

Identifying water quality and ecosystem health threats to the Torres Strait from runoff arising from mine-derived pollution of the Fly River

Synthesis Report for NESP TWQ Hub Project 2.2.1 and NESP TWQ Hub Project 2.2.2

Jane Waterhouse, Simon Apte, Jon Brodie, and Cass Hunter with contributions from Caroline Petus, Scott Bainbridge, Eric Wolanski, Katherine A. Dafforn, Janice Lough, Johanna E. Johnson, Dieter Tracey, Brad M. Angel, Chad V. Jarolimek, Anthony A. Chariton and Nicole Murphy



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Project 2.2.1 Identifying the water quality and ecosystem health threats to the Torres Strait and Far Northern Great Barrier Reef arising from runoff of the Fly River and Project 2.2.2 Impacts of mine derived pollution on Torres Strait environments and communities

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CONTENTS

Contents.....	i
List of Tables.....	ii
List of Figures.....	ii
Acronyms and abbreviations	iii
Acknowledgements	iv
1. Introduction	1
1.1 Background.....	1
1.2 Regional overview.....	2
2. Project objectives	5
3. Methodologies employed.....	6
4. Results and findings	8
5. Synthesis	11
6. Conclusions.....	14
7. Recommendations for future work.....	16
8. References.....	17

LIST OF TABLES

Table 1:	Summary of the project components and methodologies employed.	6
Table 2:	Habitat (coral reef and seagrass) sites selected for the risk assessment (and corresponding monitoring codes where relevant) and potential zone of influence. Note: SG = seagrass site; RF = reef site. The site names correspond to the TSRA coral reef monitoring locations.	12

LIST OF FIGURES

Figure 1:	Map showing the Torres Strait region showing major rivers, islands, habitats and the boundary of the Torres Strait Protected Zone.	2
Figure 2:	Dissolved copper versus salinity profiles in the Fly River Estuary (1993 to 2013, Angel et al. 2014).	4
Figure 3:	Increase in suspended sediment particulate copper concentrations in the Fly River Estuary over the period 1993 to 2013 (Angel et al. 2014).	4
Figure 4:	Location of the Torres Strait coral reefs, seagrass beds and habitat sites selected for the integrated assessment (white dots) (between 142.015°E to 144.295°E and 8.860°S to 10.354°S). Map prepared by D. Tracey, TropWATER JCU using datasets from GBRMPA, Carter et al. (2014), Haywood et al. (2008) and Carter and Rasheed (2016).	11
Figure 5:	Summary of the highlights of NESP Project 2.2.1 and 2.2.2, within the different zones of influence. Zone 1: North central; Zone 2: North East; Zone 3: North West; Zone 4: North central (south); Zone 5: Central and Zone 6: South East. Map prepared by D. Tracey, TropWATER, JCU.	13
Figure 6:	Conceptual scheme showing the importance of integrating different data sources to provide comprehensive water quality and environmental assessments.	15

ACRONYMS AND ABBREVIATIONS

AIMS..... Australian Institute of Marine Science
CSIRO Commonwealth Scientific and Industrial Research Organisation
GBR Great Barrier Reef
JCU James Cook University
MOHID..... Modelo Hidrodinamico ('hydrodynamic' in Portuguese)
NESP National Environmental Science Program
NE Northeast
NW Northwest
NTU Nephelometric turbidity unit
PNG Papua New Guinea
SLIM Second-generation Louvain-la-Neuve Ice-ocean Model
SE..... Southeast
TSRA..... Torres Strait Regional Authority
TWQ Tropical Water Quality
UNSW..... University of New South Wales

Units of measure

g gram
km kilometre
NTU Nephelometric turbidity unit
m metre
Mt/yr Million tonnes per year
µg microgram

Island names

Island	Other names
Maizab Kaur	Bramble Cay
Erub	Darnley
Masig	Yorke
Iama	Yam
Ugar	Stephens
Warraber	Sue
Mer	Murray
Poruma	Coconut
Saibai	Saibai
Boigu	Talbot
Duaun	Mt Cornwallis
Waiben	Thursday
Ngurupai	Horn

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Finally, the authors of this report are grateful for the peer review comments of the project reports provided by Dr David Haynes, Mr Barry Butler and Professor Damien Burrows whose input has provided valuable improvements to this report.

THIS REPORT

This report provides a synthesis of two projects within the National Environmental Science Program (NESP) Tropical Water Quality Hub: *NESP Project 2.2.1 Identifying the water quality and ecosystem health threats to the Torres Strait and Far Northern Great Barrier Reef arising from runoff of the Fly River* and *Project 2.2.2 Impacts of mine derived contamination on Torres Strait environments and communities*. It provides a brief summary of key project outputs in a format that is readily accessible to managers and interested community members in the region.

This report draws on information contained in the final reports prepared for each project ([Waterhouse et al., 2018](#) and [Apte et al., 2019](#)); readers are referred to these reports for further detail and explanation of the context and results of the projects.

1. INTRODUCTION

1.1 Background

Torres Strait Islanders depend on their marine resources for food, livelihoods and cultural activities. The Torres Strait is an area of Australia that has relatively few anthropogenic inputs of contaminants such as trace metals. However, concerns have been raised over the last couple of decades about the impacts of mining occurring in Papua New Guinea (PNG) and transboundary transport of metal contaminants into the Torres Strait.

The Ok Tedi copper mine in PNG has been operating since 1985 and discharges copper contaminated sediments in the form of mine tailings and waste rock into the Fly River which ultimately flow into the Fly River Estuary and Gulf of Papua. This has resulted in significant impacts on the river system including widespread contamination of the Fly River by copper (which is highly toxic to aquatic life), increased turbidity and changes to river geomorphology through widespread deposition of sediments (Bolton 2009). Estimates suggest that mining operations have increased sediment discharge from the whole of the Fly River by 40% (Wolanski et al. 1995). Given the close proximity of the Torres Strait to the mouth of the Fly River, concerns have also been raised since the start of mine operations that trans-boundary contamination may occur.

Under certain tidal and weather conditions it has been observed that plumes of water from the Fly River estuary may extend into the north east Torres Strait (Wolanski et al. 1999; Li et al. 2017). This is a natural process which has been occurring for several thousand years. However, over the last 30 years since mining began, intermittent intrusion of plumes of water originating from the Fly River provides a means for transporting mine-derived sediments into this area. Fly River plume waters have been detected across the northern Torres Strait, east of the Warrior Reefs, as far west as Saibai Island and south to Masig Island (Figure 1) (Wolanski et al. 2013; Martins and Wolanski 2015; Li et al. 2017; Petus et al. 2018). These areas contain complex and important seagrass and reef communities that are potentially threatened by changes in water quality (Carter et al., 2014). The Commonwealth Scientific and Industrial Research Organisation (CSIRO) has conducted various studies on the impacts of mine contamination in the Fly River system over the last 25 years that suggest an increase in the copper content of sediments in the Fly River estuary (Angel et al., 2010 and 2014) thus giving rise to further concerns.

To enhance our understanding of the Fly River plume intrusion into the Torres Strait and identify its potential impacts on the regions marine ecosystems and dependent communities, two partner projects were undertaken through the National Environment Science Program (NESP), building on previous work, to determine: (i) the spatial extent, temporal patterns and the water and sediment quality of the Torres Strait region and (ii) which ecosystems in the Torres Strait are exposed to the Fly River discharge. These studies were conducted by James Cook University (JCU; including TropWATER and the Centre of Excellence for Coral Reef Studies) and CSIRO in collaboration with scientists from the Australian Institute of Marine Science (AIMS), University of New South Wales (UNSW), Macquarie University, University of Algarve, the Yantai Institute of Coastal Zone Research China and C₂O Consulting. It was outside the scope of this project to conduct a full assessment of the impact of Fly River discharges on Torres Strait ecosystems, rather, this phase focused on determining when and where the influence from this discharge is likely to occur.



Figure 1: Map showing the Torres Strait region showing major rivers, islands, habitats and the boundary of the Torres Strait Protected Zone.

1.2 Regional overview

The Torres Strait and Gulf of Papua

The Torres Strait region covers an area of 48,000 km², of which only 2.6% is land mass, 6.2% is tidally inundated reef flats, and 91.2% open seas, most of which are relatively shallow (20–60 m). The region is located on the border between Australia (northern Queensland) and PNG and stretches 200 km from the tip of the Cape York Peninsula to the southwest coast of PNG (Figure 1). There are more than 247 islands and cays, 18 that are inhabited and support an estimated population of 7,000 people.

The Torres Strait has the largest continuous area of seagrass meadows in the world, significant areas of high diversity coral reefs, extensive areas of coastal mangroves and productive fisheries. It is rich in biodiversity and cultural significance, with its ecosystems being amongst the most pristine in the world and retaining a high degree of natural and wilderness values. It has strong tidal currents and irregular bathymetry with a narrow continental shelf (Wolanski et

al. 1999). The region's variety of habitats support highly diverse Indo-Pacific marine flora and fauna, including dugongs and marine turtles (Sobtzick et al. 2014; Hamann et al. 2015a, 2015b). The geographic location of the Torres Strait places it at risk from the impacts of shipping, downstream impacts of mining and land clearing in PNG (Waterhouse et al. 2013). Other major risks include climate change and over-exploitation of natural resources.

The catchment area of rivers (e.g. Fly, Purari, Bamu, Kikori and Turama) in PNG draining into the Gulf of Papua is $1.42 \times 10^5 \text{ km}^2$, and collectively its rivers deliver approximately 350 million ML of freshwater to the Gulf annually, containing about 200 million tonnes per year of suspended sediments. The catchments of these rivers are largely undisturbed, except for the pre-existing small-scale human settlements throughout the catchments, likely dating back thousands of years. In the last 50 years, two large mines Ok Tedi Mining Ltd in the headwaters of the Fly River and Porgera in the headwaters of the Strickland River, a major tributary of the Fly River (Bolton 2009; Cresswell et al. 2013). These catchments are subject to higher levels of natural disturbance than, for example, most Australian sites due to their seismicity and less stable geomorphology. For example, a landslide in 1989 contributed 125 Mt of sediment to the Fly River and in 8,800 BP a larger scale event is estimated to have contributed 7 km^3 of soil to the system (Bolton et al. 2009).

The Fly River

The Fly River discharges into the Gulf of Papua to the northeast (NE) of the Torres Strait (Figure 1). It is a large river by global standards, with an estimated flow volume of $6,000 \text{ m}^3 \text{ sec}^{-1}$ typically with $\pm 25\%$ seasonal variations (Wolanski et al. 1997) and is ranked as the 17th largest river in the world in terms of sediment discharge (Galloway 1975; Milliman and Syvitski 1992).

Mining at the headwaters of the Ok Tedi River (the Ok Tedi copper mine) in PNG started in 1985 and in the Strickland River, which is the largest tributary of the Fly River (the Porgera gold mine), in 1990. Before the construction of the Ok Tedi mine, sediment discharge from the Fly River was estimated to be approximately 85 Mt/yr (Dietrich et al. 1999) and the mining operation is estimated to have caused a 40% increase in the sediment discharge of the river (Wolanski et al. 1995), i.e. to approximately 120 Mt/yr (Canestrelli et al. 2010). By contrast, the Porgera gold mine discharges around 8 Mt/yr of mine-derived sediments into the headwaters of the Strickland River which ultimately flows into the lower Fly River.

CSIRO and other researchers have conducted various studies on the impacts of mine pollution in the Fly River system over the last 25 years including the Fly River estuary (Apte 2009). Their data for the Fly River estuary (Figures 2 and 3) suggests an increase in the copper content of sediments (Apte 2009; Angel et al., 2010, 2014) over the operating lifetime of the Ok Tedi mine. Based on a field survey conducted in 2013 (Angel et al. 2014), particulate copper concentrations in suspended sediments have increased from pre-mine levels of around $40 \mu\text{g/g}$ to $83 \mu\text{g/g}$. This increase was caused by the mixing of copper-rich mine-derived sediments (i.e. mine tailings and waste rock) with natural fine sediments. For further information on the impacts of the Ok Tedi mine on the Fly River system, readers are referred to the monograph edited by Bolton (Bolton 2009).

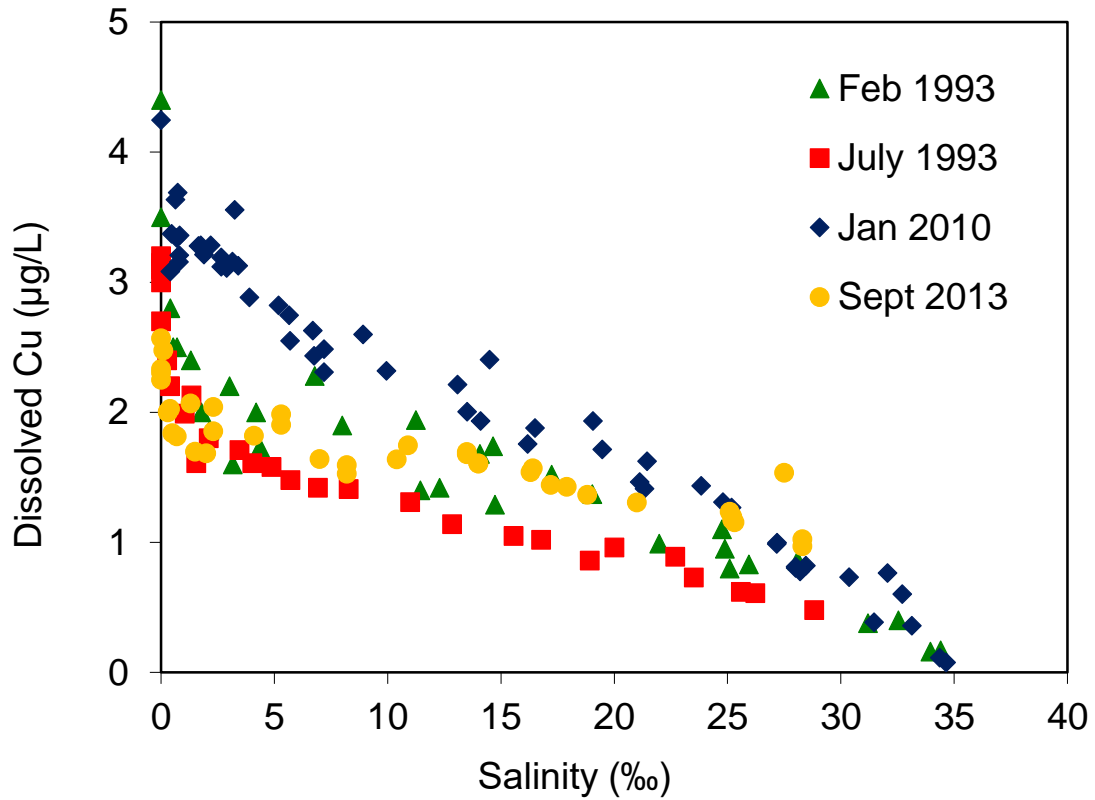


Figure 2: Dissolved copper versus salinity profiles in the Fly River Estuary (1993 to 2013, Angel et al. 2014).

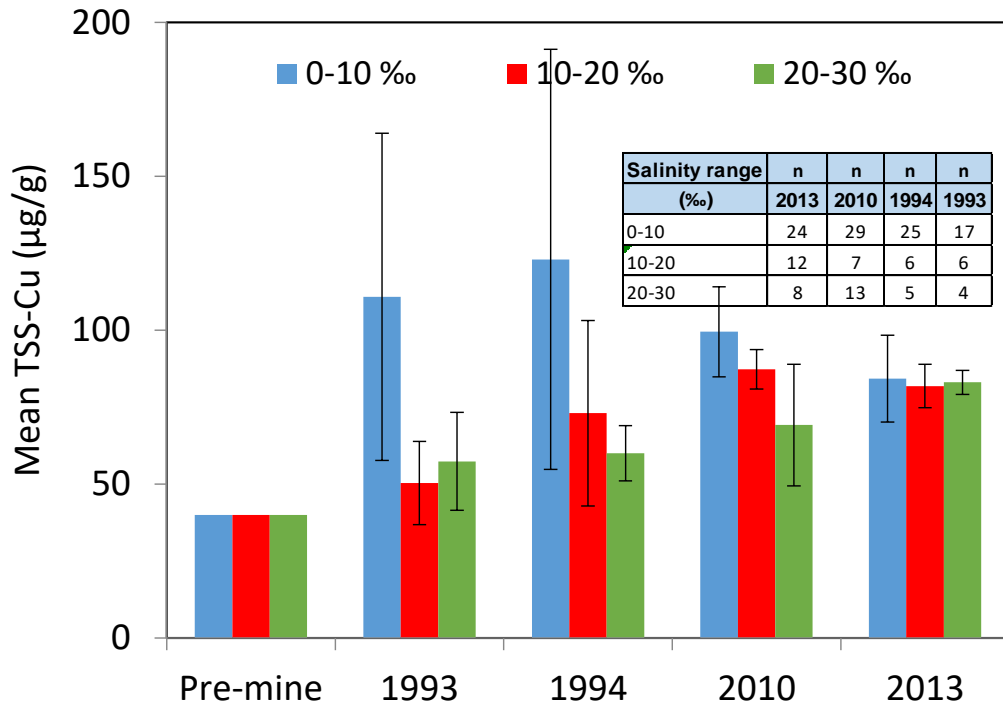


Figure 3: Increase in suspended sediment particulate copper concentrations in the Fly River Estuary over the period 1993 to 2013 (Angel et al. 2014).

2. PROJECT OBJECTIVES

The two NESP TWQ Hub projects commenced in January 2016 and were completed in November 2018. The primary **objectives** of the projects were to:

1. Summarise the characteristics of Fly River discharges including hydrodynamics, pollutant sources and material transport - particularly trace metals.
2. Define the temporal patterns (frequency, duration) of plume suspended sediment delivery and transport to the Gulf of Papua and northern Torres Strait. This included historic analysis through coral coring techniques.
3. Generate high quality data on trace metal contaminant concentrations in waters and sediments (both benthic and suspended) across the Torres Strait.
4. Determine if mine-derived contaminants were present/accumulating in the Torres Strait and have influenced water and sediment quality.
5. Identify any hotspots of mine-derived contamination.
6. Undertake a preliminary desktop analysis to estimate the spatial and temporal extent of exposure of coral reefs and seagrasses in the Torres Strait to Fly River discharge.
7. Provide the results in a form that can be spatially and temporally delivered via the Torres Strait eAtlas to inform environmental decision-making.

3. METHODOLOGIES EMPLOYED

The projects adopted a ‘multiple lines of evidence’ approach to provide a combined assessment of the hazards presented to vulnerable ecosystems and communities of the Torres Strait by mine-derived contaminants originating from the Fly River. Table 1 lists the major components of the projects and the approaches employed.

Table 1: Summary of the project components and methodologies employed.

Project component	Approach	References for detailed methodology
Analysis of the concentrations of mine-derived contaminants in waters and sediments in the Torres Strait	Execution of ‘snapshot’ field surveys in October 2016 and June 2018. Collection of water, benthic sediments and suspended sediment samples. Analysis of samples for a comprehensive range of trace elements. The first survey covered 21 sites spread across the Torres Strait. The second survey focussed on water quality around Saibai and Boigu islands.	Apte et al. (2019)
Marine hydrodynamic modelling	Development and application of the large scale MOHID ¹ 3D hydrodynamic model and smaller scale SLIM ² 2D hydrodynamic model for the Torres Strait and the Gulf of Papua.	Li et al. (2017)
Remote sensing of water quality conditions	Acquisition, classification and analysis of daily true-colour medium resolution satellite data (2008-2016) to: provide a large-scale baseline of the composition of coastal waters around the Gulf of Papua–Torres Strait region, investigate the spatial and temporal variability of the Fly River turbidity plume, and identify instances and areas with likely plume intrusion into the Torres Strait.	Petus et al. (2018)
In-situ continuous monitoring of salinity and turbidity	Deployment of real-time wind, precipitation and salinity measurements from monitoring stations at Masig Island and Bramble Cay to assess local patterns. Measurement of <i>in-situ</i> turbidity using continuous loggers at Bramble Cay.	Bainbridge within Waterhouse et al. (2018)
Weekly salinity monitoring conducted by local Torres Strait Regional Authority (TSRA) Rangers	Implementation of a weekly salinity monitoring programme by TSRA Rangers using handheld salinity and temperature meters to provide local observations. Data was collected at Boigu, Saibai, Erub, Masig, Iama, Poruma and Warraber Islands from February 2017 onwards.	Waterhouse and others within Waterhouse et al. (2018)

¹ Modelo Hidrodinamico (‘hydrodynamic’ in Portuguese)

² Second-generation Louvain-la-Neuve Ice-ocean Model

Project component	Approach	References for detailed methodology
Water quality exposure assessment and assessment of correlations between water quality datasets	Mapping of the frequency of exposure of reef and seagrass habitats to turbid waters using the classification of remote sensing true colour images into water colour classes (water types). Development of a potential turbidity exposure map for the region. Using evidence from other project components, qualitative assessment of the potential contribution of the Fly River to the areas of greatest exposure to turbid waters.	Tracey and others within Waterhouse et al. (2018)
Analysis of available coral cores for freshwater influence	Historical analysis of existing <i>Porites</i> coral cores from Erub Island and Bramble Cay using analysis of luminescence records to identify freshwater influence in these locations over many years (time period 1781 to 1993).	Lough (2016)
Scoping of gene analysis in sediment samples to provide bacterial and infaunal indices in response to environmental conditions	Targeted gene sequencing in sediment samples to investigate microbial (bacterial and eukaryotic) and infaunal (eukaryotic) biodiversity in the region. Comparison of diversity metrics and community composition from each sediment core to the metal/metalloid and organic/physico-chemical analyte profiles.	Dafforn and others within Waterhouse et al. (2018)
Pilot study for the analysis of trace metals in seagrass leaves to assess potential influence of river discharge on these levels	Collection of seagrass leaves from the area suspected to be influenced by Fly River discharge in the northern Torres Strait and analysis of metal concentrations. Metal concentrations in seagrass may be concentrated up the food chain into green turtles and dugong as an indicator of biological contamination.	Brodie and others within Waterhouse et al. (2018)
Community surveys of community members at Saibai and Boigu islands regarding their perceptions of Fly River discharge in the Torres Strait	Interviews with of community members on Saibai Island and Boigu Island to elicit their views of the frequency and potential consequences of muddy waters impacting upon their community. The interviews included a series of structured questions and were conducted one-on-one. Survey results were analysed, aggregated and summarised in the form of tables and graphs.	Apte et al. (2019)

4. RESULTS AND FINDINGS

The projects have established the following key findings:

Analysis of the concentrations of trace metals in waters, suspended sediments and benthic sediments at 29 sites across the Torres Strait showed that metal concentrations in waters were generally very low and consistent with uncontaminated marine waters from other regions of the world. Trace metal concentrations in waters and sediments were higher in the northern Torres Strait and were highest near Saibai and Boigu. The observation of elevated trace metal concentrations in this area first made in October 2016 was confirmed during an intensive water quality survey conducted around Boigu and Saibai in June 2018. The sources of higher concentrations of metals in the north remain to be fully identified. This may include some contributions from the Fly River, but inputs from runoff from the PNG mainland cannot be discounted. The concentrations of dissolved metals were below the 95% species protection guideline values of the Australian and New Zealand water quality guidelines (ANZECC/ARMCANZ 2000) which are used by regulators in most areas of Australia as default regulatory benchmarks. Dissolved copper concentrations exceeded the 99% species protection guideline values in ten water samples collected in the vicinity of Boigu and Saibai Islands.

Hydrodynamic modelling results for the region show that Fly River plumes commonly move into the northern Torres Strait and along the PNG coast, particularly affecting the northern and north western islands and reefs during the six months of the southeast (SE) trade wind season (approximately May to November). The plume extends to the northwest (NW) of the Torres Strait in the SE trade wind period, but to the SE of the Fly River mouth during the NW monsoon period (approximately December to April).

Deployment of continuous turbidity loggers at Bramble Cay (2017 to 2018) showed higher than expected levels of turbidity (average of 10.7 NTU) for a remote offshore reef (as compared to offshore reefs in the Great Barrier Reef (GBR) that average 0–3 NTU and near-shore reefs that average 3-5 NTU in the dry season and a maximum of 10-15 NTU in the wet season). The observed patterns of turbidity at Bramble Cay were correlated with wind speed and most likely represent local wind driven resuspension of *in-situ* material and not episodic movement of material from the (Fly River) north. The exception is a peak in turbidity observed in June 2017 that seems to be unrelated to local environmental conditions. Analysis of satellite imagery in this period shows evidence of Fly River discharge entering the region. The presence of fine terrestrial material at Bramble Cay indicates that there is long-term transport of material from PNG as the nearest source. However, this may be via more complex long-term transport mechanisms rather than short-term episodic events, which in turn will have implications for the potential transport of contaminants into the area.

Regular salinity monitoring conducted by TSRA Rangers in the northern Torres Strait including weekly sampling at Masig, Erub, Warraber, Poruma, Iama and Saibai Islands has identified periods of lower salinity, particularly at Saibai Island, which may be associated with river discharge (freshwater inputs).

At Masig Island, occasional reductions in salinity were measured during the trade wind seasons in 2016 and 2017. Comparison with the local rainfall data from the continuous loggers and satellite imagery, in addition to hydrodynamic modelling results, indicate that this may be

influenced by the Fly River discharge. A longer-term dataset is required to substantiate these findings.

Analysis of remote sensing imagery from 2008 to 2016 confirmed the regular intrusion of turbid waters (the Fly River plume and/or resuspension) from the Gulf of Papua into the northeast (NE) corner of the Torres Strait region, including Daru Island, the north of Warrior Reef and the north and south of Saibai Island. Turbid waters were also mapped around Boigu Island and may be linked to sediments discharged from the Wassi Kussa and Mai Kussa Rivers on the PNG mainland and potentially those transported from the Fly River, as well as to current and wind-driven resuspension. Spatial analyses of the southwest Fly River District identified (i) larger turbid areas during the trade wind period that may reflect both the presence of suspended sediment in the Fly River plume and seasonal benthic sediment resuspension during the trade winds and (ii) smaller turbid areas during El Niño conditions that may indicate an impact of El Niño–Southern Oscillation on sediment transport.

Analysis of the frequency of exposure of coral reef and seagrass habitats to waters with higher turbidity using remote sensing imagery has identified that sites around Saibai and Boigu Islands are most frequently exposed to turbid waters, compared to islands in the central areas of the Torres Strait. Habitats around the northern Warrior Reefs, Erub and Mer are also exposed to turbid waters, although less frequently. Importantly, these are sites that have healthy coral reefs with high coral cover and low macroalgae cover, making them vulnerable to ecological impact. Further analysis of these results is required, including additional *in-situ* sampling to validate the results.

Long-term annual massive coral growth and luminescence records obtained for coral cores from Erub Island (one core) and Bramble Cay (two cores) in the northern Torres Strait revealed annual coral growth rates typical of massive Porites corals living in average (tropical) sea surface temperatures. There was no evidence of growth hiatuses in any of the cores that might be associated with environmental stress events. Luminescent lines (indicative of freshwater flood plumes) were evident in both corals from Bramble Cay but not the coral from Erub Island. At Bramble Cay, there were usually several pulses of freshwater identified each year, likely associated with atmospheric or oceanic processes pushing the freshwater onto the reef. These freshwater pulses were evident back to the beginning of the core in 1781 and are likely to be linked to the discharges from the Fly River.

Gene analysis of sediment samples did not detect a clear signature of the Fly River discharge in the sediment microbial communities of the Torres Strait. Changes in microbial community composition were related to several potential environmental drivers, including sediment fines content and metals. However, the amount of variation explained by each variable was low. Spatial changes in microbial communities at most locations appeared to correlate best with a decreasing gradient of fines content from east to west. Metal concentrations best explained the community composition at the three sampling locations closest to the PNG mainland. Here, community change may be related to terrestrial run-off.

A pilot study assessing the concentrations of metals in seagrass leaves at three sites near Saibai Island and the northern and central Warrior Reefs indicated that these sites were not contaminated by metals, although the samples collected adjacent to PNG (site near Saibai Island) had higher metal concentrations than samples collected near the northern Warrior Reefs. Metal concentrations in samples from the Saibai Island site were comparable to samples collected from coastal sites in the GBR. In contrast, metal concentrations in seagrass

collected at the two sites from the Warrior Reefs were similar to metal concentrations in seagrass collected from an offshore GBR site in the Howick Island group.

Community surveys conducted on Boigu and Saibai Islands revealed that most community members associate changes in the muddiness of coastal waters changes with weather and season. Similar comments were made from participants on both Islands about muddiness depending on the time of the year with spatial differences around the islands. Across all of the survey participants, only two identified that the level of muddiness in the coastal waters had become less with more participants indicating muddiness had increased. Some differences occurred in the responses between Saibai and Boigu Island around changes in species abundance and potential source of colour change in coastal waters. On Saibai, some participants identified less abundance of turtles and dugongs, whereas on Boigu, participants identified a greater abundance of turtles and dugongs. On Saibai, more participants identified that the potential source of the colour change in coastal waters was more likely from local creek runoff rather than an outside source, whereas on Boigu, colour change from an outside source was identified nearly as frequently as local creek runoff. This response is consistent with the presence of the mouth of a large river across from Boigu (Mai Kussa River) that drains the PNG mainland.

5. SYNTHESIS

In order to draw the multiple lines of evidence into a collective view, a combined assessment of the metal analysis in the water column and sediments, remote sensing analysis of water quality exposure, coral cores, *in-situ* salinity and turbidity, hydrodynamic modelling and published literature was conducted to (i) provide an overview of the current understanding of the processes affecting the fate and transport of waters and sediments derived from the Fly River in the Torres Strait; and (ii) identify the areas within the Torres Strait that are most likely to be influenced from Fly River discharges.

Figure 4 summarises the assessment information used to derive six 'zones of influence' with different characteristics in the Torres Strait. The results are shown in Table 2 and illustrated in Figure 5, providing the final assessment of the areas of risk (high to low) from Fly River discharge. The highest risk areas are located in Zone 1 (North East), 2 (North Central) and 3 (North West) incorporating Saibai and Boigu islands, the Warrior Reefs and Bramble Cay).

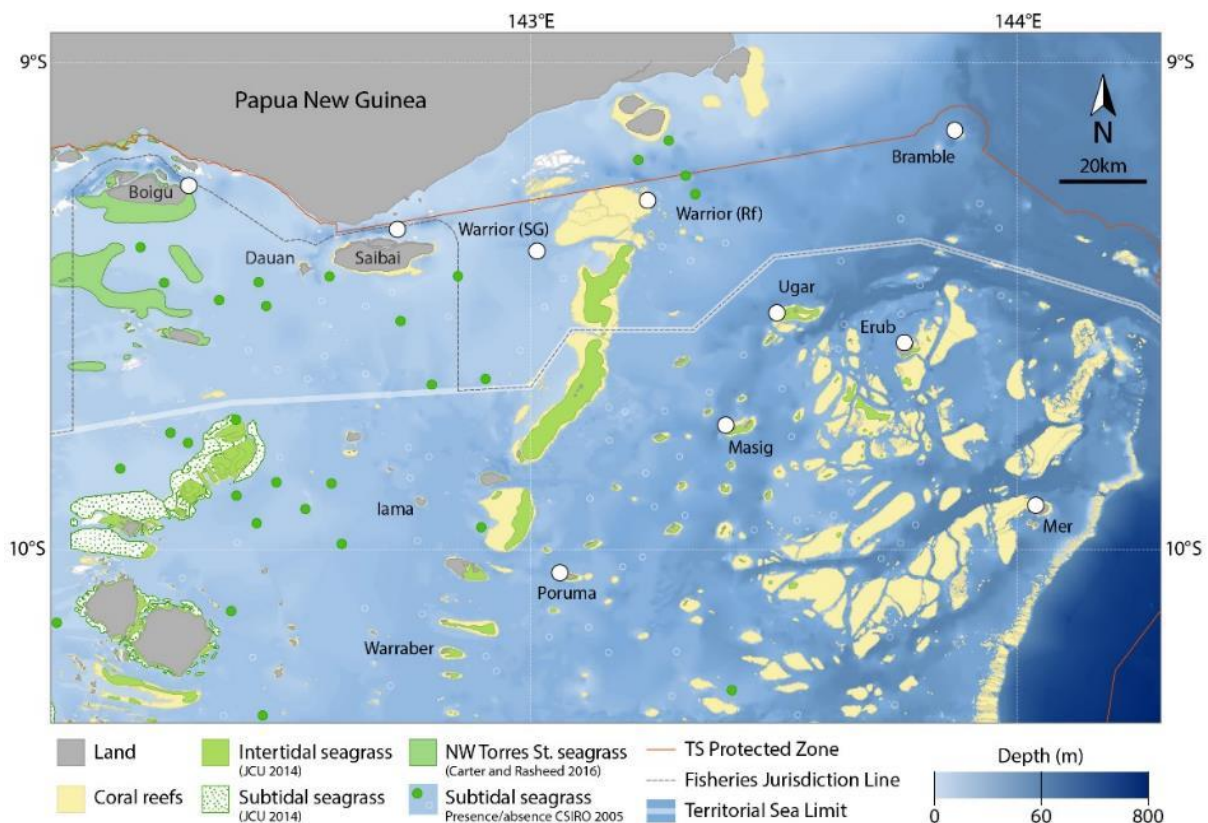


Figure 4: Location of the Torres Strait coral reefs, seagrass beds and habitat sites selected for the integrated assessment (white dots) (between 142.015°E to 144.295°E and 8.860°S to 10.354°S). Map prepared by D. Tracey, TropWATER JCU using datasets from GBRMPA, Carter et al. (2014), Haywood et al. (2008) and Carter and Rasheed (2016).

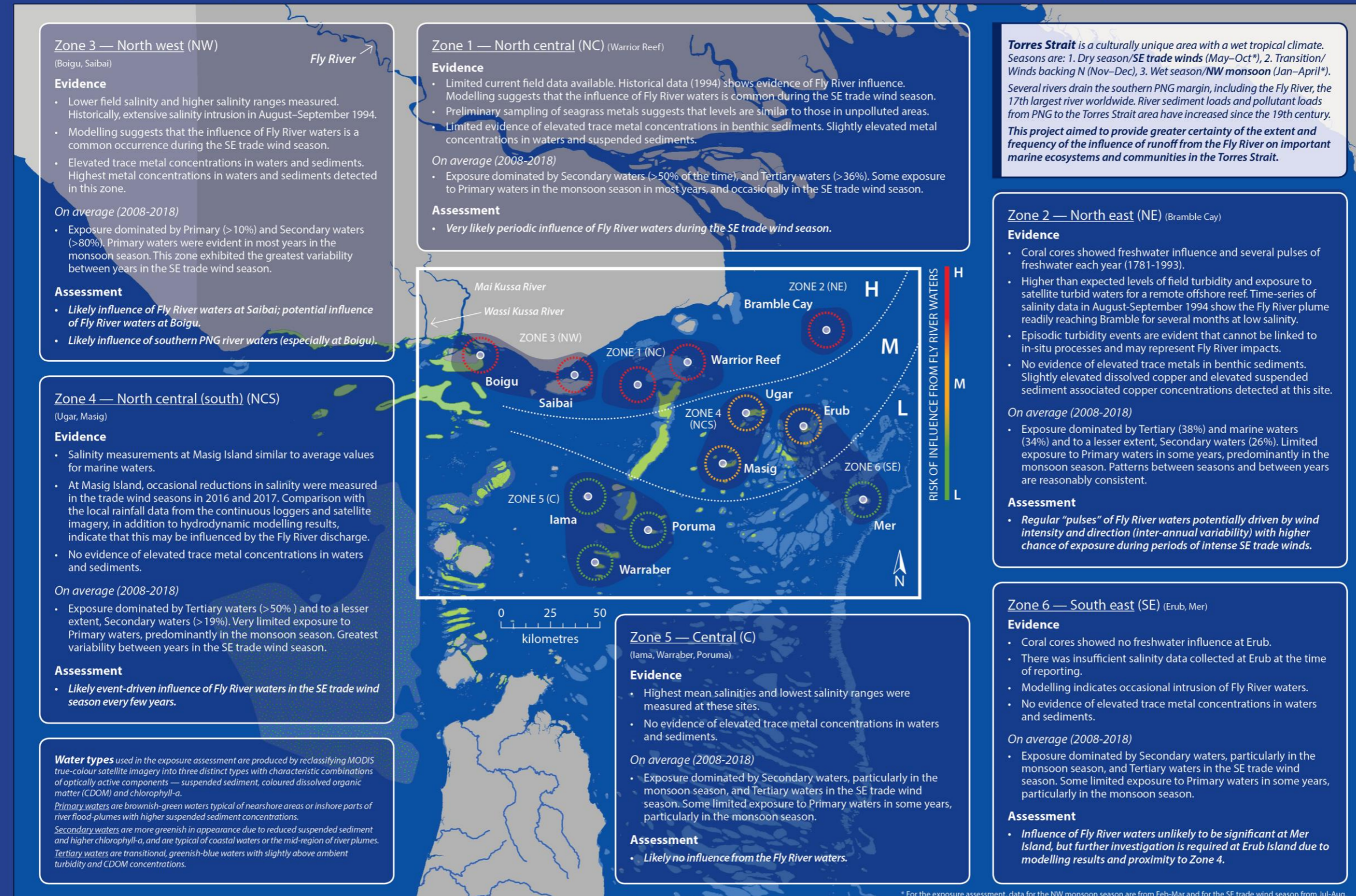
Table 2: Habitat (coral reef and seagrass) sites selected for the risk assessment (and corresponding monitoring codes where relevant) and potential zone of influence. Note: SG = seagrass site; RF = reef site. The site names correspond to the TSRA coral reef monitoring locations.

Site (station ID in brackets)	Habitat type	Zone	Description of potential risk and evidence base: Trace metals (TM), <i>In-situ</i> loggers (L), Modelling (M), Remote Sensing (RS), Coral cores (CC) and Published Literature (P)
Warrior Reef (SG)	Seagrass	1 – North Central	Very likely influence of Fly River waters (TM, M, RS, P)
Warrior Reef (RF)	Reef	1 – North Central	Very likely influence of Fly River waters (M, RS, P)
Bramble Cay	Reef	2 - North East	Several pulses of freshwater each year, likely from the Fly River (TM, L, RS,CC,)
Boigu	Seagrass	3 - North West	Potential influence of Fly River (M, RS, P) and very likely influence of southern PNG rivers (TM, RS,)
Saibai	Reef	3 - North West	Likely influence of Fly River (M, RS, P) and likely influence of southern PNG rivers (TM, RS)
Ugar (U1R1)	Reef	4 – North Central (south)	Moderate risk of influence from Fly River during SE trade wind season (TM, M, RS, P)
Masig (Y1R1)	Reef	4 – North Central (south)	Moderate risk of influence from Fly River during SE trade wind season (TM, M, RS, P)
Poruma (P1R1)	Reef	5 - Central	Low risk of influence from Fly River (TM, M, RS,P)
Erub (E2R1)	Reef	6 – South East	Moderate risk of influence from Fly River during SE trade wind season (TM, M, RS, CC, P)
Mer (M3R1)	Reef	6 – South East	Low risk of influence from Fly River (P, M, RS,TM)

While this study highlights the presence of trace metal enrichment around the islands of Boigu and Saibai, the trace metal analysis does not indicate large scale deposition of mine-derived sediments in these locations. Indeed, the application of conventional geochemical assessment procedures as used in this study has not unequivocally identified the presence of mine-derived sediments in the Torres Strait. It appears that there are dilution and/or dispersion mechanisms that attenuate the potential effects of mine-derived sediments that are transported along the PNG coast.

The Ok Tedi mine was due to close in 2024, but its life is likely to be extended to 2030 (Graham 2017). Following mine closure, inputs of mine-derived sediment to the river system will cease, however the mine wastes stored in the Fly River in the river bed and on the floodplain, will work their way through the system for decades to follow. Assuming mine closure goes ahead as planned, mine derived sediment inputs into the Gulf of Papua and Torres Strait will decline over a timescale of decades.

Identifying water quality and ecosystem health threats to the Torres Strait from runoff of the Fly River



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Figure 5: Summary of the highlights of NESP Project 2.2.1 and 2.2.2, within the different zones of influence. Zone 1: North central; Zone 2: North East; Zone 3: North West; Zone 4: North central (south); Zone 5: Central and Zone 6: South East. Map prepared by D. Tracey, TropWATER, JCU.

6. CONCLUSIONS

Using multiple lines of evidence derived from the two NESP TWQ Hub projects has provided greater certainty of the extent and frequency of the influence of runoff from the Fly River in PNG on important marine ecosystems in the Torres Strait. It is now feasible to conclude that the influence of the Fly River and associated contaminants is focused in the northern Torres Strait and along the PNG coast, i.e. northern and northwest Torres Strait. This varies from previous understanding which indicated that the area of Fly River influence in the Torres Strait extended to Bramble Cay and south towards Erub and Masig Island, with some intrusion to the northwest.

The current evidence now indicates that habitats located in the northeast corner of the Torres Strait Protection Zone including Bramble Cay, north of Masig Island and northwest as far as Boigu Island, are located in a higher potential risk area of exposure to brackish and turbid waters from or derived from the Fly River, as well as from/or derived from local PNG river discharges. While this movement of water from the Fly River is a historic pattern, the estimated 40% increase in sediment discharge associated with the operation of Ok Tedi mine is likely to have changed the characteristics of sediment and contaminant concentrations in this region. Despite the increased load, water and sediment quality is generally excellent across the region. Increased metal concentrations in waters and sediments were only observed around Boigu and Saibai islands. At this stage, it was not possible to unequivocally identify the presence of mine-derived sediments in this area or other regions of the Torres Strait. Runoff from the PNG mainland may also be a factor influencing metal concentrations around Boigu and Saibai islands.

Analysis of the likely ecological impact (if any) of these influences is a subsequent step of investigation which was outside the scope of the current study. A number of further studies are recommended to complete this assessment (Section 7).

Results from this project underline the importance of integration of data from a range of sources to provide a comprehensive assessment of water quality and environmental conditions. In the future, the (planned) integration of all these different data sources will facilitate the development of integrated water quality monitoring tools for application in the region and, where relevant, elsewhere (Figure 6).

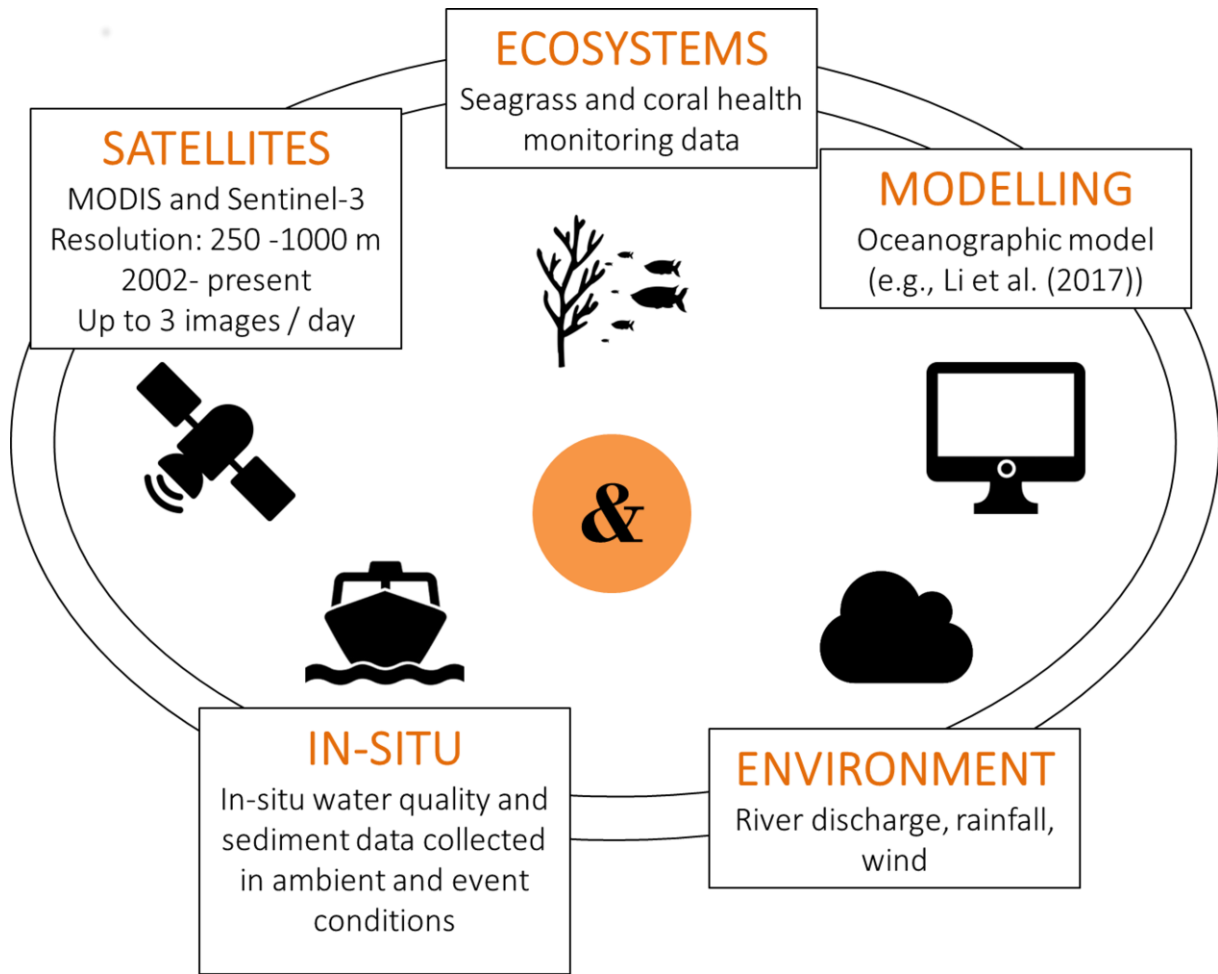


Figure 6: Conceptual scheme showing the importance of integrating different data sources to provide comprehensive water quality and environmental assessments.

7. RECOMMENDATIONS FOR FUTURE WORK

It is recommended that any additional work on the issue of impacts of the Fly River on the Torres Strait is focussed on the north and north western Torres Strait – including areas around Boigu, Saibai, Warrior Reefs, Masig Island, Erub Island and Bramble Cay. The recommended research activities are outlined below.

1. **Identification of sources of trace metals in the northern Torres Strait:** This would include the development and application of new analytical methods for tracing mine-derived sediments in marine waters and obtaining information on how trace metal concentrations vary with time (i.e. characterising seasonal and even-related changes).
2. **Continued monitoring of salinity and turbidity:** Extend the current automated monitoring network by setting up new stations at Saibai Island and the northern Warrior Reefs. This data should be supplemented by salinity monitoring carried out by TSRA rangers at additional northern locations (e.g. Boigu, Erub and Masig).
3. **Continued remote sensing of river plumes:** Continue to utilise satellite remote sensing data of plume movement, turbidity and frequency of the exposure of turbid waters in the northern Torres Strait.
4. **Continued development of a sediment transport model:** The model would support assessment of the transport of Fly River-derived sediment and its particulate metals in the Torres Strait region. The model would assist in predicting changes in the distribution of particulate material from the Fly River over time.
5. **Expanded survey of trace metals in seagrass leaves:** Seagrasses are an important food source for the highly valued turtle and dugong populations in the region. Further information on trace metals concentrations in seagrasses should be obtained around Saibai and Boigu islands and near the Warrior Reefs, and areas southwest of these (e.g. near Erub, Ugar and southwest of Bramble Cay) to establish the beginnings of effect-gradient transects.
6. **Repeat of the Torres Strait baseline food survey:** A follow up study on the trace metal concentrations in commonly eaten seafoods would provide valuable information on changes in metal burdens over the last 30 years since the previous survey.
7. **Extended community surveys:** Further community engagement would provide further insight to the views of the local community and valuable anecdotal evidence regarding the water quality issues in the Torres Strait.

Combined interpretation of the findings including an updated risk assessment to ecosystems and communities would also be required to assess the overall implications of the results of the exposure of sediments and trace metals to ecosystems in the northern Torres Strait and the probable sources. This would include a qualitative assessment of the potential implications of the findings for the local community. To support this work, local coral and seagrass monitoring efforts need to continue (and be reported) to support analysis of the potential correlations between the results and ecosystem health.

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