Marine and Tropical Sciences Research Facility
Project Milestone Report

Milestone 3: 8 June 2007

Project 3.7.2:	Connectivity and Risk: Tracing Materials from the Upper Catchment to the Reef

Project Leader: Jon Brodie
Institution: Australian Centre for Tropical Freshwater Research, James Cook University

Part 1. ANU component
Task 2: Tracing of materials in the marine environment

Task Leader: Malcolm McCulloch
Institution: Research School of Earth Sciences, Australian National University

Project Description

It is planned to undertake a comprehensive sampling of Porites corals in the Townsville-Cairns region in 2006/2007 and again in 2010 to provide quantitative constraints on the effectiveness of the Reef Water Quality Protection Plan. These will complement the AIMS collection made in the mid 1980s with the new cores covering the last 20-50 years of river discharge. Coral cores will be analysed using the state-of-the-art laser ablation analyses only possible at ANU, in conjunction with the study at AIMS of the distinctive luminescent lines that are a result of low salinities from flood plumes. In addition to the already well described Ba method (McCulloch et al. 2003) measurements of 143Nd/144Nd and 15N isotopes in coral cores and luminescent lines will be undertaken at ANU to provide a novel technique to examine changes in sediment and nutrient sources from the major rivers. This will be complemented by sediment cores from Bowling Green Bay, a major sink for sediments from the Burdekin River, as well as other cores taken from the inner and mid-shelf between Townsville and Cairns. The sediment geochemistry of these cores has already been partially characterised by the Australian Institute of Marine Science (G. Brunskill pers comm.) and additional isotopic and where necessary physical and mineralogical properties will complete this dataset. A chronology of these cores is also available from 210Pb ages, but more refined ages may be obtained using OSL dating and distinctive time transgressive terrestrial markers (e.g. onset of Hg from gold mining). The terrigenous sediment “fingerprints” from these cores will be compared to the terrestrial dataset to examine and quantify the contribution of sediment from each Burdekin sub-catchment. The isotopic composition (Sr-Nd) of suspended actually reaching coral reefs will also be determined and compared the compositions of material from the various river sources as well as sediment cores. This approach will then be applied and other wet tropics catchments in the Townsville-Cairns region. The possibility of using the oxygen isotopic composition of phosphate to distinguish how the marine versus terrestrial sources of P may have changed over time in the inner and mid-shelf regions of the GBR will also be investigated.

Burdekin, Fitzroy, Herbert, Tully, Johnstone and Russell-Mulgrave river flood plumes will be sampled on an opportunistic basis and suspended sediments and dissolved materials will be recovered along a salinity transects. The isotopic, elemental and mineralogical properties of these materials will be measured according to the methods outlined in Task 1 and linked to a sediment source within the river catchments. In addition, routine collection (weekly) of water samples will be undertaken from both the AIMS and Orpheus Island Research station in order to obtain a long-term ‘baseline’ record of water quality and trace element composition of the inner Great Barrier Reef waters covering both wet as well as dry seasons. Water samples will be also taken within the flood plume to measure the isotopic, trace element and nutrient compositions of the dissolved components of the flood plume along a salinity transect. This analysis will investigate sediment desorption within the estuarine and flood plume mixing zone.

Project Results

Due to the considerable widespread flood plumes generated from the large wet season of February-March 2007, collection of additional coral cores in the region will be delayed until November 2007. This delay is required to allow for the incorporation of the latest flood signals into the coral skeletal record. However, a long coral core collected from Magnetic Island (collected 2002) was analysed by laser ablation ICP-MS (Fig 1). Lewis et al. (2007) reported increased Ba/Ca and Mn concentrations since European settlement in the Burdekin River catchment (>1850s) in a long coral core record from Magnetic Island, although this analysis was performed at two-yearly resolution. This new analysis was able to obtain a much higher resolution (~ two-weekly) made possible by the laser ablation ICP-MS machine. The coral shows historical changes in water quality in freshwater plumes from the Burdekin River and possibly local catchments which reflects changes in bulk sediment and top soil erosion in these catchments. The data support the findings of McCulloch et al. (2003) for the Havannah Island coral Ba/Ca record. In addition, a coral record from Whitsunday Island was also analysed by LA-ICP-MS in March 2007. Results from this analysis are being processed.

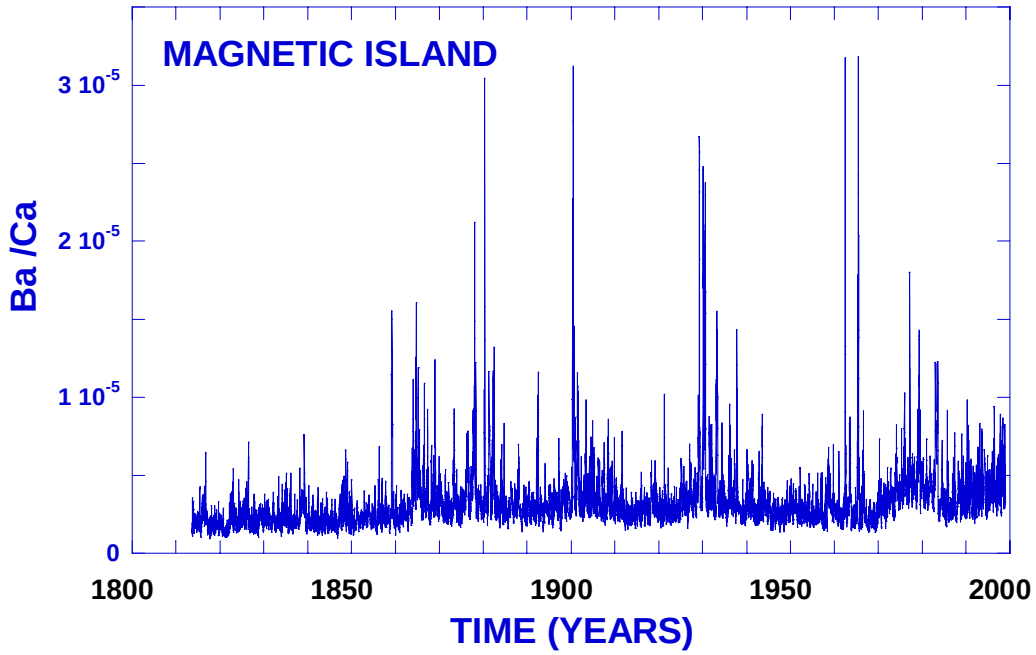

Figure 1. LA-ICP-MS Ba/Ca analysis of a Magnetic Island coral record supports the Havannah Island Ba/Ca (McCulloch et al., 2003) of increased sediment erosion in the Burdekin River catchment since European settlement in the 1850s.

Part 2. JCU component
Task 1: Tracing of materials in the terrestrial environment

Task Leader: Stephen Lewis
Institution: Australian Centre for Tropical Freshwater Research, James Cook University

Project Description

Sediments will be collected from different soil and rock types as well as from the major stream channels within the Burdekin River catchment and from selected wet tropics rivers between Townsville and Cairns. Suspended sediments will also be recovered from the tributaries of the Burdekin River catchment. The composition of Sr–Nd and other isotopes of tracing potential in the Burdekin River sediments will be measured at the Centre for Microscopy and Microanalysis (CMM: University of Queensland) and Research School of Earth Sciences (RSES: Australian National University) laboratories. The $^{87}Sr/^{86}Sr$ isotopic ratio of sediments is mainly controlled by age while the $^{143}Nd/^{144}Nd$ and other isotopic ratios are influenced by both the composition of the source rock (e.g. basalt rocks contain a different isotope signature to granites) as well as the age. These isotope tools coupled with the trace element composition and clay mineralogy provide a powerful tool to fingerprint different sediment types and to trace and quantify sediment transport through river catchments. This technique (Nd-Sr) has been applied successfully in the Johnstone River and offshore reefs (McCulloch et al., 2001) and the Murray-Darling fluvial system (Gingele and De Deckker, 2005). The trace element composition of the sediments will also be determined using XRF and ICP-MS at the AAC, CMM and at the RSES. Particular elements (e.g. Ti, Zr, Ca, K) and elemental ratios (Rb/Sr, Zr/Hf, Y/Ho, Th/Tl, Th/W) provide a useful complementary tool to trace sediment through a large river system.

To trace the transport of fine sediments throughout the Burdekin catchment, the sediments will be collected and sieved to recover the mud fraction (< 63 µm) which will be used exclusively. The particle size of this mud fraction (proportion of silt, clay and colloidal particles) will be determined on a Melvin Mastersizer® in the School of Earth Sciences, James Cook University (JCU). X-ray diffraction in conjunction with the Siroquant® program will be employed to determine and quantify the mineralogy of the sediments and, in particular the relative proportion of the major clay minerals (chlorite, smectite, kaolinite and illite) in the sediments. This analysis will be performed at the Advanced Analytical Centre (AAC), JCU. Nitrogen isotope analyses of water samples will be conducted at ANU.

We also plan to conduct preliminary research into tracing the source of nitrate in the Burdekin River catchment. The Burdekin River exports high loads of nitrate and currently the source is unknown. We plan to use nitrogen isotopes to uncover the source of this nitrate.

Project Results

During the 2007 wet season, a suite of water samples (~80 samples) were collected from the tributaries throughout the Burdekin catchment (Fig 2) and from the freshwater plume from Burdekin (and Tully) River (Fig 3). These samples are currently being stored at JCU and the suspended sediments will be recovered and analysed for trace element and isotope composition by the end of 2007. Selected sediment samples were prepared at the University of Queensland in April 2007 for trace element and isotope analyses and the results should be forthcoming within the next quarter. Once these results become available, a robust technique can be designed and the next batch of samples can be planned. One hundred and forty samples have been submitted to the School of Earth Sciences for particle size analysis and results will be available by the end of July. Water samples taken from the Burdekin River freshwater plume were analysed for trace elements by ICP-MS in March 2007. The ICP-MS analysis of these water samples will be rerun (due to some contamination issues), although preliminary analysis show the initial Ba desorption at very low salinities (~1 ppt) followed by a consistent dilution trend of Ba over the remaining salinity gradient (Fig 4). This trend is consistent with the 2002 flood plume from the Burdekin River (M. McCulloch pers comm.) and supports the interpretation of Ba/Ca ratios in corals as a proxy of sediment delivery to the Great Barrier Reef lagoon.

A comprehensive collection of daily satellite imagery from the 2007 flood plumes along the Great Barrier Reef allow the extent and movement of plumes to be traced over time as well as provide an understanding of biological processes occurring within the plume (Fig 5). Preliminary results suggest

that the movements of the Burdekin plume may switch direction by 180 degrees within days. In addition, freshwater plumes throughout the GBR lagoon became a 'green' colour within two-three days of sunlight (Fig 6); this finding provides an insight into the timeframes of biological activity in the flood plume (J. Brodie, unpublished data).

Samples for pesticide analysis were collected from the flood plumes from the Burdekin and Tully Rivers in 2007. These results should become available by August. Data from the Haughton River and Barratta Creek plumes (Fig 7) from February 2007 show the presence of diuron and atrazine in the plume waters (Fig 8). These concentrations were below marine guidelines, although these concentrations would possibly have been higher if this flood event had occurred earlier in the wet season (e.g. November- when pesticides are applied).

Suspended sediment samples collected from the Burdekin Falls Dam spillway have been analysed. 1.2 million tonnes of sediment was transported past the dam during the February-March wet season (Fig 9). Sediment loads will be calculated for the major waterways above the Burdekin Dam to assess dam trapping in the 2007 wet season once gauging and suspended sediment data become available. The comparably smaller flow event in 2006 suggests that the dam trapped approximated 80% of sediments (~ 1.8 million tonnes of sediment; Bainbridge et al., 2006b).

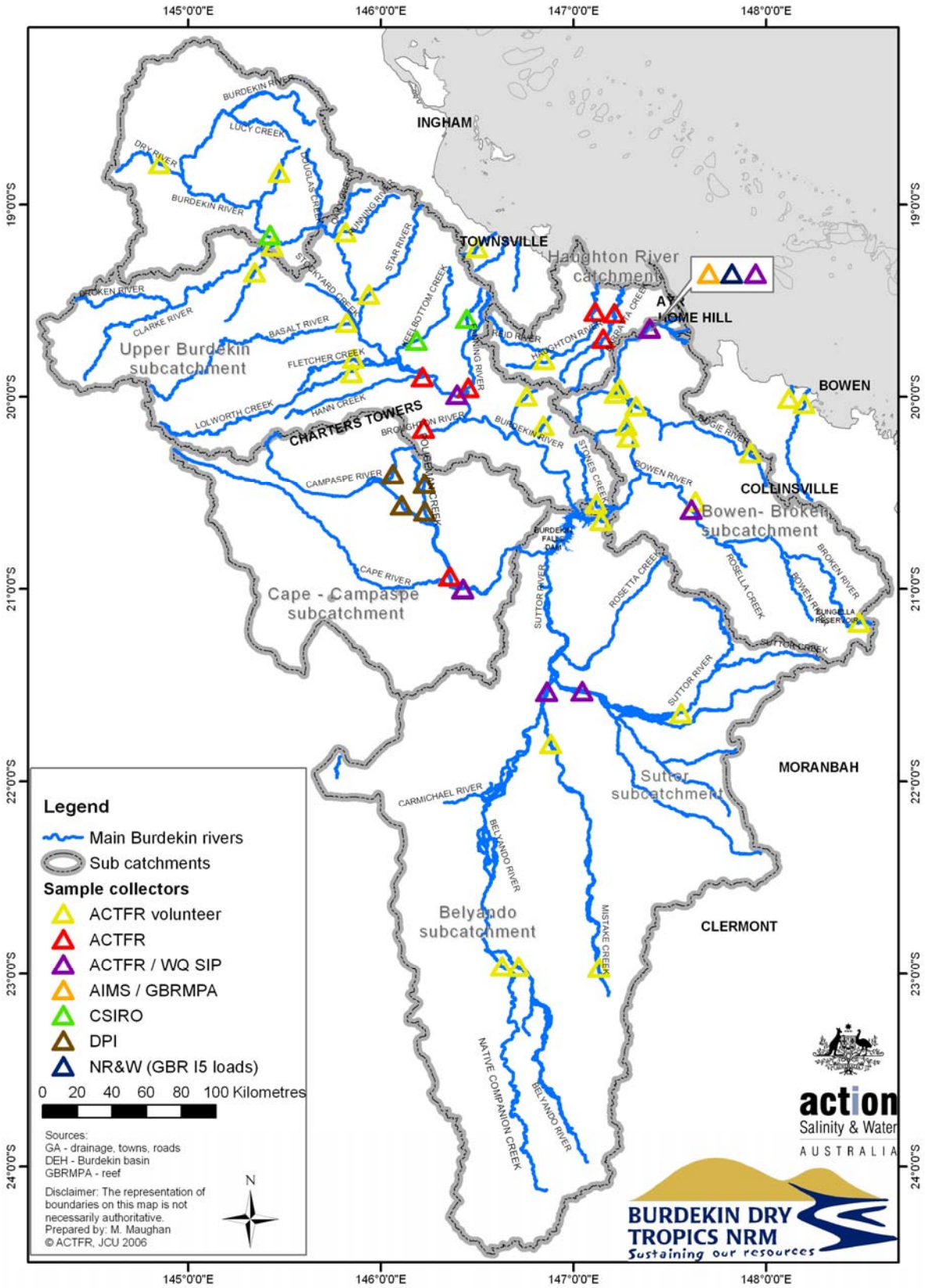

Figure 2. Sampling sites during the 2006/2007 wet season.

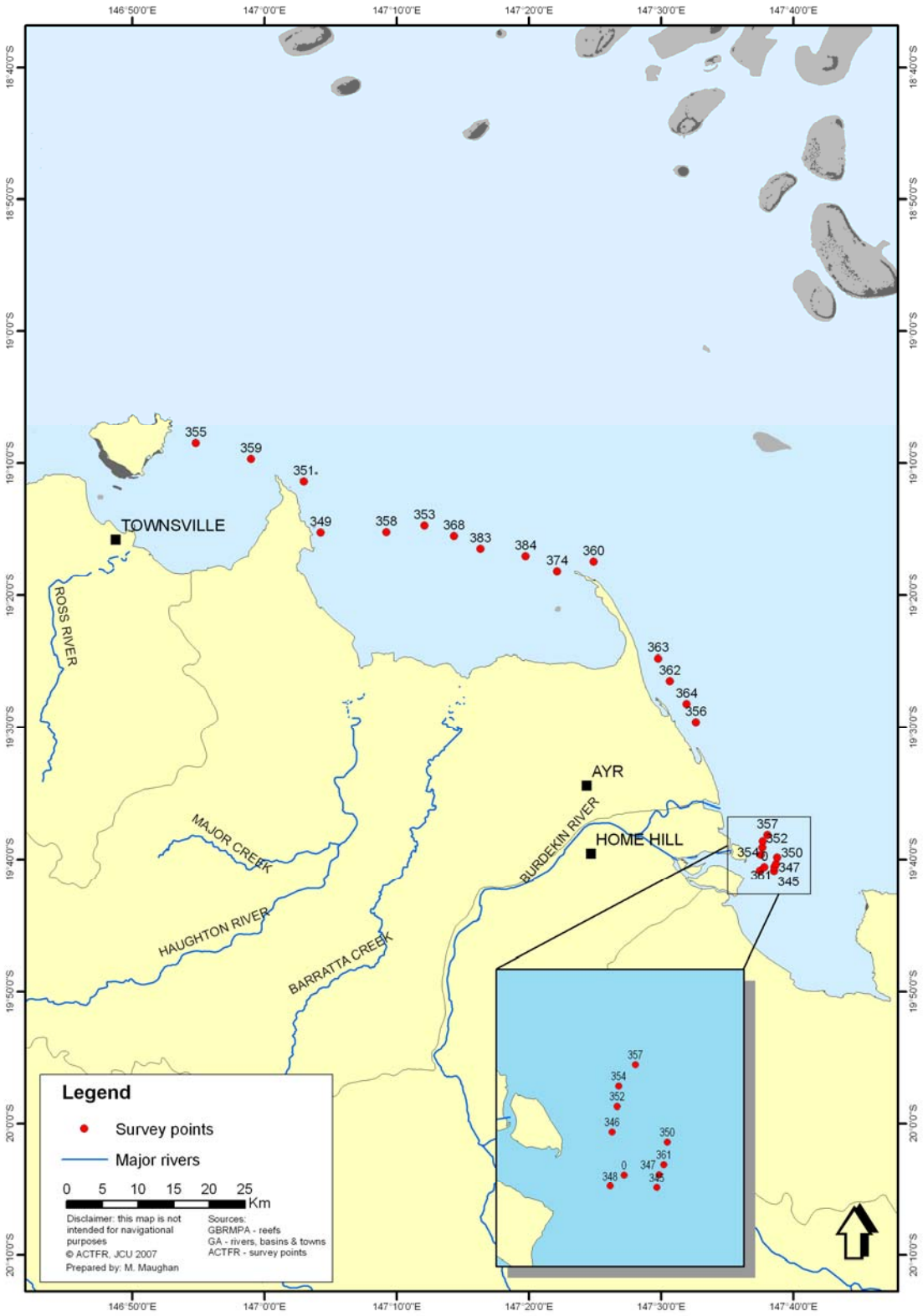

Figure 3. Map of water quality samples taken from the Burdekin River freshwater plume on the 6-7 February 2007.

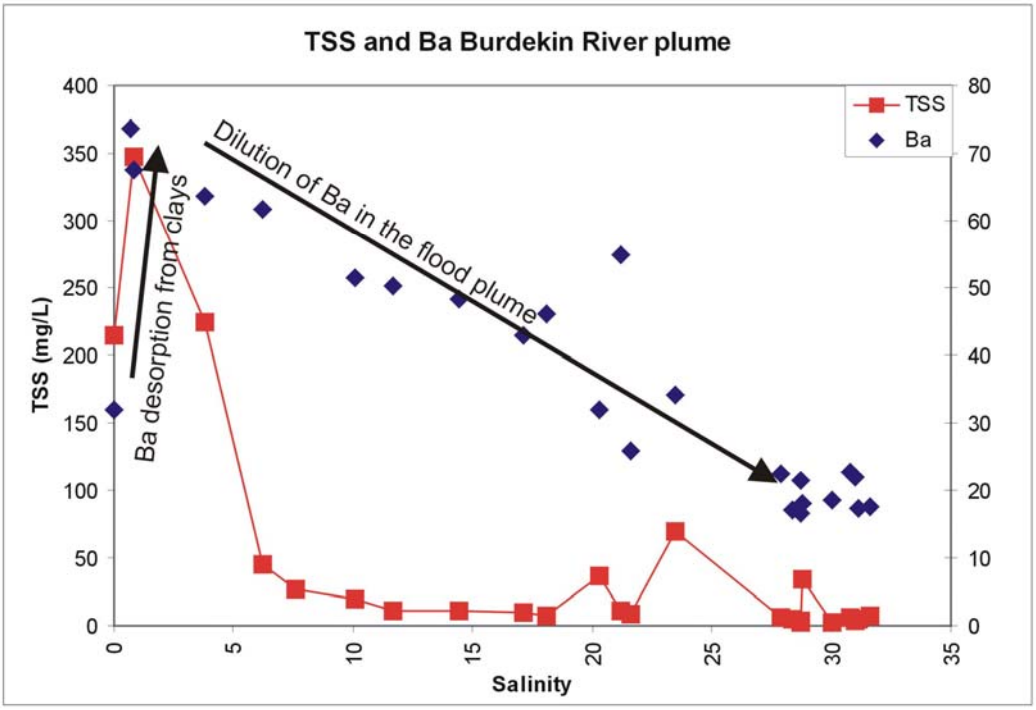

Figure 4. Graph of total suspended solids (TSS) and barium (Ba) concentrations over the salinity gradient in the Burdekin River flood plume. The data show that TSS concentrations decrease rapidly in the flood plume by the 10 ppt salinity zone where the majority of sediments have settled out in the plume. The Ba concentration follows a considerably different trend where Ba becomes desorbed from clays at low salinities and is then slowly diluted as the plume mixes with seawater. This trend supports the coral Ba/Ca proxy of sediment delivery to the GBR lagoon.

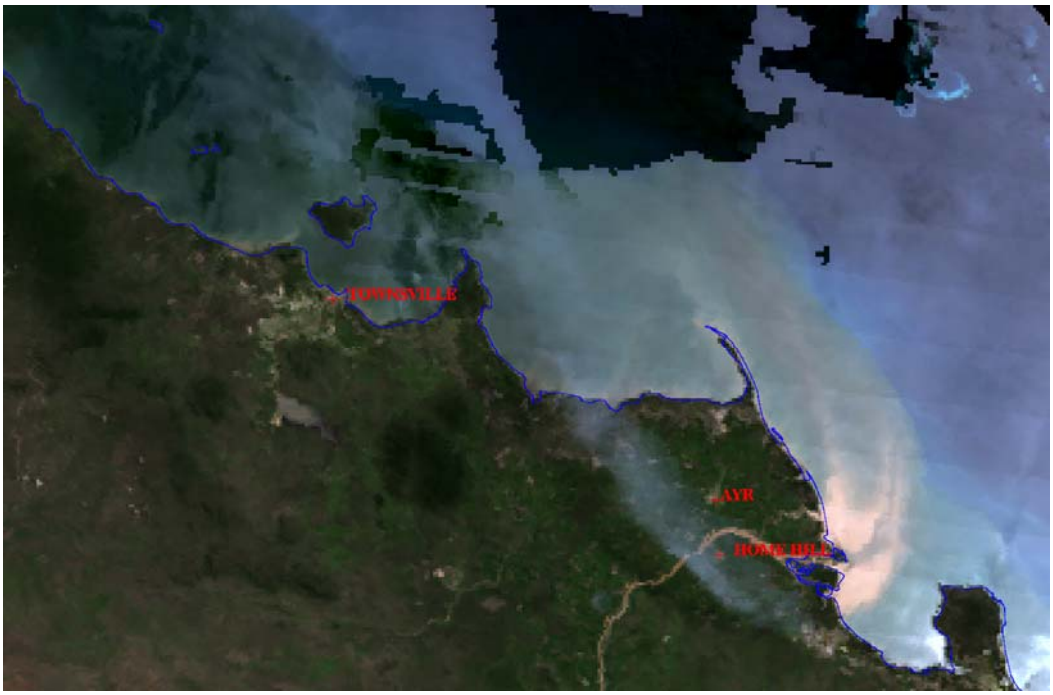

Figure 5. Satellite image of flood plumes from the Burdekin River and the Haughton River and Barratta Creek on the 9 February 2007. The data show the plume to undertake a primarily northward direction, although the Burdekin plume took a southward direction later in the flow event.

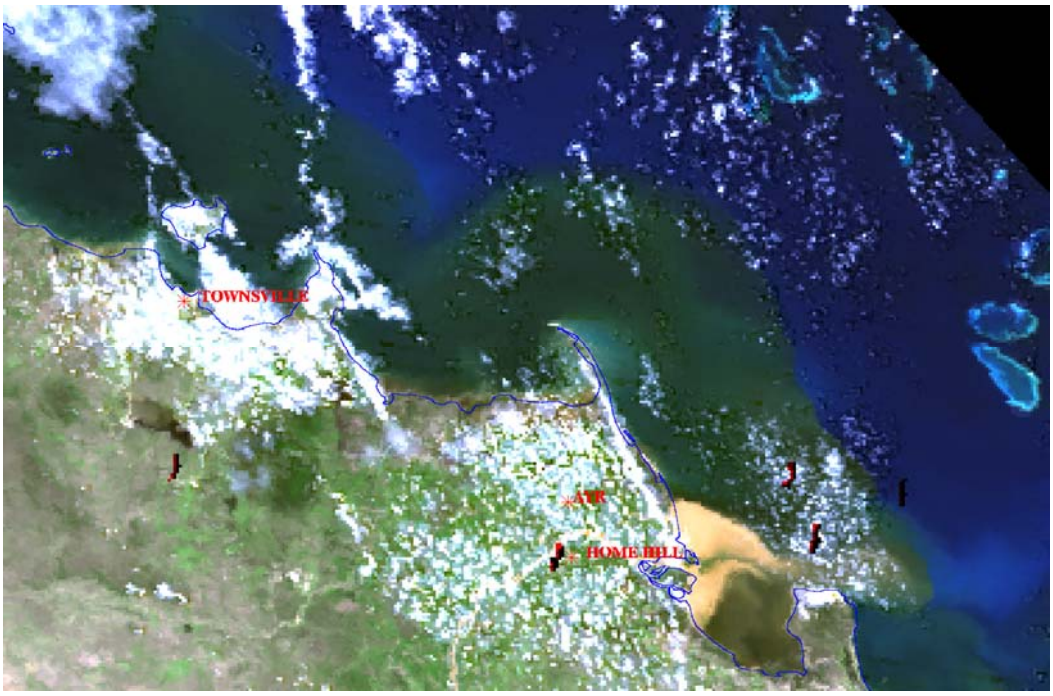

Figure 6. Satellite image of flood plumes from the Burdekin River and the Haughton River and Barratta Creek two days later on the 11 February 2007. The image shows that within a couple of days the flood plume "turns green" which indicates increased biological productivity.

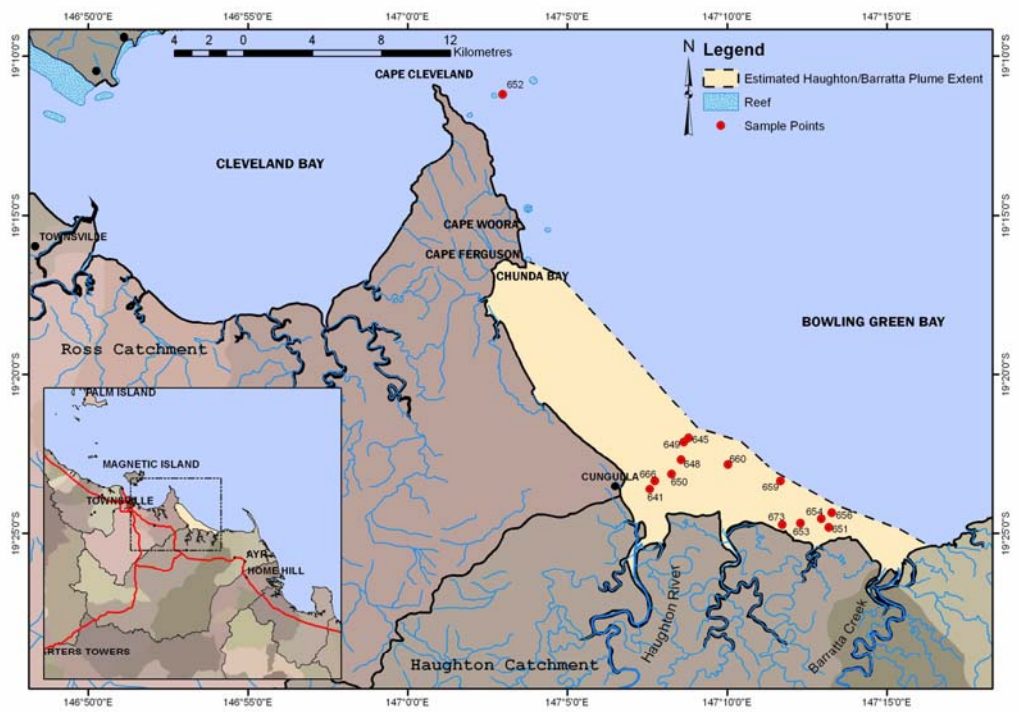

Figure 7. Map of sampling points for the Haughton River and Barratta Creek flood plume. The dotted line represents the estimated extent (by both visual and some GPS points) of the plume on the day (3 February 2007).

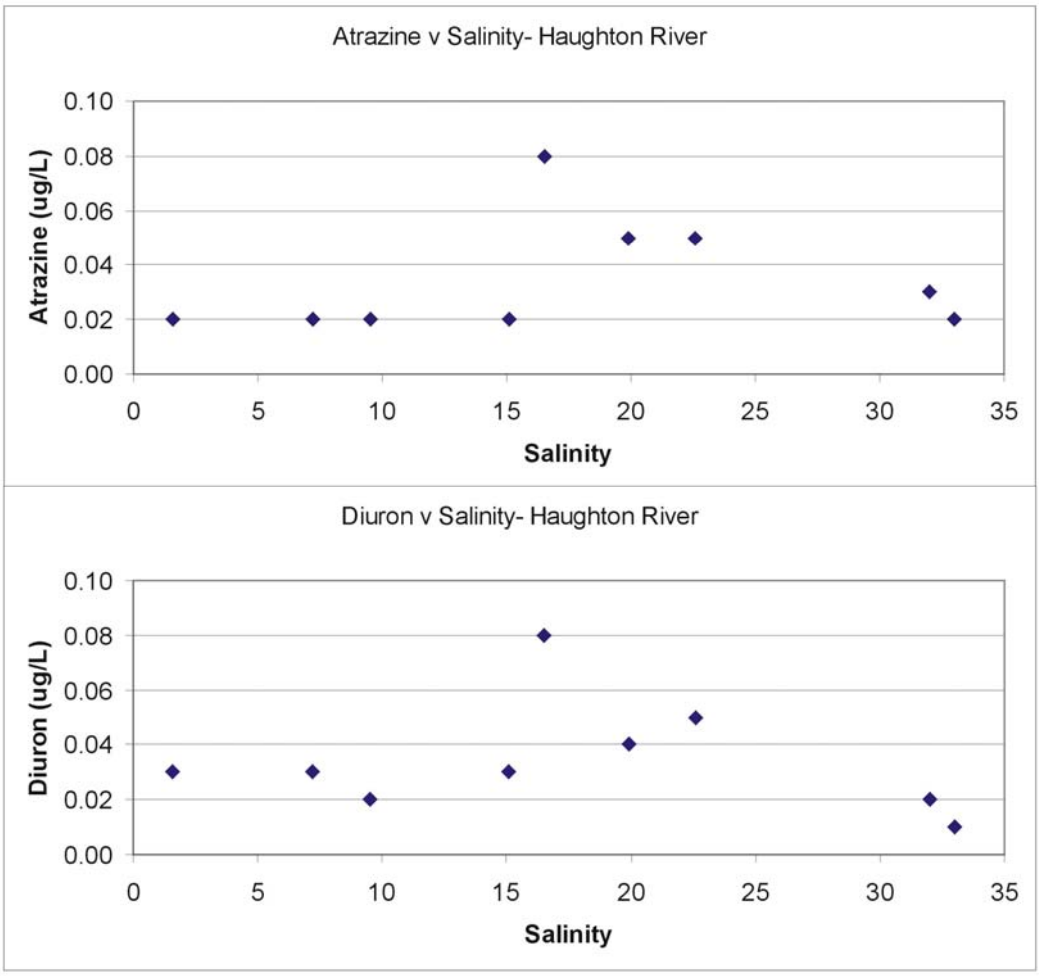

Figure 8. Diuron and atrazine residues were detected in the Haughton River and Barratta Creek flood plumes (example from the Haughton River transect). These concentrations were below the marine guidelines.

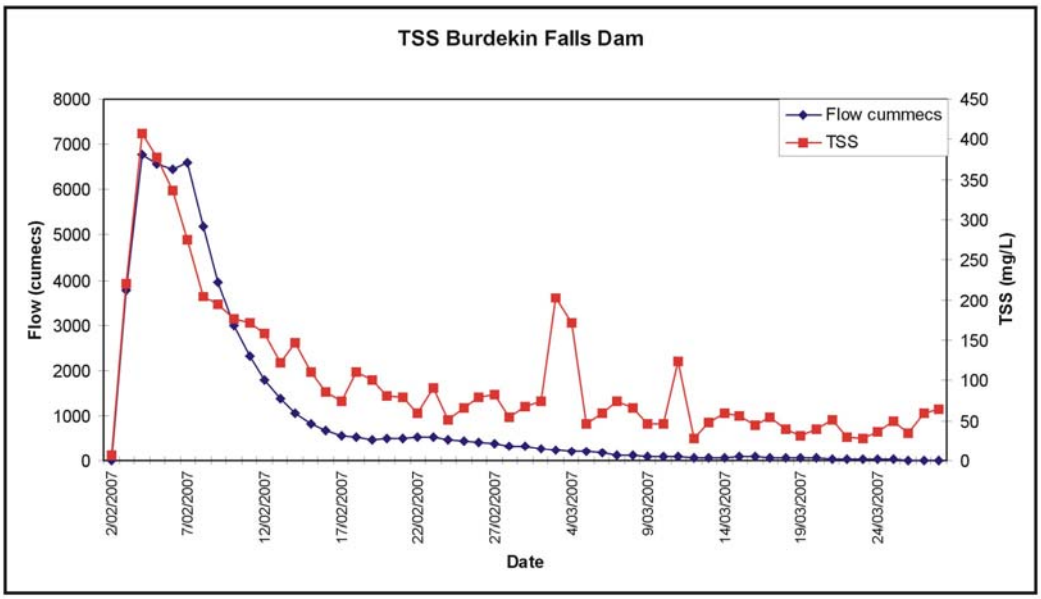

Figure 9. TSS concentrations over the flow hydrograph for the Burdekin Falls Dam. This high resolution dataset was used to calculate that 1.2 million tonnes of sediment went over the dam in the 2007 wet season.

Communications, Major Activities and Events

The water quality day of the MTSRF Research Synthesis Conference (18 April 2007) was attended by Jon Brodie, Stephen Lewis and Zoë Bainbridge. Communications have been held with the UQ laboratory on the trace element and isotopic analysis of sediment samples for tracing purposes. In addition, communications have been held with Prof. Malcolm McCulloch for the trace element analysis of the water samples from the Burdekin River freshwater plume. Jon Brodie, Zoë Bainbridge and Stephen Lewis attended an ARC (linkage) water quality workshop ("Long term changes to Mackay Whitsunday water quality and connectivity between terrestrial, mangrove and coral reef ecosystems: clues from coral proxies and remote sensing records") in Mackay. Jon Brodie presented a seminar on the 2007 satellite imagery of the freshwater plumes in the GBR lagoon at this workshop.

This project has formed valuable collaboration ties with MTSRF Project 3.7.1 (sampling of Tully flood plume), the Burdekin Dry Tropics NRM (BDT NRM) water quality monitoring program of the Burdekin sub-catchments and flood plume (samples collected also for suspended solid and nutrient concentrations) and BDT NRM CCI pesticide investigation in the lower Burdekin (pesticide measurements in the lower Burdekin sub-catchments and in freshwater plumes). In addition, collaborative arrangements have been made with the Mackay Whitsunday NRM to sample flood plumes from the Mackay region and also with the Great Barrier Reef Marine Park Authority through their pesticide Marine Monitoring Program. The extension Project of 3.7.2 has also formed collaborative links with the Australian Institute of Marine Science (Dr Janice Lough and Eric Matson) to collect coral cores throughout the Whitsunday Island Group to investigate and quantify historical changes in sediment and nutrient delivery.

Several activities are planned for the next milestone period including the analysis of additional coral cores from the Whitsunday Island Group and the preliminary analysis of sediment samples taken from the Burdekin River catchment and freshwater plume. Particle sizing of the suspended sediments collected from the Burdekin Region will also be performed. Pesticide results will also become available to investigate the transport and extent of pesticide residues off the Tully, Burdekin and Mackay Whitsunday River plumes in the 2007 wet season. Water Quality results from the monitoring of the freshwater plume from the Burdekin River will become available and processed. Load data will also be calculated from the major Burdekin River tributaries that enter above the Burdekin Falls Dam to estimate the amount of sediment trapping by the dam in the 2006/07 wet season.

Part 3. JCU extension component
Task 1: Material tracing in the marine environment. An assessment of changes in water quality in the Mackay Whitsunday Region using coral core records

Task Leader: Stephen Lewis
Institution: Australian Centre for Tropical Freshwater Research, James Cook University

Project Description

Coral core records provide excellent insights into changing water quality in the Great Barrier Reef (GBR) lagoon over the last 150 years (McCulloch et al., 2003; Marion et al., 2006; Jupiter, 2006; Lewis et al., 2007). However, the majority of research efforts have focused on terrestrial runoff from the Burdekin River catchment (e.g. McCulloch et al., 2003; Lewis et al., 2007) with limited focus on the Wet Tropics (e.g. Barron, Johnstone, Tully, Herbert) and Mackay Whitsunday catchments. These catchments drain intensive agricultural areas of significant fertiliser application (sugarcane, bananas) which contrasts the Burdekin catchment which is dominated by cattle grazing. This land use difference is reflected by the terrestrial runoff in these catchments; the Burdekin is a significant contributor of sediments to the GBR lagoon (e.g. Furnas, 2003; Brodie et al., 2003; 2004; Bainbridge et al., 2006) whereas the other catchments export elevated dissolved nutrient concentrations (Rohde et al., 2006).

Recently coral proxies (Ba, Y, Mn) have provided evidence of increased sediment export to the GBR lagoon from the Burdekin River catchment (McCulloch et al., 2003; Lewis et al., in press) while nitrogen isotopes are being developed to quantify increases in nutrient loads (Marion et al., 2005). The nitrogen isotope signature in corals has been applied in the Mackay Whitsunday Region using a transect of cores off the Pioneer River (Marion et al., 2006). This study was part of an ARC linkage project with the Great Barrier Reef Marine Park Authority (GBRMPA), Mackay Whitsunday NRM and Mackay City Council. The Changes in the isotopic signature were correlated with increased fertiliser application in the Pioneer River catchment, although additional studies are required to place the data into a regional context. The nitrogen isotopic composition in corals varies naturally across the GBR shelf (Sammarco et al., 1999). An opportunity exists to quantify changes in water quality in the GBR lagoon as well as to validate/improve coral proxies along a water quality gradient through the Whitsunday Island Group (from Repulse Bay to Hook Island). This gradient has been recognised by van Woesik et al. (1999) and Fabricius et al. (2005) and is thought to be the result of recent (~last 100 years) changes in terrestrial runoff from the Proserpine, O'Connell and Pioneer Rivers. This study will complement similar research into geochemical records of a "pristine" inshore coral reef in Princess Charlotte Bay (S. Jupiter pers comm., 2006) and expand on other studies from the Mackay Whitsunday Region (Jupiter, 2006; Marion et al., 2006).

An important question to resolve is whether the observed water quality gradient through the Whitsunday Island Group is primarily a response to suspended sediment or nutrient (particularly nitrate) inputs. It is unclear as to whether the changed light conditions observed along the transects from the river mouths out to the mid-shelf reef (Cooper et al., Catchment to Reef CRC draft paper) are associated with the direct effects of increased sediment from the rivers or organic suspended matter generated by increased nutrient flux from the rivers. As land management of these two issues (increased suspended sediment and increased nitrate export) is complex, we need to understand which issue is more important before land use management can be prioritised. Nutrient inputs will also lead to a phytoplankton bloom (Rohde et al., 2006) and probably a shift in phytoplankton species composition. This shift will have major implications for other parts of the trophic chain (e.g. crown of thorns starfish larval survival; Brodie et al., 2005). Sampling phytoplankton species will allow the first quantification of this shift for the Great Barrier Reef.

This project will be linked with existing MTSRF projects including coral cores in the path of freshwater plumes Wet Tropics (Prof. M. McCulloch) and water quality proxies in the Mackay Whitsunday Region (Dr K. Fabricius). The project is also linked to flood plume sampling by the Mackay Whitsunday NRM group in this region for the 2004-2005 water year (Rohde et al., 2006) as well as sampling in the recent 2006-2007 wet season (N. Fries pers comm., 2006). This project will collaborate with the ARC Centre of Excellence for Coral Reef Studies with Prof Malcolm McCulloch and Dr Stacy Jupiter as well

as with Dr Guy Marion. These researchers formed the basis of the original ARC linkage project and this current project is viewed as an extension of this earlier study.

Project / Task Objectives

To investigate changes in water quality over the last 150 years using coral cores along a water quality gradient in the Mackay Whitsunday Region. Luminescent lines (flood bands) from two short coral cores (last 30-40 years ~1970-2005) and from one long coral core (1816-1991) from Whitsunday Island (100 samples in total) will be sampled for trace elements (Ba, Mn, Y, Th, Ca, rare earth elements: REE) and isotopes (O and N) to quantify changes in sediment and nutrient runoff since European settlement and the geographical extent of influence of such changes. Samples of flood plume water analysed for trace elements and phytoplankton composition.

Project Results

Two short coral cores (~1960-2005) and one long core (~1816-1992) from Whitsunday Island were selected for laser ablation ICP-MS analysis at the Australian Institute of Marine Science. The samples were prepared and one short core and the long core were analysed at ANU, Canberra in March 2007. Preliminary results show an annual temperature signature in the coral with Sr/Ca and U/Ca ratios (Fig 10). The results are currently being prepared and a full report will be available by 30th June 2007 to coincide with the next milestone.

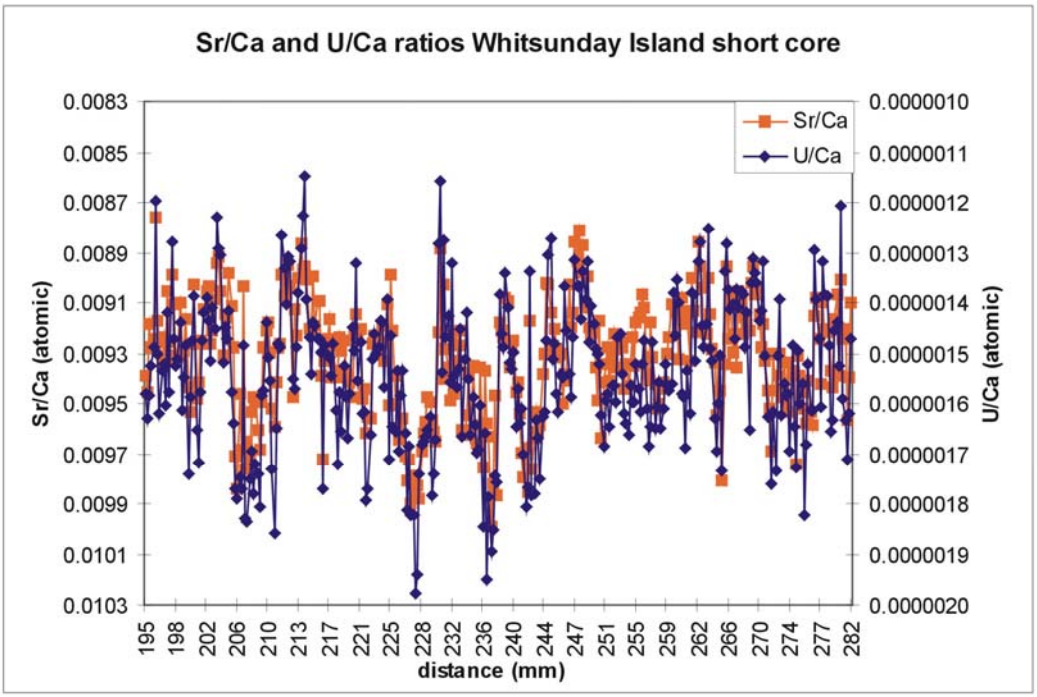

Figure 10. Sr/Ca and U/Ca ratios from the Whitsunday Island short core (W-34) collected by AIMS in 2005. This dataset shows approximately 10 years of growth. The Sr/Ca and U/Ca thermometers display excellent agreement which allows a robust chronology to be developed within the coral core.

Communications, Major Activities and Events

Communications have been held with Dr Hillary Stuart-Williams (ANU) and Dr Guy Marion about the measurement of nitrogen isotopes in coral cores. Arrangements have been made with Eric Matson (AIMS) for a coring trip to the Whitsunday Islands in September 2007 and another coring trip is scheduled for June 2008. Frequent contact has been made with Prof Malcolm McCulloch to arrange additional LA-ICPMS analyses of the Whitsunday coral cores in early 2008.

The laser ablation results will be processed by the next milestone report. Preliminary plans will be made to sample the Mackay Whitsunday flood plume for the 2008 wet season. A preliminary nitrogen isotope run to investigate the precision capacities of the ANU machine will occur by September 2007 and additional samples will be prepared in collaboration with Dr Guy Marion latter in 2007. Coral coring with AIMS in the Whitsunday Islands will take place in September 2007 and a permit application is being developed.