



National Environmental  
Research Program

TROPICAL ECOSYSTEMS *hub*

## NERP Tropical Ecosystems Hub Annual Highlights Report 2012

Compiled by RRRRC



**Australian Government**

**Department of Sustainability, Environment,  
Water, Population and Communities**





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# Introduction to the NERP Tropical Ecosystems Hub

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The NERP Tropical Ecosystems Hub (NERP TE Hub) is a \$61.9 million partnership between the Australian Government (Department of Sustainability, Environment, Water, Population and Communities (DSWEPaC)) and four core research institutions (Australian Institute of Marine Science, (AIMS) Commonwealth Scientific and Industrial Research Organisation (CSIRO), James Cook University, (JCU), and University of Queensland (UQ)) for the delivery of applied environmental research in northern Queensland.

The NERP TE Hub research program is structured around three Themes with 38 research projects organised around twelve Research Programs. The research concentrates on three geographic nodes: the Great Barrier Reef and its catchments, Torres Strait, and the Wet Tropics Rainforests.

## Theme 1 Assessing Ecosystem Condition and Trend

A clear understanding of the ecological condition and trends of environmental assets of the Great Barrier Reef, Torres Strait and the Wet Tropics rainforests is fundamental to ecologically sustainable use of those assets by industry and communities, supported by appropriate management and policy settings. Theme 1 is comprised of three inter-related Programs, each of which concentrates on a specific component of North Queensland's natural and cultural heritage, and delivers reports on the condition and trend of key ecosystems and natural living resources.

**Program 1** Historical and current condition of the Great Barrier Reef

**Program 2** Natural Resources of the Torres Strait land and sea

**Program 3** Condition and trends of North Queensland rainforests

## Theme 2 Understanding Ecosystem Function and Cumulative Pressures

Theme 2 builds on research undertaken through the MTSRF and other programs that have identified many of the primary risks and threats to the environmental assets of North Queensland. These pressures do not occur in isolation to each other, and it is clear that a greater understanding of the cumulative and synergistic impact of these pressures is required for improved management. These pressures are not static, therefore predicting and preparing for change is a significant challenge for environmental decisions makers charged with stewardship of Queensland's natural environment. Changing climates, extreme natural events, changes in natural resource use and population growth are some of the pressures facing these ecosystems.

The Theme is comprised of four Programs that will increase the understanding of ecosystem function and the impact of synergistic and cumulative pressures on the system. This understanding is essential in developing effective management responses that promote ecosystem resilience.

**Program 4** Water quality of the Great Barrier Reef and Torres Strait

**Program 5** Cumulative impacts on benthic biodiversity

**Program 6** Movements and habitat use by marine apex predators

**Program 7** Threats to rainforest health

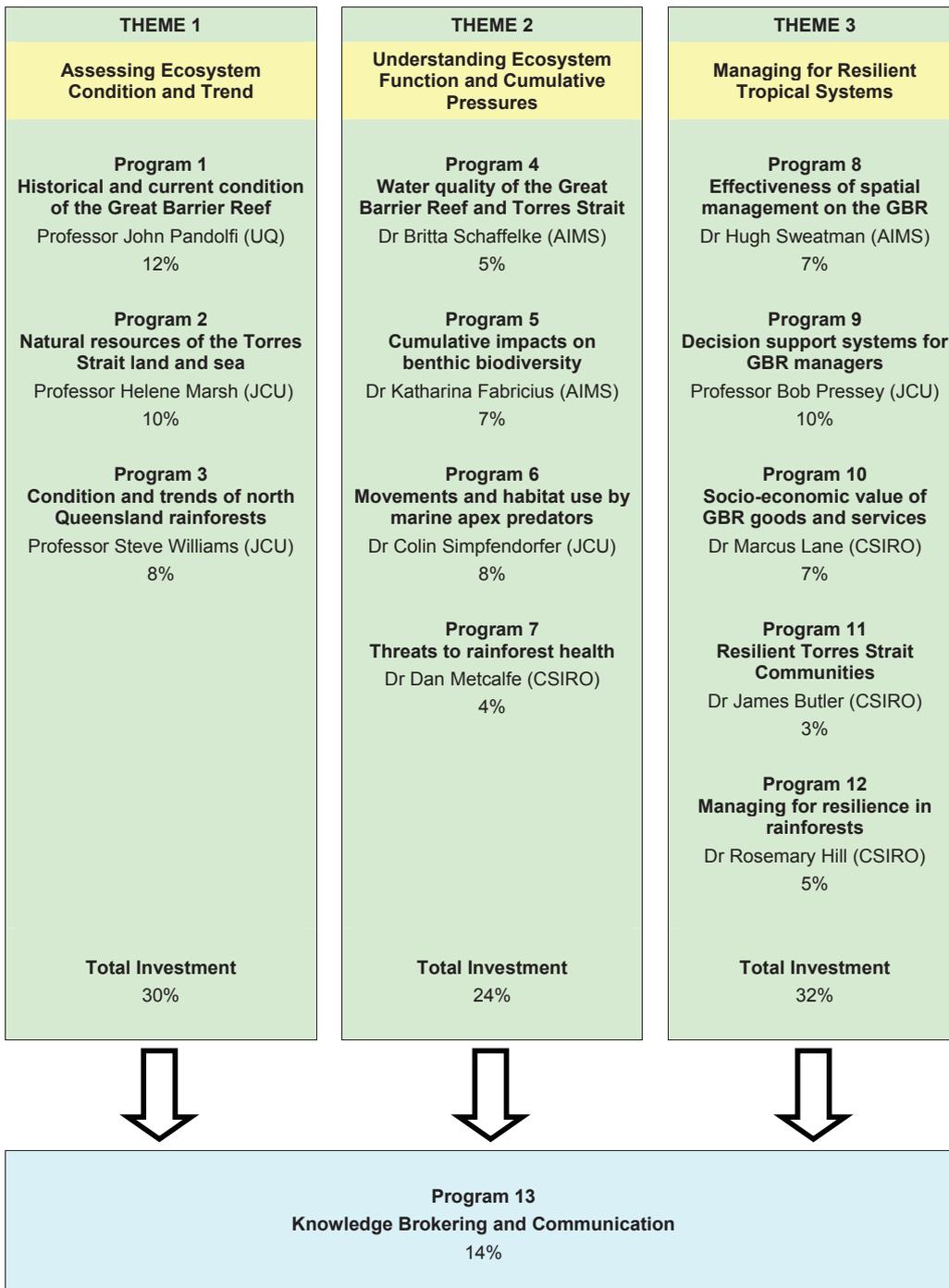
## Theme 3 Managing for Resilient Tropical Systems

Research undertaken within Theme 3 will provide knowledge and options to assist key decision makers in government, industry and the community in managing the complex ecosystems of the Great Barrier Reef, the Wet Tropics rainforest (including the World Heritage Area) and Torres Strait. Theme 3 draws on the assessment of ecological condition and trends undertaken in Theme 1 and the improved understanding of ecosystem function and cumulative pressures from Theme 2. Theme 3 is comprised of five programs and will provide tools and information for evidence-based decision making that address the pressures and sustains resilient ecological, social and economic systems.



- Program 8 Effectiveness of spatial management on the Great Barrier Reef
- Program 9 Decision support systems for Great Barrier Reef managers
- Program 10 Socio-economic value of Great Barrier Reef goods and services
- Program 11 Resilient Torres Strait communities
- Program 12 Managing for resilience in rainforests

Themes and Programs of the NERP Tropical Ecosystems Hub showing Program Leaders (institutional affiliation) and relative investment in each







## Research Highlights





## Theme 1 Assessing Ecosystem Condition and Trend

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### Program 1: Historical and current condition of the Great Barrier Reef

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#### Project 1.1: Monitoring status and trends of coral reefs of the GBR

**Project Leader:** Dr. Hugh Sweatman. AIMS

**Focus area:** GBR Biodiversity

##### *Project Background*

This project surveys 47 reefs from north of Cooktown to South of Gladstone in alternate years. These reefs have been surveyed repeatedly since 1993. In 2012, the reefs in the far southern GBR and the far northern GBR were surveyed.

##### *Project Progress*

Reefs in the southern GBR include those in the Pompey, Swains and Capricorn-Bunker sectors. These reefs have generally been damaged by large cyclones in the past few years and are in the early stages of recovery. Coral cover is generally low (<10%) except for the outer reefs in the Swains that seemed to have avoided the worst damage. Crown-of-thorns starfish were present in 'incipient outbreak' densities in the Pompey sector, which appear to be the last remnant of the southward wave that began around Lizard Island in 1994.

Reefs in the far northern GBR include those in the Cooktown/Lizard Island sector. These reefs have higher coral cover because of less severe cyclone activity in recent years, but nearly all inshore and mid-shelf reefs that were surveyed had outbreaks of the crown-of-thorns starfish in densities that were at 'incipient outbreak' or 'active outbreak' levels. Coral cover can be expected to decrease markedly on these northern reefs in the next two years or so.

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#### Project 1.2: Marine wildlife management in the Great Barrier Reef World Heritage Area

**Project Leaders:** Professor Helene Marsh and Dr. Mark Hamann, James Cook University

**Focus area:** GBR Biodiversity

##### *Project Background*

This project is focused on:

- Connectivity and ecosystem role of green turtle and dugong
- Gathering information on the distribution of inshore dolphins of the northern GBRWHA.

##### *Project Progress*

The green turtle and dugong component of the project involves stable isotope analysis, genetics and tracking. Stable isotope markers C and N were analysed from the skin of 200 turtles from three latitudes. Early indication supports omnivory in juvenile green turtles. The study of the genetic structure of juvenile green turtles from Low Isles found that 95% of turtles from that site are from the southern GBR population and there were very few turtles from the northern GBR population. And satellite tags were attached to turtles in Shoalwater Bay and Cardwell. Results are in the early stage of analysis.

The inshore dolphin component of the project involved travelling to 14 locations in Cape York Peninsula to scope the potential for traditional and local knowledge mapping workshops. The primary aim of discussions were to ascertain the sighting distribution of inshore dolphins and dugongs and the willingness, capability and feasibility of traditional owners and other community members in collaborating with JCU to record their traditional and local knowledge. Other community members included six Indigenous Ranger groups, recreational fishers, yachters, tourism operators and environmental scientists. Workshops will be conducted in 2013.



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### **Project 1.3:** Characterising the cumulative impacts of global, regional and local stressors on the present and past biodiversity of the GBR

**Project Leaders:** Associate Professor Jian-xin Zhao and Professor John Pandolfi, UQ

**Focus area:** GBR Water Quality

#### ***Project Background***

The overarching goal of this project is to establish the relationships between major historical ecological changes in GBR inshore reefs, and major anthropogenic stressors/drivers and climatic events from the past several millennia, through European settlement, up to the present day.

Innovative geochemical, geochronological and palaeoecological methods are being used to investigate the impact of rising sea-level; rising sea-surface temperature; seawater acidification; increased sediment/nutrient discharge; increased pollution from urban development; and other climatic drivers such as ENSO and cyclones on the reef ecosystem. The sampling strategy covers high- and low-impacted regions along the GBR and will allow us to test whether changes in the quality of land-based catchment runoff result in degradation of inshore coral communities.

#### ***Project Progress***

Coral cores indicate a change in the dominant corals at Pelorus Island (central GBR) between 1930 and 1950, despite relatively benign climate conditions. This scale of change was not evident in core material from the previous 1,500 years, despite large amplitude climate variability and frequent 'super-cyclones', both not seen since European settlement. This suggests that the fast growing branching corals (*Acropora* spp.) may be most sensitive to the changes in coastal water quality (e.g. increased erosion) caused by changing land use.

Coral growth was also measured using 42 cores collected from massive *Porites* heads along a transect extending from just off the Townsville coast out to the central GBR. Results indicate a distinctive cross-shelf pattern in the coral-growth response over the last 50 years with inshore reefs showing a long-term decrease in coral calcification rates, probably due to increased terrestrial run-off and higher sea-surface temperature variability. Cores also show the effects of the major coral bleaching event that occurred in 1998.

Preliminary U/Th (Uranium/Thorium) dating of 12 coral fragments from the Keppel Islands shows that these reef cores cover a period of up to 6,000 years; providing an invaluable record of coral reef development for this region. Other cores from this area have been dated between 323 BC and 2008 AD and show clusters of mortality events, possibly corresponding to cyclones and/or flood events. The timing of these mortality events will be compared with sea surface temperature, river discharge and observational records (among others) to better determine the likely causes.

Finally, cores taken from Hervey Bay show that 40% of the area's coral was lost as a result of the 2011 flood. The effect was highly variable (0-89% loss) and was particularly evident in the path of the flood plume.



## Program 2: Natural Resources of the Torres Strait land and sea

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### Project 2.1: Marine turtles and dugong of Torres Strait

**Project Leaders:** Professor Helene Marsh and Dr. Mark Hamann, James Cook University

**Focus area:** Torres Strait

#### *Project Background*

The project will use monitoring, genetics, tracking and remote sensing in the Torres Strait to determine:

- The status of green, hawksbill and flatback turtles
- Population connectivity between turtle and dugong in relation to protected areas and community based management areas, plus the threats to populations
- Dugong population estimates
- If there are seasonal differences in the relative abundance of dugongs in the western Torres Strait, especially in the Dugong Sanctuary.

The project will improve stakeholder understanding, capacity and skills to better manage turtle and dugong in the Torres Strait region, and provide information for management of these threatened species.

#### *Project Progress*

The Islands in the Mer group (Mer, Dauar and Waer) and Bramble Cay are the most significant green turtle rookeries in Torres Strait and the main nesting sites for the Torres Strait / northern GBR genetic population. Nesting success (% of female turtles that emerge each night to lay eggs) at Dauar Island and Bramble Cay was 33% in 2006, 62% in 2007 and 50–60% in 2008/09. Data suggest that nesting female green turtle size is declining. Islands in the central and western Torres Strait are significant flatback turtle rookeries. Turtle tagging and nesting surveys conducted by this project confirmed a significant population of green turtles in the region.

The estimated population of dugong in the Torres Strait is >12,000 animals, the largest in the world. Aerial surveys since 1987 indicate that the population has not changed significantly over time. These aerial surveys also found high numbers of green turtles in the region, particularly in the Dugong Sanctuary (western Torres Strait).

The project is also collecting environmental data relevant to turtle nesting, having deployed sand temperature loggers and conducted elevation mapping of key nesting islands. Deliverance Island was mapped using RTK GPS and the maximum height of the island was ~4m with most of the island (above the high tide mark) between 2 and 3m elevation.

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### Project 2.2: Mangrove and freshwater habitat status of Torres Strait islands

**Project Leaders:** Dr. Norm Duke and Dr. Damien Burrows, TropWater, James Cook University

**Focus area:** Torres Strait

#### *Project Background*

The wetland ecosystems on the islands in the Torres Strait region – mangroves, salt marsh and freshwaters – are not well documented. For most islands, there is no documentation of what wetland types are present, and what their biota, condition and status are. Whilst freshwater wetlands are rarer, most Torres Strait islands have extensive mangrove margins and several islands (e.g. Saibai and Boigu) are predominantly made up of intertidal swamps. Establishing the baseline of wetland status and condition is important, especially as many islands are low lying and the predictions of sea level rise and increased storm surge frequency mean that mangroves and coastal wetlands may be among the most threatened ecological communities in Torres Strait. The project aims to visit 20 islands to:



- Undertake a baseline survey of the status and condition of mangroves and freshwater wetland habitats in Torres Strait
- Document knowledge of selected communities about their uses of mangrove and freshwater habitats
- Survey freshwater fishes across the islands, especially for the presence of exotic fishes and aquatic plants
- Assess mitigation options for mangroves, rehabilitation needs, and climate change adaptive strategies.

### ***Project Progress***

The project has surveyed eight islands to date and already many new species records have been documented. The Torres Strait region has ~ 124 wetland species, including more than 39 mangrove species. Recent surveys have identified two new mangrove species for Australia and two new species for Torres Strait. There are ~31,390 ha of wetland area within Torres Strait, comprising 21 vegetation communities of which three are unique to the region. 83% of wetlands in Torres Strait are tidal, mostly mangrove communities (Boigu and Saibai islands have the largest areas). In freshwater habitats, 30 fish species have been recorded on Torres Strait islands, some are exotic species from PNG (e.g. climbing perch) that have been found on Saibai and Boigu islands. Other exotic fish (e.g. guppies, mosquitofish) have been found in dams on Thursday Island. The project is currently examining whether these exotic species pose a threat to freshwater ecosystems and fishing activities, and how to control the spread of these exotic fish through community and school extension.

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## **Project 2.3: Monitoring the health of Torres Strait coral reefs**

**Project Leader:** Dr. Ray Berkelmans, AIMS

**Focus area:** Torres Strait

### ***Project Background***

Coral reefs of the Torres Strait are at the northern tip and part of the Great Barrier Reef province. Despite its ecological connection to the Great Barrier Reef and its clear importance to Torres Strait communities, comparatively few biodiversity surveys have been done on these reefs. As elsewhere, climate change, crown of thorns starfish, disease, storms, and pollution from river runoff and shipping are threatening the ecological integrity of Torres Strait reefs. This project seeks to establish a monitoring program to enable resource managers to keep abreast of key indicators of coral health and to train local rangers to undertake ongoing monitoring. The project aims to help managers better predict, prepare for, and respond to major changes to their coral reefs, especially as a result of climate change.

### ***Project Progress***

The project has conducted a review of past coral reef surveys, undertaken baseline and biodiversity surveys of key reefs and established a network of in situ temperature loggers. Coral bleaching was reported in western Torres Strait in 2010, coinciding with high water temperatures and therefore the project has also developed a locally-specific bleaching threshold and installed a real-time weather station at Madge Reef near Thursday Island that will be used to provide early warning of coral bleaching. The data from the temperature loggers and weather station is used to provide monthly updates of ocean and atmospheric conditions to stakeholders. The project is also training local rangers in monitoring techniques and maintaining the temperature loggers to ensure continuity of monitoring in the future.



## Program 3: Condition and trends of North Queensland rainforests

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### Project 3.1: Rainforest Biodiversity

**Project Leader:** Professor Stephen Williams, James Cook University

**Focus area:** Rainforests

#### *Project Background*

This project assesses the vulnerability and resilience of rainforest biodiversity in Australian tropical forests. Environmental refugia will be mapped, and patterns and drivers for biodiversity identified. Biodiversity is the range of species in a given ecosystem and refugia are those places where species may go if forced by changing climatic conditions. Using a combination of available knowledge, existing datasets and strategic research the project will develop strategies for promoting persistence of biodiversity. This new knowledge will allow an identification of threats in time and space and allow prioritisation of vulnerable species, in order to maximise management efficiency. The project will act as a focus point within the broader rainforest project node, allowing strategic targeting of research gaps, and increasing our understanding of the drivers of rainforest biodiversity.

#### *Project Progress*

Two probable types of climate refugia have been identified, separated by size. "Micro" refugia have been defined as 250 metre cells that are coolest or most seasonally buffered, compared to the surrounding conditions. "Meso" (i.e. middle sized) refugia have been defined as the 5 kilometre climate cells with the greatest range of thermal micro-climate conditions. Given the combination of complex landscape, habitat and topographic features within the WT bioregion there is a considerable potential for existence of climatic refugia, particularly at higher elevations in the rainforest. The potential distributional area change for 202 rainforest vertebrate species has now been modelled and initial summaries generated. The next stage is to select the most accessible, cost-efficient locations at which to test the refugia concept. Statistical analysis suggests that each location should be sampled at least twice a year in order to detect biologically significant trends such as 10% change in species abundance over a ten-year period, possible more often for less abundant species.

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### Project 3.2: What is at risk? Identifying rainforest refugia and hotspots of plant genetic diversity in the Wet Tropics and Cape York Peninsula

**Project Leader:** Professor Darren Crayn, Australian Tropical Herbarium

**Focus area:** Rainforests

#### *Project Background*

This project will investigate the distribution of plant and fungal taxonomic richness, endemism, and genetic diversity (as a measure of evolutionary history) across the Wet Tropics bioregion at the level of genus, species, and population. This information will provide a solid foundation for conservation prioritisation efforts in the region. Australia's tropical rainforest in far north Queensland is internationally renowned for preserving one of the most complete and continuous records of Earth's evolutionary history, and harbours much of the remaining Gondwanan flora that was once widespread across the continent. Little is known however, about what, how much, and where evolutionary change occurs, particularly for plants and fungi. Where are the hotspots of this evolutionary history and what is the relationship between these endemic species and taxonomic hotspots, that is, areas where there are large numbers of species? A species is considered endemic if it is found only in a given region or place, and nowhere else in the world. The project consists of two nested subprojects. Project A is mapping patterns of genetic diversity across the NE Qld rainforests. Project B (mountain-top diversity) is taking a finer scale look at population-level genetic diversity on mountain-tops which are highly restricted rainforest ecosystems projected to be most threatened by climate change.



### ***Project Progress***

Five hundred and eighty five genera of flowering plants have been identified in the Wet Tropics and Cape York Peninsula region. Representative species and genera have been selected, and sequencing of DNA barcode markers completed. A barcode marker is a short genetic marker in an organism's DNA that identifies it as belonging to a particular species. A manuscript has been completed for publication outlining the use of molecular genetics and phylogenetic diversity measures to distinguish ancient refugia from convergence zones in northeast Queensland's World Heritage rainforests. The paper highlights that areas with more species than expected have been predominantly affected by immigration from Southeast Asia within the past few million years. This demonstrates that the integration of historical data and information on phylogenetic diversity can effectively inform conservation priority setting, particularly in areas with complex evolutionary histories such as the Queensland Wet Tropics World Heritage Area.

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### **Project 3.3: Targeted surveys for missing and critically endangered rainforest frogs in ecotonal areas, and assessment of whether populations are recovering from disease**

**Project Leaders:** Dr. Rob Puschendorf and Dr. Conrad Hoskin, James Cook University

**Focus area:** Rainforests

#### ***Project Background***

This project investigates the degree to which some frog species have declined in the rainforest but persist in the lowlands, and recent surveys suggesting that some species are starting to reappear at upland rainforest sites and whether it represents population recovery. Ten frog species disappeared from the upland rainforests of the Wet Tropics and Eungella regions during outbreaks of amphibian chytrid fungus in the late 1980s and early 1990s, representing 25% of the frogs endemic to the Wet Tropics and all of the Eungella endemics. Four of these species are found only in the uplands and have been presumed extinct as they have not been found despite intensive searches. The Armoured Mistfrog has been rediscovered during surveys in high elevation dry sclerophyll forest, very close to rainforest sites it from which it vanished. The population coexists with the chytrid fungus, suggesting the development of resistance, and that the other missing frogs may still be out there as searches have focused on the rainforest, not the adjacent dry forest. This project targets the ecotonal (i.e. transition) zones between rainforests and dry forests, zones which may be the key to understanding how frogs survive during disease outbreaks but which are rarely surveyed for these or other vertebrate species. As such, these areas represent a gap in Wet Tropics and Eungella biodiversity knowledge.

#### ***Project Progress***

Rigorous, targeted surveys are underway for the missing, critically endangered and endangered rainforest frog species of the Wet Tropics and Eungella. Whilst field surveys are conducted, disease status is also noted as is the presence of other vertebrates. The surveys have found new and important populations of Torrent Frogs and an apparent recolonisation and increase in populations of rainforest frogs into upland rainforest areas. The torrent tree frog has expanded its range at Cloudy Creek (Paluma), recolonising upstream from where it disappeared more than two decades ago. The same species is also in good numbers at sites on Clohesy River (Lamb Range) where it was absent or rare five years ago, and small number of the Australian Lace Lid Frog are also starting to appear. This strongly suggests a recovery of frog populations on these streams over recent years. Surveys of the Eungella region have found the endangered Eungella Torrent Frog has been persisting in good numbers at Rawsons Creek. A new breeding site for the endangered Eungella Tinker Frog was identified and several breeding sites for the poorly known Eungella population of the Whirring Tree Frog were also recorded. Sites north of Eungella, specifically Mt Aberdeen, Mt Hector and Mt Pluto, have produced new populations of rainforest skinks and a new population of leaf-tail gecko, with genetic analysis currently underway to determine whether this is a new species.



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## Project 3.4: Monitoring of Key Vertebrate Species

**Project Leader:** Dr. David Westcott, CSIRO

**Focus area:** Rainforests

### *Project Background*

This project employs recently developed methods to monitor the abundance and distribution of the Southern Cassowary and the Spectacled Flying Fox in north Queensland. Estimates will be provided of population sizes and structure, distributions and dynamics for management decisions. Monitoring is a fundamental component of the management of threatened species, and is of particular importance when those species come into direct conflict with humans and their interests. In such circumstances up-to-date information on population status, trends and distribution become key inputs into decision making and conflict resolution processes, with good data critical imperative to the process. In the Wet Tropics the endangered Southern Cassowary (*Casuarius casuarius*) and the vulnerable Spectacled Flying Fox (*Pteropus conspicillatus*) are the focus of repeated demands for management, and are frequently the focus of bitter debates, often with financial and legal implications.

### *Project Progress*

As our population grows and spreads, people's contact with nature increases. In the Wet Tropics Region two species that have frequently been the focus of demands for intervention in some form are the endangered Southern Cassowary (*Casuarius casuarius*), and the threatened Spectacled Flying Fox (*Pteropus conspicillatus*). Despite being the cause of much conflict over the years, for neither species is there adequate data on their population sizes and trends, or of the dynamics in the spatial distribution. In the cassowary section of the project, the June to December reporting period was focused primarily on completing the laboratory processing of dung samples collected in 2012 and analysing the resulting data. This analysis indicates that individuals can be successfully discriminated from dung samples and that recapture from different dungs is possible, something that opens up additional analysis approaches. The second year's field surveys began but due to low dung availability in the field, these were postponed until after the beginning of the wet season. Monthly flying-fox surveys were completed throughout the period, with peak numbers developing in November and December.



## Theme 2 Understanding Ecosystem Function and Cumulative Pressures

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### Program 4: Water quality of the Great Barrier Reef and Torres Strait

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**Project 4.1:** Tracking coastal turbidity over time and demonstrating the effects of river discharge events on regional turbidity in the Great Barrier Reef

**Project Leader:** Dr. Katharina Fabricius, AIMS

**Focus area:** GBR Water Quality

#### *Project Background*

Turbidity is a measure of water clarity that quantifies small suspended particles, and as such is an important measure of light availability for corals, seagrasses and macroalgae. Turbidity increases may significantly affect marine ecosystems as these particles also carry nutrients, pollutants and diseases. On the GBR such impacts have been related to a five-fold increase in macro-algal cover and a 30% reduction in coral biodiversity on some coastal coral reefs. Changes in turbidity are frequently used in environmental reporting to describe conditions in estuarine and coastal waters.

This project investigates the relationship between changes in land based runoff and clarity of coastal waters for each GBR region in the decade since 2002. Inshore turbidity in four GBR regions is strongly related to river runoff and rainfall, and the distance of a coral reef from a river mouth is a strong predictor of river discharge turbidity at the reef when sediment re-suspension is included in the calculation.

The study will also quantify turbidity differences between wet and dry years. This information can then be used to effectively predict improvements in inshore turbidity associated with improvements in land based runoff.

#### *Project Progress*

Given the huge data set available it was decided that the best strategy for Year 1 would be to process the information for the Burdekin region in the Central GBR as a case study and proof of concept. Successful analyses will be extended to other regions during the life of the Project.

Burdekin-related data have been obtained from the Bureau of Meteorology and the Queensland Department of Environment and Resource Management, and prepared for analysis. The data cover the period from January 2001 to October 2012, and include sea level, water and air temperature, barometric pressure and wind direction, gusts and speed as well as river flow and wave height data from Wave Rider Buoys off Townsville, Cairns, Mackay and Rockhampton.

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**Project 4.2:** The chronic effects of pesticides and their persistence in tropical waters

**Project Leader:** Dr. Andrew Negri, AIMS

**Focus area:** GBR Water Quality

#### *Project Background*

Pesticides, particularly herbicides from agricultural sources, have been detected all year round in coastal waters of the GBR except in the remote Cape York region. This project aims to identify the herbicide concentrations that cause chronic stress in marine biota and to use that information to refine pollution targets for the GBR. These data will be combined with information on herbicide persistence, water quality and climate to contribute to cumulative risk models, and thus to the development of policy designed to protect the GBR from the cumulative effects of pollution and climate change.

#### *Project Progress*

Work is underway to quantify the chronic effects and toxic thresholds of herbicides detected in the



GBR on seagrass and corals under a range of climate change scenarios, to determine the persistence of herbicides in tropical waters and to test the toxicity of their breakdown products.

The sensitivity of the seagrasses *Zostera muelleri* and *Halodule uninervis* was tested for four herbicides commonly found in GBR waters. The order of toxicity was Diuron > Hexazinone > Atrazine > Tebuthiuron for both species which is generally consistent with the known impacts of these herbicides on corals and microalgae.

With respect to herbicide persistence, after 100 days the PSII (Photosystem II) herbicides Atrazine, Hexazinone and Tebuthiuron degraded by 15-40% whereas the non-PSII herbicides Metolachlor and 2,4-D degraded by 50-60% and 15-70% respectively. Temperature and the presence of moderate levels of light have little effect on degradation rate and it appears that PSII herbicides may be broken down in part by natural microbial communities in seawater.

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### **Project 4.3:** Ecological risk assessment of pesticides, nutrients and sediments on water quality and ecosystem health – Phase 1

**Project Leaders:** Professor Jon Brodie, JCU and Rai Kookana, CSIRO

**Focus area:** GBR Water Quality

#### ***Project Background***

Completed in June 2012, this project developed ecological risk assessment (ERA) tools to guide contaminant impact monitoring, management and alleviation in relation to GBR water quality and ecosystem health. The first phase of the work developed a systematic, objective and transparent ERA methodology that, in the second phase, will allow an ERA to be carried out on nutrients, fine suspended sediments, and pesticides used in agriculture in the GBR region. This methodology included ranking the relative risk of individual contaminants originating from priority catchments to the GBR ecosystems.

#### ***Final Outcomes***

Following a review of existing methods used in ERA on the GBR, CSIRO developed a five-tiered ERA methodology intended to provide a systematic, objective and transparent approach to measure relative contamination risks faced by the GBR ecosystems due to pesticides, nutrients and sediments.

The tiered ERA method allows rivers draining into the GBR lagoon to be ranked based on the level to which they exceed GBRMPA water quality guidelines, at those marine sites where measurements could be attributed to a particular river (Tiers 1-4), and across the GBR lagoon as a whole (Tier 5).

Tiers 1-4 were designed to deal with progressively higher quality data in terms of exposure to, and effects of, pollutants, and are able to handle any time and location stamped information. Tier 5 requires time series data from many sites, and a technique designed to look back through the data to attribute and characterise risk with respect to individual rivers.

CSIRO's ERA method also includes two sets of loss functions designed to measure the consequences of exposure to pollutants.

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### **Project 4.4:** Hazard assessment for water quality threats to Torres Strait marine waters, ecosystems and public health

**Project Leaders:** Jon Brodie and Jane Waterhouse, TropWater, James Cook University

**Focus area:** Torres Strait

#### ***Project Background***

An understanding of the status of water quality in Torres Strait and its influence on marine foods, human health, marine ecosystems and ecological processes in the region is important. Potential water quality issues include regional pollution – discharge of metal (and other) pollutants from the Fly



River associated with mining, the port at Daru, other mines in PNG and land clearing – local pollution – sewage and stormwater discharge – and pollution associated with shipping (dredging, oil spills, ship groundings, shipyards). No detailed water quality issues hazard analysis has been done for the region. The project aims to:

- Assess and describe all existing and potential sources of pollution to the Torres Strait marine environment
- Assess the hazard (and risk) of these pollutant sources to marine ecosystems and public health
- Facilitate uptake of project outputs and outcomes to key end-users and stakeholders
- Design a basic monitoring program which would allow reporting on the status of water quality in the Torres Strait and assessments to be made as to the success of pollution management.

### ***Project Progress***

The project reviewed all available past research on water quality in the Torres Strait region and completed site inspections of eight islands. The project also developed a 2D SLIM hydrodynamic model that can model transport of water-borne material to determine the delivery and fate of pollutants since many potential issues are large-scale and derive from outside the region. The model revealed the large-scale flow dynamics in Torres Strait, highlighting that some areas are flushed relatively quickly while water tends to stagnate in others. The model also revealed the prevalence of highly energetic small scale flow dynamics near shoals, reefs, islands and passages. Information on the current status of pollutant sources (including future potential sources) in the region has been collated, and incorporated into a spatial database. The main pollutant sources documented are:

- Island waste management including sewage and waste disposal
- Shipping, commercial vessels and marine infrastructure
- Large-scale developments in adjacent areas (such as PNG).

While the study identified a number of minor local pollutant sources that may pose a risk to the ecological values of the region, the largest threats are most likely to be associated with the potential risks from the transit of large ships.



## Program 5: Cumulative impacts on benthic biodiversity

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### Project 5.1: Understanding diversity of the Great Barrier Reef: Spatial and temporal dynamics and environmental drivers

**Project Leader:** Dr. Glenn De'ath, AIMS

**Focus area:** GBR Biodiversity

#### *Project Background*

We have little information on the diversity of the GBR, or the mechanisms responsible. This project will map the diversity of biota and environments of the GBR, and will relate biotic diversity to spatial, environmental and temporal drivers. The project will be based on existing long-term and large-scale data from the GBR including the long term monitoring program on coral cover, data on density of crown-of-thorns starfish and seafloor diversity, large-scale diversity surveys of octocorals and corals, water quality and coral bleaching history, satellite derived sea surface temperature and ocean colour history data, and tropical cyclone path and intensity information from the Bureau of Meteorology.

#### *Project Progress*

A new statistical method has been developed for analysing diversity. The application of this multinomial diversity model (MDM) to studies of diversity should enable researchers and managers to make better informed and consistent judgments about the influence of spatial and temporal drivers on GBR diversity patterns.

Spatial and temporal changes in GBR coral cover were also assessed using three decades of monitoring data collected by AIMS. The analysis showed that coral cover on reefs adjacent to the urban coast of Queensland has declined by half since 1985, while no change was observed on reefs adjacent to the undeveloped coast of Cape York. Causes include cyclones (48% of the effect), crown-of-thorns starfish (42%), and coral bleaching (10%). Coral diseases and other factors (e.g. replenishment impaired by poor water quality) may have also contributed to the observed decline.

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### Project 5.2: Experimental and field investigations of combined water quality and climate effects on corals and other reef organisms

**Project Leader:** Dr. Sven Uthicke, AIMS

**Focus area:** GBR Water Quality

#### *Project Background*

Organisms and ecosystems on nearshore reefs of the GBR are particularly vulnerable to increased water temperatures and ocean acidification arising from climate change because of negative interactions with coastal water quality changes (eg. reduced light availability, increased nutrients).

#### *Project Progress*

Laboratory experiments have shown that elevated pCO<sub>2</sub> (i.e. a more acid pH) can reduce settlement of coral larvae on crustose algae, an important natural substrate for coral recruitment. Similarly, even a slight increase in pCO<sub>2</sub> can hamper sea urchin reproduction, and influence adult physiology. Experimental work has also revealed that fresher water normally associated with flood plumes actually has a stronger negative effect on coral growth than increased pCO<sub>2</sub>.

The situation in the field is inevitably more complex; although increased pCO<sub>2</sub> (i.e. decreased pH) was evident on all 14 near-shore reefs sampled during the recent wet season, associated high temperatures meant that there was no measurable change in the amount of aragonite (CaCO<sub>3</sub>) available for calcifying organisms such as corals (called the aragonite saturation state). This indicates that some reefs may be able to buffer the effects of increasing CO<sub>2</sub>. In addition, aragonite saturation state on all inshore reefs was somewhat below that found on mid and outer shelf GBR reefs.



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**Project 5.3:** Vulnerability of seagrass habitats in the Great Barrier Reef to flood plume impacts: light, nutrients, salinity

**Project Leader:** Dr. Catherine Collier, JCU

**Focus area:** GBR Water Quality

***Project Background***

Seagrass meadows are a vital habitat as they support the biodiversity of estuarine, coastal and reef communities, including fisheries species, and they are a direct food source for obligate seagrass feeders such as dugongs. Seagrass meadows in the coastal zone also form a buffer between the catchment and the reef, trapping sediments and absorbing nutrients, with their high productivity rates facilitating rapid nutrient cycling.

Unfortunately, seagrass meadows along the GBR have declined in the majority of areas surveyed, and many sites lack the seed bank that would enable rapid recovery. Most of these sites have either high turbidity (reducing light) and/or extra nutrients (destabilizing the natural balance for these marine plants). Flooding and cyclones have caused further declines in an already fragile system, particularly through flood plume effects. This project investigates the impacts of exposure of seagrass meadows to light, nutrients and salinity for the purpose of predicting thresholds to be used in future risk assessments.

***Project Progress***

The project aims to deliver an understanding of the extent to which seagrass meadows are impacted by extreme events and changes in water quality in the GBR.

Experiments have been run to determine light thresholds for seagrass growth, and a review of light reduction indicators completed. Tests have also been completed on seagrass responses and threshold tolerances during low salinity events for three dominant seagrass species.

The current plume exposure model has been improved to increase information retrieval from satellite images even if under moderate cloud cover and sun glint conditions, in very turbid areas or those with high total suspended solids (TSS). Mapping of images has also been automated, reducing processing time and human error associated with visual interpretation of plumes. Outputs include evidence of declining seagrass area under high TSS loads.



## Program 6: Movements and habitat use by marine apex predators

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### Project 6.1: Maximising the benefits of mobile predators to GBR ecosystems: the importance of movement, habitat and environment

**Project Leader:** Dr. Michelle Heupel, AIMS

**Focus area:** GBR Biodiversity

#### *Project Background*

This project aims to define the extent of movement of mobile predator species in coastal and reef ecosystems. It aims to determine: the factors that lead to changes in residency and movement; the role that active mobility plays in connecting populations; and the appropriate management tools.

#### *Project Progress*

To date a series of 48 acoustic receivers have been deployed, downloaded and maintained. Acoustic transmitters have been deployed in 30 stingrays at Orpheus Island; and 124 coral trout, 16 red emperor and 62 sharks in the Capricorn Bunkers to contribute to and enhance the results obtained adjacent to Townsville. Within the Townsville reefs 127 individuals have been fitted with transmitters including: 8 bluespot coral trout, 60 common coral trout, 19 red throat emperor, 3 giant trevally, 11 bull sharks, 17 grey reef sharks, 4 sliteye sharks, 4 silvertip sharks and 1 whitetip reef shark. Data will be downloaded in late 2012-early 2013 to facilitate movement analysis. In anticipation of these data, analytical tools have been in development, including calculating activity space based on distance moved around a reef platform correlated with depth utilisation and three-dimensional home ranges. This will determine movement in and out of areas subject to different zoning.

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### Project 6.2: Drivers of juvenile shark biodiversity and abundance in inshore ecosystems of the Great Barrier Reef

**Project Leader:** Dr. Colin Simpfendorfer, James Cook University

**Focus area:** GBR Biodiversity

#### *Project Background*

This project examines the importance of different types of inshore habitat and marine park zoning for shark biodiversity, and how environmental factors affect how these nursery areas function.

#### *Project Progress*

The 2011/12 summer survey in nine bays along the central GBR coast caught 529 elasmobranchs. Results indicate that there is considerable variation in the elasmobranch fauna between bays, in part resulting from differences in environmental parameters. The next phase of the project – intensive season surveys of five of the bays – have been running since April, and so far has almost completed three full survey rounds. Other project activities, including the acoustic monitoring components in Cleveland Bay and at Orpheus Island are proceeding with a suite of tags released in target species, including blacktip reef sharks, Australian sharpnose shark, creek whalers and Australian blacktip sharks.

The variable assemblage of elasmobranchs caught in nearshore waters is dominated by requiem sharks (whaler, hammerhead and weasel families), but abundance of each species varies between the bays surveyed. Theoretical work undertaken has shown that this diversity in abundance between bays can be a successful strategy employed by species to ensure stable numbers of animals are produced across the region through time. The management implication of such a strategy is that the condition of the range of nursery areas needs to be maintained to enable such a strategy to be successful. Further research being undertaken with the intensive seasonal surveys will provide more data to test these preliminary observations.



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### **Project 6.3: Critical seabird foraging locations and trophic relationships for the Great Barrier Reef**

**Project Leader:** Dr. Brad Congdon, James Cook University

**Focus area:** GBR Biodiversity

#### ***Project Background***

This project aims to identify and map foraging grounds for boobies and shearwaters; overlay satellite derived information on biophysical oceanographic characteristics; quantify prey availability; and establish linkages between areas, processes and anthropogenic activity.

#### ***Project Progress***

Results to date include:

- Analyses of 2012 shearwater tracking data confirmed that many important seabird foraging sites are outside of the GBRMP and that foraging activity overlaps significantly with known commercial fishing activity
- Tracks encompassing the 7-8 month winter migration period (May to October) have been obtained for wedge-tailed shearwaters. These tracks identify the oceanic region and resource base used by this population during the non-breeding season
- Foraging tracks for marked boobies in the Swain Reefs show consistency of foraging location among individual boobies. Overlap occurs between booby foraging sites and those used by wedge-tailed shearwaters breeding at Heron Island during the chick-rearing season (Feb-Apr 2012)
- Birds returning from migration have accepted artificial nest boxes deployed on Heron Island. The uptake of these nest boxes represents a major advance for our future data acquisition, as they provide birds with a safe, secure and reliable site in which to breed over the entire nesting season
- In addition to previously planned activities researchers in this program have been involved in an extensive population survey of seabirds nesting in the Capricorn-Bunker group of Islands in January 2013.



## Program 7: Threats to rainforest health

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### Project 7.1: Fire and rainforests

**Project Leader:** Dr. Dan Metcalfe, CSIRO

**Focus area:** Rainforests

#### *Project Background*

This project aims to increase the understanding of the rainforest and fire dynamic, its impact on key species, and to inform fire management in the Wet Tropics. Mahogany Gliders are endangered vertebrates that are reliant on lowland eucalypt forest in the Wet Tropics. Changed fire regimes and indifferent intensities have allowed rainforest species to colonise these lowland eucalypt systems and in some places dominate it, suppressing eucalypt regeneration and interfering with glide paths. Fire however, has the potential to reduce rainforest invasion whilst encouraging regeneration of eucalypt communities.

#### *Project Progress*

The project has been concentrating particularly on the development of mapping protocols for the EPBC-listed critically endangered littoral rainforest community, and understanding the key threats posed to the community through inappropriate management, fire, transformer weeds and natural processes. Severe Tropical Cyclone Yasi caused massive structural change to the community through much of its range in the Wet Tropics, and understanding how threats combine (e.g. weedy grasses providing fuel loads when introducing fire into the system) will help to target future management priorities. The project also continues to monitor the effects of fire on cyclone-ravaged Mahogany Glider habitat in the coastal lowlands of the Wet Tropics between Cardwell and Tully. This work includes the monitoring of seedling plots in disturbed rainforest and burned leaf litter to record the response of each rainforest species to being 100% scorched. Vegetation changes will be monitored over the next two years to allow a better understanding of rainforest-sclerophyll (i.e. drier forest) dynamics so that an informed management approach to controlling fire in mahogany glider habitat can be established.

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### Project 7.2: Invasive species risks and responses in the Wet Tropics

**Project Leader:** Dr. Helen T Murphy, CSIRO

**Focus area:** Rainforests

#### *Project Background*

This project focuses on understanding the current and future risks and responses of invasive species in the Wet Tropics. Invasive species management in the Wet Tropics is currently driven by a species focussed approach, as are weed and pest animal management activities globally. The aim of the project is to develop a strategic approach to pest management for land managers in the region who are increasingly recognising the need for regional-scale population prioritisation tools that incorporate complex ecological processes of invasive species spread and establishment, and take account of the values and assets in the landscape. Additionally, climate change and intense cyclones will enhance the capacity of non-native species to establish, spread and transform the Wet Tropics ecosystems. Such emerging risks will be considered under future climate scenarios and factored into long term strategic management strategies across northern Australia.

#### *Project Progress*

Climate matching analyses have been used to identify high-risk source areas for future Wet Tropics weeds. A database was generated of known invasive species whose native (and/or invasive) range intersects areas globally with high climate similarity to the Wet Tropics. To address future threats from



existing weeds or from sleeper weeds, the project has compiled climate models to understand which species will experience improving conditions and which will experience deteriorating conditions under future climate scenarios. A novel methodology has been developed to understand networks of weed spread within the Wet Tropics to inform management tactics and strategies for early intervention. The project is working with stakeholders to develop Pest Adaptation Response Plans to underpin strategic management of weeds at a regional scale. The modelling component of the work has already produced results useful for management and submitted for publication. The most recent results quantify the improvement in likelihood of eradication gained by considering landscape context and structure in management tactics and strategies for invasive species.

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### **Project 7.3: Climate change and the impacts of extreme climatic events on Australia's Wet Tropics biodiversity**

**Project Leader:** Dr. Justin A. Welbergen, James Cook University

**Focus area:** Rainforests

#### ***Project Background***

This project investigates in detail the exposure and sensitivity of Wet Tropics animals to extreme climate and weather events, such as heat waves, fires, flooding rain and cyclones. The resulting information will be used to assess and map the vulnerability of biodiversity to the impacts of current and future extreme events in the Wet Tropics bioregion. The information gathered in the Wet Tropics can potentially be applied to other regions in Australia and elsewhere to predict and mitigate the impacts of extreme climatic events on biodiversity

#### ***Project progress***

In the second half of 2012, the project quantified the 'resilience' of all the Wet Tropics vertebrate species from known traits that affect a species' ability to survive and recover from an environmental disturbance. The quantitative measure of resilience used in the project relies on the novel idea that extinction filtering will tend to have removed less resilient species from areas where habitat was less stable over the past 18,000 years. It was found that the mean habitat stability within a species' range was closely correlated with traits that are conventionally thought to affect a species' ability to bounce back from a disturbance, indicating that a species' mean habitat stability can be used as a valid quantitative index of resilience. Secondly, the project aimed to quantify the 'adaptive capacity' of species, that is, the reduction in thermal exposure that results when, for example during a hot day, individuals move into the microhabitat that is most thermally favourable and available to them. This was calculated for the 95th percentile of maximum daily temperatures encountered by Wet Tropics vertebrate species in their respective microhabitats, and the methodology that was developed allows for quick quantification of a species' capacity to adapt to any regime of extreme temperature events.



## Theme 3 Managing for resilient tropical systems

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### Program 8: Effectiveness of spatial management on the Great Barrier Reef

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**Project 8.2:** Do no-take marine reserves contribute to biodiversity and fishery sustainability?  
Assessing the effects of management zoning on inshore reefs of the GBR Marine Park

**Project Leaders:** Professor Garry Russ and Dr. David Williamson, James Cook University

**Focus area:** GBR Biodiversity

#### *Project Background*

This project aims to assess the effects of multiple use management zoning of the GBR on reef fish, fishery target species, coral health and benthic communities. It also assesses usage patterns of recreational fishers and compliance with zoning regulations. The project has carried out Underwater Visual Census surveys on fringing reef slopes at Magnetic Island and in the Whitsundays. The surveys were conducted in zones that are open to fishing and those that are closed to fishing.

#### *Project Progress*

The Magnetic Island surveys found average live hard coral cover to be 20.7%. Coral cover was significantly higher in zones open to fishing, which was attributed to the orientation of the sites relative to the storm front of Cyclone Yasi. The project found no significant difference between sites open or closed to fishing with regard to densities and biomass of coral trout, although densities were generally low relative to previous surveys.

The Whitsundays survey found average live hard coral cover to be 38.8% with no significant difference between zones. However, the prevalence of coral disease was significantly greater in sites that are open to fishing. Sites that were closed to fishing had significantly higher densities and biomass of coral trout. There were more larger coral trout in zones that were closed to fishing in the 1980s than those closed to fishing in 2004. The project also collected abandoned fishing line from all sites and found no significant difference between sites open or closed to fishing. However, removing the lines creates a baseline from which to measure re-accumulation at these sites.

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**Project 8.3:** Significance of no-take marine protected areas to regional recruitment and population persistence on the GBR

**Project Leaders:** Professor Geoff Jones and Dr. David Williamson, James Cook University

**Focus area:** GBR Biodiversity

#### *Project Background*

The aim of this project is to apply genetic parentage analysis and biophysical modelling to assess the role of marine reserve networks for coral trout (*Plectropomus* spp.) conservation and fisheries on a regional scale.

#### *Project Progress*

In this reporting period the project has completed the development of new genetic methods to accurately assign juveniles that are progeny of parents in marine reserves ("green" zones). This entailed developing and testing a new set of 24 hyper-variable microsatellite genetic markers for assessing parent-offspring relationships in both *P. leopardus* and *P. maculatus*. Validation results have demonstrated that the marker set is able to successfully discriminate the two *Plectropomus* species and identify parent-offspring relationships in natural populations. The project also completed the planned large-scale sampling program in which the DNA of adult and juvenile coral trout was sampled at three locations (Percy, Keppel islands and Capricorn-Bunker island groups). This will enable assessment of larval export from marine reserves over a distance of up to 200 kilometres. Observed dispersal patterns will be compared with predictions from a biophysical model that takes into account water currents and the behaviour of coral trout larvae.



## Program 9: Decision support systems for Great Barrier Reef managers

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### Project 9.1: Dynamic Vulnerability Maps and Decision Support Tools for the Great Barrier Reef

**Project Leader:** Dr. Ken Anthony, AIMS

**Focus area:** GBR Biodiversity

#### *Project Background*

This project aims to develop a framework for a dynamic spatial vulnerability model for the GBR.

#### *Project Progress*

The results of this project are a significant step towards fulfilling a long-standing request from reef managers to understand the vulnerability of the GBR spatially and temporally. During the past six months the team has advanced the modeling of coral reef resilience and vulnerability substantially by functionally integrating spatial and temporal environmental data from multiple sources into a spatially explicit model for coral risk i.e. generating dynamic vulnerability maps. As part of this framework the project has developed a novel resilience metric that enables managers assess to what extent different actions on manageable stressors (management levers) can offset vulnerability. Our method builds on resilience modeling (developed by Mumby and Anthony) in which key ecosystem processes including recruitment, growth, competition and mortality are directly informed by a suite of environmental variables and disturbance types.

Calibrated results for the major reef framework builders have been achieved, including structural corals of the genus *Acropora*, and the project has defined vulnerability as the risk that coral cover is lost over a management time frame (e.g. 10 years). Preliminary coral vulnerability layers for the recent past have been modelled, integrating risks from coral bleaching, COTS, cyclones and nutrients/turbidity. The model skills demonstrated by these outputs provide confidence that the tool, following further calibration and testing, will be effective in supporting management planning and decisions under complex environmental scenarios including climate change.

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### Project 9.2: Design and implementation of Management Strategy Evaluation for the Great Barrier Reef inshore

**Project Leader:** Dr. Cathy Dichmont, CSIRO

**Focus area:** GBR Biodiversity

#### *Project Background*

This project aims to use a stakeholder driven approach to qualitatively integrate an understanding of key drivers of change in the inshore GBR ecosystem and its human uses, with an emphasis on biodiversity and inshore multi-species fisheries management.

#### *Project Progress*

The project has worked in collaboration with GBRMPA and other end users to determine case study areas for the development of qualitative models that will allow stakeholder input to develop a joint understanding of the inshore system, including human interaction with it. The primary geographical focus has been the Mackay region, which has formed the project's initial case study. Further consideration will focus on the Bowen/Burdekin region.

The case study region was based on input from a sub committee of the Mackay Local Marine Advisory Committee and completed draft qualitative models of seagrass, coastal development and creeks with governance.



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### Project 9.3: Prioritising management actions for Great Barrier Reef islands

**Project Leaders:** Professor Bob Pressey and Dr. Mirjam Maugham, James Cook University

**Focus area:** GBR Biodiversity

#### *Project Background*

The aim of this project is to develop an explicit decision-making framework for cost effective management actions across the islands of the Great Barrier Reef. A sub-region for the decision support model was selected. Islands in the selected sub-region are diverse and include inshore islands in the Keppel region to the Capricorn-Bunker group and offshore in the Swains group.

#### *Project Progress*

The technical framework and data sources for the project were explored at a three-day workshop on Magnetic Island in October 2012. Further progress identifying features and data sources was made during a reconnaissance trip November 2012, including project team leaders, island managers and scientists, visiting 19 islands in the study area. During this trip it was also agreed to apply the technical framework initially on a subset of islands to test the framework and perform a sensitivity analysis. The outcome of those tests will inform which data gaps are most important to fill using workshops and interviews eliciting expert judgment. A journal article on 'Island biosecurity for the GBR' (an identified key issue for managers) was also drafted on the reconnaissance trip.

The project team is now compiling data on our selected islands in the southern GBR, a method to elicit expert information to fill data gaps is being developed, the decision model is being designed, and journal papers are being drafted.

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### Project 9.4: Conservation planning for a changing coastal zone

**Project Leader:** Professor Bob Pressey, James Cook University

**Focus area:** GBR Biodiversity

#### *Project Background*

This project aims to compile spatial data on biodiversity patterns in Great Barrier Reef coastal ecosystems and key biodiversity and connectivity processes and socio-economic characteristics, for direct input to conservation planning analyses and as a basis for modelling dynamics. It will apply scenario-based modelling to develop spatially explicit representations of alternative futures for the coastal zone, using models of climate change, trends in land use, potential changes based on social and economic drivers. The project will advance world's best-practice in systematic conservation planning, both scientifically and in terms of collaboration with managers and other stakeholders, allowing more informed decisions about the conservation of Queensland's tropical coastal zone and the GBRWHA.

#### *Project Progress*

Major events in this reporting period were: 1. A technical working group with many stakeholders focussed on the drivers of change in land use along the GBR coast, and exposed to different approaches to spatially explicit modelling; 2. A second working group, funded by the Australian Centre for Ecological Analysis and Synthesis (ACEAS), attended by stakeholders and scientists representing the Tropical Ecosystems and North Australia Hubs; and 3. A meeting of the Project Reference Group to consider the feedback from these two meetings combining technical experts and consumers for this information.

From these inclusive processes, the main drivers of change in the GBR coastal zone have been defined as: foreign demand for food and mineral resources, governance, community values, advances in science, and tourism. Given these scenarios, the Project Team will model outcomes for biodiversity at landscape and regional levels to inform the planning process about the likely costs and benefits of different land use decisions.



## Program 10: Socio-economic value of Great Barrier Reef goods and services

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### Project 10.1: Social and economic long-term monitoring programme

**Project Leader:** Dr. Nadine Marshall, CSO

**Focus area:** GBR Biodiversity

#### *Project Background*

This project aims to develop world-class social and economic monitoring program that will directly inform the management of the Great Barrier Reef.

#### *Project Progress*

The project has established a number of Working Groups involving a range of participants from various sectors of the community and identified end users. These groups have identified the type of primary data that the project should seek to collect through surveys and existing secondary data sets that the project can access. Through this process, the project has identified the need to report on: i) the relationship between people and the Great Barrier Reef, ii) human and community wellbeing, (iii) indirect drivers of change, and (iv) direct drivers of change. The project has developed a 12-point framework for monitoring the relationship between people and the Great Barrier Reef and is currently in the process of identifying the important indicators of human and community wellbeing.

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### Project 10.2: Socio- economic systems and reef resilience

**Project Leader:** Professor Natalie Stoeckl, James Cook University

**Focus area:** GBR Biodiversity

#### *Project Background*

This project aims to gain an improved understanding of the manner in which GBR ecosystem services are valued, including an intrinsic value for characteristics of the GBR, such as natural beauty. It also seeks to understand how external socioeconomic pressures can inadvertently diminish those values. To gain this understanding, surveys targeting residents and tourists were carried out.

#### *Project Progress*

To date, the project has entered data from 1,040 visitors, from which some preliminary observations can be made. Most visitors go to the mainland beaches at least once during their stay (85%), with the average number of beach visits exceeding two. Very few visitors (just 11%) went fishing. The median number of nights spent along the coast near the GBRWHA was six. Median daily expenditure was \$106 (mean = \$135). Most money was spent on accommodation and at cafes/bars/restaurants. When asked about the 'importance' of various factors when deciding whether to come to the region or not, the highest scores were given to clear oceans, healthy coral reefs, and healthy reef fish. When asked to indicate how they would respond to various hypothetical 'changes' to the GBRWHA, respondents reacted most negatively (e.g. with a large number of people saying that they would not have come at all) to the prospect of 'twice as many oil spills, ship groundings and wastes spills from ports', the 'ocean changing from clear to murky'; or having 'twice as much rubbish on the beaches'. When asked to indicate if they would be willing to pay to help 'fix' various threats to the reef, visitors indicated that they would be willing to pay \$10 (median response) each time they visited to improve water quality; they were willing to pay \$5 (median response) to protect top predators or reduce the risk of shipping accidents.



## Program 11: Resilient Torres Strait communities

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### Project 11.1: Building resilient communities for Torres Strait futures

**Project Leader:** Dr. James Butler, CSIRO

**Focus area:** Torres Strait

#### *Project Background*

The Torres Strait is a region of rich natural and cultural values, with strong linkages between its environmental assets, ecosystem services and the livelihoods of communities that rely upon them. The Torres Strait Treaty explicitly aims to protect these communities' livelihoods, and improve them through sustainable economic development. As Australia's northern border with Papua New Guinea (PNG), however, the region is under increasing pressure from PNG population growth, mining development, and exploitation and pollution of shared Torres Strait resources. Global pressures such as peak oil, shipping traffic and climate change will also have complex impacts on environmental assets, particularly when combined with human pressures. This uncertain future will present challenges for achieving resilient Torres Strait communities, but may also provide opportunities for sustainable economic development (e.g. ecotourism, aquaculture). Through participatory scenario planning with Torres Strait and PNG communities and stakeholders, informed by integrated ecosystem and climate modelling, this project aims to explore potential future scenarios for the region, and identify 'no regrets' strategies to protect livelihoods and achieve sustainable economic development.

#### *Project Progress*

This project depends on strong partnerships with end-users and completed a participatory workshop in 2012 that explored potential future scenarios for the region. The Torres Strait Futures scenario planning workshop was attended by 20 participants representing Australian, Queensland and local government stakeholders, NGOs and private enterprises that have interests in the Torres Strait. The results of the workshop, including 'no regrets' adaptation strategies that can support livelihoods and build resilient Torres Strait communities, are detailed in the workshop report. A summary Workshop Statement was also produced by participants. The project has also downscaled climate projections, synthesised projections of human population and socio-economic drivers in Torres Strait and Western Province, PNG, completed a preliminary identification and valuation of ecosystem services underpinning Torres Strait livelihoods.

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### Project 11.2: Determining disease dynamics across the Torres Strait

**Project Leader:** Dr. Susan Laurance, James Cook University

**Focus area:** Torres Strait

#### *Project Background*

The Torres Strait has long been recognised as a biological bridge to mainland Australia, including for emerging infectious diseases, and there is concern regarding its potential to facilitate disease movement to the mainland. These diseases represent serious threats to human health, to agriculture and to biodiversity. This project focuses on improving understanding of how diseases move across the Torres Strait and what methods are best for detecting disease incursions and managing outbreaks within the region. The project aims to:

- Develop improved methods for detecting disease incursions in the Torres Strait
- Analyse the influence of inter-island and PNG Western Province traffic on insect vectors of disease and the subsequent the disease load of birds (as an indicator)
- Identify options to mitigate the establishment and the persistence of serious diseases of wildlife in the region.



### *Project Progress*

Emerging infectious diseases are on the rise with future outbreaks predicted to occur in frontier regions of tropical countries. Disease surveillance in these hotspots is challenging because sampling techniques often rely on vector-attractants and battery-operated traps that are difficult to operate in remote locations. The project has developed a novel method for sampling mosquitoes in remote regions with low cost passive traps using an attractant that produces CO<sub>2</sub>-from yeast and sugar. Ten passive mosquito traps have been built and trials have tested different baits to determine the best way to capture vectors in remote sampling. Field trials to capture mosquitoes near and far from human communities was completed during the 2013 wet season on Saibai, Boigu, Badu and Moa (Kubin) Islands. Preliminary results show that mosquito captures are higher in the natural habitats far from humans on Saibai and Boigu Islands, but more mosquitoes were captured near humans on Badu Island. Mosquito identification is in progress and will provide a greater understanding of disease risk.



## Program 12: Managing for resilience in rainforests

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### Project 12.1: Indigenous co-management and biodiversity protection

**Project Leader:** Dr. Rosemary Hill, CSIRO

**Focus area:** Rainforests

#### *Project Background*

This project will undertake co-research with Indigenous peoples and protected area managers to further investigate the potential of Indigenous Protected Areas and other collaborative models and tools to engage Indigenous values and world views, and to identify the conditions under which these arrangements could lead to effective protected area joint management. The overall goal of the project is to provide a means for recognition of Indigenous knowledge and values, and joint management of the Wet Tropics World Heritage Area between governments and Rainforest Aboriginal people, in partnership with communities. Although key planning initiatives in the Wet Tropics region more recently have improved engagement with Indigenous peoples in biodiversity management, both government agencies and the Rainforest Aboriginal Peoples identify that a gap remains between the current status, and aspirations for equitable co-management arrangements of conservation areas, including the Wet Tropics World Heritage Area. The current Girringun, Eastern Kuku-Yalanji, and Mandingalbay Yidinji Indigenous Protected Area (IPA) consultation projects are showing potential as an effective means of capturing Indigenous knowledge and values into conservation decision-making and management. IPAs may provide a means to integrate rights-recognition (through ILUA and native title), cultural-values recognition (through heritage listing) and engagement in management (through NRM arrangements) as an effective platform for co-management. Traditional Owners are also engaging with national park management planning in the Wet Tropics region, and opportunities exist to make these collaborations more effective in delivering mutual benefits for biodiversity conservation and integration of Indigenous rights, cultural knowledge and management practices.

#### *Project Progress*

A workshop held in October 2012 considered the status of Indigenous co-management of biodiversity protection in the Wet Tropics. The themes identified were:

- Effective and responsible co-management now and in the future involving local-level TO groups;
- Conflict resolution, particularly with respect to boundary understandings across TO groups;
- The need for an overarching document recognising tribal autonomy to support the framework, including principles such as free, prior and informed consent, and recognition of Indigenous rights, as set out in the United Nations Declaration on the Rights of Indigenous Peoples (UNDRIP);
- That the case for government investment with respect to protection and transmission of Aboriginal cultural values, health, well-being, education and employment;
- Change to mainstream organisations is required with respect to cultural self-awareness, and intercultural awareness and competency;
- Greater clarity and consistency in government policy would assist to progress implementation of co-management.

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### Project 12.2: Harnessing natural regeneration for cost-effective rainforest restoration

**Project Leaders:** Professor Carla Catterall, Griffith University

**Focus area:** Rainforests

#### *Project Background*

This project is focused on naturally-regenerating forests (regrowth) and the potential to offer a much



needed low cost option to restore critical habitat over large areas. The project is based in the Wet Tropics uplands and is measuring and monitoring the rate and pattern of vegetation development in both replanted sites and regrowth sites. The project will combine three inter-related approaches: field investigation and data analyses of how regrowth rainforest develops and how it differs from replanted rainforest; information synthesis and field trials of novel approaches to accelerate regrowth development; and landscape analysis to identify areas of highest potential for low-cost regrowth. The project will provide decision-support options to optimise regional investments in restoration using the most appropriate restoration method for any particular ecological and economic scenario.

### ***Project Progress***

The project has successfully established a network of 20 accessible re-growth sites of different ages (2-40 years) with fourteen sites now marked on the ground and data collection completed at four of the sites. All remaining sites will be established in the first half of 2013. A literature review completed on approaches to stimulating natural regeneration of tropical forest on degraded land has found that interventions combining simultaneous suppression of unwanted vegetation and increased propagule (i.e. a bud or other offshoot that aids in species dispersal) supply worked best in promoting forest restoration. These combined interventions have only been tested in a few studies. Other important deficiencies that hamper progress in this area include: poor reporting of implementation costs; inadequate use of “do nothing” controls in experimental studies, and the small scale of manipulation experiments relative to applied restoration projects. The establishment of local experimental trials of different approaches to manipulation for regrowth acceleration is improving capacity to address some of these deficiencies. The project has also developed a “notional menu” of diverse potential approaches to manipulation for regrowth acceleration relevant to the Wet Tropics uplands.

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## **Project 12.3: Relative social and economic values of residents and tourists in the WTWHA**

**Project Leader:** Professor Natalie Stoeckl, James Cook University

**Focus area:** Rainforests

### ***Project Background***

This project will identify and prioritise social and economic values that tourists and residents place on the Wet Tropics World Heritage Area (WTWHA) and test non-monetary values against traditional economic valuations of the area. Critical information gaps will be addressed with regard to the relative importance of these key attributes (or ‘values’) to stakeholders (e.g. tourists, Indigenous and Non-Indigenous residents, business owners) and the way in which those ‘values’ might be affected by a range of external influences (e.g. different types of economic development, increases in population, changes in the mix of visitors). The project will also allow researchers to make predictions about the way in which residents and tourists assign ‘values’, and thus management, conservation and marketing priorities may alter in the future as both population and tourist numbers change. Finally, methods for assessing ‘value’ will be improved. State-of-the art non-monetary valuation techniques will be compared with more ‘traditional’ valuation techniques, highlighting the strengths and weaknesses of each. The project will provide managers throughout the world with an illustrated, easy to understand, example of a cost-effective, robust, and equitable means of assessing the relative value (or importance) of non-market goods and services (i.e. aesthetics).

### ***Project Progress***

A working group of tourism businesses, associations and local government met in September 2012 to identify the core values and attributes for assessment with tourists and residents. As expected, many values overlapped between residents and visitors. For residents, natural, cultural and economic values of the WTWHA were deemed as imperative for assessment. These included: forest health; rainforest aesthetic values; Indigenous and European (e.g. mining, cattle) culture of the region; accessibility to the WTWHA; quality of access; sense of community (i.e. social cohesion); and the ability to provide employment (a value which could potentially be compared to and/or traded off against other ‘core’



values). For tourists, the most important assessment values identified were the presence of iconic species; landscape (e.g. waterfall, scenic drives); water quality; and walking tracks. Other values for evaluation included: therapeutic values; opportunities for solitude; the quality of guided tours; uniqueness of Australian rainforests; accessibility to WHA sites; cultural festivals; botanical gardens; cultural history; and healthy parks. The most significant development changes &/or management issues identified that affect the 'core' values of the WTWHA were related to access; roads and other infrastructures; iconic species, and water.

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**Project 12.4:** Governance, planning and the effective application of emerging ecosystem service markets to secure climate change adaptation and landscape resilience in Far North Queensland

*Project Leader:* Associate Professor Allan Dale, James Cook University

**Focus area:** Rainforests

***Project Background***

The project will guide policy and program directions associated with the national and regional scale roll-out of the Australian Government's \$1.6 billion Clean Energy Package Land Sector Abatement Program. The project directly underpins a significant National Working Group proposal supporting the effective development of a clear national approach to the treatment of carbon-related issues in next generation NRM planning; and an emerging significant Extension and Outreach Fund proposal being developed by the National NRM Working Group. Global agreement on Greenhouse Gas Abatement (GGA) and climate change adaptation is rapidly evolving, with recognition that regionally-prioritised land management practices have the potential to deliver both significant abatement and bio-sequestration opportunities, and improved landscape resilience, in the face of climate change. Partnerships will be developed with the region's key stakeholders to review, trial and evaluate the most effective governance systems and planning foundations for regional and landscape scale adaptation to climate change. In particular, within the context of these governance systems and planning arrangements, focus will be on the potential application of emerging ecosystem service markets to secure landscape-scale resilience for biodiversity in the face of climate change.

***Project Progress***

A comprehensive "Practical Manual" has been developed for NRM Bodies on regional scale planning and carbon market integration. Arrangements are in place for the completion of State-wide training based on the manual, to be delivered across Queensland regional NRM bodies in early 2013. Three theory-based publications have been completed on NRM governance systems and planning for adaptation and ecosystem service market guidance. These publications have influenced the development of regional principles across north Queensland for the next generation of regional NRM planning and hence the region's Stream II research proposal for the Wet Tropics Cluster. Preliminary project work and the original discussion paper are continuing to influence national NRM Body and Commonwealth Government policy and the recently established Australian Government and the Queensland Regional Group's Collective principles for next generation NRM plans.



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## Project 13.1: e-Atlas

**Project Leader:** Dr. Eric Lawrey

**Focus area:** All

### *Project Background*

This project aims to further develop the e-Atlas, which is a website, mapping system, and a set of data visualisation tools for presenting research data in an accessible form to allow greater use of the information.

### *Project Progress*

The design of the e-Atlas has been enhanced to more comprehensively capture, warehouse and communicate the outputs of the research projects. To achieve this there have been a range of designed changes to the e-Atlas systems. Most of these key system changes are now in place. New datasets emerging from the NERP TE will be recorded using these new standards and systems, and over the next six months legacy content will be migrated to ensure all content in the e-Atlas is handled in a consistent manner.

The new metadata system is now in production and is integrated into the mapping system and front page of the website. It now contains records for over 30 datasets. Existing dataset records in the website are now deprecated and will be migrated into the new metadata system.

The e-Atlas mapping software (AtlasMapper) has been extended to include improved support for ArcGIS data sources, location search, additional base maps and support for creating print maps. It was also used to create a portal for WTMA to highlight their Wet Tropics vegetation dataset.

In August 2012 a workshop in the Torres Strait was run to prioritise datasets that should be prepared from CSIRO historical collection of spatial research data for the region.

During this reporting period the e-Atlas has started integrating content from the NERP-TE projects. Project pages have been setup and several datasets have been fully prepared and available online for download and accessible through the mapping system.



## Pathways to Impact

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- Over the last twelve months modelling of data from the AIMS Long Term Monitoring Program has demonstrated declining coral cover over the past 27 years, particularly in the south of the Great Barrier Reef (GBR). The work, conducted under NERP TE Hub Project 5.1 (Glen De'ath: Understanding diversity of the GBR: spatial and temporal dynamics and environmental drivers), has important ramifications for the management of outbreaks of crown of thorns starfish (COTS), and has led to a further allocation (\$800,000) of DSWEPaC funds to support COTS control, in partnership with GBR tourism operators. A further \$100,000 has been allocated to the Australian Institute of Marine Science to undertake studies into the control of crown-of-thorns starfish by single injection.
- Much of the research that pertains to the GBR has also assisted in the development of the Outlook Report, a guide to priority setting for the Great Barrier Reef Marine Park Authority (GBRMPA).
- Capacity building has also been achieved as project leaders and researchers work in close collaboration with resource managers from the portfolio agencies and authorities, and the department itself. Much of the research in the GBR Biodiversity and Water Quality nodes is used for the publication of the Outlook Report, which guides priority setting for the GBRMPA.
- Rob Puschendorf & Conrad Hoskin (Project 3.3: Targeted surveys for missing and endangered frogs) have supplied information to protected area managers on camping sites which are impacting or have the potential to impact on endangered frog populations.
- David Westcott (Project 3.4: Monitoring of key vertebrate species) has been discussing flying fox management with Christmas Island and all levels of government.
- Allan Dale (Project 12.4: Governance, planning and application of emerging ecosystem service markets to secure climate change adaptation and landscape resilience in FNQ) has had direct involvement with State and Commonwealth governments.
  - The preliminary project work and original discussion paper continues to influence national NRM Body and Commonwealth Government policy, and recently established Australian Government and Queensland Regional Group's Collective principles for next generation NRM plans.
  - Publications to date have helped determine the regional principles developed across north Qld for the next generation of regional NRM planning and hence the region's Stream II research proposal for the Wet Tropics Cluster;
  - The project directly underpins a significant National Working Group proposal supporting the effective development of a clear national approach to the treatment of carbon-related issues in next generation NRM planning; and
  - The project directly underpins an emerging significant Extension and Outreach Fund proposal being developed by the National NRM Working Group.



## Hub Engagement Activities





## Development of the NERP Tropical Ecosystems Hub Indigenous Engagement Strategy and Implementation Plan

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The NERP TE Hub is focused on the sustainable management of environmental assets in northern Queensland including the Great Barrier Reef, the Wet Tropics Rainforests and the Torres Strait.

These natural areas are strongly connected to the region's Aboriginal and Torres Strait Islander peoples. Twenty Traditional Owner groups, 120 clans and at least 6 language groups have been identified within the Wet Tropics region, and there are approximately 70 Traditional Owner clan groups whose sea country includes the Great Barrier Reef Marine Park (Great Barrier Reef Marine Park Authority, 2012). The Torres Strait has 20 Traditional Owner groups (19 Torres Strait Islander Corporations, and one Aboriginal Native Title Corporation) and is in a post native title environment.

The NERP TE Hub is committed to engagement with the Indigenous people of Far North Queensland and the Torres Strait to the benefit of all researchers and research users, Indigenous and non-Indigenous. To that end an Indigenous Engagement Strategy and Implementation Plan (IES&IP) has been developed, the primary aim of which is to scope opportunities and encourage research leaders to consider methods of engagement with Traditional Owners and Indigenous communities into the existing NERP TE Hub research projects, and to assess opportunities for knowledge transfer between Indigenous groups and researchers during the remaining term of the Hub (2013-2014). The overall objective of the Strategy is to facilitate the recognition of the benefits of combining and acknowledging Indigenous ecological knowledge with western science to manage the natural and cultural environment.

Indigenous ecological knowledge is a fundamental pillar for the sustainable environmental management of the natural resources of north Queensland, and the NERP TE Hub recognises the importance of Indigenous engagement to the understanding and management of north Queensland's natural assets.

The IES&IP will be available on the TE Hub website shortly.



## The NERP Tropical Ecosystems Hub / Reef Rescue R&D Conference 2013

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More than 290 delegates from research, government, industry and community attended the first annual joint conference of the Tropical Ecosystems Hub of the Australian Government's National Environmental Research Program (NERP TE Hub) and the Caring for Country Reef Rescue Water Quality Research and Development Program (RRR&D). The conference discussed solutions to some of the most urgent issues affecting the Great Barrier Reef, the Wet Tropics rainforests, and the marine and terrestrial environments of Torres Strait. The discussions were held at the Pullman Reef Hotel Casino in Cairns and organised by Cairns-based RRRCLD.

Sediments, nutrients and pesticides discharged during Wet Season floods have caused significant changes to the inner Great Barrier Reef, and critically threaten inshore biodiversity in the coastal zone. The Chairman of the Great Barrier Reef Marine Park Authority (GBRMPA), Dr Russell Reichelt, opened the joint conference with broader reflections on the challenges of managing multiple cumulative pressures in World Heritage-listed environmental properties. Dr Peter Doherty, Science Leader of the NERP TE Hub, said "Dr Reichelt was one of the first to recognize that management of Queensland's coastal marine systems should start from the top of the Great Dividing Range. In 2002, he initiated the first "Catchment to Reef" research program and championed the co-operative research model, joining researchers and users in the search for solutions. It was particularly appropriate to have him open the conference given recent improvements in water quality achieved through greater adoption of best practice land management".

Climate change, as well as pests and weeds, also threaten the conservation of our World Heritage-listed Wet Tropics region. Andrew Maclean, Executive Director of the Wet Tropics Management Authority says "Listing and reservation alone don't guarantee conservation". A forum focused on how the Wet Tropics conservation effort was proceeding, particularly with regard to the biodiversity of the region.

Delegates traveled from the Torres Strait and presented to a forum on the future of that area and its Indigenous people. This region is of national and international significance, and faces human pressures as well as those of shipping traffic and climate change. The combination of these will have a complex impact on the region's environmental assets, particularly turtle and dugong populations. The extent of potential climate change effects, along with the geographic, social and cultural characteristics of the region make the Torres Strait communities among the most vulnerable in Australia.

Conference Chair, Ms Diane Tarte, said "It was pleasing to see that discussion will take place on such a broad range of topics, including Indigenous co-management of land and sea country, frog extinction, control of crown-of-thorns starfish, weeds, fire, rainforest regeneration, and adaptation to climate change".

Many stimulating discussions were had on how to better manage the many impacts on Torres Strait, the Great Barrier Reef and our tropical rainforests, all internationally recognised environmental assets supporting the livelihoods and culture of north Queenslanders.

Conference presentations and forum synopses may be found on the NERP TE Hub website: [www.nerptropical.edu.au](http://www.nerptropical.edu.au) and the Reef Rescue R&D website: [www.reefrescueresearch.com.au](http://www.reefrescueresearch.com.au).



## Government, Industry and Community Stakeholder Meetings

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Project Leaders report project progress biannually, including the number and nature of meetings with departmental and portfolio staff, researchers from other Hubs, plus research users from other government agencies, regional natural resource management groups, industry associations and the conservation sector.

All projects are presented at Implementation Group meetings that are focused on knowledge transfer. During 2012, there were eight Implementation Group meetings across the nodes. Researchers reported participating in more than a hundred meetings and numerous workshops and symposia. Some projects had extensive interaction with Indigenous groups and shared their research findings with other researchers from other Hubs and institutions in other countries.

Highlights include:

- Project 2.1, which presented at the Australian Sea Turtle Symposium that included SEWPAC representatives.
- Project 3.2 being in regular liaison with SEWPAC's ANHAT unit
- Project 3.4 being in regular meetings of the National Flying-fox Monitoring Steering Committee
- Project 4.2 communicating with DSEWPaC and the APVMA to clarify project methodology
- Project 5.3 presenting exposure mapping to DSEWPaC as part of MMP presentation in Canberra
- Project 9.1 attending a resilience workshop on Fitzroy Island with 30 researchers, managers and stakeholders from across the globe, including SEWPAC and GBRMPA managers
- Parks Australia attending the Project 9.3's technical workshop on Magnetic Island
- Members of DSEWPaC International Section were present at the regional scenario planning workshop for Project 11.1
- Project 12.1 meeting with DSEWPaC IPA and Indigenous Policy staff to discuss potential collaboration with the international Indigenous Land and Sea Network Conference.



## Publications





## Academic Publications From NERP Tropical Ecosystems Hub researchers

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