National Environmental Research Program

TROPICAL ECOSYSTEMS hub

NERP TE Hub Research Snapshot: Great Barrier Reef Water Quality

January to June 2013 Compiled by RRRC

About the NERP

National Environmental Research Program

The overall objective of the National Environmental Research Program is to improve our capacity to understand, manage and conserve Australia's unique biodiversity and ecosystems. It will achieve this through the generation of world-class research and its delivery to Australian environmental decision makers and other stakeholders. The Program features five research hubs, including the Tropical Ecosystems Hub.

The Tropical Ecosystem Hub

The Tropical Ecosystem Hub is a $61.89m investment that address issues of concern for the management, conservation and sustainable use of the World Heritage listed Great Barrier Reef and its catchments; tropical rainforests, including the Wet Tropics World Heritage Area; and the terrestrial and marine assets underpinning resilient communities in the Torres Strait.

www.nerptropical.edu.au

Image to the left and front cover image: Wayne Spencer (RRRC)

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Great Barrier Reef Water Quality

The TE Hub supports 38 research projects, with seven focused on GBR Water Quality within four Programs:

- Assessing Ecosystem Condition and Trend
- Water Quality of the Great Barrier Reef and Torres Strait
- Cumulative Impacts on Benthic Biodiversity
- Managing for resilient tropical systems

For further information on TE Hub structure please go to:
www.nerptropical.edu.au

Image: Wayne Spencer (RRRC)

The NERP TE Hub Great Barrier Reef Water Quality Node

Program 1: Assessing Ecosystem Condition and Trend

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

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

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

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Program 5: Cumulative Impacts on Benthic Biodiversity

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

Program 9: Managing for resilient tropical systems

Project 9.4: Conservation planning for a changing coastal zone.

Image: Wayne Spencer (RRRC)

Researcher Profiles

Associate Professor Jian-xin Zhao

University of Queensland (UQ)

Associate Professor Jian-Xin Zhao is Principal Research Fellow in geochemistry at the Centre for Microscopy and Microanalysis, University of Queensland. His work focuses on palaeoclimate/palaeoenvironmental reconstruction and archaeological/palaeocological studies based on coral reefs at sea and karst cave deposits on land. Dating methods such as mass spectrometry U-series developed in his University of Queensland (UQ) lab, have been applied to dating of coral reefs in the Great Barrier Reef, Moreton Bay, and coastal Western Australia.

Professor John Pandolfi

University of Queensland (UQ)

Professor Pandolfi is Chief Investigator and palaeoecologist at the ARC Centre of Excellence for Coral Reef Studies, University of Queensland. He has broad research interests in marine palaeoecology, with emphasis on the effects of anthropogenic impacts and climate change on the recent past history and ecology of modern coral reefs.

Professor Pandolfi investigates long-term ecological and environmental time-series data over broad spatial scales to discover major past influences of natural variability, human impact, and climate change on coral reef resilience. This research program enables direct linkage among physical variables and biological responses; attempts to tease out the effects of human versus natural variability; provides natural baselines which managers can use to place restoration goals in context; unveils processes that contribute to the resilience of coral reefs over long time frames and changing environmental conditions, and fosters a deep temporal perspective of the role of climate change in coral reef ecology.

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

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

Seventy reef-matrix cores and 351 samples from southern, central and far-northern GBR dated using U-series and other measures have been taken to generate long term time series data. U-series dating, elemental X-ray fluorescence (XRF), calcification data and Boron isotope data are all providing historical measurements in the GBR.

Two important management considerations from this work include calcification data generated from *Porites* which show a long-term increase in growth and calcification over time in mid- and outer-shelf reefs, while inner-shelf corals show a decrease over the same time period, with the differences attributed to coastal water quality.

Boron isotope data obtained for three coral cores from the central GBR show a clear seasonal and inter-annual variability. Long-term changes are consistent with global decrease in seawater pH. At an inter-annual scale reconstructed seawater pH shows a significant correlation with terrestrial runoff. The observed relationships between boron isotopes or calcification and terrestrial runoff could be caused as nutrient input during runoff events promotes phytoplankton blooms that in turn deplete CO_2 (i.e. pH goes up).

Team members from UQ preparing to extract a 3m long core from the reef. *Image: Markham, UQ*

Researcher Profile

Dr. Katharina Fabricius

Australian Institute of Marine Science (AIMS)

Dr. Fabricius is a Principal Research Scientist and coral reef ecologist at AIMS. She has worked as a coral reef ecologist since 1988, with most of her research directed at better understanding the roles of disturbances (especially ocean acidification, climate change and terrestrial run-off) on ecological processes in coral reefs, and their consequences. In this context, Dr. Fabricius has worked across a very broad range of scientific questions and organism groups, including corals, octocorals, crown-of-thorns starfish, coralline algae, sedimentation, marine snow, organic enrichment, water clarity, storms, bleaching, zooxanthellae, thermal tolerance, biodiversity, bioindicators, calcification, and the interactive effects of multiple stressors.

Dr. Fabricius presently leads a study investigating how long-term exposure to CO_2 alters coral reef communities and she is also involved in three projects to investigate cumulative impacts of climate and water quality changes on reef diversity, funded through the Australian Government's National Environmental Research Program (NERP).

MODIS-Aqua Quasi-True Colour Image of the Burdekin Region, from 23 October 2008.

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

Project Background

Turbidity is a measure of water clarity caused by the load of 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.

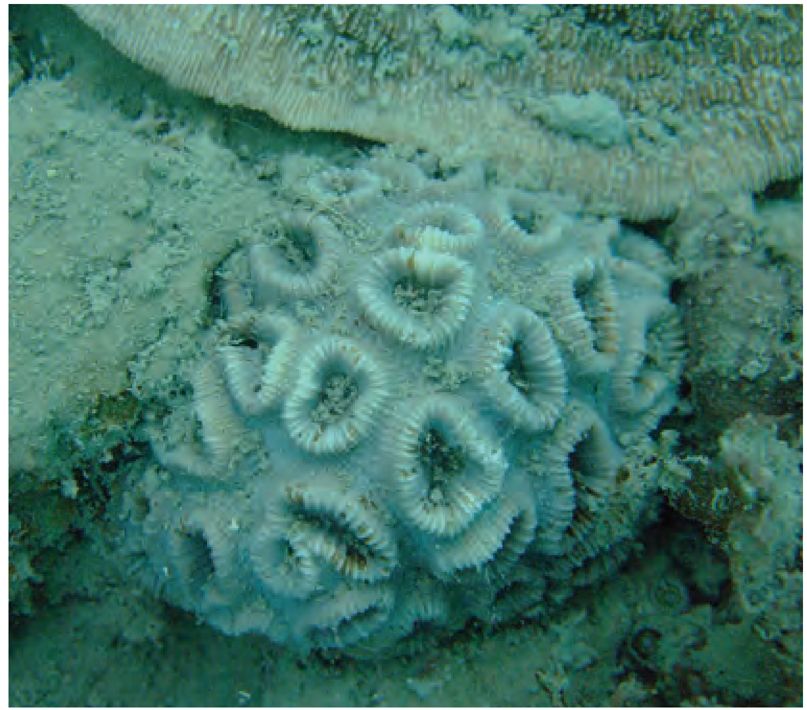
The study will also quantify turbidity differences between wet and dry years. This information can then be used to effectively predict improvements in inshore turbidity associated with improvements in land based runoff.

Project Progress

Mean annual water clarity appears strongly related to the annual freshwater discharge from the Burdekin River, with reductions (~20%) in water clarity in flood years.

Across the shelf, the depth to which light penetrates is most strongly related to Burdekin discharge for inshore, lagoon and mid-shelf bands, weaker within the chronically turbid coastal strip, and very weak for outer shelf waters.

There also appears to be a strong intra-annual relationship between river discharge and water clarity trends. Water clarity (standardised for environmental drivers) was highest from September to December, then declined to a minimum in March-May. Clarity then gradually increased back to maximum levels in September/October. Regional daily mean water clarity was thus reduced from its dry season maximum for an average of about 7 months after the Burdekin started flowing, including a period of at least 4 months after the river discharges had subsided. The adverse river effects therefore lasted on average 5 - 8 months per year, but data also showed intra- and inter-annual capacity for water clarity to recover. Reducing terrestrial runoff of nutrients and sediments should therefore measurably improve water clarity in the GBR, leading to significant ecosystem benefits.



Corals exposed to sedimentation on an inner reef of the Whitsunday Islands. While high sediment loads can be tolerated by a few coral species adapted to live in turbid waters, sediments with high organic content are lethal because they enhance microbial pathogens.
Image: Katharina Fabricius, AIMS

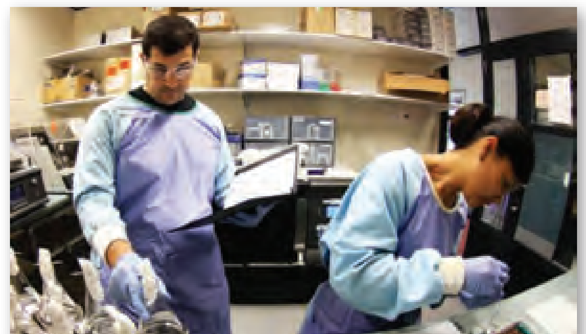
Researcher Profile

Dr. Andrew Negri

Australian Institute of Marine Science (AIMS)

Dr. Negri is a Senior Research Scientist in Water Quality & Ecosystem Health at AIMS. His background and training is in analytical chemistry and toxin research and he has spent 10 years at AIMS and CSIRO studying the chemistry, distribution and accumulation of natural toxins in marine and freshwater ecosystems. In the late 1990s, his research became more coral reef-oriented, including studies on the natural chemistry and microbiology responsible for coral larval settlement. Since 2000, Dr. Negri has been identifying the toxic thresholds of anthropogenic contaminants on a range of marine species, including corals (all life history stages), sponges and algae. Recent research focuses on understanding the combined effects of climate change and pollution on tropical marine organisms.

His current research focuses on understanding the combined effects of pollution and climate change on tropical marine organisms. Pollutants of interest include pesticides, metals, persistent organic pollutants (POPs), petroleum products and sediments from dredging, while the marine organisms studied include all of the life history stages of coral, micro and macroalgae, sponges and fish.



NERP PhD student Phil Mercurio and Florita Flores prepare herbicides for persistence experiments. *Image: Phil Mercurio*

Project 4.2: The chronic effects of pesticides and their persistence in tropical waters. *Project Leader: Dr. Andrew Negri, AIMS*

Project Background

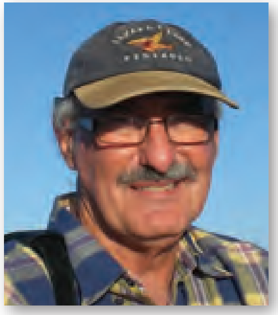
Pesticides, particularly herbicides from agricultural sources, have been detected all year round in coastal waters of the GBR except in the remote Cape York region. This project aims to identify the herbicide concentrations that cause chronic stress in marine biota and to use that information to refine 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

Results to date include the final analysis of the acute herbicide toxicity experiments. Effect concentrations for 24 and 72 hour exposures to Diuron, Atrazine, Hexazinone and Tebuthiuron have been calculated for two seagrass species *Zostera muelleri* and *Halodule uninervis*. A chronic herbicide exposure experiment for both seagrass species has been completed and is currently being analysed.

During this period the long-term flask experiment to measure degradation in seven herbicides in natural seawater at 25°C, 31°C and in the dark and light has been completed (365 days duration in total). The analysis of these samples is now underway. So far most of the glyphosate samples have been analysed, revealing a long half-life in seawater of over 260 days in the dark, reducing to approximately 40 days in low light conditions. Metolachlor has a half-life of over 150 days while 2,4-D had a half-life of at least 80 days in all conditions.

Herbicide persistence experiments using flasks in an incubator. *Image: Phil Mercurio*



Jon Brodie

James Cook University (JCU)

Prior to taking up the position of Water Quality Scientist at JCU, Jon Brodie spent some years as a lecturer in chemistry at Queensland University of Technology (Brisbane) and at the University of the South Pacific (Suva, Fiji). For the past 30 years, his interests have been in environmental research and consultancy and the management of marine and freshwater pollution in Australia and overseas.

Mr. Brodie's primary area of research involves water quality issues on the GBR, from the catchment to the GBRWHA itself. Work includes estimation of water composition, pollutant loads and source areas as well as modelling, catchment monitoring and target setting for suspended sediments, nutrients and pesticide loads. He is also involved in projects aimed at understanding the dynamics, distribution and land-use specific composition of river plume waters discharging into the Great Barrier Reef lagoon, and assessment of exposure of GBR ecosystems to terrestrial pollutants. Pollutants are also traced from the catchment to the GBR to help prioritise targeted areas for catchment management initiatives and investigations are underway on best management practices for rangeland grazing and sugarcane cultivation in order to improve water quality management. Finally, his team is assessing best management practices in palm oil plantation development to protect off farm aquatic ecosystems (in PNG).

Dr. Rai Kookana

Commonwealth Scientific and Industrial Research Organisation (CSIRO)

Dr. Kookana is a Senior Principal Research Scientist at CSIRO and has had more than twenty year's experience as a research chemist, focusing on the environmental fate of organic contaminants including pesticides and endocrine disrupting chemicals. His studies have included: the fate of micro-pollutants during aquifer storage and recovery of reclaimed water; the role of soil organic matter chemistry on pesticide sorption (i.e. attachment to another substance), mobility and bioavailability, and risk based approaches for minimising off-site impacts of pesticides.

Dr. Kookana leads a research team studying chemistry and ecotoxicology of organic contaminants, and is involved in developing pesticide risk indicators and management practices, and tools and approaches for ecological risk assessment, all with a view to minimising adverse impacts on aquatic and terrestrial environments. He is also studying the environmental fate and behaviour of organic micro-pollutants in reclaimed water and biosolids, and the role of biochar (i.e. charcoal) on sequestration and bioavailability of organic contaminants.

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

Project Leaders: Jon Brodie, JCU and Dr. Rai Kookana, CSIRO

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

The final report describing (a) review of methodology (b) meta-database of readily available and usable data and information (c) recommendations for process of performing the full risk assessment has been submitted.

Water quality testing. *Image: Michelle Devlin*

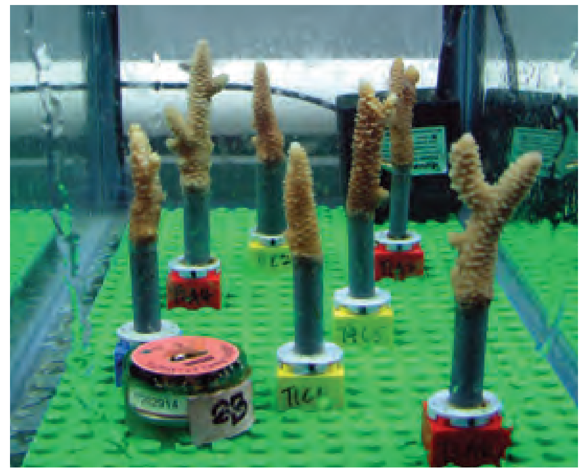
Researcher Profile

Dr. Sven Uthicke

Australian Institute of Marine Science (AIMS)

Dr. Uthicke is a Research Scientist in Water Quality & Ecosystem Health at AIMS and has expertise in experimental ecology, molecular ecology, and population genetics. In previous studies, he has investigated genetic connectivity and ecological function of coral reef invertebrates with special focus on echinoderms. His work combines field-based ecological surveys and experimental aquarium studies with "state-of-the-art" laboratory techniques and molecular analyses.

Dr. Uthicke is particularly interested in the effects of climate change, especially the warming and acidification of the oceans, on the process of calcification by animals in symbiotic relationships with plants (e.g. corals, foraminifera).



Corals (*Acropora millepora*) in an experiment manipulating CO_2 and salinity. Coral nubbins are mounted on Lego® blocks allowing easy access to the replicates during physiological measurements. *Image: Andrew Negri*

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

Project Background

This project is using complementary laboratory and field experiments to investigate the combined impacts of declining water quality (increased nutrients and sediments, and reduced light and salinity), increased sea temperature and ocean acidification on key reef species groups such as corals, foraminifera, crown-of thorns starfish and rock-boring sea urchins.

Project Progress

Results show a range of stress-related responses, in particular to decreasing salinity, additive effects of salinity and temperature, and additive effects of ocean acidification and temperature. Minor reductions in salinity also significantly affect the photosynthetic performance of corals, and coral recruits were found to be very sensitive to sedimentation, with enriched sediments containing organic carbon causing high mortality rates.

Elevated pCO_2 (i.e. dissolved carbon dioxide) reduces pH and can reduce recruitment of Crustose Coralline Algae (CCA), which can impact the natural replenishment of coral populations since CCA is a preferred surface for the attachment of coral spat. Settlement can also be hindered for echinoderm larvae. The work on corals and CO_2 shows that additive effects can sometimes be positive, with elevated CO_2 promoting pigmentation and photosynthesis and so partly offsetting the reductions in photosynthesis observed under heat stress.

Outputs from all experiments under this NERP project have provided a wealth of data, adding to our knowledge on interactive stressors on keystone coral reef organisms.

Field incubation experiment to assess the impacts of a natural CO_2 enriched environment on calcifying green algae. *Image: Nikolas Vogel (AIMS)*

Researcher Profile

Dr. Catherine Collier

James Cook University (JCU)

Dr. Collier is a Postdoctoral Fellow and seagrass ecophysiologist at JCU. She has a background in ecophysiology and marine conservation with work on morphology, physiology, growth and meadow characteristics of seagrasses, and their vulnerability to climate change. Between 2007 and 2010 she was a postdoctoral fellow in the Marine and Tropical Sciences Research Facility, supported by the Commonwealth Environmental Research Program (CERF).

Dr. Collier is broadly interested in coastal marine ecology, with a particular emphasis on seagrass eco-physiology and ecology. Her current work focuses on flood impacts on seagrasses, with the interest triggered by widespread loss of such habitat throughout Queensland and the Great Barrier Reef following record floods in 2011. It is intended that these studies generate information that will improve coastal system management. Dr. Collier's temperate and tropical research experience has heightened her interest in systems comparisons, and her aim is to further our understanding of tropical seagrass ecology and to contribute to the protection of seagrass meadows in regions where livelihoods are particularly dependant on productive natural ecosystems.

Image: Catherine Collier

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

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.

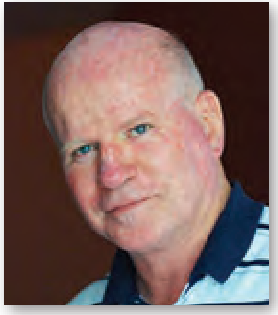
Unfortunately, seagrass meadows along the GBR have declined in the majority of areas surveyed, and many sites lack the seed bank that would enable rapid recovery. Most of these sites have either high turbidity (reducing light) and/or extra nutrients (destabilizing the natural balance for these marine 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

Light thresholds for seagrass abundance have been derived and experiments run to test seagrass tolerance to a range of salinities (3 – 36ppt, i.e. from freshwater to seawater). Productivity measures such as C:N (carbon:nitrogen) ratios and the delta ^{13}C have been tested to determine their usefulness as indicators for marine monitoring.

Flood plume exposure analysis using true colour remote sensing is complete, and results have been compared to seagrass abundance and composition using data from the Reef Rescue Marine Monitoring Program. The analysis has demonstrated that long-term exposure to primary (i.e. muddy) water characterised by high TSS (total suspended solids), moderate chlorophyll and CDOM (coloured dissolved organic matter) coincides with low seagrass abundance and shows that seagrasses are vulnerable to floods.

This seagrass bed has healthy shoot density but some blades already carry the signs of colonising animals that can be deleterious to the plant at high cover. *Image: Catherine Collier*



Researcher Profile

Professor Bob Pressey

James Cook University (JCU)

Professor Pressey is Chief Investigator, ecological modeller at the ARC Centre of Excellence for Coral Reef Studies at JCU. He is also a conservation planner with extensive experience in marine, freshwater and terrestrial environments. His experience includes seven years as a private environmental consultant, working mainly on survey and conservation evaluation of freshwater wetlands and nineteen years as a research scientist with the New South Wales National Parks and Wildlife Service, focused on semi-arid and forest ecosystems. During this time, Professor Pressey contributed to the establishment of the field of systematic conservation planning. He has been in his current role since 2007, with marine (as well as terrestrial and freshwater) research projects across Australia, through the Asia-Pacific region, and further afield.

Stakeholders listen to Allan Dale during the first reference group meeting for project 9.4. Numerous meetings and workshops with stakeholders are organised to ensure that the project and its results will be relevant and useful to managers. *Image: Amélie Augé*

Project 9.4: Conservation planning for a changing coastal zone.

Project Leader: Professor Bob Pressey, JCU

Project Background

This project will 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.

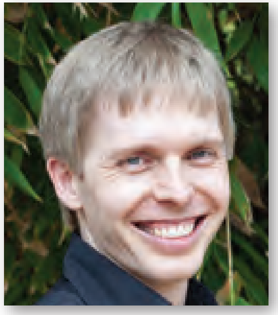
Project Progress

A report has been produced on the technical working group on land-use change, taking into account comments from the Reference Group meeting.

The spatial modeling method was also finalised using Idrisi Land Use Change Modeller software and algorithms, and a workshop was organised by the Australian Centre for Ecological Analysis and Synthesis (ACEAS) on catchment-to-coast planning. Talks with Girringun Aboriginal Corporation leaders, and the GBRMPA Indigenous Partnerships team, and a presentation at a TUMRA meeting, were invaluable in communicating outputs from this work.

Lastly, the coastal zone marine boundary was finalised using data on flood plumes, and a paper published on GBR governance analysis.

Sugar cane fields in the Great Barrier Reef coastal zone. Fertilizers used in these fields are one of the threats to the marine ecosystems of the Great Barrier Reef World Heritage Area (GBRWHA) as they reach the sea with water run-offs into rivers and then into the sea. Project NERP 9.4 estimates the impacts of land use change (such as increase or decrease in sugar cane area) for the health of the GBRWHA. *Image: Amélie Augé*



Researcher Profile

Dr. Eric Lawrey

Australian Institute of Marine Science (AIMS)

Following completion of a PhD on modelling improved techniques for wireless communication, Dr. Lawrey took up the position of Chief Technical Officer at Code Valley; a software engineering company researching a new way of developing software using distributed computing. In 2008 Dr. Lawrey joined AIMS as the e-Atlas developer and in 2011 took over as project leader for the e-Atlas, where he now focuses on data processing and stakeholder engagement.

Dr. Lawrey's current research interest is in design and development of the e-Atlas web platform, enabling knowledge developed through environmental science to be spatially visualised and told as data driven stories. This work includes development of web technology for delivery of the content, tools for processing environmental data and base-maps for the Great Barrier Reef, its catchments and the Torres Strait.

Project 13.1: e-Atlas. *Project Leader: Dr. Eric Lawrey, AIMS*

Project Background

This project is further developing the e-Atlas which is a website, mapping system and set of data visualisation tools for presenting research data in an accessible form that promotes greater use of this information. The e-Atlas serves as the primary data and knowledge repository for all NERP Tropical Ecosystems Hub projects, which focus on the Great Barrier Reef, Wet Tropics rainforest and Torres Strait. The e-Atlas captures and records research outcomes, making them available to research-users and hosts meta-data records, providing an enduring repository for raw data. It is also developing and hosting web visualisations to allow viewing of information using a simple and intuitive interface. In doing so the e-Atlas is assist scientists with data discovery and allowing environmental managers to access and investigate research data.

Project Progress

The e-Atlas (http://e-atlas.org.au) has a new front page, revised meta-database and individual project pages have been established as have links with the NERP TE Hub website. The project leader has now received data contributions from many NERP projects and is working closely with TSRA to integrate e-Atlas with their Integrated Management Strategy.

Additions and updates include shearwater seabird feeding tracks (Project 6.3 Brad Congdon); long term monitoring program (LTMP) COTS density modeling, update and animation; a new version of Atlas mapper (http://code.google.com/p/atlasmapper) and Torres Strait monitoring reef pages (http://e-atlas.org.au/ts/nerp-te/aims-monitoring-health-torres-strait-reefs-2-3).

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The Reef and Rainforest Research Centre (RRRC) administrates the Australian Government's National Environmental Research Program Tropical Ecosystems (NERP TE) Hub.

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