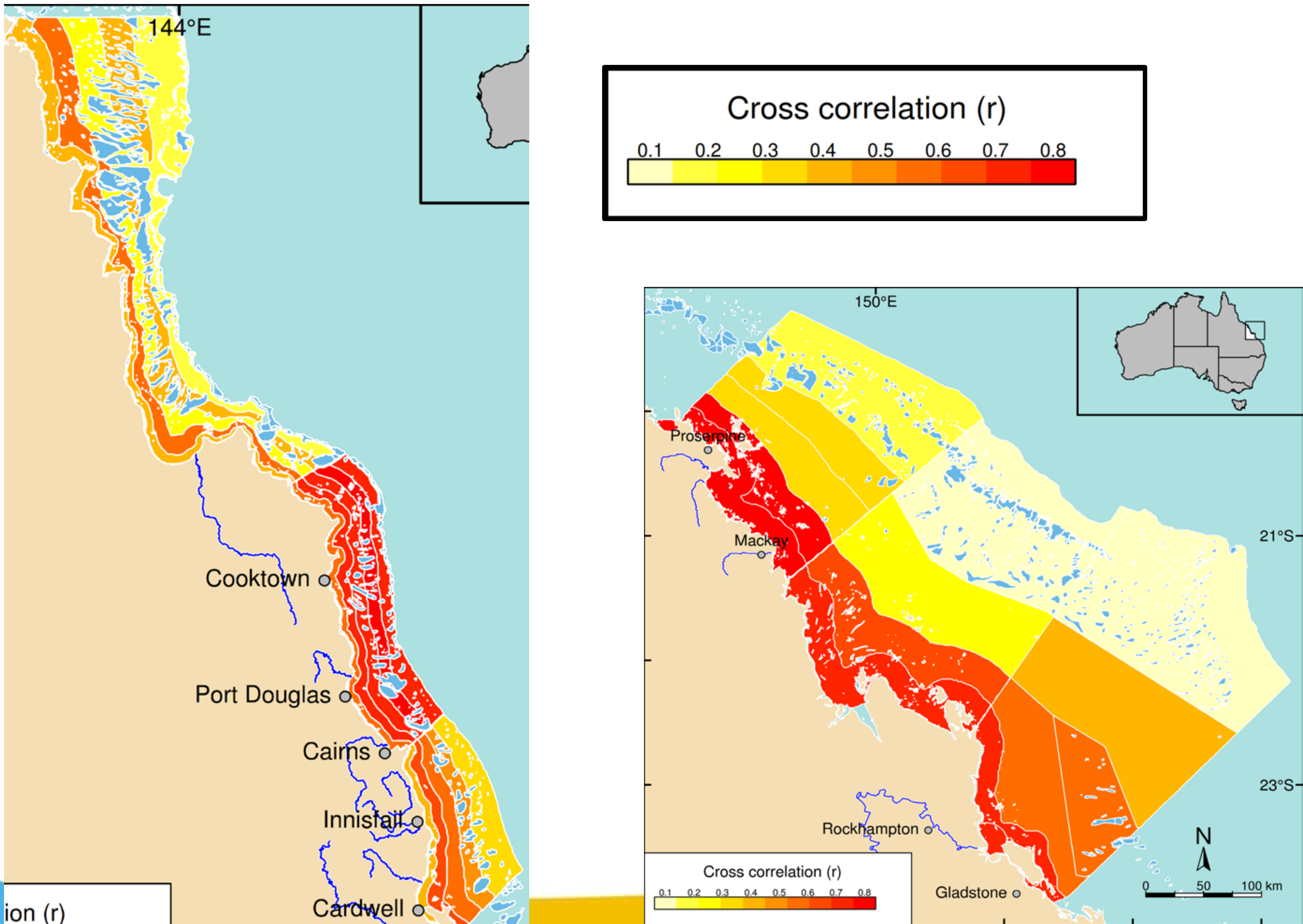


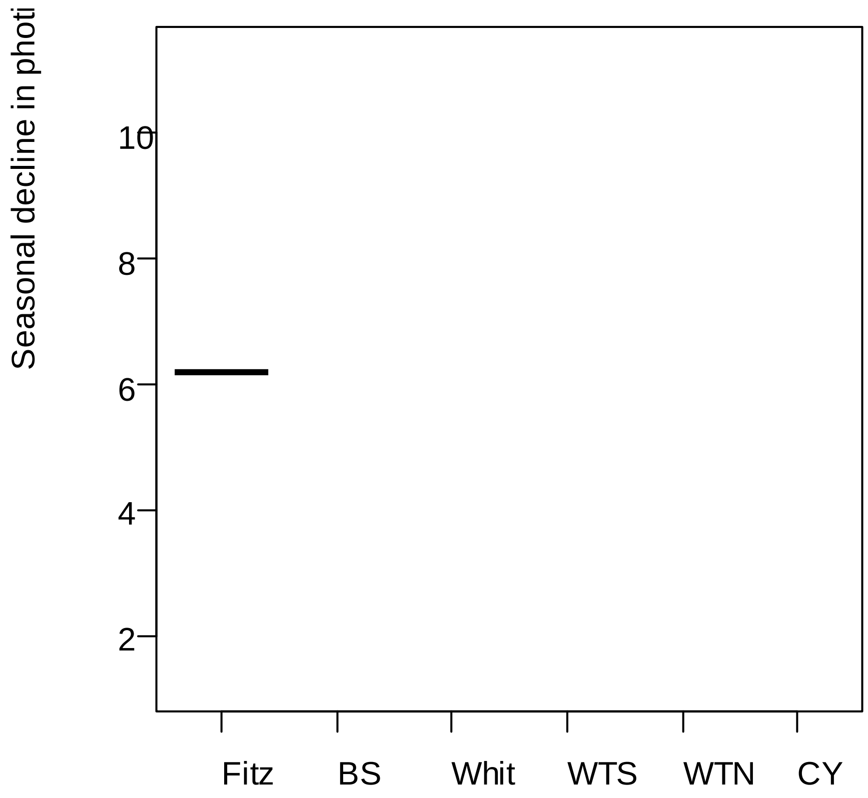
DAILY RIVER DISCHARGES 2002 - 2013




CapeYork Outershelf
r = -0.49 lag = -66
NorthWetTropics Outershelf
r = -0.7 lag = 0
SouthWetTropics Outershelf
r = -0.37 lag = 0
CapeYork Midshelf
r = -0.46 lag = -94
NorthWetTropics Midshelf
r = -0.82 lag = 0
SouthWetTropics Midshelf
r = -0.5 lag = 0
CapeYork Lagoon
r = -0.44 lag = 0
NorthWetTropics Lagoon
r = -0.75 lag = 11
SouthWetTropics Lagoon
r = -0.56 lag = 7
CapeYork Inshore
r = -0.54 lag = -48
NorthWetTropics Inshore
r = -0.7 lag = 27
SouthWetTropics Inshore
r = -0.67 lag = 35
CapeYork Coastal
r = -0.5 lag = 0
NorthWetTropics Coastal
r = -0.56 lag = 56
SouthWetTropics Coastal
r = -0.46 lag = 69
2002 2004 2006 2008 2010 2012 2014

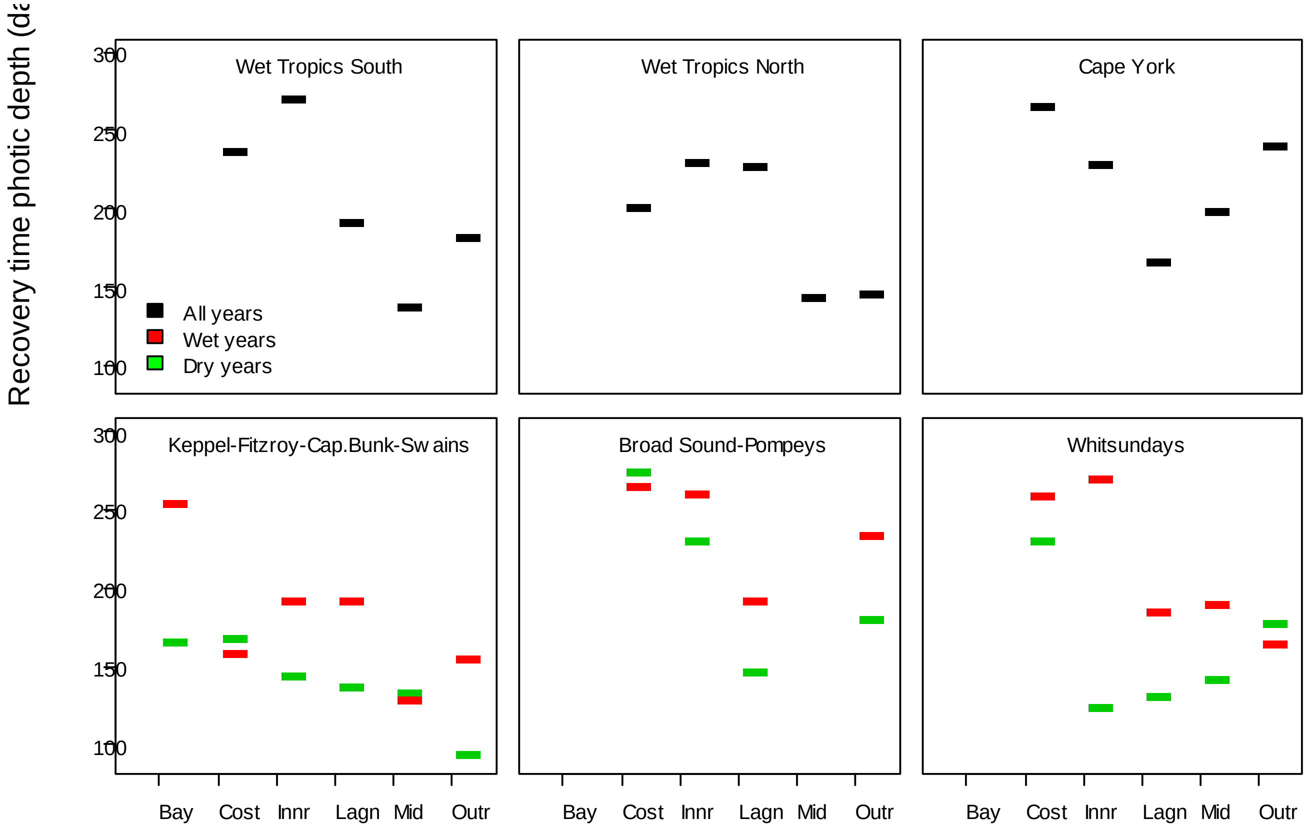
CORRELATION DAILY RIVER DISCHARGE - PHOTIC DEPTH





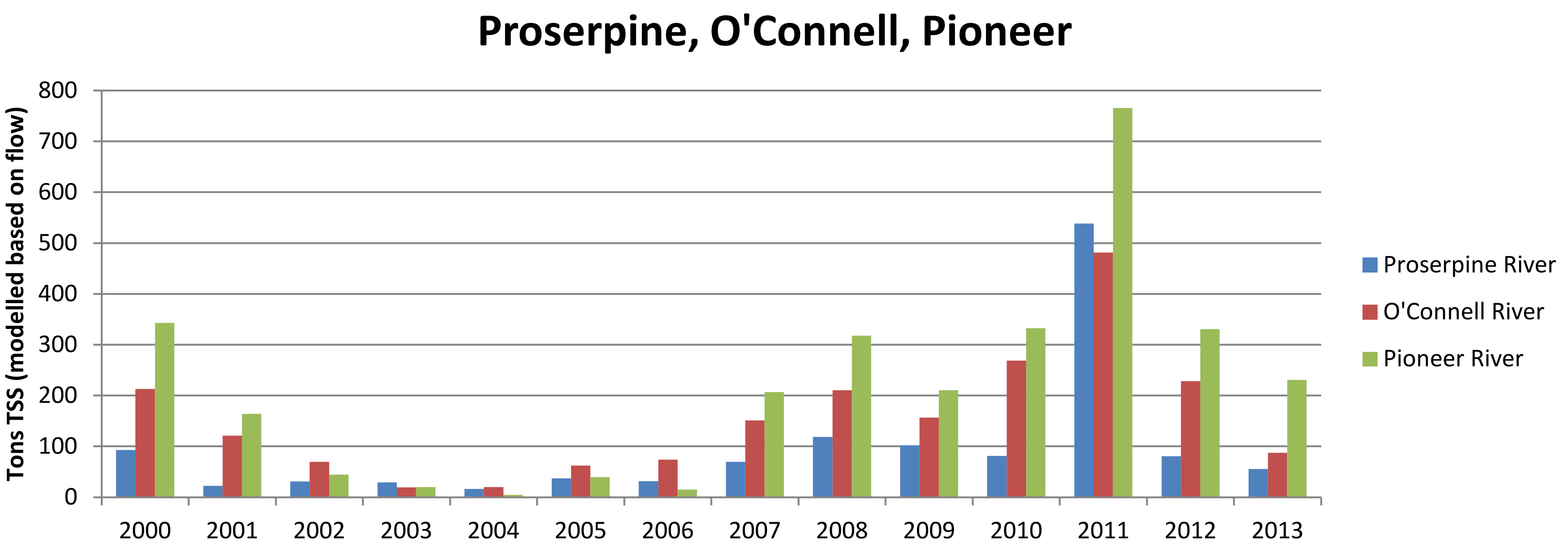
Seasonal decline in photi
10
8
6
4
2
Fitz
BS
Whit
WTS
WTN
CY

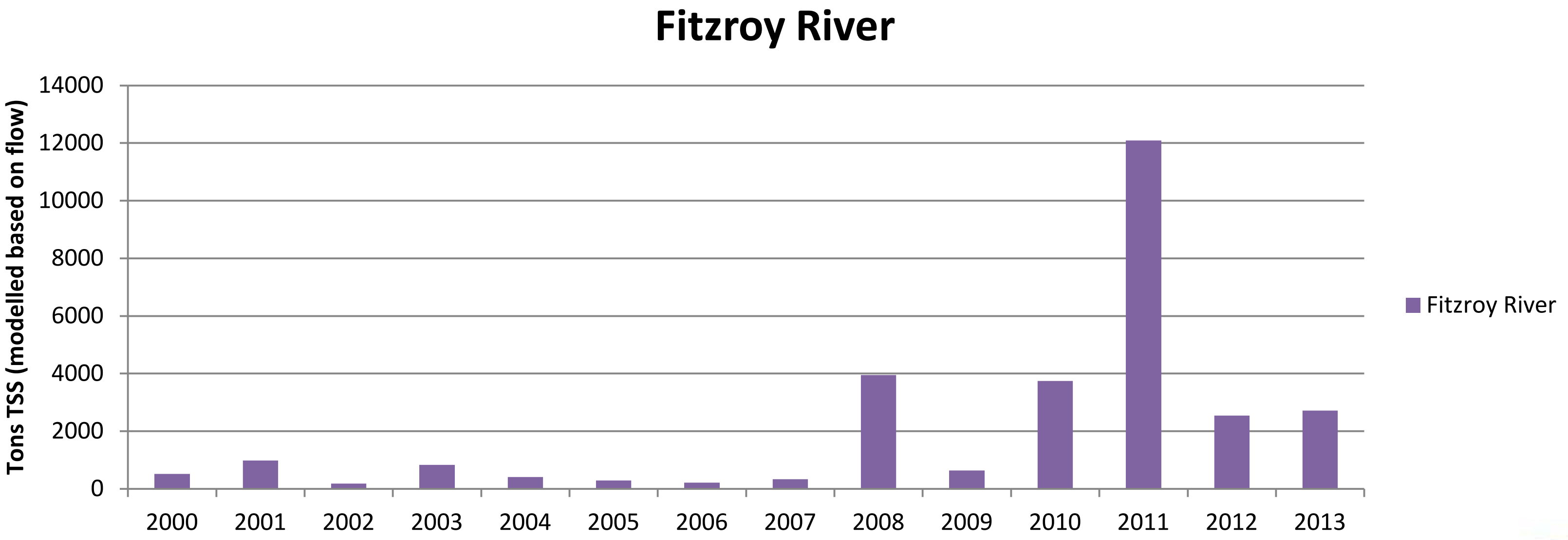
NUMBER OF DAYS FOR 95% RECOVERY



- Number of days for recovery to 95% of seasonal maxima varied between 114 and 268 days (~4 to >8 months)
- Recovery was typically slower near the coast than away from the coast.
- Recovery was typically 10 to >100 days slower in wet vs dry years

RIVER LOADS: e.g., TSS IN SOUTHERN REGIONS

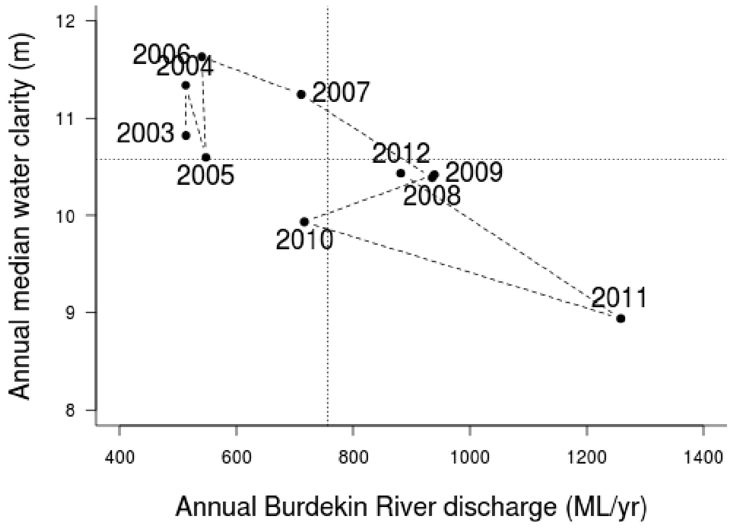


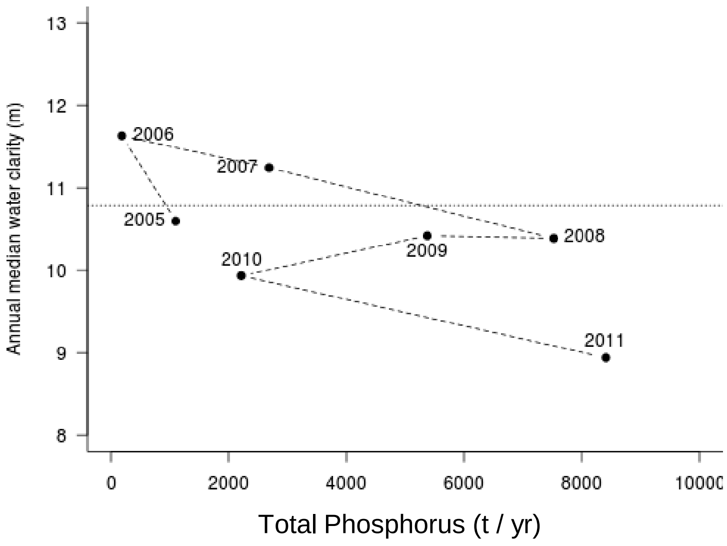


RELATIONSHIP ANNUAL WATER CLARITY – ANNUAL LOADS

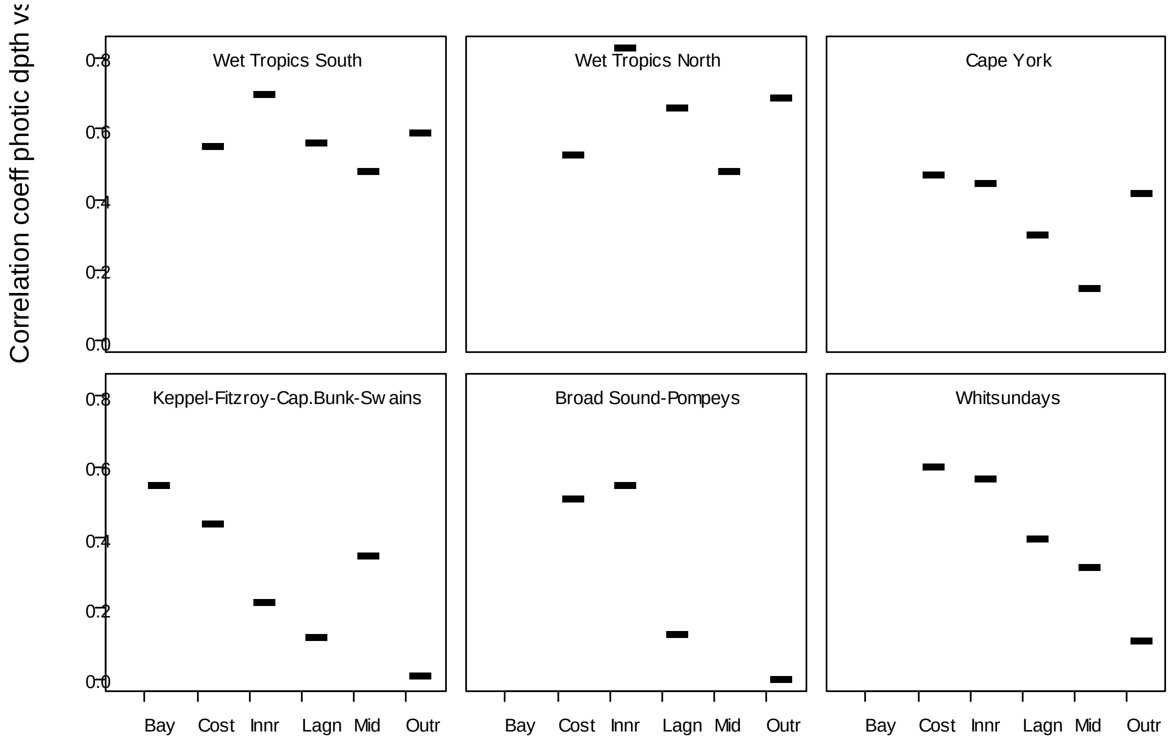
E.g., Burdekin discharges:

- Freshwater: R^2 = 0.65
- Total phosphorus: R^2 =0.51
- Total nitrogen: R^2 = 0.33
- Total suspended solids: R^2 = 0.14





RELATIONSHIP ANNUAL WATER CLARITY – ANNUAL LOADS



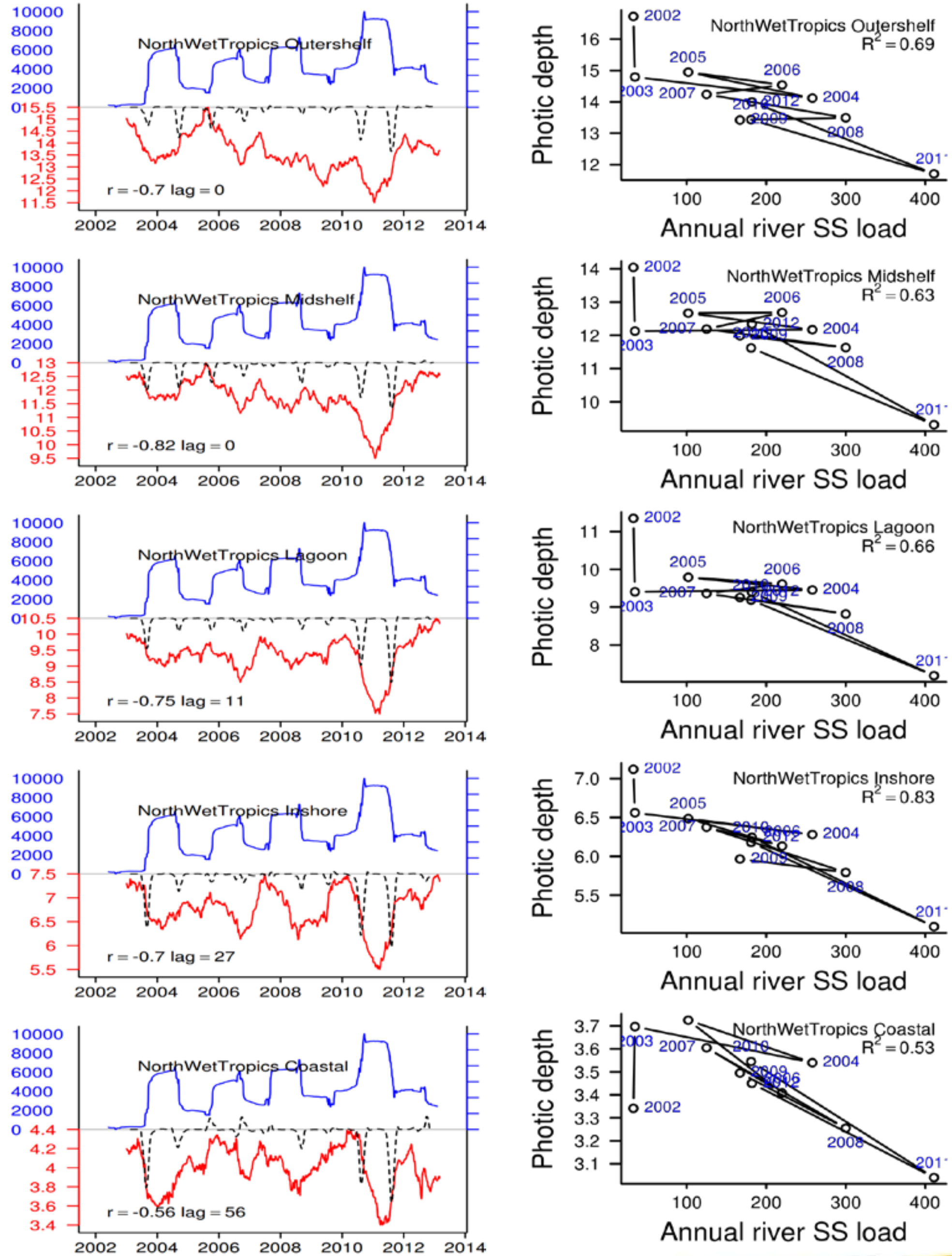
Strong relationships between TSS, PN, PP, DIN and DIP -> impossible to calculate their relative contributions to the loss in photic depth.
TSS used as a proxy for the loads of other nutrients.

Relationships Highest in the Wet Tropics all the way across the shelf

Also very high inshore in the south

Northern Wet Tropics:
Both daily and annual values:

Correlations very strong across the whole shelf, Including mid- and Outer-shelf zones



CONCLUSIONS (1)

- GBR water clarity is strongly related to river discharges in many parts of the GBR.
- Effects extend to lagoon in southern region, to midshelf in Burdekin Region, and to outer shelf in Wet Tropics; weaker patterns in Cape York
- River influence is NOT restricted to the inshore !!
- The river effects last on average 6 - 8 months per year.
- There is intra- and inter-annual capacity for water clarity to recover.
- Reducing terrestrial runoff of nutrients and sediments should therefore improve water clarity in the GBR, leading to significant ecosystem benefits.
- What we didn't do: asses the effects of additional drivers of turbidity (dredging,… – they may well exist, but we didn't test them!)

CONCLUSIONS (2)

Studies of water clarity issues (including EIS) need to :

- Be done over long periods of time, ie many seasonal cycles
- Control for relevant co-variates (wind/waves, tides, bathymetry, seasons, …)
- Be done at the right spatial scales

PATHWAY TO ADOPTION

WHO, HOW, WHEN?

- We urgently need better river load data, including from more rivers in Far North, Cape York
- Results used in the setting of regional targets for fine sediment in the Burnett-Mary and Wet Tropics WQIPs.
- Planned to be used in the Fitzroy, CY and Burdekin WQIPs (September 2014 – June 2015).
- ERTs for sediment delivery now based on fine sediment only (probably <16um fraction)

THANK YOU

DERM for providing wave, tidal and river data
BOM for providing rainfall data
AIMS Weather stations provided wind data
NERP-TE, AIMS, UQ, JCU for funding the study