Australian Government

Department of the Environment, Water, Heritage and the Arts

Marine and Tropical Sciences Research Facility (MTSRF)
November 2007 Milestone Report

Project 3.7.1 – Marine and Estuarine indicators and thresholds of concern

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Summary

All activities within the MTSRF Project Marine and estuarine indicators are on track. The experimental and research design for the Estuarine Indicator Research for Year 2 has been written (see below). It proposes extensive and repeated sampling of 12 estuaries in the Burdekin Dry Tropics region (6 undisturbed, and 6 disturbed estuaries). A first draft of a study on the synergistic effects of nutrients and sediments on coral reproduction, and the assessment of dose-response relationships, has been completed. An experimental setup to test the response of foraminifera and other biofilms to changes in water quality has been developed and tested. Several foraminifera species can now successfully be kept in the AIMS aquarium system and experiments subjecting these to different light and nutrient conditions have commenced.

Project Outputs / Milestones

Objective	Targeted Activity	Completion Date
(a)	Field testing and analysis of marine biofilms (bacteria, diatoms, foraminifera) for their suitability to indicate changes in water quality. [AIMS]	June 2008
(b)	Field testing and analysis of coral reef organisms and physiological change tested for their suitability to indicate changes in water quality and ecosystem condition. [AIMS]	June 2008
(c)	Report on relationships between seagrass communities and sediment properties along the Queensland coast. [QDPI]	June 2008
(d)	Conduct research towards identifying potentially useful ecological indicators of the condition of North Queensland's estuaries [JCU, GU]	June 2008

For reference: Milestone extracted from Project Schedule
Description: Report 1 submission

- Complete development of culture methods for benthic foraminifera at AIMS, and complete first laboratory experiment on dose-response relationships to nutrients and light in foraminifera (objective (a) (above). [AIMS]
- Progress update for objective (b) (above). [AIMS]
- Progress update for objective (c) (above). [QDPI]
- Completed experimental design for year 2 studies for objective (d) [JCU, GU]
- Summary of any liaison activities undertaken to date. [AIMS]

Project Results

Milestones, and progress so far:

- ***Progress update for objectives a,b:***

Objective a) • Complete development of culture methods for benthic foraminifera at AIMS, and complete first laboratory experiment on dose-response relationships to nutrients and light in foraminifera (objective (a). [AIMS]:

We have conducted two field trips to the Whitsundays to field test an experimental setup to expose and transplant individual foraminifera. These tests were highly successful: after four weeks of exposure foraminifera could be recovered and their growth and mortality in response to different environmental conditions measured. Supported by one honours student, a Graduate diploma student and a PhD student (in collaboration with UQ) about 10 foraminiferan species have been kept at the aquarium system at AIMS. At least four of these showed high survival rates and measurable growth. These species are thus suitable for manipulative experiments to investigate dose response relationships. Several experiments on this have been conducted investigating growth of foraminifera under different light conditions. A first experiment investigating the interactive effects of lights and elevated nutrients has also been conducted and is currently being analysed. A new honours student is commencing work on foraminifera in November. A masters student from the Max Planck Insititute of Marine Microbiology (Bremen, Germany) has started to investigate bacterial communties along the Whitsunday water quality gradient. This student is going to expand his studies into a PhD from March 08 onwards.

Objective b) Field testing and analysis of coral reef organisms and physiological change tested for their suitability to indicate changes in water quality and ecosystem condition. [AIMS]

Tim Cooper has finished his PhD to investigate the use of coral reef organisms as indicators of water quality conditions, and completed his employment as experimental scientist at AIMS. A field trip was conducted (13 – 18 Sept 07) to investigate the role of ephemeral macroalgal blooms to the physico-chemical conditions underneath algal mats, which is relevant for coral recruitment. A first draft of a study on the synergistic effects of nutrients and sediments on coral reproduction, and the assessment of dose-response relationships has been completed. This study was the first to investigate the interactive effects of various water quality parameters (salinity, various types of suspended sediments, and dissolved inorganic nutrients) on fertilisation success and larval development in a scleractinian coral, *Acropora millepora*. The results from this experiment confirmed previous studies that have shown that salinity, suspended sediments and nutrients at environmentally relevant levels have an effect on the reproductive processes of *A. millepora* and showed for the first time clear dose-response relationships. It furthermore demonstrated that these effects are interactive. We also demonstrated that the type of suspended sediments, based on their organic, nutritive and geophysical properties, had differential effects on rates of fertilisation and larval development.

- ***Progress update for objective c. [QDPI]***

Objective c) Report on relationships between seagrass communities and sediment properties along the Queensland coast. [QDPI]

- ***Progress update on the literature review on potentially useful ecological indicators of the condition of North Queensland's estuaries. [JCU, GU]***

Conduct research towards identifying potentially useful ecological indicators of the condition of North Queensland's estuaries [JCU, GU]

A research proposal has been written (see below), and the field work is about to commence.

- ***Summary of any liaison activities undertaken to date. [AIMS]***

1. Katharina Fabricius participated and gave a presentation at the GBRMPA/Reef Partnership WQ Integration and Synthesis Workshop with Bill Dennison and Joelle Pange (Townsville, 10-12 Sept 07) to identify and compile water quality specific indicators.
2. Meeting with GBRMPA (David Haynes, Joelle Pange et al) on coordination of GBRMPA needs with MTSRF research priorities (21 Aug 07).
3. Meeting with GBRMPA Outlook Team to discuss GBRMPA plans for the Outlook Report (18 jUL 07).
4. Katharina Fabricius participated in Marine Modelling Workshop, Townsville (16/17 July 07).
5. Katharina Fabricius gave a presentation at the CERF conference in Canberra (22/23 October 07). Meetings were also conducted to set up and coordinate some of the synthesis work that will be done jointly with project 1.1.5 (ReefAtlas Work, with Bill Venables, Glenn De'ath and David Souter).
6. Tim Cooper presented the results of his research on indicators at a seminar at AIMS and as Exit Seminar at JCU.
7. Meeting with GBRMPA (Hugh Yorkston, David Haynes et al) on GBRMPA's Water Quality Guidelines.
8. Katharina Fabricius gave several presentation on the effects of water quality on coral reefs (Reef Talk at the Chamber Music Festival, JUC Lecture for Postgraduate Intensive Course, etc).

Communications, major activities or events

During next milestone reporting period

We will conduct a 10-days and a 7 -days field trip to the Whitsunday Islands to deploy and retrieve biofilms samplers and instruments for a month, in order to better characterise water quality conditions along the ecological gradients tested. The Coral reproduction Report will be completed, and field sampling for the Estuarine Health study will have commenced.

MTSRF Task: 3.1.1d: Estuarine Indicators of Ecosystem Condition: Experimental Design for Year 2 Studies

Marcus Sheaves, Rod Connolly, Ross Johnston

Introduction

There is clear evidence that Australia's tropical estuaries are facing increasing levels of anthropogenic stressors at levels that can be detected in aquatic organisms. Humphrey et al. (2006) investigated biomarkers of pollutants in barramundi, *Lates calcarifer*, across 5 estuaries in North Queensland, and found clear biochemical responses that correlated with the presence of chemical contaminants in the environment. Despite the detection of these biomarkers, Humphrey et al. (2006) found no evidence of impacts on the general fitness of the fish. This highlights a problem; we know that stressors are present at levels where they can be taken up by organisms but, up until now, we have not been able to find unambiguous evidence of deleterious impacts on estuarine ecosystems. There are two possible reasons for this. Firstly, it may be that levels of stressor are too low to produce detectable deleterious effects. Alternatively, it may be that there are impacts but the techniques we have been employing can not detect them. Whether the problem is one of lack of effect or lack of ability to detect effects we need to ensure we have developed tools capable of detecting ecosystem impacts if they are present or occur in the future.

An additional problem has been highlighted in more extensively studied temperate systems. Even if individual species responses are found (MacFarlane & Booth 2001), it is often difficult to extrapolate these to a clear understanding of impacts at an ecosystem level (Elliott 2002). This problem becomes much greater when dealing with tropical ecosystems which harbour more diverse biotic assemblages (Robertson & Blaber 1992) with more complex ecological interactions (Sheaves and Johnston in press).

If we are to develop clear indicators of *Ecosystem Condition* we will need to go beyond traditional approaches and focus on indicators specific to detecting change at assemblage, community and ecosystem levels.

Objectives

This study plan is aimed at developing and evaluating a variety of promising measures which have the potential to yield specific information on the integrity and functional health of tropical estuarine ecosystems. The study will focus on nekton because the ecology of tropical nektonic organisms is very well understood compared to that of other estuarine organisms. The measures evaluated will concentrate on detecting impacts at assemblage and ecosystem levels, and will include both direct measures of ecosystem functioning and indirect measures that focus on particular species to provide information on the integrity and health of estuaries as nursery and spawning grounds. The approaches evaluated include a mixture of standard approaches, adapted to the unique aspects of tropical environments and ecosystems, and a series of novel approaches based on recent advances in understanding of tropical estuarine ecosystems. Because of funding limits these studies will focus only on dry tropics sites but the study will be extended to wet tropics areas if supplementary funding becomes available.

Methods

Individual and process level indicators of ecosystem health will be evaluated across perceived gradients of potential anthropogenic impacts of different types. Additionally, measures of the presence of key stressors will be collected to allow evaluation of the extent to which the perceived gradient is reflected in specific indicators of pollution.

Study Sites:

A range of study sites have been selected (Fig. 1) to represent 4 major categories of anthropogenic impact threatening North Queensland's estuaries, as well as a series of control sites (Table 1).

Figure 1. Proposed sampling sites

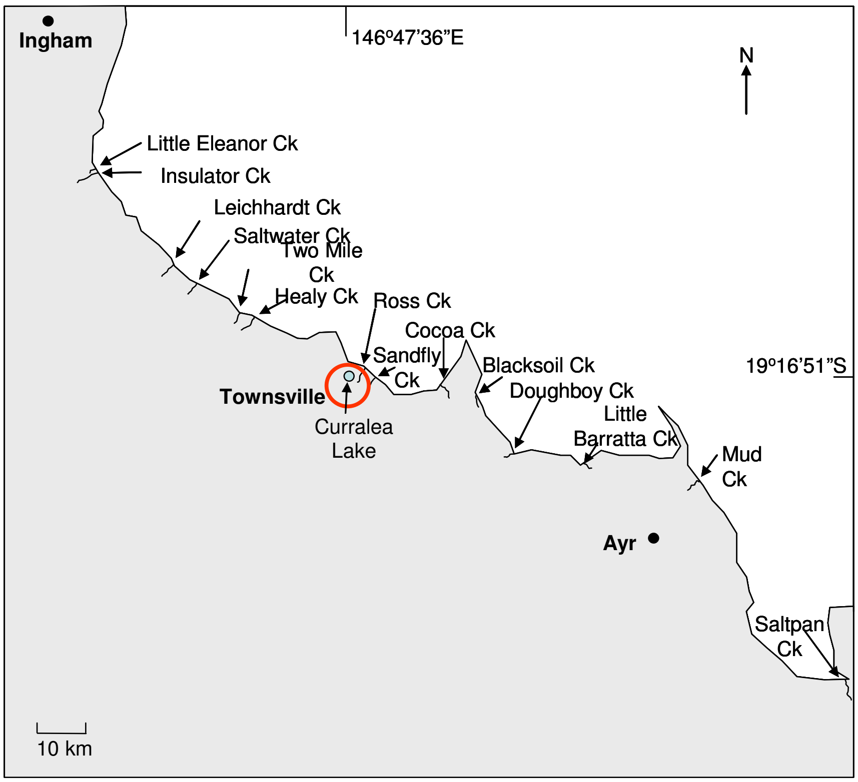

Table 1: Study sites

Agricultural	Insulator Ck, Mud Ck
Aquaculture	Two Mile Ck, Saltwater Ck
Urban	Ross Ck upstream, Curralea Lake, Sandfly Ck
Industrial	Healy Ck
Control	Little Eleanor Ck, Little Barratta Ck, Cocoa Ck, Blacksoil Ck, Doughboy Ck, Saltpan Ck

GIS survey, followed by detailed ground-truthing, was used to identify replicate study sites presenting potential adverse impacts to estuaries from 4 categories of sources; agriculture, aquaculture, urban and industrial, as well as replicate control sites (Tables 1 & 2, Fig. 1). Selection of each category of estuary was based on a series of explicit criteria (Table 2). Although the "control" sites were selected because of an absence of obvious sources of impact, in reality impacts from human activities are pervasive, so most sites can be expected to be under some level of impact. Consequently, the control sites are likely to represent a gradient of sites with reduced levels of impact rather that being totally un-impacted sites.

Budgetary considerations limit the number of sites that can be studied, but experience suggests that sampling at least 12 sites (6 impact and 6 control) will be viable. Iinitial sampling will extend to all sites and decisions on whether all sites can be included in the full study will be made once the first round of sampling is complete. Six control sites are crucial because recent studies (Sheaves 2006), and studies currently underway, indicate that there is considerable variability in estuarine fauna among North Queensland systems, meaning that useful comparisons to control conditions rely on the representation of a broad spectrum of control conditions.

Table 2: Criteria for selection of different categories of study sites

Agricultural	The presence of sugarcane plantations across 50% or more of the apparent catchment area
Aquaculture	At lease one extensive aquaculture development adjacent to the site
Urban	The presence of extensive urban development adjacent to the site, or the presence of infrastructure adjacent that services a major urban area
Industrial	Reported past impacts of an adjacent industrial site
Control	Obvious anthropogenic development in less than 5% of catchment area

Four criteria were applied to the selection of specific study sites (Table 3).The substantial variation among estuaries also indicates that individual estuaries are the logical sampling units for this study. However, representing the fauna of a tropical estuary is difficult because tropical estuaries present unique challenges to collecting representative samples of biological attributes. Turbid waters and the presence of estuarine crocodiles make sampling physically difficult. Moreover, the ability of organisms like fish to move extensively within an estuary can make it difficult to ensure that a sample collected at one time is comparable with that collected at another, while spatial patchiness makes it difficult to ensure that samples are representative if only a very small part of the total area can be sampled. For these reasons the study is limited to estuaries small enough that the majority of habitat area could be sampled extensively.

Table 3: Criteria for study site selection

Attribute	**Criterion**
small enough to be sampled efficiently within one day	maximum length ~ 5km
semi-enclosed	depth at entrance < 20 cm at low tide
access	be assured of consistent access for the duration of the project
sampled efficiently using sampling gear	maximum depth < 3 m at low tide

<u>Variables</u>

Three categories of variables will be measured;

(a) indicators of the quality of the physical environment,
(b) indicators of impacts on individual species, and
(c) direct indicators of the integrity of key ecological processes.

Environmental quality

A small suite of variables (**Table 4**) will be measured to enable the actual status of stressors in each of the estuaries to be evaluated. This will allow the perceived categorisation to be validated and provide the opportunity to evaluate the actual level of key stressors present in control sites. Key stressors were selected on the basis of being recognised indicators of particular types of impacts and having been previously shown to be detectable in tropical estuarine environments.

Table 4: Indicators of environmental quality to be measured

Diuron [sediment]	pervasive agricultural chemical
$\delta^{15}N$ [site attached organisms]	as indicator of organic or chemical nitrogen contamination
$\delta^{13}C$ [site attached organisms]	as indicator of input of sugarcane carbon
dO_2 vertical profiles	to detect the presence and extent of an anoxic bottom layer. Indicative of high levels of organic pollutants.
chlorophyll A [water column]	an indicator of eutrophication
turbidity	indicator of decreased water clarity

Individual species level indicators

Three abundant, site attached (Sheaves 1993) estuarine fishes, the lutjanids, *Lutjanus argentimaculatus* and *L. russelli*, and the sparid, *Acanthopagrus berda*, will be studied in detail to provide assessment of the quality of estuaries as nursery and spawning grounds, two key ecological functions (**Table 5**).

The two lutjanids use tropical estuaries as nursery grounds (Sheaves 1995). They have the peculiar attribute of storing fat in discrete fat bodies in their gut, and the relative size of these fat bodies increases steadily during their estuarine residence. These fat bodies are used to sustain migration to offshore adult habitats and to support the production of gonads during their first spawning season. As well as being crucial to future reproduction, the development of these fat bodies would seem to afford a direct measure of the quality of estuarine nursery grounds. The development of these fat bodies will be assessed in fish captured during tri-monthly trap sampling. In addition to this measure of overall status of energy stores, liver hepatocyte and vacuole density will be assessed as a measure of short term changes in condition (Molony & Sheaves 2002), providing the potential to investigate any impacts from pulsed events (eg. the import of pollutants during wet season flooding). Otoliths aging will be used to evaluate growth rates as an additional measure of the overall quality of the estuarine nursery habitat.

The sparid, *A. berda*, is a generalist omnivore that is resident in tropical estuaries and spawns at the estuary mouth in mid winter (Tobin et al 1997). Because it derives its nutrition from a variety of estuarine benthic food sources, the presence of environmental stressors at sub-lethal, but biologically damaging, levels should be reflected in the amount of gonadal material elaborated and the pattern of gonadal development.

Table 5: Individual indicators of ecosystem health to be measured

Lutjanid total gut lipid (corrected for size)	a long-term measure of the extent of storage of energy during nursery ground residence.
Lutjanid growth rate	a measure of the overall quality of the nursery ground over time.
Lutjanid hepatocyte and vacuole density	short-term measures of fish condition.
Acanthopagrus berds gonado-somatic index and gonad histological development	measure of reproductive quality.

Process-level

A suite of approaches will be used to directly assess the integrity of ecological processes (**Table 6**).

Recruitment varies greatly between estuaries, making it difficult to separate anthropogenic impacts from natural variability. However, once recruits are established in an estuary any differences in overall ecosystem quality (chronic effects) or periods of pulsed impacts (eg. flood driven inputs of pollutants) is likely to impact recruit persistence. Changes in the abundance of recruits, subsequent to entering the estuary, will be monitored during monthly sampling.

Detritivorous fish dominate most tropical estuarine fish fauna (Sheaves et al in press). They feed on detritus and microalgae on the sediment surface which is a major site of pollutant accumulation (Humphrey et al. 2006), so any impacts of pollutants are likely to be seen first in phyto-detrititus feeders. Benthic feeders are the other dominant trophic group in tropical estuaries (Sheaves 2006). They also feed at the sediment surface, but prey on invertebrates relying on deeper detritus and therefore are vulnerable to pollutants in a different way. The abundance of these groups, and their positions low in the tropic pyramid, mean they occupy key positions in the trophic organisation of estuaries. Consequently, systematic changes in these groups are likely to provide direct indications of ecosystem impairment. Impacts are likely to be reflected in changes in the dominance of phyto-detritivores, the phyto-detritivore: benthivore ratio, and phyto-detritivore and benthivore species richness (Table 6). Information on the presence and abundance of these groups will be collected during regular monthly sampling.

Regular monthly samples will also be used to provide material for Carbon and Nitrogen stable isotope studies, which will provide information on the length of trophic linkages, food web complexity, and the extent of omnivory (**Table 6**).

Scavengers perform an essential function of consuming carrion that would otherwise build up and generate toxic effects of decomposing bacteria. Scavenging also increases the rapidity with which nutrients in carrion are recycled to the environment. Scavenging is thus a high level ecological function that in theory will be linked with water quality in estuaries.

Table 6: Process-level indicators of ecosystem health to be measured

recruit persistence	a measure of the success of species occupancy of nursery ground.
phyto-detritivore dominance	changes in the dominance of this important group provide a measure of the relative quality of in-situ phyto-detrital material as support for food webs.
phyto-detritivore: benthivore ratio	a measure of the relative importance of food chains based directly on phyto-detritus versus those where energy flows through benthic invertebrates. This is likely to change in response to differential impacts of pollutants on surface phyto-detritus, fed on directly by fish, and deeper detritus processed through invertebrates. These trophic groups are likely to be most directly affected by sediment bound pollutants.
phyto-detritivore species richness & species composition	a measure of the extent of change of key faunal elements in response to different levels of anthropogenic impact. Expected to change if individual species are less able to cope with altered conditions than others.
benthivore species richness & species composition	a measure of the extent of change of key faunal elements in response to different levels of anthropogenic impact. Expected to change if individual species are less able to cope with altered conditions than others.
food web height	to detect any variations away from typical food web height of estuaries, which is much more consistent among un-impacted systems than is taxonomic composition.
food web complexity	a measure of the complexity of ecosystem function. Complex food webs are expected in healthily functioning estuaries, with complex trophic functioning supporting ecosystem meta-stability.
extent of onmivory	a measure of the complexity of ecosystem function. Low levels of omnivory are likely where anthropogenic modification (eg. conversion of diverse low-land vegetation to agricultural mono-culture) has reduced the diversity of nutritional input.
scavenging pressure	a measure of ability of scavengers to process carrion.

Sampling & experimental methods

Field sampling will be conducted with cast nets, which have proven effective at representing the bulk of the fauna of tropical estuaries (Johnston et al 2007, Sheaves & Johnston in press). Cast nets will be used to collect samples representing the entirety of each estuary system, with approximately two cast net throws for each 100m of linear extent of the estuary distributed at random along the length of the estuary. These will be the principal gears used for sampling during recruitment and trophic studies. These data will be supplemented by gill net samples (100mm & 200mm mesh) to ensure that larger mobile fish are represented for food web studies. Fish traps (Sheaves 1995) will be employed to capture lutjanids and sparids for species-specific studies, and to ensure that highly structured habitats are well represented in trophic studies (Sheaves 1996).

Scavenging pressure will be measured using a protocol that has been developed to determine the weight loss of replicate baits (whole pilchards) deployed on a platter for 30 minutes on the sea bed. Preliminary tests show that the effects of tidal stage, time of day, soak time, bait size and type, and distance from estuary mouth are less important than variation among estuaries. With some further testing, the protocol will be suitable for measuring scavenging pressure efficiently across multiple estuaries.

This measure of scavenging pressure is independent of the types of scavengers present. Scavenging pressure will be assessed with the deployment of 3 sets of 12 baits in each estuary.

Sampling periodicity

Each system will be sampled at monthly intervals using cast nets to allow investigation of changes in the abundance of recruits over time, and to provide samples for trophic studies. These will be supplemented with tri-monthly sampling using gill nets and fish traps, which will provide additional material for trophic studies and samples for species-specific studies.

Scavenging studies will be conducted during tri-monthly sampling.

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