THE AUSTRALIAN RIVER RESTORATION CENTRE

RipRap

Australia's northern rivers and estuaries

EDITION 38

CONTENTS

Aboriginal and Torres Strait Islanders are warned that this publication may contain images or names of deceased persons which may cause sadness or distress.

CONNECTING *over a Cuppa!*

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Editorial

I have always been fascinated by Northern Australia, a place rich in culture, seasonal extremes and opportunities. For me, the opportunities lie in doing things differently, learning about and listening to our rivers so that we can develop enterprises that complement rather than exploit. I sincerely thank all the contributors to this edition for the work they are doing, and the efforts they are making to protect, restore and share their findings about this fabulous part of Australia.

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Cover photo: A Kakadu floodplain. Michael Douglas.

A northern forecast

FINE AND SUNNY, 32°C WITH A CHANCE OF SHOWERS IN THE AFTERNOON. THE LONGER-TERM OUTLOOK IS MOVING IN A NORTHERLY DIRECTION.

"We are all visitors to this time, this place. We are just passing through. Our purpose here is to observe, to learn, to grow, to love, and then we return home."

Indigenous proverb

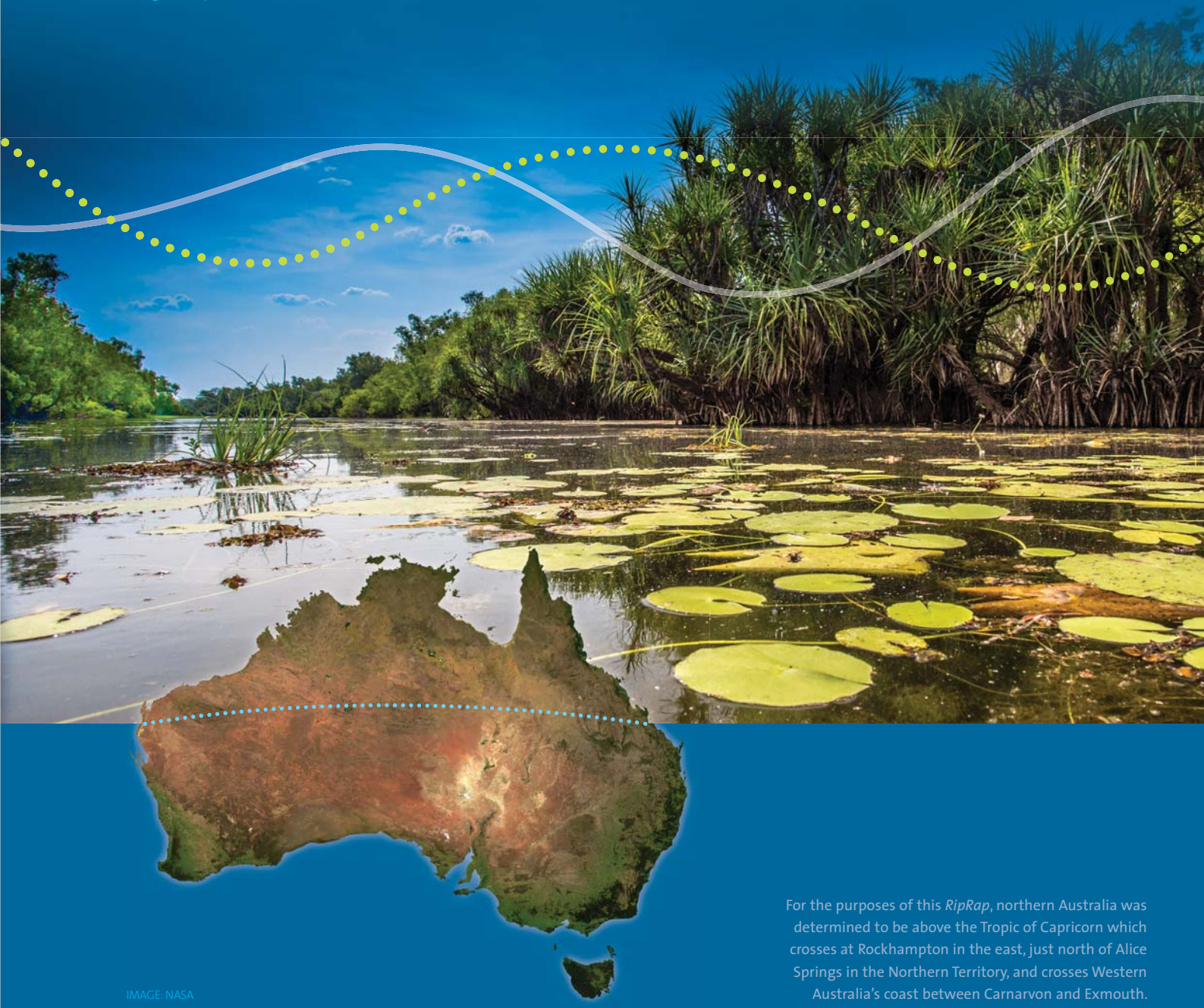

IMAGE: NASA

For the purposes of this *RipRap*, northern Australia was determined to be above the Tropic of Capricorn which crosses at Rockhampton in the east, just north of Alice Springs in the Northern Territory, and crosses Western Australia's coast between Carnarvon and Exmouth.

PROFESSOR MICHAEL DOUGLAS IS LEADER OF SEVERAL NORTHERN RESEARCH INITIATIVES (SEE PAGE 5)...

Developing the north has long been a goal of Australian governments. In the mid-2000s, at the peak of the millennium drought, the lack of water in southern Australia led to renewed interest in the seemingly limitless waters flooding from the tropical river systems in the wet season. This interest has continued to grow, and northern development is now a national imperative. Whether it is the need for water to irrigate crops, the need for river flows to support coastal fisheries, or the need to maintain water quality in the face of more intensive development, water is often at the centre of many debates and plans around developing the north.

Northern Australia does hold vast water resources. More than half of all water flowing through Australia's river systems flows through the rivers and tributaries that flood into the Arafura and Timor Seas, or into the Gulf of Carpentaria. Importantly, the rivers of the north are valued for much more than just this potential resource. They have outstanding conservation and cultural values, and are central to the lifestyles and livelihoods of most people living in the north. This is particularly so for the Indigenous people who have been managing these landscapes for millennia, and who continue to rely directly on the wild foods that these rivers systems provide.

...AND A PROLIFIC PHOTOGRAPHER WHO HAS SUPPLIED THE IMAGES IN THIS ARTICLE AND OTHERS IN THIS EDITION OF *RIPRAP*.

Globally, our track record of developing water resources is very poor. Initially seen as limitless, development has often led to over allocation, and this has resulted in degraded river systems requiring billions of dollars to repair. The Murray-Darling Basin is a striking example of this well-worn path, and one that has been repeated in many river basins around the world. In northern Australia there is the potential to do things better. There is still time to get critical information in place to inform good policy, planning and management, before major water allocation decisions are made for most of our northern rivers.

To help avoid a repeat of the problems that have arisen elsewhere, in 2004 researchers became active in trying to build the level of information available to ensure a more sustainable approach to developing the north. Recognition that no single agency has the capacity to tackle the breadth of research needed to do this, led to the formation of new research alliances such as the Tropical Rivers and Coastal Knowledge (TRaCK) consortium, which continues to this day. Involving more than 100 researchers, TRaCK brought an unprecedented level of collaboration and coordination to water research focusing on northern Australia.

The need for research to support and improve decision making has been recognised by the Australian Government which has increased funding for research in the north over the last decade. This support has been bolstered by significant co-investment from the Queensland, Northern Territory and Western Australian governments.

This issue of *RipRap* brings together some of the research carried out by the National Environmental Research Program's (NERP) Northern Australia Hub, as well as from other organisations interested in the north. The articles focus largely on the research related to aquatic ecosystems in this part of Australia, but also feature stories that describe important collaborations between researchers and Indigenous land managers. A number of themes emerge that demonstrate the important contributions of this research.

Picture perfect.

RESEARCH THEMES

New knowledge on the biodiversity of these river systems.

Targeted surveys of fish in the estuaries of Kakadu National Park have uncovered a much greater diversity of species than was known, and long-term fish surveys in the Daly River catchment have revealed new information on seasonal changes in their distribution and abundance.

New understanding of the fundamental ecosystem processes that support this biodiversity.

Research in Kakadu has helped us understand the critical importance of natural flows for maintaining the seasonal movement of sediment transport between the river and the sea—a process that helps to maintain aquatic habitats and connects the river channel with hot-spots of production on the floodplains.

New tools to understand and monitor these systems.

We have learnt to use acoustic and radio tracking combined with stable isotope analysis to understand the movement and feeding patterns of aquatic animals. Rapid surveys of aquatic species (including invasive) using eDNA are being trialled, as well as the development of protocols for camera trapping to standardise terrestrial biodiversity surveys.

New tools and approaches to evaluate social, economic and environmental outcomes of future scenarios and management.

We have also developed new tools to understand the trade-offs of different land and water use scenarios and management actions, including agricultural development in the Daly River catchment and the Gulf, weed management in Kakadu National Park, and grazing management and sediment delivery to the Great Barrier Reef.

The benefits of Indigenous ranger programs and partnerships with Western science.

The articles documenting work in Arnhem Land, the Daly, Cape York and the Kimberley all provide evidence of the wide range of benefits of Indigenous natural and cultural resource management for north Australia's rivers, coasts and catchments.

New partnerships to improve planning for development and management of rivers and catchments across northern Australia.

New alliances are forming to create a broader dialogue around the future of northern Australia, including the Kimberley to Cape initiative and other organisations such as The Wilderness Society lending their perspectives about how we need think carefully about any decisions we make in the region. The articles in this edition of *RipRap* also highlight the great benefits for all parties that arise when Indigenous land managers and Western scientific researchers work in partnership to implement and evaluate bio-cultural management.

Although not elaborated in any of the articles, research infrastructure and capacity has benefited enormously from the continuity of funding across the past decade. This has not only allowed for a structured assessment of long-term trends, but also led to the follow up of research questions arising from initial projects. Perhaps most importantly, it has led to the increase in capacity for doing research in northern Australia, including the training of students and early-career researchers, the development of long-term partnerships among researchers and land managers, and the capacity and soft infrastructure to manage successful research programs.

This decade of sustained research funding has led to a dramatic increase in the knowledge base and evidence available to underpin improved planning, management and policy in northern Australia. We have learnt a great deal about the environment, the people and the values of the regions's catchments and rivers. This research is now being used to improve the management of the north. We have also learnt much about doing research in this region, including the benefits of a coordinated, interdisciplinary, issues-driven approach that makes use of Western science and Indigenous knowledge in collaborative partnerships.

There is still more work to be done. The vastness and remoteness of the region, the low baseline level of scientific knowledge, and the relatively recent focus on research in this region, means that we have only scratched the surface and we need to continue our investment in new knowledge about this amazing part of Australia.

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We are fortunate that the lessons from this past decade are being applied in the design and delivery of the newly-established Northern Australia Environmental Resources (NAER) Hub. This is one of six hubs funded by the Australian Government's six-year National Environmental Science Programme (NESP). The NESP NAER hub will focus on research to support the sustainable development of northern Australia's environmental resources. It will include a strong focus on the sustainable use of water resources, and will engage the TRaCK consortium partners in delivering the research program.

We are delighted that a new phase of research into northern Australia is building on the findings highlighted in this edition of *RipRap*. This ongoing investment is timely as it follows the release of the Government's White Paper on developing northern Australia. It is also a well-timed reminder that while research has the potential to improve development and management of this region by providing the information to support policy, planning and management, there has to be the political will to make use of this information. Sound decision making underpinning a strong evidence base will be critical for achieving a sustainable future for northern Australia.

We appreciate the opportunity to have the Australian River Restoration Centre (ARRC) feature the work we are doing and hope that the articles and stories inspire those interested in the research being done in Australia's rivers, whether they are down south or in the Top End.

FUNDING MECHANISMS

The Australian Government is committed to realising the potential of northern Australia, funding a range of multi-disciplinary research in the region over the last decade. Significant research outcomes include the former Land & Water Australia's Tropical Rivers Program, and the former National Water Commission's North Australia Water Futures Assessment and Northern Australia Sustainable Yields study. Science to support decision making in the north has also been delivered through the Australian Government national environmental research programs.

The TRaCK hub was one of six operating under the Commonwealth Environmental Research Facilities between 2005 and 2011. It focused on improving research needed to sustainably manage Australia's tropical rivers and coasts. As part of NERP, and operating from 2011 to June 2015, the Northern Australia hub—one of five multi-disciplinary cohorts—provided science to improve biodiversity conservation and management in northern Australia. Australian Government research investment builds on these initiatives through the NESP, with six hubs funded to 2021. The Northern Australia Environmental Resources Hub will deliver research that connects scientists, policy makers and communities, working collaboratively towards sustainable development in northern Australia.

PROFESSOR MICHAEL DOUGLAS IS LEADER OF THE NESP NORTHERN AUSTRALIA ENVIRONMENTAL RESOURCES HUB, DIRECTOR OF NERP NORTHERN AUSTRALIA HUB AND OF THE TRaCK CONSORTIUM.

The NERP articles in this edition of *RipRap* have been brought together by Briena Barrett and Jaana Dielenberg.

BIG WET ebbs and flows

DAVID CROOK AND RESEARCHERS FROM CHARLES DARWIN UNIVERSITY AND NORTHERN TERRITORY FISHERIES ARE TRACKING TWO OF KAKADU'S MOST IMPORTANT FISH SPECIES TO UNDERSTAND WHERE AND WHY THEY MOVE DURING THE WET SEASON.

The Northern Territory is an unrivalled fishing destination, drawing interstate and international anglers to the region in droves every year. Australia's mighty Barramundi are arguably the fish icon of the Top End. The quest to find the best spot to hook the impressive sports fish is, however, easier said than done. New research is proving there is a good reason why Barramundi keep anglers on their toes.

ABOVE: TRACKING FISH BY BOAT. PHOTO MICHAEL LAWRENCE-TAYLOR. BELOW: A PRIZED BARRAMUNDI. PHOTO MICHAEL DOUGLAS.

Secrets below the surface

Solid progress has been made in understanding freshwater ecosystems in northern Australia, however, there is still much to learn about the key factors that sustain aquatic species. Floodplains have long been recognised as critical to the maintenance of aquatic food webs, where small fish feed on microscopic plants and animals, later providing sustenance for larger species. To better understand how these floodplains function, researchers from Charles Darwin University and Northern Territory Fisheries, funded under the Australian Government's National Environmental Research Program, have been studying the movements of two large-bodied fish; Barramundi (*Lates calcarifer*) and Salmon Catfish (*Neoarius leptaspis*).

Both these fish are major players in healthy food chains in the rivers and estuaries of Kakadu National Park, where the research took place. Anglers have long been attracted by the abundant numbers of Barramundi—but just what is sustaining them and the large populations of catfish?

"Previous research has shown that the productivity of fish populations in rivers is very reliant on the transport of energy from the floodplain and estuary," said Charles Darwin University Associate Professor David Crook.

"For example, only about one fifth of the energy contained in the tissue of Barramundi was derived from sources within the river itself. We wanted to explore the importance of fish movement as a means of transporting energy from floodplains and estuaries into freshwater fish populations."

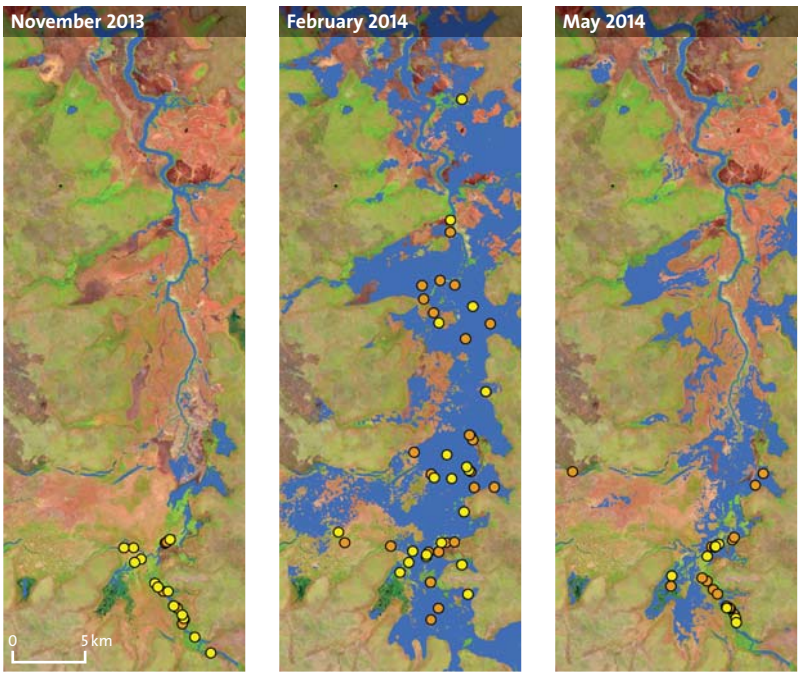
Along with other research on floodplain function and food webs (see article on page 8), this project is helping to establish the importance of having large wet season flows over floodplains.

Reeling in the numbers

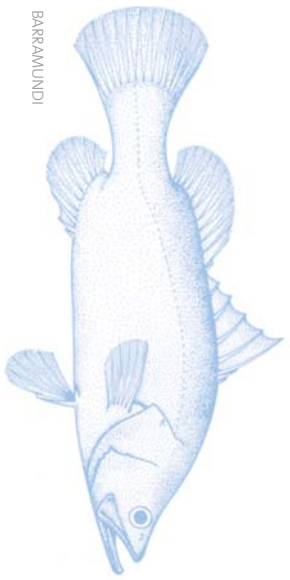
Between October 2013 and May 2014, David and his team tracked the movements of 65 Barramundi and 50 catfish in the South Alligator River and associated wetlands. The initial field work took place in the Yellow Water wetland system and nearby billabongs; the Barramundi were caught by electrofishing, while the catfish were hooked from a boat with help from Traditional Owners.

Acoustic and radio-transmitters were surgically implanted into the gut cavity of the fish. Movements of the radio-tagged fish were tracked every two weeks by boat and, eventually helicopter, to cover more ground as the floodplains became inundated. Fish tagged with acoustic transmitters are still being monitored, using an extensive array of fixed receivers extending from the Yellow Water area downstream to the estuary mouth.

The results provided some surprises, with the tagged fish wasting no time when the first significant rain of the season fell in November. Having spent the dry season moving only small distances within their local area, the fish started moving much longer distances and began to use inundated floodplains as habitat as soon as the first major flows of the wet season arrived.



Examples of the results of fortnightly tracking surveys conducted throughout the wet season. The fish start to return to their home billabong as the floods recede.
■ Flood extent ● Barramundi ● Salmon Catfish


BARRAMUNDI


CATFISH

January's monsoon brought even more movement, and by February the fish had dispersed widely. One Barramundi travelled an incredible 80 kilometres downstream within a few days. Most other Barramundi and catfish moved around extensively on the inundated floodplains and channels 5–20 kilometres downstream of their tagging location. As the wet season progressed, the fish began returning. By early March, most of the fish had returned to the same billabong from where they were originally collected.

Interestingly, the return to billabong habitats began before the area of floodplain inundation had peaked, with this earlier than the researchers expected. It could be because dissolved oxygen levels decline and vegetation thickens on the floodplain as the wet season progresses, making it less hospitable for the fish.

Lazy lovers

The overwhelming pattern of the Barramundi to remain within fresh water throughout the wet season was particularly interesting to the researchers. Barramundi require salty water to successfully spawn, yet only one of the tracked fish moved into the lower estuary where the salty water occurs. David says until now we would have expected most adult fish to move down to estuaries and the ocean to spawn each year.

"It's really turned a lot of our ideas on their head—along with other recent research, we are beginning to build a picture showing that many fish don't contribute to spawning each year." It also raises the possibility that many freshwater Barramundi aren't contributing at all to the reproductive output of the population. We'll monitor the tagged fish for another season; if we can confirm our first year's results, it will have important implications for the management of Barramundi fisheries in Australia."

Lessons learnt

The research demonstrates the importance of large-bodied fish as key transporters of energy from floodplains to main channels. The fish are not simply a product of the channel from where they were caught. The tracking results show how critical it is to maintain connectivity between the floodplain, river and estuary. Without this connectivity our rivers couldn't support as many of these large-bodied fish as they do. This work provides more information for policy makers to consider when making trade-offs between development, and ensuring the environment can sustain the ecosystems that depend upon it.

Principal research scientist at the Department of Primary Industry and Fisheries, Thor Saunders, says the research has increased their understanding of these two key species.

"Barramundi are incredibly important to the Northern Territory's fishing sector. The species is worth about $120 million to the recreational, charter and commercial fisheries. It's also of high cultural significance to Indigenous communities, as well as catfish. This research demonstrates how critical it is to ensure these species continue to have access to inundated floodplains during the wet season."

While the research has addressed many knowledge gaps, it has also raised more questions. It has certainly challenged previous theories about Barramundi breeding patterns and highlights the need for further research. The project team will continue to analyse the data to help build a better picture of how floodplains function and what is required to preserve these treasured fisheries.

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TOP FUELLED PREDATORS

DOUG WARD AND OTHER RESEARCHERS HAVE BEEN SAMPLING EVERYTHING THAT CAN EAT OR BE EATEN IN KAKADU RIVERS AND WETLANDS TO BETTER UNDERSTAND FOOD WEBS IN NORTHERN AUSTRALIA'S FRESHWATER ECOSYSTEMS.

Any good Top End fisherman will tell you that floodplains are important to fish production, and that a big wet season results in more fish in rivers, estuaries and connected coastal areas. Until recently, however, there were still many gaps in our understanding of the natural processes underpinning this relationship.

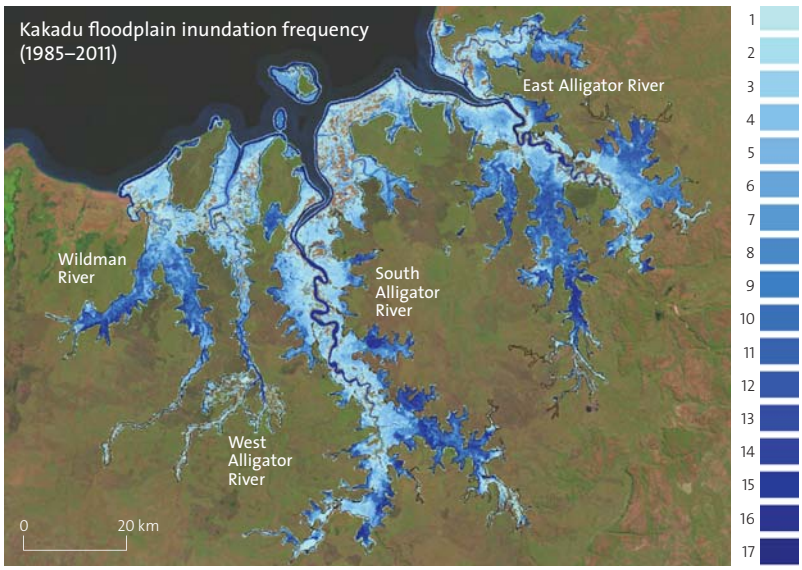
Under the Australian Government's National Environmental Research Program, researchers at Griffith University have been working to unpick the science behind Kakadu National Park's highly productive and diverse aquatic ecosystems. The answers will not only provide a more detailed understanding of the importance and function of floodplains to freshwater biodiversity, but will also help managers to better protect the biodiversity and fisheries of Kakadu's iconic wetland ecosystems, as well as other Top End floodplain systems like the Daly, Mary, Adelaide and Goyder River systems.

The big wet

The amount of floodplain inundated over the wet season greatly influences the extent of habitat available to aquatic animals. Analysis of satellite images from 1985 to 2011 (see map) shows that after each wet season (March/April), on average, some 1800 square kilometres (km^2) of the entire Alligator Rivers region are underwater. This ranges between about 1300 km^2 in a drier year, to nearly 2300 km^2 in a wet year. On average, the flood extent recedes to about 25–30 per cent by August/September.

Earlier work has shown that at a broad scale, larger flooding areas and longer duration does increase productivity, however, researchers wanted to find out more about what is happening in these flooded areas that fuels the food chain, and whether some food sources or specific locations on floodplains are more important than others in supporting aquatic food webs in the north. The study area was the Alligator Rivers region which is located entirely within the Kakadu National Park, and has no dams or water extraction. In systems where water is caught in dams or extracted for agriculture, reducing the extent and duration of water on floodplains would be expected to reduce fish productivity.

An example of the extent of para grass in Kakadu National Park. Photo Michael Douglas.



Flood inundation frequency can be used to represent the duration of flood inundation—the deeper 'blue' areas are inundated for the longest periods. Inundation frequency was calculated by assigning 1 to a flooded state and 0 to a non-flooded state, then adding the incidence of inundation over 17 image captures.

Food cycles

Stable isotope analysis is a technique that allows researchers to trace the chemical signatures of different plants and algae up the food chain. In 2012, the team began collecting samples of plants, algae, leaf litter, plankton, insects, prawns and fish from across the rivers and floodplains of Kakadu National Park. They also worked with Traditional Owners to obtain samples of crocodiles, wallabies and magpie geese eggs.

Senior research fellow Doug Ward says the chemical analysis shows that animals at the top of Kakadu's aquatic food webs are highly dependent on food resources that originate from floodplains or the surrounding savannas. As much as 80 per cent of the diet of larger fish and crocodiles came from floodplain sources. At the top of the food chain, half of the crocodiles' diets were made up of mammals from the surrounding savanna—mainly wallabies and pigs.

Interestingly, the research found that while the small insects and fish at the bottom of the food chain were consuming a wide variety of plants and algae, as you moved further up the food chain, one type of food source became increasingly important—epiphytic algae.

"This indicates that epiphytic algae is a higher quality food resource than other plants and algae," Doug said.

Plant architecture and light

Epiphytic algae grows as a film over the submerged leaves and stems of plants. The quantity of algae produced is strongly influenced by the amount of light that can reach the algae, rather than the surface area of the plants.

"Submerged aquatic plants, such as hornwort, bladderwort and najas, with lots of branching and open structures, produced the most algae—up to four times more than dense grasses. On the other hand, aquatic grasses and, in particular two very dense exotic grasses, para grass and olive hymenachne, are the least productive to algae," Doug said.

"These two highly invasive species are now established in parts of the Kakadu floodplains. If they continue to spread and become denser, we would expect fish productivity to decline due to a reduction in epiphytic algae." (See article page 11.)

Hotspots for productivity

By drawing together all of the different parts of the research, the team has been able to identify the most productive floodplain areas: these are the back water swamps on the edges of the floodplains, like Nourlangie, Yellow Water, Boggy Plains and the Magela Creek floodplain (see map page 12. The things that characterise these areas and lead to their high productivity are that they are deeper and hold water for much longer than the areas dominated by grasses.

"For most of the year large parts of these back swamps are between one and four metres deep. This is ideal for the floating plants that support the highest amounts of epiphytic algae growth," Doug said.

"The greatest risk to productivity in these areas is in the shallower areas between one and two metres deep—a depth suitable for either submerged aquatic plants or grasses. If para grass or olive hymenachne took over large areas of submerged aquatic plants, we would expect to see a reduction in productivity throughout the food web, which is an important consideration for floodplain management."

FOR FURTHER INFORMATION

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Lessons learnt

Kakadu National Park has been working closely with the researchers as part of the Park's biodiversity management approach under the Kakadu Management Plan. Park Manager Sarah Kerin welcomed the findings, and says Kakadu is adapting its weed management approach to take account of these new understandings of floodplain ecosystems.

"The link between invasive grasses and reductions in floodplain aquatic food chain productivity is another new piece of information for us to integrate into our floodplain planning and weed management strategy," Sarah said.

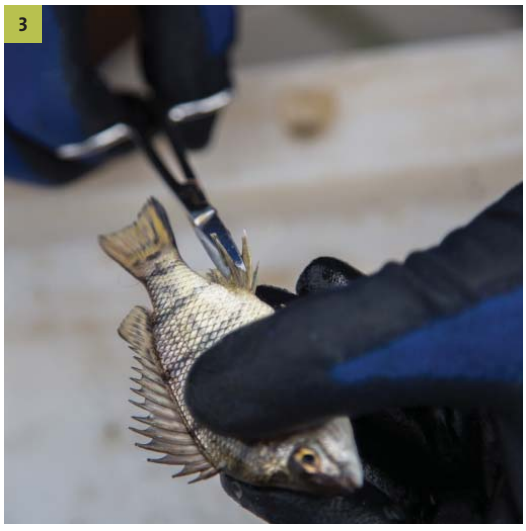
Doug says the research has led to a better understanding of the key factors underpinning the productivity of Kakadu's aquatic food webs, and their most significant threats.

The research is also relevant to the current interest in developing northern Australia. This knowledge can be used to predict how proposed changes, like water extraction or dams, will impact on the productivity of other northern Australian floodplain river systems.

"In general, we found that hydrologic connectivity between the dry season refuges, such as billabongs, floodplains and river systems is critical for the maintenance of biodiversity in these tropical floodplain systems. The impacts of changes in hydrologic connectivity can cascade through the entire flood chain which has the potential to significantly affect the aquatic biodiversity in these types of river-floodplain systems," Doug said.

PHOTOS 1 AND 3: MICHAEL LAWRENCE-TAYLOR.

PHOTO 2: MICHAEL DOUGLAS.



1. Researchers used stable isotope analysis to trace the chemical signatures of different fish. 2. Sampling epiphytic algae. 3. Sampling fish tissues.

PROTECTING BUSH TUCKER

RESEARCH BY **SAMANTHA SETTERFIELD**, **SUE JACKSON** AND COLLEAGUES HAS IDENTIFIED KEY STRATEGIES TO PROTECT BIODIVERSITY AND BUSH TUCKER BY TURNING BACK THE CLOCK ON INVASIVE PLANTS I N THE FLOODPLAINS OF KAKADU'S NATIONAL PARK.

Kakadu National Park is globally recognised as a living cultural landscape. To this day, it continues to provide opportunities for Indigenous people to fish, hunt and gather bush tucker. Much of these traditional resources are found in the Park's spectacular floodplain wetlands. A major drawcard for tourists, these unique ecosystems are bursting with wildlife and hold great cultural significance for Indigenous landowners.

Two invasive plants are, however, posing a threat to these wetlands and the way of life they support. Para grass (*Urochloa mutica*) and olive hymenachne (*Hymenachne amplexicaulis*) are historical legacies of previous land use that Kakadu is dealing with. These exotic grasses have spread extensively in the Park's freshwater communities. With so much at stake, a team of researchers, Kakadu staff and Traditional Owners have been working to determine the most effective strategies to manage the weed threat. The research team includes experts from Charles Darwin University, Griffith University and the CSIRO, funded by the Australian Government's National Environmental Research Program, in collaboration with the Northern Territory Government.

Unwelcome tourists

Para grass (see photo page 8) and olive hymenachne were first planted in, or near Kakadu in the 1940s and 1980s respectively. The highly invasive, semi-aquatic species were promoted as effective grasses to feed livestock, but their introduction has come at a significant cost to the World Heritage listed park.

WEEDS RESEARCH TEAM COLLECTING DATA ON THE MAGELA FLOODPLAIN. PHOTO MICHAEL DOUGLAS.

Kakadu has been working to minimise the impact of these invasive weeds, which can choke out native grasses, destroying aquatic habitat and reducing food for native fauna in the process. For example, the grasses can take over areas of water chestnut (*Eleocharis*), an important food for magpie geese, as well as areas of wild rice where the geese feed and nest.

"These invasive grasses also have different fuel characteristics to the native grasses they replace. Para grass produces about twice the dry season fuel of wild rice. This threatens turtles that nest in the floodplain soil during the dry season," said Associate Professor Samantha Setterfield.

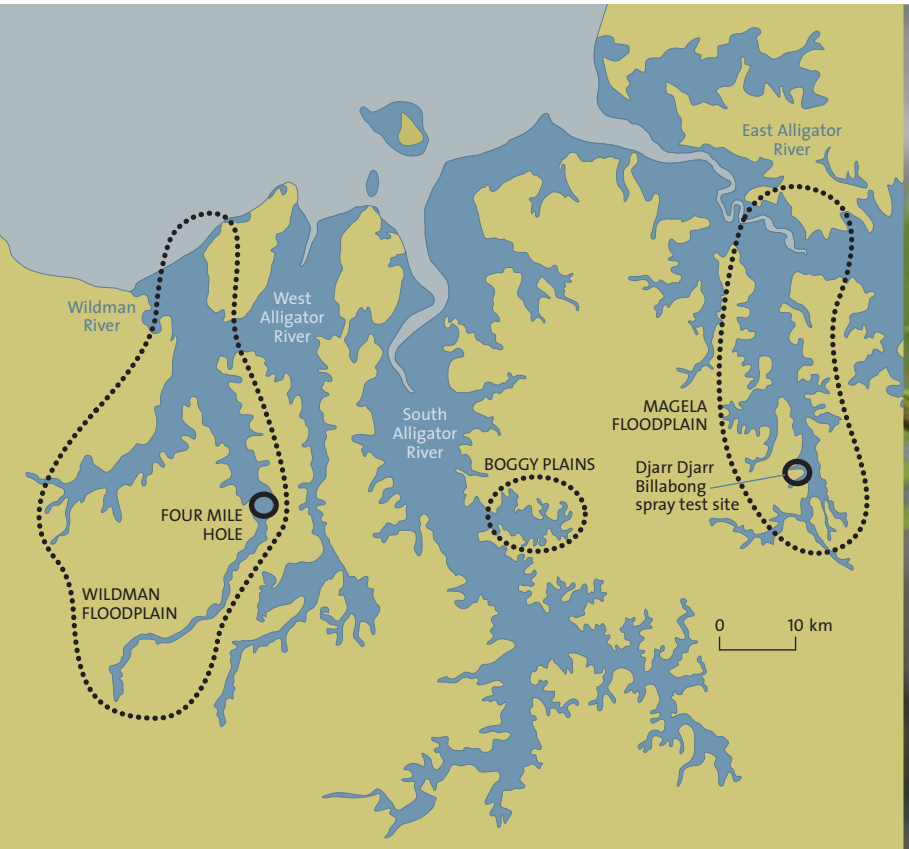
The important initial step of the research was to determine the extent of the weeds and how quickly they were spreading. The team undertook helicopter-based aerial surveys of all of Kakadu's floodplain area. This showed that para grass now covers more than 3200 hectares of Kakadu, mainly in the Magela and Wildman floodplains, and new populations are continuing to be reported. Some of the patches are large and dense, while other infestations are still scattered and small. Olive hymenachne, which was first recorded in Kakadu in 2001, also occurs in scattered infestations across Kakadu's floodplains, with a large infestation on the Wildman floodplain.

Based on knowledge about the history of invasion and maps of the current pattern of invasion, the researchers were able to build a model that predicts future patterns of spread. This provides an important tool for determining the long-term threat of these weeds to Kakadu's biodiversity and cultural resources.

Indigenous participation

To respond to concerns from Traditional Owners and better understand the impacts weeds were having on Indigenous livelihoods, the researchers sought input from Traditional Owners affiliated with the floodplains of Kakadu. Thirty-seven Traditional Owners helped to describe and map areas of cultural and economic importance, such as sites used for hunting and fishing. The results showed that almost a quarter of the floodplains were being used for hunting and gathering. Many of the participants were able to describe the harmful impacts of these weeds first-hand. One Traditional Owner told researchers para grass has damaged a highly valued river system.

"I go to Four Mile Hole—beautiful turtle place, nearly every year and to Boggy Plains. Para grass changes it. It's like a spring, a mat. Turtle sits underneath, harder to get them out. Donkeys, pigs, spread it. One day it's going to be over-run. There were never any weeds here until they started to bring feed in for the cattle," she said.



Comparing weed management strategies

Kakadu has a weed management strategy in place, and a strong focus on floodplain health as part of its Threatened Species Strategy. This research adds an extra layer of data to that work, providing models to help the Park tailor its weed control work to have the greatest impact.

To assist Park managers to make strategic decisions about protecting floodplain resources from weeds, the researchers developed a model that could compare the future patterns of invasion if different weed management activities were undertaken. The project team evaluated the performance of several strategies in Kakadu over a 20-year period.

"We considered three management scenarios, as well as associated costs and benefits," said postdoctoral researcher Dr Vanessa Adams. "The first was simply no additional management, which was used as a base from which to compare the other scenarios. The second involved a strategic weed management approach to contain and control infestations. The last scenario considered the same management approach, with the addition of actions to help Traditional Owners regain access to important bush tucker sites, which have become overrun by weeds."

The final strategy that both supported weed management and Indigenous values delivered the greatest cultural and biodiversity benefits. "Under this scenario, significant progress can be made in slowing the spread of weeds, protecting the habitats of key species and in achieving the recovery of many hunting sites. For example, our results showed that without weed control, about a fifth of magpie geese hunting sites and one-third of turtle hunting sites would be impacted," Vanessa said.

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The final scenario was the most costly — almost double the budget of the second scenario for an initial management period, however, Associate Professor Sue Jackson says further cultural benefits could outweigh these initial costs.

"These costings can help Park managers plan their weed management activities and make strategic choices about investments in weed control over many years. In Kakadu, Traditional Owners have a widely recognised role in environmental management and this strategy presents further opportunities to employ Aboriginal rangers and maintain connections to country."

Lessons from a fine example

While controlling these two invasive grasses will be an ongoing battle, action taken by Park staff and Traditional Owners to manage the threat from the alien shrub *Mimosa pigra*, has been widely used as a case study of best practice.

The shrub was first discovered in Kakadu in 1981 and a strong management approach was implemented soon after. A team of four people dedicated to its eradication has been operating for almost 30 years — locating, mapping and destroying new populations. Samantha warns, however, that the gains made by eradicating mimosa from floodplains will be lost if those same floodplains become invaded by alien grasses, and urgent decisions need to be made about protecting the floodplains' key biological and cultural assets.

"This research will help Park management, including Traditional Owners, plan strategies that not only prioritise the management of weeds, but deliver additional biodiversity and cultural values," she said.

"It is critical that these values are protected. Floodplains outside of Kakadu are being degraded by many threats, including weeds and feral animals, and facing the impact of sea level rise. Future research will consider the current health of all of the region's floodplains and we will apply the modelling approach developed by NERP to improve strategic management at the regional scale."

TOP LEFT: PARA GRASS. PHOTO FOREST AND KIM STARR. TOP RIGHT: HYMENACHNE. PHOTO ROCHAE CAMERON. MAIN: MIMOSA PIGRA. PHOTO NORTHERN TERRITORY GOVERNMENT, WEED MANAGEMENT BRANCH. OPPOSITE INSET: KAKADU TRADITIONAL OWNERS. PHOTO CSIRO. THIS PAGE INSET: MAGPIE GOOSE. PHOTO BENJAMINT444 (WIKIMEDIA COMMONS).

ALLIGATOR POWER

Yellow Waters region in Kakadu National Park during the wet season. Photo Michael Lawrence-Taylor.

NEW RESEARCH BY **DAVID WILLIAMS** IS SHEDDING LIGHT ON HOW TIDES AND WET SEASON FLOWS TRANSFORM THE ESTUARIES AND COASTS OF NORTHERN AUSTRALIA ON AN ANNUAL BASIS.

Coastal oceanographer David Williams from the Australian Institute of Marine Science has been working in the tropical macro tidal environments of northern Australia for over 30 years. The researcher's recent work has seen him frequent the Alligator Rivers region of the Northern Territory, where crocodiles, sharks and almost 340 fish species inhabit wide turbid rivers with massive mud banks, and tides which can rise six metres in a few hours.

The pulse of these large tides drives huge volumes of water in and out of the estuaries twice each day. The rushing water also carries high concentrations of sediment. The dynamic movement of water and sediment has a significant impact on the aquatic biodiversity of the region by creating different types of habitat. It also strongly influences water quality and light penetration, which in turn affects the growth of plants including algae.

Climate change is predicted to result in sea level rise and more intense rainfall and cyclone activity, but just how will climate change, as well as coastal and land use changes impact on these unique systems? David says a better understanding of water and sediment flows is helping to provide those answers.

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Secrets revealed

The project, funded under the Australian Government's National Environmental Research Program, focuses on the South and East Alligator River estuaries, from their mouth to their tidal limits within Kakadu National Park, a distance of over 100 kilometres. The estuaries occupy a wide, flat floodplain within the Park. The iconic region supports outstanding cultural, natural and economic values — values that Indigenous and non-Indigenous people are working hard to preserve.

"The South Alligator is the only river system in Australia that is completely contained within a national park," David said.

"The two Alligator river systems are only minimally disturbed by outside human activities and they encompass a wide range of features such as gorges, wetlands, escarpments, coastal floodplains and estuaries. This makes it an ideal location to research natural macro tidal estuarine processes and how they interact with the adjacent freshwater wetlands and riverine systems."

Hydrodynamic and sediment monitoring paints a fascinating model of seasonal sediment movement within these highly turbid systems. During the dry season, without large upstream flows, the area transforms into a large saltwater estuary where tides are the dominant force. With the force of the ocean behind them, the incoming tides are faster and have higher water velocities, compared to the outgoing tides which drain out of the estuary channels more slowly over a longer period. The combined result is that incoming tides carry more sediment in from Van Diemen Gulf and the lower estuary than the outgoing tides can take out. Over the course of the dry season this muddy sediment is pushed upstream along the entire length of the estuary right up to the tidal limits, depositing up to two metres of sediment in the channels.

During the wet season, large freshwater flows from the above catchment scour the sediment out again, pushing it back to the lower estuary and Van Diemen Gulf, resulting in low salinity throughout the estuary's entire length. As a result, two very distinct habitats form over the course of a year. These habitats are not only controlled by water velocity and sediment movement, but also by the large changes in salinity.

Over a three-year period researchers carried out many observations, including basic water quality measurements. "We found that the majority of the nutrients come from the adjacent freshwater wetlands where the growth of plants, algae and phytoplankton are high," said David.

"During the wet season these nutrients and organic matter are flushed into the estuary by the large freshwater flows and tides. When the freshwater flows cease at the end of the wet season, so does the vast majority of the nutrient inputs. The material delivered over the course of the wet season sets up the estuary with nutrients for the remainder of the year."

David says the biodiversity and productivity of the estuary is very dependent on the function and health of the upstream wetlands. As many of the fish in the wetlands also spend part of the life in the estuary, the wetlands and estuary are intrinsically linked. The productivity of the estuary is dependent on the wetlands and the riverine inflows.

"Understanding this has allowed us to develop models where we can reasonably accurately predict the impacts to the estuary from climate change, weed invasion or development within the catchment," he said.

Crocodiles on Kakadu's mud banks during the wet season. Photo Duncan Buckle.

Predicting patterns

Detailed hydrodynamic models were created based on extensive field measurements. The research team surveyed the bathymetry (bottom of the estuary and channels) and measured tides and water velocity during both the wet and dry seasons. The team then used LIDAR remote sensing to survey the adjoining floodplain and the tributary channels, which carry water between the estuary and floodplain.

These models were compared against observations researchers took in the field. They were then used to run a number of potential future scenarios, such as elevated sea levels, to predict the effects on the estuary, coastal floodplains and freshwater wetlands.

"These models are particularly relevant to research looking at estuarine plant and animal species, as well as the management of water quality. They show that saltwater intrusion depends on the rate of sea level rise, as well as how stable the channel banks are—which is also partly dependent on sediment transport," David said.

"Even small sea level changes could alter these system's freshwater habitats, which would have damaging impacts to the life they support and also local industry. Park managers will be faced with difficult choices about where to prioritise resources to protect areas and they need to be well informed about which actions could work."

"Our modelling can be used as a base on which to develop strategies in areas where managers choose to undertake actions to mitigate the effects of saltwater intrusion. Understanding where and how salt water travels into floodplains is vital to planning any development."

The model can also be used for other applications such as combining with fish data to look at fish passage, or the movement and fate of herbicides used in the control of weeds on floodplains. Additionally, these observations and techniques could be applied to other aquatic systems to predict how water quality varies between seasons, and the impacts that may be felt due to environmental changes.

CROCODILE PHOTO ANDERS FREY BIRKMOSE (WIKIMEDIA COMMONS).

Getting it right in the Daly

PHOTO DAVID WITZKE.

VANESSA ADAMS DESCRIBES A NEW PLANNING FRAMEWORK WHICH STRIKES THE RIGHT BALANCE BETWEEN DEVELOPMENT AND CONSERVATION IN THE DALY RIVER CATCHMENT.

Conserving the things a community values and meeting its potential for development can be a hard act to juggle, especially if there is strong interest in agricultural development, outstanding natural and cultural values, and differing perspectives in the catchment. For the past three years, researchers funded under the Australian Government's National Environmental Research Program, have been working to achieve exactly that in the Daly River catchment by developing a framework that combines environmental, social and economic values to inform sound policy.

Future potential

The Daly catchment supports an abundance of wildlife, is home to some of the best recreational fishing in northern Australia, and is highly regarded for its Indigenous values. Research fellow Vanessa Adams, who has been working in the catchment since 2008, says the potential for further development is also understandable.

"Its water resources, suitable soil and proximity to Darwin are all favourable factors for future development and people do have an interest in increasing land production for agricultural uses. So it's important to have a plan that can tell us where the best places are to undertake those types of intensive activities, but also the best places to conserve natural and cultural values," Vanessa said.

Straight to the source

Public opinion formed an essential part of the framework. Vanessa says respecting the different values people have for the region was a top priority.

"We wanted to know what aspects of life in the catchment were most important to people, what they like to do there and what areas were of most value," she said.

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www.nerpnorthern.edu.au/publications/citation/nerp626

PHOTO MICHAEL DOUGLAS.

Over 200 residents participated in a survey, equating to about 10 per cent of the households in the catchment. Results showed that the environment is the most important value for people. They choose to live in the catchment because it is a special place. Commercial values on the other hand, were ranked the least important, even though they were still important to people because they have to have a livelihood.

The survey also found people were concerned about pollution, water extraction and the sustainability of future development when it came to commercial land uses. Transparency was also a top priority. Residents felt that any decisions made should be transparent and based on the best available knowledge to ensure that the future land uses within the catchment support livelihoods and protect the environment.

The magic number

Residents were asked how much environmental change they would accept in the future, such as vegetation clearing across the catchment. The results showed that most would be satisfied if 10 per cent of the catchment was cleared, but would accept up to 20 per cent across the catchment.

"This was a really interesting finding, because it aligns with existing clearing guidelines that the Northern Territory Government developed in 2010, to cap clearing at 20 per cent," Vanessa said.

"Our research also indicates that around 20 per cent of the catchment area has soils that are suitable for developments like farming. So, in fact, these existing guidelines could support development and conservation goals at the same time."

Vanessa says, however, development is not just about clearing land to access suitable soils; it is also about making sure there's enough water to support the proposal.

"Surveys in northern Australia consistently find that people think the most important use of water is to keep rivers, plants and animals in good shape for future generations. Similarly, the people in our Daly survey also wanted to see the river supporting plants and animals, and providing a place for fishing."

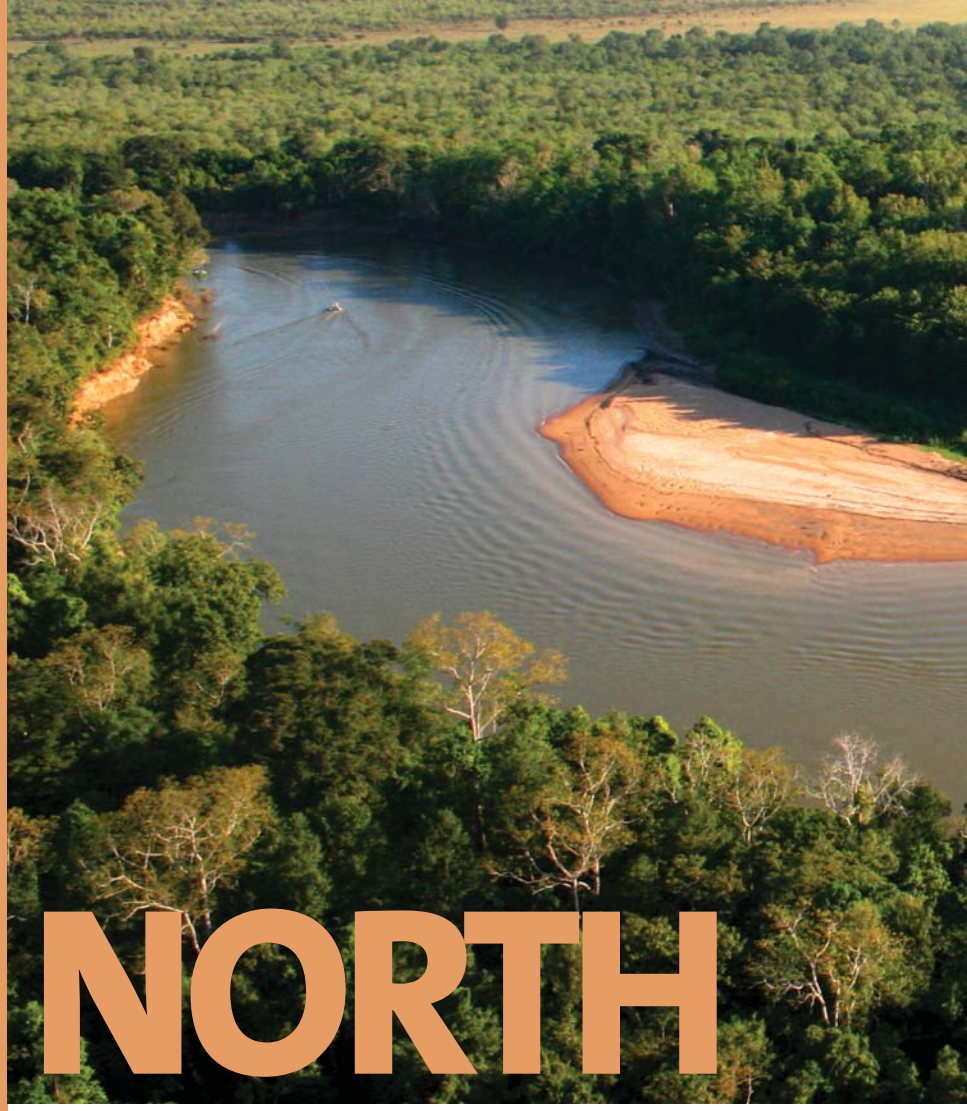
Moving forward

The framework, which considered both freshwater and terrestrial environments, can be used across the north and in other parts of Australia. It allows planners to draw together all the available information (environmental, social and economic) to test different strategies and to assess the trade-offs.

Vanessa says getting development right means bringing together scientific evidence and public values to inform good land and water resource policies.

"We believe that planning is a really important part of decision making. The framework we developed can be used by decision makers to evaluate opportunities as they arise, to ensure that decisions are transparent and deliver the best outcomes for residents in the catchment."

LAND MANAGERS WERE AN INTEGRAL PART OF THE SURVEY. PHOTO MICHAEL LAWRENCE-TAYLOR



FLOWS AND FISH IN THE NORTH

A TEAM OF RESEARCHERS IS INVESTIGATING THE IMPORTANCE OF FRESHWATER FLOWS ON THE ECOLOGY OF FISH IN THE DALY RIVER CATCHMENT.

Australia's tropical rivers account for about 50 per cent of the country's freshwater resources and hold an amazing diversity of aquatic fauna and flora. Governments have a strong vision for future development in northern Australia, particularly for the expansion of irrigated agriculture. The ecological impacts of changes to river flows are, however, poorly understood in the region. Making decisions involving trade-offs between the water needs of communities, the environment and future industries, is made even more challenging without this knowledge.

The need to understand how our river systems work is particularly pressing in the Daly River catchment in the Northern Territory. Most of the Northern Territory's current irrigation activity occurs in the Daly, and its reliable groundwater reserves and relatively good soils make it a prime candidate for further agricultural development.

The amount of water within a river, particularly during the dry season, as well as the timing of flow pulses in the wet season, are important for supporting healthy rivers and the fish within them. The freshwater fish of northern Australia are of high recreational, economic and cultural importance. Filling some of the critical ecological knowledge gaps such as the distribution, habitat and movement needs and breeding cycles of these fishes is key to understanding and maintaining their water requirements.

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Main image: Daly River study site. Photo Stuart Blanch. Inset: Adult Sooty Grunter. Photo Amy Kimber.

Keeping tabs on fish populations

In 2006, a team of researchers from Charles Darwin University, Griffith University, the Northern Territory Government and Traditional Owners, began investigating the ecological requirements of fish in the Daly River catchment. The project was part of the 'Daly River Fish and Flows' research project. Traditional Owners have been a central part of the project; assisting with field sampling and providing valuable Indigenous knowledge on fish ecology, and their cultural significance.

Sampling initially occurred at 55 sites throughout the catchment, and has been ongoing in eight main channel sites from close to the Katherine township, and downstream to near Nauiyu in the lower reaches of the Daly River. Led by Michael Douglas along with Mark Kennard, Brad Pusey and Sue Jackson, the project became a flagship activity for the Tropical Rivers and Coastal Knowledge program (TRaCK). It has continued under the Australian Government's National Environmental Research Program as part of the research on river connectivity (with Alison King joining the project team).

This year the project team is entering its 10th year of sampling, making it one of the longest running assessments of freshwater fishes in northern Australia. Professor Brad Pusey says the data is continuing to shed light on the distribution, abundance, habitat use and influence of river flows on fish in the river.

"This is a highly diverse area for freshwater fish, with nearly 100 species recorded in the Daly. We have collected species from a wide variety of taxonomic groups, from a diversity of habitat types, reproductive process and feeding strategies," Brad said.

"The fish assemblage changes throughout the catchment. The location in the catchment, distance from river mouth, flow permanence and habitat structure are all important determinants of the fish assemblage."

Principal research fellow Alison King says catches of most species vary considerably between sites, among years and among sampling occasions.

"Barramundi are an important recreational and cultural fish species for the region and are regularly caught at all of our main channel sites throughout the catchment," she said.

DA[I]LY FISHING

ELECTROFISHING WAS ONE OF THE CHOSEN METHODS TO SAMPLE FISH.

Top two images: Ooloo Crossing, photos Michael Douglas. Below: Boat operating at the Bamboo Creek site, photo Alison King. Bottom: Researchers recording measurements, photo Michael Lawrence-Taylor. Opposite: Otoliths being removed from a Sooty Grunter, photo Michael Douglas.

The surveys have also provided insight into the impact and recovery from natural catastrophic fish kill events in tropical rivers. In October 2012 a blackwater event, which occurs when large amounts of organic material removes oxygen from the water, caused a substantial fish kill at Galloping Jacks on the Katherine River. The impact of the event varied across species.

"There was an obvious decline in catch of some species such as juvenile Sooty Grunter immediately after the fish kill, but numbers soon increased. Numbers of some small-bodied species, such as strawmen and rainbowfish, appeared to increase straight after the event. Whereas, freshwater sole, which were regularly recorded at the site prior to the fish kill, haven't been recorded since," said Alison.

Predicting the impact of future development

The river and its catchment are in relatively good environmental condition compared to many other major rivers in Australia. Principal research fellow Dr Mark Kennard warns, however, that current and future development, particularly around water use, could start to impact on the health of the river and its fish. For example, groundwater extraction from bores for agriculture will reduce dry season river flows.

"Preliminary risk assessments identified several fish species at high risk from dry season groundwater water extraction, including large-bodied fish of cultural and recreational importance, such as Black Bream and Barramundi, as well as less iconic, but nevertheless ecologically important smaller-bodied species," Mark said.

Researchers used more complex modelling involving a mixture of primary data, scientific knowledge and Indigenous knowledge to predict the effect of dry season water extraction scenarios on Barramundi and Sooty Grunter populations.

"The modelling predicted that both Barramundi and Sooty Grunter populations would be impacted by lower flows. For Sooty Grunter, the juveniles appear to rely on shallow, riffle habitats as a nursery area, which are vulnerable to reduced flows. Barramundi, on the other hand, were particularly impacted by the timing of water extraction, with greater impact occurring with late dry season extraction.

The abundance of adult Barramundi grew with increasing magnitude of recent wet season flows, whereas juvenile Barramundi decreased," Mark said.

The study has also shed light on the importance of river connectivity for these fish; with nearly half requiring access to the estuary or ocean to breed. Mark says this has obvious implications for potential barriers to movement such as instream structures, road crossings, levees or low flows.

Moving forward

Much progress has been made in understanding the distribution, abundance patterns and flow-related ecology of fishes within the Daly River. While data collection is continuing, further research is now underway to quantify the importance of river flows on the distribution and abundance of fish in the main channel.

"We are now analysing the nearly 10 years of survey data to predict with more certainty how wet season and dry season flows influence fish populations in the Daly River," said Alison.

Professor Michael Douglas says the long-term project continues to provide foundation science and knowledge about fish in the Daly River for the management of its water resources and aquatic ecosystem, and preservation of its environmental values.

"The project's findings can contribute to water resource management by the Northern Territory Government to avoid over-allocation of water resources, which have caused so many problems for rivers in southern Australia, as well as the broader development of the catchment, notably for the river's floodplains which are vital habitats for many fish."

INDIGENOUS KNOWLEDGE

While the scientific community still have more to learn about the ecological requirements in the Daly, there is already an established Indigenous knowledge base that has accrued over generations for the purpose of hunting fish for food. The catchment is home to at least 10 Indigenous language groups, who own almost a third of the land. Two language groups in the middle and upper reaches of the region, Wagiman and Wardaman, provided input to the project on their existing knowledge, management actions and cultural responsibilities to sustain fish.

The researchers found much of the existing traditional knowledge was congruent with their own findings, and in some cases helped to extend their understanding of fish ecology. Traditional Owners were able to provide more knowledge about fish distributions within the river system, such as plentiful sightings of the Snubnose Garfish in the King River by Wardaman participants, which had only been collected by researchers on one occasion. Indigenous knowledge also supported scientific observations on habitat use, for example, Wagiman participants were able to confirm sightings of the Giant Gudgeon commonly occurring in billabong habitats.

The research partnership was also beneficial for the Indigenous participants. The field trips provided opportunities for storytelling and passing on knowledge about fish and their cultural significance to younger generations.

Senior research fellow Dr Sue Jackson says cross-cultural collaborations like these can contribute positively to water resource planning by generating shared understandings of management objectives and values.

"They also improve regional capacity to evaluate and apply scientific and local knowledge to water use pressures," she said.

ABOVE: BUSH TUCKER (FISH AND FOWL) IN THE NORTH. PHOTO GLENN CAMPBELL.

Fresh or salty?

SAMPLING BY **BRAD PUSEY** AND **MARK KENNARD** IS SHEDDING LIGHT ON THE TRUE EXTENT OF ESTUARINE FISH DIVERSITY IN KAKADU NATIONAL PARK.

Top: Returning from a successful sampling trip. Photo Mark Kennard.
Above: Three common species (Streamer Threadfin, Threadfin Scat and Paperhead Jewfish) discovered during fish sampling. Photo Brad Pusey.

Fish are a critical component of the aquatic habitats of northern Australia, especially its rivers. They are essential to riverine food web dynamics, support viable fishing and tourism industries, and are of great recreational and cultural significance. Recent research investigated how many species of fish call Kakadu National Park home, and how their size and abundance varies between seasons.

Kakadu National Park is regarded as one of the richest biological and cultural regions in Australia. It encompasses several rivers almost in their entirety—a level of riverine protection no other national park in northern Australia can boast. These rivers and connected water bodies support an outstanding array of fish diversity, containing a quarter of Australia's estuarine and freshwater fish species. Climate change, especially sea level rise, threatens to put this unique biodiversity at risk.

As part of the Australian Government's National Environmental Research Program, tropical river scientists have extensively surveyed Kakadu's estuaries to better describe its fish fauna, and have undertaken an assessment of the potential impacts on them from sea level rise.

Coastal fish

Estuaries are a distinctive and key feature of the northern Australian landscape, with 40 per cent of all fish recorded in the Northern Territory occurring in estuaries. Importantly, the Territory's estuaries are also in overwhelmingly good ecological condition, which is in stark contrast to elsewhere in Australia, or indeed the world.

Good ecological condition equates with high biodiversity. Kakadu contains almost 340 species of teleost or bony fish—about 80 per cent of which spend all or part of their life in estuarine habitats. In 2012, the team sampled the estuaries of the Park to document the species present, look for patterns in size and abundance, and learn how these vary between the wet and dry season. James Cook University Professor Brad Pusey says they collected 26 species of fish not previously recorded from the Park.

"Croakers and anchovies were more than three quarters of the fish collected. These fish are important in the diet of larger fish that are sought after for recreational fishing," Brad said.

The research also demonstrated the significance of estuaries as breeding grounds for many freshwater species. "In northern Australia, about one third of freshwater fishes need access to estuarine areas to complete their life cycle. Over half of all species of estuarine fish collected during the Kakadu study were juveniles. Estuaries are vital nursery areas for many fish, including those that are of economic value such as the iconic Barramundi, and which therefore underpin the long-term sustainability of many commercial fisheries," Brad said.

Distinct seasons

Despite only two families dominating the catches, the project team found there were significant differences in the fish species present in the wet season compared to the dry season.

"We recorded 74 types of fish over the study—63 of which were recorded during the wet season, compared to only 43 during the dry season. Of the 26 new species we recorded from Kakadu, 10 were collected during the wet season, while six were collected during the dry season, and the remaining 10 were present in both seasons," Brad said.

Prior to this project, all previous surveys of fish in the Park had only been undertaken during the dry season. "The large number of new fish we discovered leads us to believe that the biodiversity of estuarine fishes in Kakadu could still be higher. In particular, we would expect to discover more species in future wet season sampling."

Brad says this incomplete inventory of biodiversity, combined with significant seasonal differences, has important management implications.

"The estuarine environment itself is notoriously challenging to predict because of its natural variability. Without clear patterns it is hard to know how these estuarine species would respond to habitat changes. In order to develop a useful monitoring program based on estuarine fish, more sampling would be needed to determine a more accurate reflection of fish biodiversity."

A wet season beam trawl sample. Photo Brad Pusey.

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Changing tides

Kakadu is also among the most species rich areas in northern Australia for freshwater fish, with 62 species recorded in the Park. Griffith University principal research fellow Mark Kennard says many of these species are at risk of sea level rise. In the Kakadu region as sea level rises, large areas of freshwater wetlands will become inundated by salt water. As salinity goes up, freshwater plants die, causing areas affected by salt to change from wetlands to saline mud flats.

"While some estuarine species may benefit from expanded tidal habitat, some lowland freshwater species, especially those confined to floodplains, are particularly vulnerable," Mark said.

The project team used existing predictions of sea level rise in Kakadu to predict the locations and areas of freshwater habitat that will be impacted. There are 55 freshwater fish in the areas that are predicted to be affected. Of these fish, those that also occur widely in upstream freshwater river reaches, or that are tolerant of a wider range of salinity levels, will be less vulnerable.

"In total we found 12 species of fish that we consider vulnerable, and six that are highly vulnerable. The most vulnerable species are fish that have a large part of their range covered by the wetlands that could be influenced by salt water and that cannot tolerate increases in salinity."

Mark says the makeup of estuarine environments could also be impacted. "Freshwater wetlands produce a lot of food that flows into estuaries and coastal marine areas in the form of fish, plants, algae and nutrients. By changing wetlands, sea level rise could reduce the food sources within estuaries, and this could impact on estuarine and even coastal fisheries."

Building a complete picture

The importance of Kakadu's rivers, wetlands and estuaries as valuable repositories of biodiversity is clear. This project has done much to improve the understanding of Kakadu's fish fauna. Other research undertaken in the region is also looking at the processes within freshwater wetlands that underpin their incredible productivity (see article page 9), and the importance of fish movements and energy transfers between wetlands and estuaries (see article page 6).

"Northern Australia's rivers and estuaries remain in good condition, in contrast to many parts of southern Australia and elsewhere in south east Asia, and we need to ensure they remain so into the future," Brad said.

Chasing cherabin

ANGUS SMITH WRITES HOW **PETER NOVAK** IS EXPLORING THE LIFE CYCLE OF THE MYSTERIOUS NORTHERN CHERABIN.

The north of Australia is internationally recognised as one of the most ecologically important regions on the planet. Across this immense landscape run its life-supporting arteries, a remarkable network of rivers largely untouched by human development. The remoteness of these river systems has offered significant protection for the life forms that depend on them for survival, but has also provided challenges in their continued management and conservation.

Traditional Indigenous knowledge and modern science tell some of the story of these great rivers, however, much is still not known. This is particularly the case for the life and times of a small, yet prolific species of north Australian freshwater prawn, known locally as the cherabin. This purple-clawed river dwelling crustacean is cherished by fishers and Traditional Owners alike. Until recently, however, there was limited data on the cherabin's ecological role and life history, including whether they migrate, and where and when they breed.

Charles Darwin University, Research Institute for the Environment and Livelihoods (RIEL) PhD candidate, Peter Novak, is changing all that. Peter has been conducting the first ever study into the life cycle of this mysterious cherabin (*Macrobrachium spinipes*) species. To understand their natural history, Peter researched the species' annual migration, and breeding process .

Peter's research has involved monitoring a 400-kilometre stretch of the Daly River, from Katherine to the mouth and through the Edith and Ferguson River. Over a three-year period he surveyed more than 4500 adult prawns and tens of thousands of juveniles and larvae. He collected females with egg clutches of ready-to-hatch larvae from the Daly River and, in the lab, tested the survival rates of the larvae in freshwater over a period of days. Peter discovered that for a larva to survive it needed to reach the saltwater nursery grounds within seven days of hatching. Without this annual journey downstream the species would not survive.

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> “Now we know how important river flow is to the survival of these cherabin populations.

Peter discovered that the cherabin’s annual journey is timed to be in tune with river flow and season. Reproduction and the hatching of larvae began with the rains of the wet season from December to March. After the rains, the cherabin which have been developing in the estuary as larvae, migrate back up stream as juvenile mini prawns.

From these observations it was estimated that up to 14 to 15 million juvenile cherabin migrate upstream over about 30 days in April/May, along with other iconic species like Barramundi and mullet. The migration is like a replenishing of nutrients and food for the river system. The findings about the annual migration will provide valuable baseline data about the species that can now be used to improve management of cherabin populations in the Northern Territory.

“Now we know how important river flow is to the survival of these cherabin populations, and also how vital the species is in the linkage between freshwater and estuarine food webs. Any developments that might impede the migratory behaviour of cherabin could have significant impacts at an ecosystem scale.” Peter said.

In the future Peter hopes to conduct research on cherabin in other regions of Australia such as the Kimberley and Gulf country, to determine if the life history that he has uncovered in the Daly region is consistent among rivers with different flow regimes. Further work could also investigate the ability of larvae to survive at sea. For instance, larvae could reach the estuary at the Daly, drift further out and these larvae could then settle in, say the Finniss River. If this occurs and the populations in different rivers are connected, then this may confer stability to the cherabin population.

Opposite page: Peter Novak measures a cherabin on the Daly River. Left: Peter with a cherabin at the aquaculture research facility at Charles Darwin University. Photos Michael Lawrence-Taylor. Below: Two male cherabin (dominant above with the other subordinate). Photo Peter Novak.

The cherabin project is supported by Charles Darwin University, the Research Institute for the Environment and Livelihoods, the Northern Australia Hub of the National Environmental Research Program, the Northern Territory Government Research and Innovation Post Graduate Scholarship, and Holsworth Wildlife Research Endowment.

Learning from past mistakes…

DAMIEN BURROWS BELIEVES THAT IN THE DEBATE OVER DEVELOPING IRRIGATED AGRICULTURE IN NORTHERN AUSTRALIA, MANY HAVE COMPARED THE RISKS TO THE PROBLEMS ASSOCIATED WITH THE MURRAY-DARLING.

HE SAYS WE NEED TO LEARN FROM THE DEVELOPMENTS ALREADY IN PLACE UP NORTH, RATHER THAN LOOKING TO THE SOUTH FOR IRRIGATION MANAGEMENT ANSWERS…

PHOTO AT TOP: GSOLSEN, INSET CSIRO (BOTH WIKIMEDIA COMMONS).

… I am not talking here, about historical examples like Camballin Barrage or Fogg Dam or Lakeland (actually a moderate success, depending on one's definition of such). There are three major irrigation areas in northern Australia—the Ord River scheme, the Burdekin-Haughton scheme and the Mareeba-Dimbulah irrigation scheme. All three provide enough examples of how irrigation development could be better planned and managed—we don't need to look to southern districts for answers.

In the Burdekin-Haughton for example, the 1978 report of the development committee including leading aquatic scientists (a sort of early environmental impact statement), claimed that not only would the Burdekin Falls Dam be clear, but that it would actually improve the clarity of the river below the dam. When the dam first filled and remained highly turbid all year, this was attributed to lingering effects of the construction process. A few years later, limnological research showed that due to the flow and sedimentary characteristics of the catchment, the dam would always be highly turbid, as it has been for most of the time since. For 159 kilometres below the dam, the river is now persistently turbid, when naturally it was clear. Water from the river is pumped into numerous delta distributaries for delivery to farms on the floodplain. The floodplain waterways and numerous deepwater lagoons and wetlands are also now persistently turbid when naturally, they were clear. This catastrophic impact is due to the highly seasonal nature of flow in the dry tropics, with large volumes of turbid wet season flow trapped by the large volume dam and unable to be diluted by the clear, but very small, dry season inflows.

...to inform future growth

Opposite page above: Budekin River, and below Burdekin Dam. This page above and below: two clear lagoons.

How did we so badly misunderstand the system? You might say well, we didn't know better in the 1970s, our knowledge has advanced since then so we won't make the same mistakes. I'm not convinced by this. For starters, most northern impact studies have not attempted to predict the limnological characteristics of the proposed impoundment, despite this being an obvious starting point for impacts on the river below. I don't think we can accurately predict the actual impacts of a particular development. Sure, we have volumes of scientific data on the wide range of impacts out there, so in a generic sense, we understand what can happen, but each development is different. It has different crops planted, catches, stores, and distributes water in different ways, occurs in different flow regimes, and delivers to different receiving environments. Predicting the specific impacts of any proposal remains elusive, especially when most proposals are simply to deliver water. What the customers receiving that water may do with it, or how they manage their farm/industry is an unknown at the development stage, yet is ultimately the determinant of many ecological outcomes.

PHOTOS ON THIS PAGE PROVIDED BY THE AUTHOR.

In lieu of making accurate predictions, adaptive and responsive management is required once a development is underway. Having studied two of the major irrigation schemes in northern Australia (Burdekin and Mareeba-Dimbulah, plus irrigation in the wet tropics) over many years, I'd say it has been the cumulative impacts of tailwater dispersion, diverted flows, altered fire regimes, small fish passage barriers and instream weed infestations that have negatively affected aquatic ecosystems. These 'small' impacts receive little attention in impact assessments.

If we are to understand how to better develop and manage irrigation areas in northern Australia, we need to be studying and understanding the existing examples we have, not just referring to southern examples. There have not been any commissioned studies into the impacts of the Burdekin or Mareeba schemes on their downstream environments (the Ord faring only a little better), or any review of what should be done differently in future developments. Anything that we currently know has come from incidental studies carried out in those waterways, and years of local observation by regional scientists like myself. A systematic overview of what has worked and what hasn't in existing northern areas, would be invaluable in ensuring we don't repeat the mistakes 'of the north'.

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THE GILBERT'S SOIL
A cautionary tale

RESEARCH BY **ANDREW BROOKS** AND **JOHN SPENCER** IS CONTRIBUTING KNOWLEDGE TO THE RISKS AND CHALLENGES FACED BY NEW IRRIGATED AGRICULTURAL DEVELOPMENTS IN NORTHERN AUSTRALIA.

There has been much talk of the great promise for irrigated agriculture in northern Australia, and the Gilbert River catchment within the Gulf Country has been at the forefront of plans to turn this promise into reality. While it is anticipated that this sort of development has sweeping benefits, it doesn't come without its challenges, especially within a landscape highly susceptible to erosion.

Dr Andrew Brooks, senior research fellow with the Australian Rivers Institute at Griffith University, has been investigating the soils and geomorphology of catchments in the Gulf, and his research findings can be used to guide new irrigation developments away from areas which are highly likely to experience major erosion. Funded under the Australian Government's National Environmental Research Program (NERP), the project considered the challenges confronting these types of developments due to the extreme variability of rainfall and the particular characteristics of the landscape with its ancient, weathered and infertile soils.

"Any proposal which would see land developed in the Gulf Country needs to look at the underlying soils and topography of the catchments. While some floodplain areas may offer relatively suitable, flat land with fertile soils, other areas have relatively steep, nutrient poor and highly erosive ancient soils," said Andrew.

Case in point

Using a major proposal in the Gilbert River catchment as a case study, Andrew and colleague John Spencer examined the risks associated with transforming the land use from the current low-density grazing land to high-intensity irrigated agriculture. The proposal is to create a 65,000 hectare integrated farm and processing precinct producing mainly sugar and guar beans (*Cyamopsis tetragonoloba*) for the Asian market.

Above: Exposed tree roots within an alluvial gully in the Gilbert catchment, highlighting the susceptibility of this landscape to erosion. Photo Andrew Brooks.

Traditionally, new irrigated agricultural projects are developed for areas with good quality soils that are suitable for intensive development, and then water storage and infrastructure are designed around these good soils. This new proposal is, however, using an approach called fertigation, where fertiliser is dissolved and distributed within the water of the irrigation system, in a process akin to large-scale hydroponics. Andrew says this approach changes the emphasis for site selection to locations suitable for water infrastructure development, while soil quality is a secondary consideration.

The approach has been typically used on smaller-scale projects where the water and nutrients are delivered via sub-surface drip irrigation. In a proposal of this scale, however, there are major logistical issues to be overcome in setting up sub-surface drip irrigation in the poorly-drained sodic soils that characterise this landscape.

The development includes plans for two off-stream dams, that will take 40 per cent of mean annual flows from the Einasleigh and Lower Etheridge Rivers, equating to 550,000 megalitres per year. Andrew says this will significantly reduce the frequency of large scouring flows in the river. These flows are important to scour deeper pools in the wide sand river bed. The flow diversion only takes the water, leaving all of the sand in the river and preventing the deep pools from being formed. These deep pools last into the dry season, acting as critical refugia for many aquatic animals, including endangered sawfish. To date, the necessary research has not been done to fully evaluate the impact of such a scenario on these refugial habitats.

In comparison to other northern Australian developments, this is proposed to be 80 per cent of the size of the existing Burdekin Irrigation area, and around four times the size of the Ord irrigation scheme.

These existing agricultural areas are sited on flat floodplains with relatively young and fertile soils. This new development, however, is planned for a geological unit known as the Holroyd Plain, which is the oldest part of an ancient fluvial megafan. The megafan has a well-developed network of drainage channels, considerable topography, with very little suitable flat land, and soils that have been weathering since they were deposited two to 10 million years ago. These soils are potentially highly susceptible to erosion if disturbed.

While there is a thin (5–10 centimetres) veneer of stable soil on top, it is the subsoil beneath that Andrew says is problematic. The laser levelling that will be needed to set up the paddocks for trickle-tape irrigation will require the mixing of the shallow stable 'A' horizon soils with the sub-surface soils, which are generally sodic, highly dispersable, and on an average gradient three times that of the Burdekin irrigation area, further increasing the erosion risk, particularly in the development phase.

"While it is true that the sodicity can be neutralised with the addition of gypsum (at considerable cost), this will not change the deep drainage problems, and it will not reduce the potential for accelerating gully erosion, which is a major risk in this landscape, particularly where rainfall-runoff ratios are altered by land-use intensification.

In other areas with similar soils and topography, we have documented gully erosion stripping metres of soil off the landscape due to catchment changes that are relatively subtle compared to development for irrigated agriculture."

Andrew Brooks inspecting soils within the proposed development site. Photo John Spencer.

The proposal also requires an extremely dense network of farm tracks, and it is well known that vehicle tracks are a major initiation point for gully erosion in these landscapes. Great care would be required to design and build the track network so that it doesn't initiate gully erosion.

Andrew says the Gilbert River case study highlights development constraints associated with topography and soil structure, and emphasises the need for wider research to underpin land use planning for development in northern Australia.

"Although technology has the capacity to overcome the very poor fertility of the soil in this region, it can't ensure that soils won't wash away. For irrigated agriculture to succeed in the north it needs to take soil and topography into account as a first order priority."

"The assessment of soil erosion susceptibility must be ranked as one of the highest priorities for consideration in the planning process for any new agricultural development in northern Australia. Careful consideration needs to be given to accounting for soil structure and composition to ensure development opportunities are maximised for the short and long term, and that the built infrastructure does not become a stranded asset."

Future decisions

As northern Australia enters another period of renewed focus and interest, Regional Development Australia, Townsville and North West Queensland chair Paul Woodhouse says agriculture will continue to play a leading role. He says that there is a need for demand.

"Clear long-term policy agreement, certainty of tenure in areas where there are suitable soils, clearly defined but long-term water licencing arrangements, and access to good science and peer support. These factors alone will decrease the risk of lending by curious, but still conservative investors."

Paul believes that the construction of a sustainable agricultural and pastoral sector across northern Australia will also require removing impediments which have perhaps been convenient barriers in the past.

"Growth in areas of the region which have not been exposed to traditional agriculture may well begin as benignly as the individual growing of sorghum and other limited fodder crops, which offer more flexibility to beef operations outside of accepted seasonal marketing periods. Growth will also no doubt continue in areas of already intensive agriculture and cropping as producers move to spread their risk and maximise returns."

An example of significant alluvial gully erosion in the Gilbert River catchment. Photo by Andrew Brooks with John Spencer circled.

The major proposal in the Gilbert River catchment is 80 per cent of the size of the existing Burdekin irrigation area of 80,000 hectares (Burdekin region pictured). Source Burdekin Shire Council. Inset: Guar bean cluster. Photo Ton Rulkens.

"It won't be perfect—leaders will continue to lead and sometimes overstep, many will follow good examples, some will follow bad, some will succeed, others not as well. But such is life in the growth stages of what could become a significant industry if well managed and supported. Such was life in the infancy of extensive experimental farming in Australia, such is life now. It will be an interesting journey for policy makers, producers, inventors and scientists together, we can only hope the language is a common one, and the direction is a shared one."

While Andrew agrees that we have to proceed in a partnership between scientists, farmers and business entrepreneurs, he has a slightly different view about the need to make mistakes, as we have in the past.

"We have the capacity to do it much better today than in the past, when 'trial and error' was the only way to go, because we didn't have the technologies at our disposal that we have today. The whole point of programs like the NERP is that through research we can learn from the mistakes of the past, and we can apply technologies such as high-resolution remote sensing, coupled with good old-fashioned field data collection, to map out areas that are appropriate for high-value agricultural investment."

"Not only is this better for the environment, but it is better for business, because it will help us maximise the return on investment by reducing the waste associated with unproductive ventures."

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eDNA

TRANSFORMING FIELD SURVEYS

TROPWATER RESEARCHERS ARE REVOLUTIONISING HOW WE INVESTIGATE LIFE UNDERWATER USING WATER SAMPLES AND SOME SOPHISTICATED eDNA TECHNOLOGY.

As the pace of development increases, there is a pressing need for ever more information on the status of biodiversity within our aquatic environments. Field sampling, especially in remote locations of northern Australia is expensive, and poses many resourcing, safety and logistical challenges. This has limited our knowledge of aquatic biodiversity in such areas. Recent developments in DNA technology, collectively called 'environmental DNA' or 'eDNA', however, gives us the potential to easily and rapidly assess species presence within any given waterbody.

eDNA refers to DNA that can be extracted from air, water or soil, as plants and animals shed cellular material in their surrounding environment. The use of eDNA technology allows positive identification of the presence of certain aquatic species from the collection and analysis of DNA material in water samples, complementing traditional field sampling. In practice, this means surveying an aquatic field site is as easy as collecting a water sample. The widespread application of eDNA technology currently under development will revolutionise the way field programs are conducted, and greatly increase the flow of information about aquatic biodiversity.

There are many potential uses of eDNA technology in aquatic ecosystems. One of the first applications being trialled is the detection of introduced invasive species. These are a major problem in Australian waterways, especially in the tropics where warmer water favours the many tropical species found in the aquarium trade (the main source of fish introductions). The Ross River, which runs through the city of Townsville in north Queensland, has more invasive species than any other river in Australia. At the last count, 20 species of exotic fish had established in this river, tilapia being the most problematic.

Title photo: Electrofishing is the standard method for surveying freshwater fish. Inset: eDNA gel picture. Images throughout provided by TropWATER unless credited otherwise.

Above left: Filtering eDNA samples in the field. Above: Tilapia in the hand. Below: Tansyn Noble collecting water samples for eDNA at Eureka Creek. Photo Heather Robson.

Tilapia, a member of the Cichlidae family, were introduced to Australia as aquarium fish. They have been slowly spreading in Queensland, and are now present in 21 of the 76 catchments. They are considered the most problematic invasive fish across the state, and have recently been found in northern New South Wales. Their success lies in their highly efficient breeding strategies, flexible habitat and dietary preferences. They tolerate a wide range of temperatures, high salinities and low levels of oxygen, and are also very aggressive, easily out-competing and displacing native Australian fish. It is vital to prevent their further spread into new catchments. This goal relies upon a combination of public education (not to spread the fish) and early detection of any newly-created populations to guide management responses, including eradication attempts where feasible. Early detection, and understanding the distribution of nascent populations, are key to deciding on appropriate management responses for new incursions. At James Cook University's TropWATER, Drs Damien Burrows and Dean Jerry along with PhD student Heather Robson, are developing field and laboratory methods for the application of eDNA to assist tilapia management.

The first step taken by the research team was to develop primers specific to tilapia. Primers are very short genetic sequences from a standard part of the genome, and distinguish DNA in a water sample the way a supermarket scanner distinguishes products using the black stripes of the barcode. As no two species have the exact same 'code', the primers are species specific. The TropWATER team have been developing cheap and rapid means of collecting, filtering and analysing water samples, as well as doing experimental work to verify detection probabilities under a range of varying conditions (e.g. temperature, salinity, flow, time since tilapia were present).

The technique has a high reliability of detection and has been used to pinpoint the distribution of tilapia in the Mitchell, Townsville, Fitzroy, and Pioneer catchments in Queensland, as well as the recent incursion into New South Wales.

The detection of invasive species is just one application of this transformative technology. At James Cook University, eDNA primers have been developed and are being used to survey for endangered frog species and the rare freshwater sawfish. TropWATER are currently working on developing primers for otherwise hard to detect cryptic species, as well as Barramundi and various turtle species. The focus on using eDNA for other invasive pest species also continues. Within a few years, they plan to be able to detect most aquatic species in northern Australia via the collection of water samples.

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Snap happy

GRAEME GILLESPIE AND OTHER NORTHERN TERRITORY GOVERNMENT SCIENTISTS HAVE DEVELOPED A PROTOCOL FOR WILDLIFE SURVEYS USING MOTION DETECTION CAMERAS THAT HAS PAID OFF FOR WILDLIFE MANAGERS.

Photo above: Used with a consistent method, motion detection cameras can provide reliable wildlife survey information. Right: An acquired taste, this crocodile was captured taking a 'selfie' at a motion detection camera. Photos Michael Lawrence-Taylor.

Native frogs and toads are a natural part of the diet of the northern quoll (*Dasyurus hallucatus*), but their appetite for the highly toxic cane toad has greatly contributed to their decline across northern Australia. Elusive by nature, there had been very few sightings of this endangered marsupial across many parts of its former range, including Kakadu National Park. That was until 2012, when cameras captured one scurrying through bushland in the Kapalga region of Kakadu. Dr Graeme Gillespie, from the Department of Land Resource Management, says further surveying revealed a small, but healthy population in the area.

"Since the beginning of our project we've documented about 20 sightings using intensive camera surveying. We also used conventional monitoring methods, but they detected the quolls at a much lower frequency than the motion detection cameras," he said.

An attractive tool

Monitoring animals is a valuable tool in planning how to protect them and their environment. Many of northern Australia's mammals are nocturnal and shy, and without targeted sampling techniques land managers may not be aware of changes in the number or health of these animals.

Interest in camera trapping for wildlife management and research is growing worldwide. Motion detection cameras are cost effective, less labour intensive than other surveying methods and cause minimal stress to animals.

"The camera traps are a highly accessible tool for a wide range of practitioners, including rangers, Indigenous groups and other non-professional ecologist community members," said Graeme.

The cameras record the presence of wildlife at a particular location and time. Used as part of a comprehensive monitoring program, they can help identify the animal species present in an area and detect trends in their populations. They are also a valuable tool for land managers wanting to better understand the impacts of their land management activities. The photographs captured are not only insightful, but often entertaining.

"We have learnt to expect the unexpected when checking on our camera traps; you never know what you might discover, like a saltwater crocodile that took a shine to a camera lure station, that contained peanut butter and oats."

From top: A family of northern quolls, black-footed tree rat, feral cat and a feral pig.

High standards

In order for groups to collect and share meaningful information, it is important that they use a rigorous standardised method. To meet this need, Northern Territory Government scientists have developed a protocol for wildlife surveys using motion detection cameras, as part of the Australian Government's National Environmental Research Program (NERP).

"During our research, we trialled different arrangements for setting up cameras, until we found a method that consistently gives good detection rates for most species, so other groups can benefit from our experience. There will be a lot of value in groups adopting the same method when they are doing general biodiversity surveys, because then we will be able to compare results from different areas," Graeme said.

Traditional knowledge

The research team worked closely with Indigenous rangers and Traditional Owners in the Warddeken and Djelk Indigenous Protected Areas (IPA) in Arnhem Land to trial and assess the approach. These IPAs have a combined terrestrial area of over 30,000 square kilometres, the majority of which is highly remote and difficult to access. Department Flora and Fauna scientist Alys Stevens says the camera trapping method is an attractive option.

"There are no sealed roads, and most tracks are barely that, and usually only dry-season accessible," Alys said.

"The IPAs now have a meaningful tool which provides results, as well as suits the landscape in which they are functioning, and this can be promulgated as a viable option to other Indigenous ranger groups."

Alys says the method can be largely undertaken independently by rangers and furthers opportunities to spend time on country.

"Wildlife surveys can be designed to connect the socio-cultural goals of landowners. Old and young come together on country and observe and engage with the natural environment in a way that has Western-scientific value at the same time."

Valuable discoveries

The Northern Territory Government has also adopted the method as part of its biodiversity monitoring protocol and it has already delivered promising results. Scientists have been using the cameras to complement monitoring of feral cats to help assess their distribution. Prior to refining methods of camera trap deployment in the Top End, there was very little information on patterns of feral cat distribution. This technology is now helping to shape understanding of the ecology of this invasive species and how it is affecting our native mammals.

"In addition, remote cameras are proving to be far more sensitive at detecting a range of rare species than conventional sampling methods. We have found out that threatened species such as the black-footed tree rat are persisting in several areas of the Northern Territory where they were thought to have disappeared," Graeme said.

The finer details of the method can be found in *A guide for the use of remote cameras for wildlife surveys and surveillance in Northern Australia*, which is available on the NERP Northern Australia Hub website. The guide provides information on the general uses and application of motion detection camera technology for wildlife projects, and the planning and implementation of remote camera surveys across northern Australia.

Djelk Rangers show a Munguru Munguru Gurindi Ranger the CyberTracker sequence for setting out camera traps.

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Seeing grasslands through the trees

TRADITIONAL OWNER INDIGENOUS ENTERPRISES AND SCIENTISTS ARE COLLABORATING TO INCREASE THEIR UNDERSTANDING OF INDIGENOUS-LED APPROACHES TO LANDSCAPE MANAGEMENT.

For thousands of years Indigenous Australians successfully used fire as a tool to manage and modify the landscape in northern Australia. Knowledge about traditional fire regimes has been carried through generations, and there is further potential to adopt these practices where possible. In Ngallabigee, in Cape York Peninsula, the practice of traditional burning has been absent for over two decades.

"Ngallabigee is a very significant place for the family, purely because of its historical value, and I think it's a place where there's a lot of burial sites as well," said Traditional Owner Dion Creek.

"When I first came up here, there was kilometres of open grasslands. Over the past 20 to 30 years I think, the whole landscape has kind of changed around here. It's different because of the change of fire regime."

In 2013, Kalan Rangers joined forces with CSIRO scientists to develop environmental management strategies to care for their country, as part of research under the Australian Government's National Environmental Research Program. Kalan Rangers manage 350,000 hectares in central Cape York for biodiversity and other natural resource management objectives.

CSIRO researcher Justin Perry says the past management practices of the Ngallabigee grasslands demonstrate the importance of cultural practices to the landscape.

"These grasslands are a really important part of biodiversity in northern Queensland, especially in this region, and they used to be maintained by Indigenous people living up here," Justin said.

Until now, traditional fire regimes have been absent from Ngallabigee for over two decades. Photo Jaana Dielenberg.

"So if you remove fire from the landscape, you start to get a change in the landscape, so maintaining the grassland requires fire, which requires people."

Dion, who is also the Chief Operations Officer with Kalan Rangers, says the impact on Ngallabigee from threats such as invasive weeds and feral animals is clear. Together, he and other rangers are beginning to turn things around. In early 2015, Dion visited Ngallabigee to burn the grassland, returning traditional practices to the area.

Research project leader Melissa Sinclair says re-establishing Ngallabigee grasslands is a great example of Indigenous bio-cultural management. "The work Kalan Enterprises and CSIRO are doing through this program is increasing the capacity to monitor and evaluate management approaches like this," she said.

"Federal Indigenous environmental programs such as Caring for our Country and Working on Country have specific outcomes which Indigenous people are engaged to deliver. For projects to be meaningful to local groups, however, they may need to incorporate other locally important objectives, such as traditional burning."

"This case study is part of a wider initiative to provide specialist technical support to Kalan Rangers and Traditional Owners to adapt existing monitoring frameworks to better suit local objectives and work plans. Through working with this group and others on Cape York, our research team is developing recommendations for how policy and monitoring frameworks can be adapted to better incorporate local aspirations."

Above: Kalan Rangers in action and right: CSIRO researcher Justin Perry and Traditional Owner Dion Creek. Photos Michael Lawrence-Taylor.

You can see Dion and Justin working together in this video, https://vimeo.com/120326523

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RoC

RIVERS OF CARBON

Rivers of Carbon is an exciting initiative based in the southern tablelands of New South Wales with current projects in the Yass, Lachlan and Murrumbidgee catchments.

Rivers of Carbon is working with landholders to extend riparian corridors into the wider terrestrial landscape to create win-win outcomes with multiple benefits, including future tradeable carbon credits, agricultural productivity, biodiversity and healthier rivers.

Rivers of Carbon offers a range of financial incentives for fencing, establishment of vegetation, stock water and ongoing support.

INTERESTED?

riversofcarbon.org.au

Protection and jobs or development dreams

GAVAN McFADZEAN DISCUSSES THE WILDERNESS SOCIETY'S NORTHERN AUSTRALIA RIVERS CAMPAIGN.

Northern Australia is a unique, interconnected mosaic of savanna woodlands, wetlands, rivers and estuaries, rainforests, dune fields, islands and coral reefs. The region's many traditional cultures and languages reflect the incredible diversity of this environment, and reveal a rich history of interaction between nature and the world's oldest living culture.

The natural values of the region are staggering by national and international standards. Northern Australia is home to 40 per cent of Australia's reptile species and 75 per cent of our freshwater fish species. The Kimberley supports about 2000 species of native plants, around 300 of which are endemic. Cape York Peninsula has extraordinary biodiversity in its own right, including 3000 plant species (at least 260 endemic), half of Australia's bird species, one third of our mammal species, and a quarter of our reptile and frog species.

FOR FURTHER INFORMATION
wilderness.org.au

PHOTOS THROUGHOUT PROVIDED BY THE WILDERNESS SOCIETY.

The region contains no less than 25 per cent of the world's remaining tropical savanna. This is by far the largest proportion of savanna habitat in the world, and the only significant area of tropical savanna in an economically developed, politically stable country. Similar woodlands once covered parts of Africa, Asia and South America. Tragically, more than 70 per cent of the world's tropical savanna has been lost forever.

But it is the river systems, wetlands and floodplains that bulge and burst their banks over vast areas during the wet season, and then often dry up completely in the long dry season, that form—along with the region's fire regimes—the most important ecological characteristics of northern Australia.

Northern Australia contains 55 river systems that have not suffered significant changes to their flow or catchments—the highest density of continuous, intact tropical river ecosystems left on the planet. Combined, these rivers extend over one million kilometres and carry approximately two-thirds of Australia's fresh water. This statistic hides the fact that for much of the year this region is characterised by water scarcity. Only a handful of these rivers are perennial. The flooding wet seasons and hot dry seasons mean these rivers have the most variable flow regimes on earth.

The future of our northern rivers hangs in the balance.

Northern Australia's vast wetlands are also an important stop-off point for migratory bird species. For example, the 353,400 hectare wetlands in the lower Daly River floodplain and estuary, satisfy waterbird-specific criteria for RAMSAR listing and provide habitat for 22 species of migratory birds listed under Commonwealth legislation. Extensive wetland systems occur across the floodplain, with large areas supporting flooded savannas.

Not only are the river systems of the north the arteries around which natural and cultural values depend, they are also the key to unlocking large scale agricultural, or 'foodbowl' developments.

Those with an interest in northern Australia have lost count of the number of parliamentary inquiries and policy committees established by federal, state and territory governments. Each time they are launched in the deluded hope that they will come to a different conclusion to those before—that the huge constraints to building mega-scale dam and land clearing projects to grow food for expanding Asian markets can be overcome.

But the lure of developing northern Australia for large-scale agriculture has proven a mirage, and not through lack of trying. Invariably each inquiry reports the hostile and unpredictable climate, impoverished soils, poor infrastructure and extreme evaporation.

Even without these massive constraints, the north faces a host of environmental impasses that southern Australia is already grappling with—the impacts of vegetation clearing on a massive scale, drained and polluted rivers, soil erosion, industrialising pristine coastlines with ports, dredging and infrastructure development, salinity and loss of species.

This obsession with an outdated business model meant that June 2015's Northern Australia Development White Paper missed a huge opportunity to support growth in nature- and culture-based tourism, defence, natural resource management, Indigenous Protected Areas, carbon farming, relocating government departments such as the Australian Quarantine and Inspection Service (AQIS) and CSIRO and positioning the region as the Asia-Pacific hub for tropical health and education.

Instead, the Abbott government threw up its hands and passed the buck to state and territory governments and the private sector when it announced the $5 billion Northern Australia Infrastructure Facility in the May budget. The fund offers long-term, low-interest loans to government and private sector partnerships to propose large-scale industrial schemes that won't stack up without a taxpayer handout.

This approach will only encourage government and foreign investment into risky, expensive and environmentally destructive mining and agriculture projects that no one in their right mind would consider without a taxpayer handout from the federal government. It's the Ord all over again.

Already $140 million has been earmarked for the Ord River Irrigation Area on top of the $1.45 billion taxpayers have donated thus far, despite crop failures and no financial return to the public purse.

Last November, ANZ chief economist Warren Hogan expressed surprise at just how unprofitable new irrigated cropping projects in northern Australia on current commodity prices would be, despite the Asian food-boom story. "I think there is romanticism about developing the north; when you look at just how little land and water is actually available it is more constrained and expensive than we thought," he said.

These policies reveal an Abbott government stuck in a romantic federation-era model of nation building, rather than an innovative plan for economic growth and jobs for the 21st century. In doing so, the Coalition has refused to accept the expert Northern Land and Water Taskforce's 2009 report *Sustainable development of northern Australia*, which found little scope to expand irrigated agriculture, from the current 20,000 hectares to just 60,000 hectares—less than the size of some Australian farms.

Those with a historical interest in the region have heard this before. The White Paper is just the latest in a plethora of policy committees and studies that have been commissioned over the years hoping for a different conclusion to those that went before, namely, that the potential for harnessing wet season flows for large-scale agricultural development is extremely limited.

While northern Australia is a vast intact landscape with two-thirds of Australia's rainfall, a number of significant climatic, environmental and logistical constraints mean that the agricultural potential of the region is extremely limited.

Northern Australia is a graveyard for failed agricultural developments. The climate is extreme, with four months of flooding rain followed by eight months of drought. Rainfall is highly variable from year to year. The soils are among the most impoverished on earth, the geology is flat and unsuitable for dams, and evaporation is so extreme that less than 20 per cent of rainfall ever makes it into rivers.

The region's proximity to expanding Asian markets is offset by poor infrastructure. The location of the north within the tropical zone gives us a comparative advantage, not in food production, but in positioning the region as an Asia-Pacific leader in tropical health and education, and expanding the range of tourism experiences available to the rapidly growing Asian middle class.

Generally speaking, since federation we have not treated Australia's fragile river systems with the care they deserve. Old habits die hard—now the Murray-Darling system is costing the taxpayer $10 billion to repair. It is critical that we don't migrate our approach to river and water management to our northern rivers. Many of the development options outlined in this article depend on keeping northern Australia's rivers free flowing and intact, and this is where both federal, state and territory governments should focus their attention.

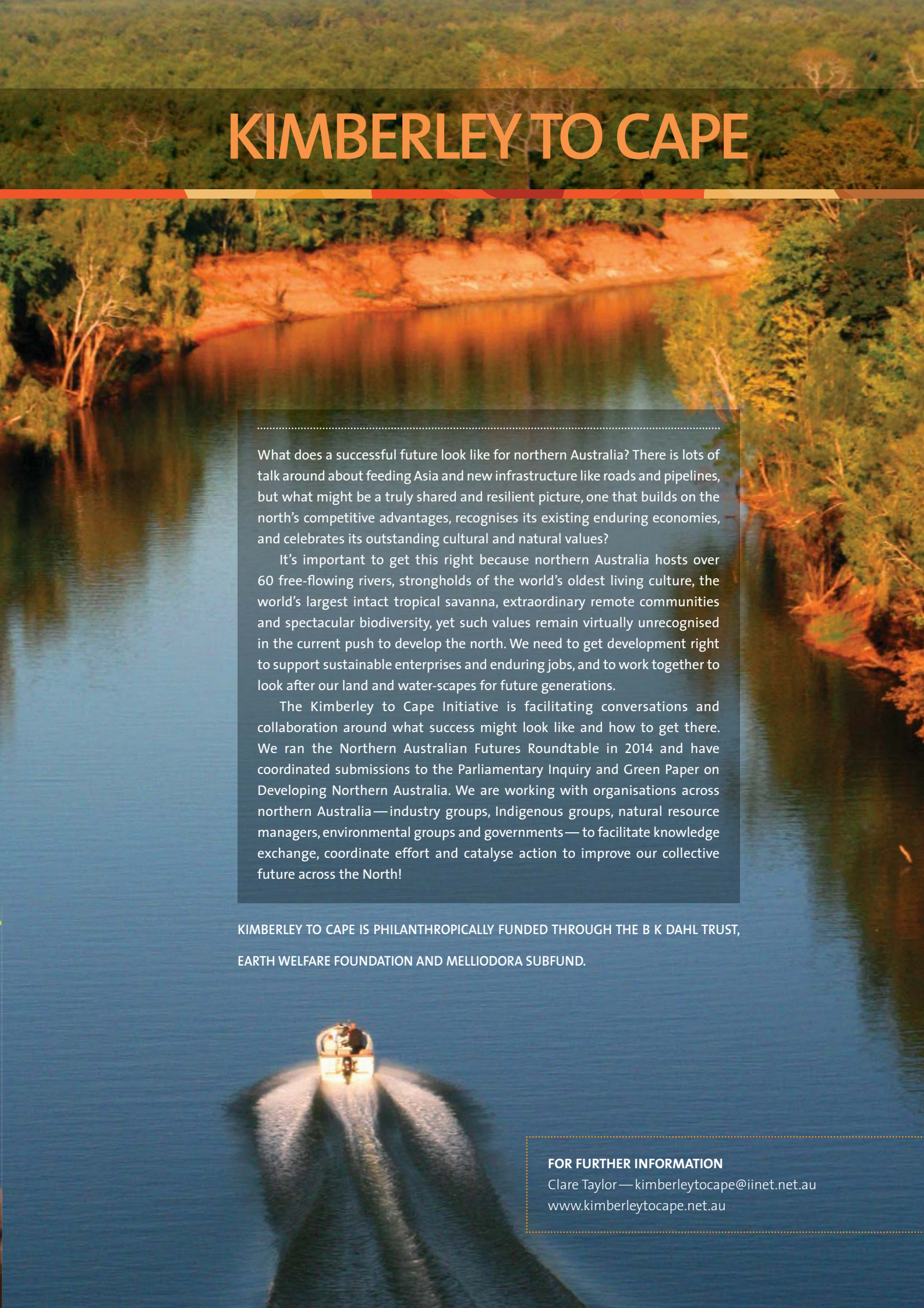
KIMBERLEY TO CAPE

What does a successful future look like for northern Australia? There is lots of talk around about feeding Asia and new infrastructure like roads and pipelines, but what might be a truly shared and resilient picture, one that builds on the north's competitive advantages, recognises its existing enduring economies, and celebrates its outstanding cultural and natural values?

It's important to get this right because northern Australia hosts over 60 free-flowing rivers, strongholds of the world's oldest living culture, the world's largest intact tropical savanna, extraordinary remote communities and spectacular biodiversity, yet such values remain virtually unrecognised in the current push to develop the north. We need to get development right to support sustainable enterprises and enduring jobs, and to work together to look after our land and water-scapes for future generations.

The Kimberley to Cape Initiative is facilitating conversations and collaboration around what success might look like and how to get there. We ran the Northern Australian Futures Roundtable in 2014 and have coordinated submissions to the Parliamentary Inquiry and Green Paper on Developing Northern Australia. We are working with organisations across northern Australia — industry groups, Indigenous groups, natural resource managers, environmental groups and governments — to facilitate knowledge exchange, coordinate effort and catalyse action to improve our collective future across the North!

KIMBERLEY TO CAPE IS PHILANTHROPICALLY FUNDED THROUGH THE B K DAHL TRUST, EARTH WELFARE FOUNDATION AND MELLIODORA SUBFUND.



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Listen to what the research tells us

DR RICHARD CRESSWELL

IS A FELLOW OF THE PETER CULLEN TRUST AND WAS PART OF THE TEAM CONTRIBUTING TO THE NORTHERN AUSTRALIA LAND AND SCIENCE REVIEW.

Development of water resources for use in agricultural enterprises in northern Australia should be based on existing scientific and economic research findings. A key recommendation (no. 4) of the Joint Committee on Northern Australia[1] is 'that the Australian Government gives priority to the development and funding of water resource proposals that have been scientifically identified as being sustainable …'.

Over many years there have been several assessments of the potential for developing water resources in northern Australia. Most recently, around five years ago, a team including CSIRO scientists identified the importance of groundwater for many northern systems, and the critical nature of surface–groundwater interactions.

Our team found that 'the development of irrigated agriculture in northern Australia is limited by water availability and poor soils. The best development option for agriculture might be small cropped areas, irrigated with groundwater, and scattered over the landscape'. In its Northern Australia Land and Water Science Review[2], for the Australian Government, the team also found that there is great potential for sustainably increasing groundwater use for development.

The Ord River scheme in northern Western Australia is one example where science—and experience—should be heeded in developing the north. Here, *too much* groundwater is likely to be a concern for the Ord River Irrigation Scheme, because science predicts that irrigation from the Ord River will drain too much water through the landscape.

The Ord scheme continues to cause concerns both politically and environmentally. Damming the Ord River is certainly generating sustainable hydro-electric power for the Argyle Mine and Kununurra, but on the downside the now perennial river is perfect for proliferating Weeds of National Significance. Further, the reduction of major outflows to the Bonaparte Gulf has decimated the coastal prawn fisheries.

BELOW: WALL OF THE ORD RIVER DAM. PHOTOS IN THIS ARTICLE RICHARD CRESSWELL.

1. www.aph.gov.au/Parliamentary_Business/Committees/Joint/Northern_Australia
2. www.regional.gov.au/regional/ona/nalwt_files/337388_NLAW_Review_2009.pdf

Conditions in the north include year-round heat, extreme wet and dry seasons, soils of generally low and variable fertility and opportunistic wildlife. These factors all favour adaptable labour-intensive farming practices. Numerous attempts to grow food crops within the Ord scheme (and similarly in the Daly River scheme in the Northern Territory) have succumbed to these conditions, and agriculture currently defaults to mainly tree crops. Only in a few small areas are limited-demand high-value food crops being grown (such as chia seeds). If the entire Ord scheme goes ahead, the irrigated area will still be only three per cent of the area irrigated in the Murray-Darling Basin. The on-going question is whether the Ord can stack up under full cost–benefit analysis.

The Joint Committee on Northern Australia recommends (no. 23) 'that large-scale extraction of water from the river systems and aquifers in Northern Australia needs to be preceded by thorough scientific evaluation' and that (no. 4) priority be given to those 'water resource proposals … with the strongest cost–benefit case, and consistent with National Water Policy'.

The next step is to ensure that those recommendations are heard and acted upon.

FOR FURTHER INFORMATION
www.petercullentrust.com.au

PHOTO PETER CULLEN TRUST.

Peter Cullen Trust Fellows: leading in water and environment

The Peter Cullen Water & Environment Trust trains current and emerging leaders in water and environment. The Trust's acclaimed 'Science-to-Policy Leadership Program' has produced 72 graduates during 2010–14. They enter the program as 'rising stars' in their professions, and emerge — with improved leadership skills — as Fellows of the Peter Cullen Trust. Over the five years, 20 employers or others have sponsored participants.

Fellows lead in science, policy and communication, and are found in regional areas and metropolitan centres across Australia. They have formed a national network to support each other in their work for the benefit of Australia's water resources and environment as a whole.

The leadership programs comprise two intense weeks during spring, in two locations, indoors and outdoors. Training culminates in the graduation event held in November in Canberra at which the participants — now the new Fellows — interact with invited senior personnel in science, government, policy and the community.

For further details of the program — www.petercullentrust.com.au

Everyone is invited to the annual graduation event where new Fellows present the results of their program. Further information is available on the website.

To sponsor an applicant, please contact CEO Dr Sandy Hinson 02 6206 8606 or sandy@petercullentrust.com.au

The Peter Cullen Water & Environment Trust was formed to carry on the work of the late Professor Peter Cullen AO, who excelled in leadership and communication. The National Water Commission provided the Trust's initial funding in 2009.

A LOCAL PERSPECTIVE on development pressures

DAMIEN BURROWS

In recent years, there has been a significant and growing interest in developing northern Australia. The level of such interest has waxed and waned over 150 years or so, but this time it feels more persistent. In the present debate, we seem to have concluded, and this appears to have become fixed in the mind of the general public that northern Australia is dry, remote, undeveloped, and with limited infrastructure and other requirements to support substantial development. While that well describes most of northern Australia, there are significant sections that do not meet that description.

It is interesting, for example, that Cairns, which is geographically located in the north, is not always thought of as truly northern Australia. We have come to define northern Australia by its remoteness, yet this is an incomplete and distorted picture of the thriving urban centres and agricultural enterprises that exist in some northern areas. If you drive from Sarina (south of Mackay) to the Daintree (north of Cairns), a journey of some 11–12 hours, you will (apart from dry sections surrounding Townsville and Bowen) pass through an otherwise unbroken chain of agricultural development with numerous thriving urban communities. That level of development does not disqualify it from being 'northern Australia'.

Townsville and Cairns are the 13th and 14th most populous cities in Australia, with four major and a dozen minor towns in between. They are easily reached by air, road, rail or sea. They may be a long journey from 'southern Australia', but they are not remote.

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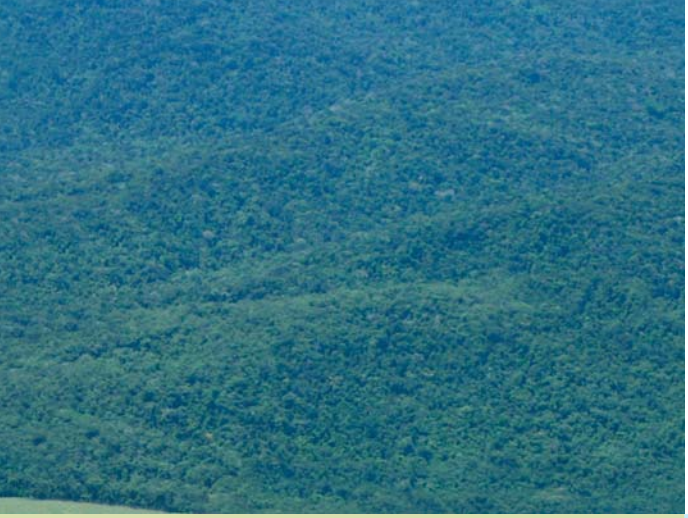

The two largest extant irrigation schemes in the north—the Burdekin and Mareeba-Dimbulah—are centred within a one-hour drive from Townsville and Cairns respectively, not to mention the extensive agriculture of the coastal floodplains between these two cities. Two of the biggest agricultural developments proposed for northern Australia (in the Flinders and Gilbert catchments) are within five to six hours drive of these two cities. Likely future development is not even that far afield. The Burdekin Falls Dam, already the second largest in northern Australia, is just two hours from Townsville. Raising its existing dam wall by just two metres would double its storage volume, and there are ample suitable soils and existing infrastructure to support this expansion. The proposed Nullinga Dam, one of the high priorities of the federal government's northern agenda, is just one-and-a-half hours from Cairns, set amongst an already well-established irrigation area.

Northern Australia is a diverse landscape across a huge area that cannot easily be defined. Not all of it is as pristine as usually portrayed. I am not saying that I welcome irrigation expansion and altering river flows, only that in the debate, we must recognise that parts of northern Australia have been successfully developed. These areas will be the focus for further development and we can learn from the experiences of these industries to inform likely future expansion. As scientists, we risk betraying an inner green ideology if we adhere to old mantras about the north not being suitable for development, and that all the rivers likely to be targeted are wild. Each proposal should be assessed on its merit, not pre-judged by history or the romance of wild and remote rivers.

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FRESH partners

RESEARCHERS FROM THE UNIVERSITY OF WESTERN AUSTRALIA'S **CENTRE FOR EXCELLENCE IN NATURAL RESOURCE MANAGEMENT** BRING NEWS OF THE COLLABORATIVE RESEARCH PARTNERSHIPS BETWEEN TRADITIONAL CUSTODIANS AND WESTERN SCIENTISTS THAT ARE DEVELOPING NEW MONITORING AND MANAGEMENT PRACTICES.

Michelle Shaw in the pink shirt with two women Nyul Nyul Rangers sampling macroinvertebrates and fish at Ngilbardiny spring. Photo Neil Pettit.

Nyul Nyul people have lived on their country —around Beagle Bay on the Dampier Peninsula in the Kimberley region—for thousands of years in a deep relationship with the ocean, rivers, waterholes and Pindan bushland that sustain them. Wetlands are identified as being important not only as a water source for people and all life, but as a central part of the Nyul Nyul people's identity. They are special places providing habitat for hunting and fishing, and supporting many different plants that are valuable as food, medicine, or materials. Wetlands are places of learning, family time and play, as well as being a source of memories from past times.

Since 2013, through funding from the Northern Australia Hub of the National Environmental Research Program (NERP) and the Hermon Slade Foundation; researchers from the University of Western Australia, Griffith University, and I-Tracker staff from the North Australian Indigenous Land and Sea Management Alliance Ltd (NAILSMA), have been working with the Nyul Nyul Rangers to study the freshwater wetlands on Nyul Nyul country. The Nyul Nyul Rangers are part of the Kimberley Ranger Network, facilitated by the Kimberley Land Council, and are employed to manage their country.

Nyul Nyul Rangers and Traditional Owners are committed to the management of their country and invited the project team, including The University of Western Australia's (UWA) Centre for Excellence in Natural Resource Management (CENRM)—with ongoing research interests in river ecology and collaborations with Indigenous ranger groups in the Kimberley—to work with them to better manage and monitor wetlands by combining Western science and their traditional knowledge.

CENRM's Dr Neil Pettit—and colleagues Fiona Tingle, Rebecca Dobbs, Professor Brad Pusey, Dr Paul Close and Michelle Walker, along with Christy Davies from NAILSMA —made three trips to Beagle Bay, each lasting about a week. The Nyul Nyul Rangers and research team worked together to sample a range of freshwater habitats across the Rangers' operational area. This provided the opportunity for Nyul Nyul Rangers to introduce researchers to these freshwater systems, and combine scientific sampling of baseline data with Indigenous ecological knowledge, to gain a broader understanding of the biodiversity and pressures/threats to these systems.

Nyul Nyul Traditional Owner, Rangers and researcher at a local waterhole. Photo D. Tunbridge.

For Traditional Owners, the Indian short-finned eel (*Anguilla bicolor*), known locally as Nigilibuninj/Nigilbardiny, is an indicator of healthy wetlands. It is an important totemic species, and this significance is highlighted by its inclusion in the Nyul Nyul Ranger logo. While this species is common in the Fitzroy River drainage basin (and potentially elsewhere in the Kimberley region), it is not widespread across northern Australia.

During their expeditions to the Kimberley, the research team, comprised mainly of freshwater ecologists, learned a great deal from the Nyul Nyul men and women.

"They had so much knowledge they wanted to share and were keen to educate Western scientists in the importance of acknowledging cultural values. The area is full of special sites and important animals for them. Some of the wetlands are ground-water fed and have water there all year round," Neil Pettit said.

The team learnt that the Nyul Nyul people were worried about the future of their wetlands; and particularly concerned about how the development of water resources in the region—one of the key pressures across the northern Australian landscape—would take away the water from their waterholes. To address concerns about the potential negative impacts of future water demands, monitoring programs were established to allow the Rangers to assess changes in water quality, vegetation health, aquatic macroinvertebrates and fish communities.

By working together on country knowledge was exchanged, baseline ecological data was collected, and information about the wetlands documented. Sampling methods and monitoring tools were developed to provide the Nyul Nyul Rangers a means of detecting any change in the condition of waterholes over time. The collaborative approach to field work, as well as the integration of cultural knowledge and Western science, further developed the capacity of Nyul Nyul Rangers to manage country. Developing these skills is important, as working at the landscape scale is difficult, across areas of mixed land tenure and management responsibilities. This means that Rangers need to learn how to manage different views about many factors, for example, fire management, invasive species management, stock incursions from other properties, allocating funding, building community capacity, and preventing the loss of knowledge through people leaving the region (particularly through staff turnover within the ranger group). There are also often competing views in communities about vegetation and animal management (invasive animals versus a food supply).

By working together, Rangers and scientists are continually learning about the Kimberley region; from its inherent and varied values, to how best to sustain them into the future. It is a unique and expansive landscape, encompassing a large network of Traditional Owner groups, each with specific knowledge of the cultural and social needs underpinning approaches to environmental management. This knowledge is being shared in the wider scientific community, and capacity is being built within the Ranger group to share that knowledge. Rangers are now confident enough to deliver presentations at both international (World Indigenous Network conference, Darwin 2013) and national (Australian Society of Limnology and Australian Society of Fish Biology Joint Congress, Darwin 2014) conferences.

> "We are freshwater people but also connected with the sea, which is special and unique."
> (NYUL NYUL RANGERS)

Nyul Nyul Rangers are now passing on the skills they have learnt through the project to other Rangers. It has also given them the opportunity to pursue fee-for-service work with government agencies. Photo Mark Rothery.

"There are women as well as men rangers. We were pleased to see that the young people have a strong feeling for their land. Our research in northern Australia contributes to the knowledge base, providing the science of wetland ecology as well as baseline data crucial in a changing climatic and developmental landscape," Neil said.

Developing practical tools to assist Rangers

CENRM has been undertaking ecological research and working with Indigenous people to help manage their lands in the Kimberley for the last eight years through collaborative initiatives such as Tropical Rivers and Coastal Knowledge, the Northern Australia Water Futures Assessment, Framework for Assessing River and Wetland Health and Northern Australia Sustainable Yields project. These programs have included numerous Indigenous Ranger groups, local communities, government agencies and scientists based at UWA, Charles Darwin University, Griffith University and CSIRO.

Research projects under these initiatives have included investigations into groundwater/surface water interactions, environmental water requirements of aquatic biota, food webs, and the development of tools and processes for identifying ecological assets and Indigenous values of water. This information has been used to develop a range of applications for planning, on-ground training, collaborative management and integrated on-ground management.

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Rebecca Dobbs—a CENRM researcher living and working in Kununurra—has coordinated the Waterways Education program since 2009. Developed as a collaborative partnership between CENRM and the Western Australian Department of Water, the program has built the expertise and capacity of local and regional communities to identify environmental management issues, implement standard ecological monitoring techniques, and integrate traditional knowledge and values into the broader management of natural resources across the Kimberley region.

The program was delivered using four key themes: waterways awareness, training, research and management, and long-term monitoring. These themes were developed following extensive consultation with stakeholders, and were designed to accommodate the unique capacity and requirements of stakeholders in the Kimberley, recognising participants' existing skill levels, knowledge and needs, as well as having on-ground applicability and relevance.

The delivery of the program—through training, workshops, on-ground delivery and follow-up support—was highly successful and obtained the support of a large number of stakeholders from across the Kimberley, including government and non-government agencies, land councils, language centres, Indigenous Protected Areas (IPAs) and schools. The program continues to contribute to the objectives of initiatives such as IPA planning and management priorities under Working on Country Indigenous Ranger programs.

Over time, the program has progressed from the initial focus on training in data recording and monitoring, to now producing a data analysis tool that enables Rangers and the community to assess the success of management actions and undertake adaptive

Right: Boat electrofishing at Nyul Nyul waterhole. Photo Neil Pettit. Far right: Sorting macroinvertebrates. Photo D. Tunbridge.

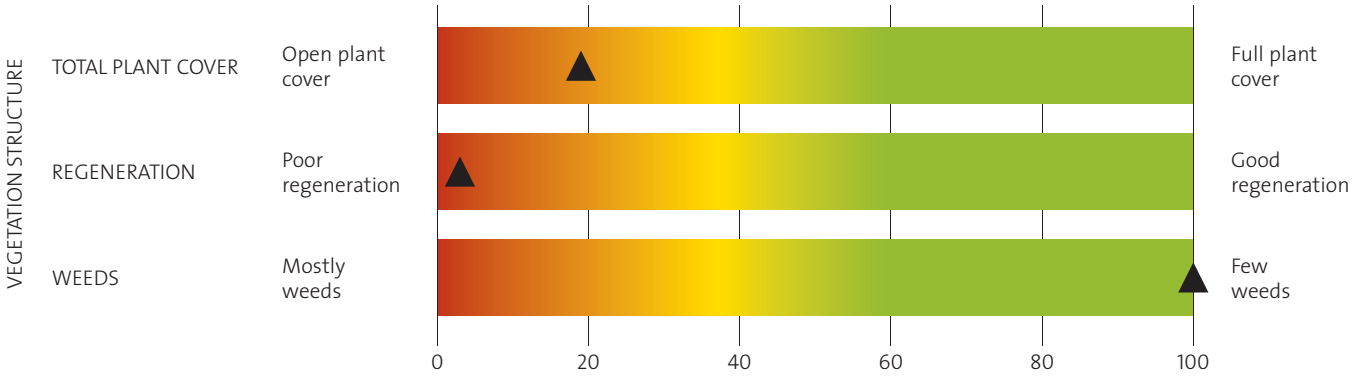
management. The program also includes tools to assist in interpreting the information collected using an I-Tracker application created specifically for this purpose. The I-Tracker program (short for Indigenous Tracker) is an initiative of NAILSMA and was developed to support Indigenous land and sea managers in the collection, management and reporting of environmental and cultural data (www.nailsma.org.au/hub/programs/i-tracker); by using freely available CyberTracker software (www.cybertracker.org/software/introduction).

An analysis of riparian vegetation, for example, has been designed to calculate index scores for plant cover, regeneration and weeds. These scores are calculated and graphed automatically by a Microsoft Excel spreadsheet that the Rangers copy and paste directly into, after extracting the pre-formatted monitoring data from the I-Tracker database. The selection of indices and calculation of condition scores align with Western science methods used more extensively across northern Australia. The visual representation of the data is represented by range bars to show the variation in scores.

This allows Rangers to track changes visually, and pick up significant changes at a site that may warrant further investigation by examining the raw data, and also taking into account changes across seasons. With the ability to document changes, Rangers are better able to prioritise on-ground work, which is also important when developing funding applications.

With continued uncertainty, a lack of knowledge of the possible effects of a changing climate, and increased pressure for regional development, there is a need to strengthen ecological-social resilience in northern Australia. Ultimately, it is hoped that this work will contribute to collaborative management of aquatic ecosystems by developing methods that build on commonalities and differences between Indigenous and Western science understanding of these ecosystems. This approach will provide synergies of local knowledge and capability, management and environmental monitoring and research and ensure it is relevant and acceptable to all stakeholders.

Below: Visual representation of riparian and aquatic vegetation scores.



The research team thanks the Nyul Nyul Rangers and Traditional Owners for welcoming them onto country and sharing their traditional knowledge. Article authors are Rebecca Dobbs, Fiona Tingle, Neil Pettit, Christy Davies and Paul Close.

Partnerships help wetland health

RESEARCHERS ARE WORKING ALONGSIDE INDIGENOUS RANGERS TO ACHIEVE HEALTHY COUNTRY OUTCOMES IN NORTHERN AUSTRALIA.

Peter Liddy is a Traditional Owner on Lama Lama country in far north Queensland. He has a long spiritual connection with his country and brings a wealth of knowledge to his role as a ranger. His work allows him to follow in the footsteps of his grandfather, who is buried on the land.

"I get visits from him now and then, he sort of encouraged me to stay down here, you know, be part of the country like he is," he said.

"They were, sort of, really strong in their way. You know, they didn't know about pest plants and that, but now we know about it we start doing something about it, looking after the land…"

Special places

Northern Australia is home to enormously diverse and plentiful wetlands, many of which have thankfully escaped the impacts of large-scale developments. These freshwater habitats in Cape York are of high cultural significance to the Lama Lama people; providing a connection to country.

"A lot of our lagoons around here are sacred sites… and all of our bush tucker comes from around this place too, even the medicines we've got around lagoons," Peter Liddy said.

The ecological health of wetlands is, however, being put at risk by threats including feral mammals, weeds, grazing and historical small-scale mining activities. Managing these threats is a high priority for the Lama Lama Rangers.

Unique opportunities

The growing workforce of Indigenous land and sea rangers represents an unprecedented opportunity to better manage and monitor biodiversity across northern Australia. While rangers across the north undertake critical on-ground management actions such as feral animal control, often there is little or no baseline data against which they can measure their success.

Valuable data is now being generated through ongoing freshwater monitoring. For over three years, the Yintjingga Aboriginal Corporation's Lama Lama Rangers have been working together with researchers and other experts to develop new tools to keep track of, and better manage wetland health.

This has been an opportunity not only for the rangers to gain valuable expertise, but for the researchers to learn about freshwater places from local people who have relied on these sites for food, clean drinking water, and spiritual fulfilment for thousands of years.

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"It's just like, you're learning my way and I'm learning your way."

PETER LIDDY

Tradition meets science

The rangers have partnered with the North Australian Indigenous Land and Sea Management Alliance Ltd (NAILSMA), local natural resource management group South Cape York Catchments, and experts from Griffith University, with funding under the Australian Government's National Environmental Research Program, to better meet their wetland management needs, primarily through an improved capacity to monitor wetland condition.

The result has been the development of a rapid assessment technique to assess the condition of their wetlands, which is supported by a customised 'I-Tracker' application created using world-renowned CyberTracker software.

Short for Indigenous Tracker, the I-Tracker program is an initiative of NAILSMA that was developed in response to requests from Indigenous land and sea managers for culturally appropriate and scientifically robust tools to record, analyse and map data.

NAILSMA Executive Chair Peter Yu says too often in the past, data was collected about Indigenous people and their land, but remained inaccessible to them.

"The I-Tracker program is a commitment to ensuring that knowledge and data remain in Indigenous hands and can be used to address their priorities," he said.

The software is coupled with field-tough hardware, ideal for use in remote areas.

"These tools improve the way people can collect and manage both natural and cultural information. Looking ahead, it will allow rangers to continue to monitor their wetlands, without scientists or experts coming out to help them," Peter Yu said.

Positive signs

Feral pigs are especially problematic to the health of wetlands on Lama Lama country. They dig up soil in their hunt for food and damage large areas in the process. Wetlands that used to hold water most of the year were drying up much more quickly due to substrate disturbance. Wildfires, grazing and water extraction for road maintenance were also impacting some areas.

To combat these impacts, the rangers have been fencing off some wetland areas from pigs and other feral animals, and have been monitoring the changes since. Peter Liddy says the results have been encouraging.

"When we first did our assessment, we were doing it in the middle of the lagoon, because it was bone dry. But it's real good now, there's water holding every year."

Looking ahead

Long-term results from this freshwater case study, as well as another case study on Nyul Nyul country in the Kimberley region of Western Australia (see page 46), will help shape and inform local freshwater policy and allow for more informed management of these resources.

Through this collaborative work, the rangers have become more skilled in scientific monitoring and data management. Ongoing work will generate baseline data which can then be used to detect changes resulting from future management actions such as feral animal control.

Peter Yu says the Lama Lama case study is a fine example of Western science and traditional knowledge systems working hand in hand to achieve sustainable conservation and management outcomes across northern Australia.

"By working together, we can build on our contributions to a resilient and thriving future that benefits the entire community."

OPPOSITE: A HEALTHY WETLAND ON LAMA LAMA COUNTRY. **TOP RIGHT**: RESEARCHER CHRISTY DAVIES WORKS WITH RANGERS JOHN GRAHAM AND BRYAN KULKA TO MONITOR WETLAND HEALTH. **BELOW**: RESEARCHER JESSIE PRICE SITS WITH RANGERS LEON AND PETER LIDDY (RIGHT) WHO TAKE PRIDE IN MANAGING THEIR TRADITIONAL COUNTRY.

ALL PHOTOS MICHAEL LAWRENCE-TAYLOR.

WORKING WITH LAND UPSTREAM

HELPING WATER DOWNSTREAM

SCOTT WILKINSON FROM CSIRO TALKS ABOUT HIS RESEARCH ON GRAZING LAND IN THE WET-DRY TROPICS TO COMBAT EROSION AND IMPROVE COASTAL WATER QUALITY.

Above: Grazing landscape in the Burdekin River basin. Hillslope surfaces are a minor source of sediment provided coverage of perennial grasses is maintained. The majority of erosion occurs in degraded bare areas, gullies and streambanks. Photos Scott Wilkinson unless credited otherwise.

In early 2013 I had a cuppa with a grazing family on their property deep in the wet-dry tropics catchments that drain to the Great Barrier Reef. After several years of above-average rainfall, the grass down on the flats was thick and tall, so much so that it was taking more rain than usual to deliver surface runoff into dams. This property had transformed since the 1990s drought, when bare soil was exposed to an empty sky. At that crunch-point, a new generation had come to the reins, with new ideas about running the property focused on the long-term future for themselves and the next generation. The family's decision to destock and allow the land to recover had now paid off and the pasture is today producing more forage than it has in a long time.

Sadly, not all properties have bounced back to this degree, and after a wet period the climate cycle has turned again in the past two years. On many grazing properties the legacy of successive droughts has been ongoing soil erosion, and a transformation of pasture grasses from native perennial tussocks to annuals or colonising species. These colonising species can spread rapidly, but don't grow as much forage or survive dry years as well. They often have shallow roots and small basal areas which are less effective at retaining soil and runoff during intense rainstorms.

Sediment loads in many of Australia's tropical river basins are now several times higher than those before the 1850s. In some areas especially along the Great Barrier Reef, ecosystems are struggling under the extra load. Coral cover has halved since the 1980s, due to crown-of-thorns starfish (COTS) outbreaks, cyclones, and so far a relatively small amount of thermal bleaching. COTS outbreaks have followed large floods, which deliver considerable amounts of nitrogen in particulate and dissolved forms. Water clarity, coral diversity and coral disease are also affected by fine sediment loads and organic matter. Coastal water quality has been shown to recover between flood events and this means that aquatic ecosystems will benefit if erosion rates are reduced across extensive grazing areas.

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Top: Gully, scald and rill erosion in the Burdekin River basin. Above: Surface runoff from grazing land into a gully. Photo Rex Keen.

Management changes can improve pasture productivity and downstream water quality

A robust understanding of land use impact on water quality is essential to guide public investments and to galvanise private efforts. While sheetwash erosion of grazing lands was once thought to be the dominant source of sediment delivered to the Great Barrier Reef lagoon, source tracing studies have revealed that most river sediment is derived from subsoil in channel banks, gully networks which developed in the late 1800s after the introduction of livestock grazing, and deeply rilled and degraded zones covering a small proportion of the catchment area. Similar findings have been made in the Ord catchment in Western Australia. These dominant erosion processes are much the same as those that catchment management agencies have become familiar with in temperate Australia.

We now know that managing sheetwash erosion will not be enough to effectively reduce sediment loads in tropical Australia. It is easy to query 'what can we do about gullies', which have often been present for many decades, but a targeted and low-cost approach to erosion management can be effective if taken up as a priority.

Rehabilitating vegetation can shield subsoil erosion features like gullies and riverbanks from surface scour, trap seeds, and build root systems that reinforce soil and moderate soil moisture, increasing soil stability. Locating fencing to control grazing access is an essential first step. Low-cost revegetation techniques are currently being trialled in gullies, including porous timber or stone traps. Planting may be required in very degraded areas. Intense grazing followed by long rest periods is being trialled in higher-rainfall areas. Tropical Australia also requires some important adaptations. Large floods and extensive properties mean that it can be more feasible to fence the floodplain in with the river, not just the riparian zone. Techniques will continue to develop, but we will need to see more targeted rehabilitation of channel erosion.

Upslope from gully and bank erosion, the runoff volumes which drive erosion can be reduced by maintaining high levels of perennial tussock grass biomass, and retaining woodland trees. High surface roughness, large root systems, and healthy soil biota increase the size and availability of the soil moisture store, reducing runoff volumes in the most common small to medium events.

Managing biomass means managing grazing pressure, which is a big challenge in the extremely variable climate of northern Australia. Independent of whether continuous stocking or rotational grazing is practiced, informed decision making requires a 'forage budget'. This is an annual or seasonal calculation of how many cattle can be supported for what period before the proportion of available biomass removed by grazing will exceed a threshold (commonly 20–30 per cent) that puts pasture sustainability at risk. Cattle numbers in northern Australia are near record high levels, and need to be managed to sustain hydrologic function and forage production.

Above: Installing porous check-dams to initiate revegetation on the bed of a gully, Burdekin River basin (reproduced from Wilkinson et al., 2013, *Gully erosion and its response to grazing practices in the Upper Burdekin catchment*, CSIRO Water for a Healthy Country).
Below: Fencing is highly effective at controlling grazing pressure to maintain high biomass and ground cover in areas vulnerable to erosion such as gullied areas and streambanks (reproduced from Thorburn et al., 2011, *Prioritising practice changes in reef rescue*, Water for a Healthy Country Flagship Report, CSIRO).
Bottom: Controlling stock access is a priority for managing streambank and gully erosion.

This big place deserves our best efforts at managing water quality.

Working with the landscape

The twist in the tale is that grazing impact is never uniform due to variable distance to water and preferential grazing of 'sweeter' country. The landscape resistance to erosion also varies with terrain and soil. To graze within the erosion resistance and productive capacity requires tailoring land management to each landscape unit. Fencing is critical to distribute grazing pressure away from vulnerable areas like gullies and frontages.

The good thing for graziers is that rehabilitating vegetation to control erosion is complementary to sustainable forage management. Fencing and water points enable pasture resting, as well as controlling the distribution of grazing. Maintaining pasture at high biomass levels reduces erosion and runoff, but also expands the capacity of soil and plants to store and retain moisture and nutrients, which better supports plant and protein growth in the weeks and months after rainfall. Grazing within the land's carrying capacity has been shown to deliver more reliable and higher profits in the long run. For large properties worth millions of dollars, the long run is a big deal.

Strengthening adaptive management

Our work with landholders in the tropics is showing that erosion management in grazing land needs to focus on rehabilitating vegetation within legacy problem areas such as eroding gullies. Minimising grazing pressure is essential in these areas; elsewhere it should be managed to sustain pasture productivity and reduce surface runoff. This approach can produce a win-win outcome for landholders and the environment by improving pasture productivity and sustainability. As yet, we have little hard data on erosion responses to these management strategies in tropical Australia. Monitoring and learning about the responses should underpin adaptive management, to ensure effective and efficient land management policies and programs. While there are many challenges, many freshwater and coastal environments across northern Australia remain in relatively good shape.

SYSTEM REPAIR IS THE NEW BLACK

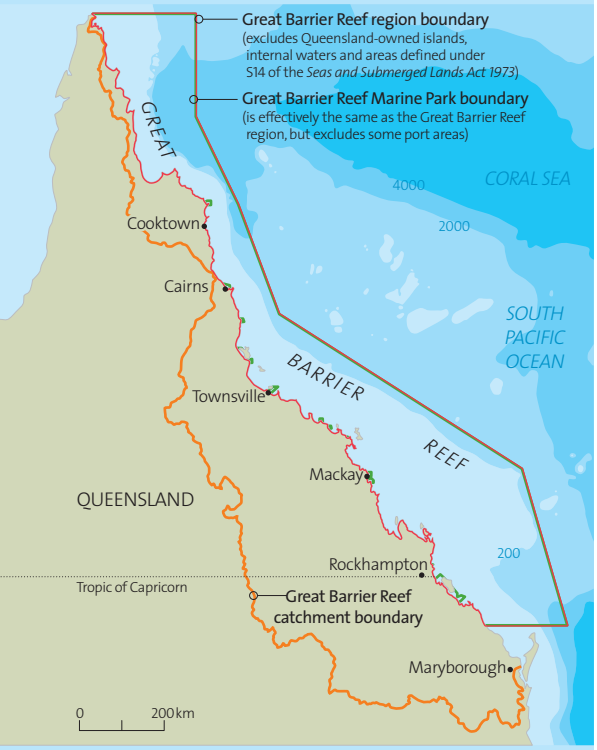
MANAGING THE GREAT BARRIER REEF HOLISTICALLY IS, ACCORDING TO **DONNA-MARIE AUDAS**, THE NEW 'BLACK' OF SYSTEM REPAIR.

PHOTOS THROUGHOUT COURTESY OF GBRMPA.

System repair is the new black. It's exciting that we are now talking about the values and services that the Great Barrier Reef (referred to as the Reef) catchment provides to support a healthy Reef. Managing the health of the Reef has often been defined by issues such as water quality, salinity and acid sulphate soils. Programs and projects have been, and continue to be, initiated to address these issues; however, they are often in response to a single issue and, as a result, are very targeted and focused.

Over the last six years, the Great Barrier Reef Marine Park Authority (GBRMPA) has been working to change this single issue focus with the introduction of programs that seek to consolidate and understand the values, functions and services provided by the Great Barrier Reef catchment, and how these physical, biological and biogeochemical processes support the health of the Reef.

GBRMPA is a marine agency that focuses on managing a multi-use marine park in perpetuity. GBRMPA is acknowledged as a world leader in marine park management. In 2009, the agency released the Great Barrier Reef Outlook Report which highlighted water quality and coastal development as two major threats to the health of the Reef. These issues were also identified again as high priorities in the most recent 2014 report.



In response to the 2009 Outlook Report, GBRMPA began analysing existing spatial data to understand the changes that have taken place in the adjacent Reef catchments. Understanding what it would have looked like in its natural state and what has influenced these changes, is important for guiding management. The catchment is approximately 424,000 square kilometres in area (see map) and has been heavily modified since European settlement, especially south of Cooktown. The Great Barrier Reef catchment continues to experience pressure from agriculture, industrial uses, urban expansion, and mining development and its associated infrastructure. Mapping of the Queensland regional ecosystems in 2009 indicated that about 64 per cent of the vegetation in the Great Barrier Reef catchment remains intact; however, these figures are heavily skewed due to the apparent intactness of the Cape York Peninsula north of Cooktown. Further analysis shows that although large areas of the catchment are intact, with almost 10 per cent within protected areas, open grazing occurs across most of these ecosystems as 74 per cent of the catchment is grazed, with most of the remaining areas under other developed land uses.

Major changes and modifications have occurred in the coastal zone, with land use activities such as cropping and grazing extending into marginal areas due to pressures to extend production. Many commercial and recreational fish species require marine, estuarine and freshwater habitats, and the connections between them for part of their life cycle. For example, species such as the Mangrove Jack have been found to migrate inland up to 140 kilometres and travel back to the marine environment to reproduce.

At the local scale, pressure from development has led to a high degree of modification to coastal ecosystems. Estuarine ecosystems have been altered to allow for expansion of extensive grazing and intensive agriculture through, for example, bunding that prevents tidal flow. These areas can then retain fresh water, but can be poorly drained and choked with weeds, resulting in poor water quality. These changes reduce the feeding areas for many aquatic species, which in turn may be impacting on commercial and recreational fisheries. Importantly, around 33 per cent of saltmarshes, which are key fish and crustacean foraging areas, have been bunded to increase the extent of grazing land, and further areas have been cleared for sugarcane. Increased delivery of sediment, nutrients and pesticides to the Reef has been a major consequence of the land use changes and landscape modifications described above.

Floodplains in the catchment naturally slow the velocity of water and the associated sediment, nutrients and pollutants that run off the land. Land use change has, however, modified this natural hydrological function, largely in response to the need to redirect or remove water from developed areas. As a result, more water is typically moving faster out of the catchments, therefore scouring banks and changing the way water moves across the landscape. These changes have also altered processes such as the recharge of groundwater in the catchment, and increased the delivery of pollutants to the Reef.

Scientific studies indicate that poor water quality is impacting coral reefs, seagrass, dugong, turtles and some commercial and recreational fish species. Considerable amounts of funding have been allocated to monitor the status, extent and health of species and ecosystems important to the Reef and the enterprises reliant upon its survival.

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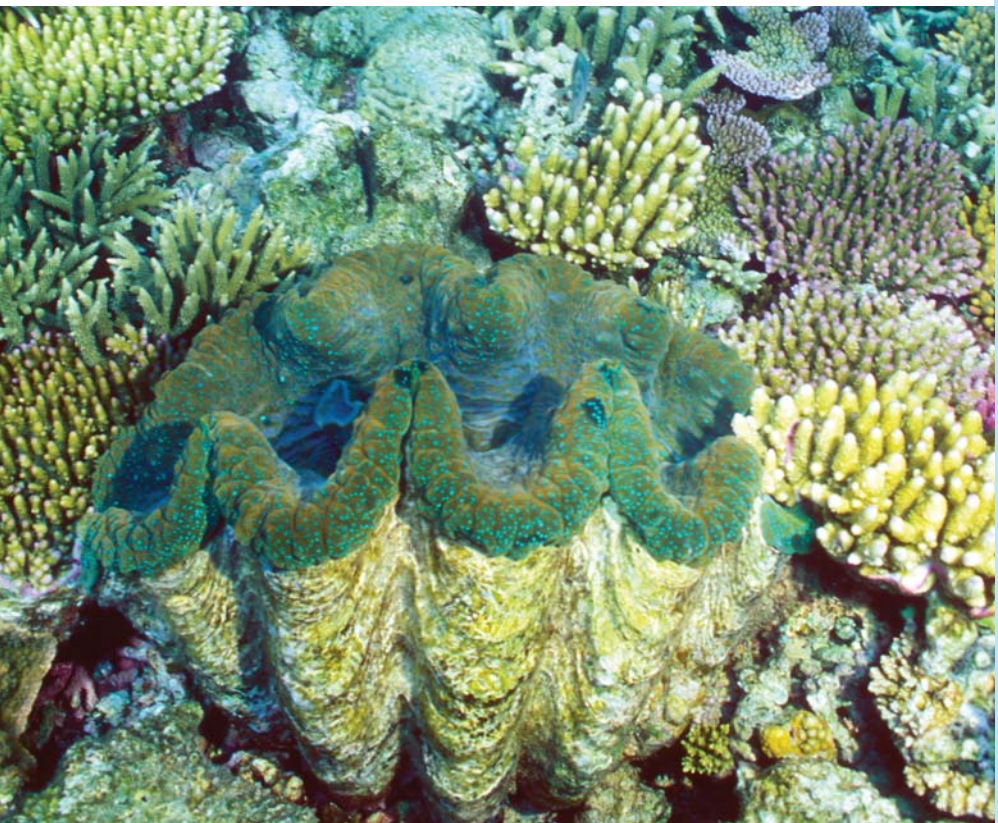
Taking action

Holistic management of the Great Barrier Reef and the catchment (Ridge to Reef) is required to address declining water quality and to restore many of the lost ecological processes that traverse the Reef landscape. The Australian and Queensland governments have been working with agricultural industries to halt and reverse diffuse source pollution (sediment, nutrients and pesticides), with funds allocated through a range of programs to address declining water quality in the catchment. In addition, the recent *Reef 2050 Long-Term Sustainability Plan* recognises the role of coastal ecosystems and hydrological connectivity in maintaining important species and habitats in the Reef.

GBRMPA has been developing a suite of tools which includes 'Bluemaps' and an 'Ecological Processes Calculator'. The Bluemaps tool maps the frequency of hydrological connections in the pre-European state of the Reef catchment, based on existing data such as floodplain extent, highest astronomical tide, storm surge, Queensland wetlands and a wet vegetation signature (used as a proxy for groundwater dependent ecosystems). The Ecological Processes Calculator is a tool for eliciting expert opinion to assess the changes to ecological processes provided by catchment ecosystems that support the health and resilience of the Reef. Experts engage and populate the calculator by participating at workshops on a regional scale; this provides an opportunity to tailor the information at a basin scale. The calculator compares the capacity of pre-European (pre-clear) coastal ecosystem ecological processes, to those of a present (2009) catchment made up of natural and modified ecosystems using a relative scoring system. This information is then used with marine resource information to identify where ecological function and process has been modified or lost, and management actions can then be targeted to highlight areas for system repair. The calculator can also be used to estimate the impacts of improved practices (current best practice) on the ecological processes provided at a broad functional scale. The Bluemaps and calculator have been designed to be used together to assist in identifying areas in the catchment for protection, restoration or management of coastal ecosystems and their functions.



Initiatives such as the Queensland Wetland Program are working in collaboration with GBRMPA to better understand the extent, health and role of wetlands in filtering sediment, trapping pollution and sequestering carbon. A suite of tools has now been developed to map, measure, understand, rehabilitate and protect Queensland's wetlands. Wetland*Info* is a new web-based portal that provides this information online, and contributes to ensuring a consistent and coordinated approach to managing wetlands.

The future for system repair is exciting and ground breaking, and recognises that we need to forge and strengthen partnerships between agencies and stakeholders and work collaboratively to develop a strong understanding of the catchments in which we live.

As we move into a new era of catchment and marine management, GBRMPA's Coastal Ecosystems Program has highlighted the need for developing on-ground actions with our partners and stakeholders. This must be based on a holistic adaptive management approach, supported by consistent whole of system understanding and guided by an agreed toolbox of data and information. This type of understanding will allow for targeted on-ground works which will benefit the long-term health of the Great Barrier Reef. Clear focus is now on healthy catchment — healthy water — healthy reef.

YIRRALKA RANGERS
SUPPORTING COMMUNITIES

CSIRO RESEARCHER **MARCUS BARBER** HAS BEEN INVESTIGATING THE WIDER COMMUNITY BENEFITS OF THE YIRRALKA RANGER PROGRAM IN BLUE MUD BAY, NORTH EAST ARNHEM LAND.

Travel about 1000 kilometres in an easterly direction by road from Darwin and you'll find the homeland community Baniyala, situated in Blue Mud Bay, in north east Arnhem Land. The extremely remote homeland was established in the early 1970s as the home of the Madarrpa clan of the Yolngu people. As well as a school and shop, the community also has a ranger station, which is the base for the 10 Indigenous rangers employed by the Yirralka Ranger program. On any given day, you might find a group of women rangers grinding leaves from native trees to make bush soap while at the same time a group of men is keeping a close eye on the coast, looking out for illegal fishing activity. Though distinctively different activities, these groups not only share a uniform, but a goal: looking after their country.

The Indigenous Cultural and Natural Resource Management (ICNRM) sector is continuing to grow rapidly in Australia. The Yirralka Rangers deliver essential services to their community by managing and protecting environmental and cultural values on their homeland. These programs have been mostly supported for their environmental outcomes, however, the ranger program brings multiple benefits such as improved health and well-being which will be of interest to policy makers.

The full extent of the wider social, cultural, and economic benefits to the local community of rangers living in their homelands has not been assessed, until now. For the past three years CSIRO researchers, funded under the Australian Government's National Environmental Research Program have been working with the Yirralka Rangers, in an effort to understand the wider benefits of their activities. The results of the research are found in a report called 'Rangers in Place', as well as in a community-generated documentary called 'Let's care for this country'.

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Opposite page: Rangers on sea patrol and removing ghost nets. Photos throughout Marcus Barber and Ishmael Marika.

Origins of the rangers

The Yirralka Rangers were established in 2003 as one of a series of initiatives developed by Blue Mud Bay communities (particularly Baniyala) to better protect their country, especially against commercial fishing activities. A second initiative was a court case, which in 2008 saw Blue Mud Bay Traditional Owners awarded formal High Court recognition of their rights to the intertidal zone. This set a precedent for Indigenous coastal land across the entire Northern Territory. One Baniyala resident and Traditional Owner explained how the struggle for coastal rights and coastal management responsibilities are intertwined.

"[The court case] was launched here because of the fishermen going in to kill all the totems for Yolngu people, or to enter the sacred areas without knowing or without permission. That is why we need to protect the country with this [ranger] program. It is coming from the sea rights, following on from that."

The Yirralka Rangers now have over 50 staff living in 17 homeland communities, of which Baniyala is just one. Collectively, these rangers manage the 17,000 square kilometres of the Laynhapuy Indigenous Protected Area (IPA). Caring for the landscape and its people is an enormous and admirable task. The activities are diverse: coastal and sea country patrols, removing ghost nets, biodiversity monitoring, weed management and fostering intergenerational knowledge transfer are all among the key goals.

The community's experience

Previous work has already pointed to a number of significant benefits associated with ICNRM, including: improved physical and mental health outcomes; social benefits such as improved family structures; the mitigation of racism; and economic and livelihood benefits. While these benefits are clearly identifiable through existing studies, the evidence remains small, and is classified in different ways by different studies. To build a better picture of the wider outcomes produced by ranger activities, the researchers interviewed not only ranger staff, but their families and wider-community residents.

From the outset, there were a number of obvious benefits including; physical health from increased exercise, as well as economic benefits such as additional income and employment stability. Although significant, increased income came second to the primary goal of caring for country as the key benefit of the program for those interviewed.

"When I got that job, my family was proud. The money was second. They were really happy someone was looking after Gurkawuy," said one Yirralka-based Ranger.

"They [the rangers] are doing it for the future. Because those young ones who are coming, they will learn about this country, they will learn about the sea and the patterns and the designs, all the stories, it is all written here. I think it is really important—we are doing it for the future," said a homeland community elder.

Psychological benefits, such as increased confidence and pride, also took precedence over physical ones.

"Being a ranger, working as a ranger has been very enjoyable, I enjoy it very much, being a ranger, I suppose, you are feeling you are giving something back to the community, to the people of this country," said one homeland-based Yirralka Ranger.

Keeping culture alive

The Yirralka Ranger program is largely compatible with Indigenous cultural principles of landscape management and protection. This includes the ability for rangers to acquire and share important cultural and customary knowledge. One homeland-based Yirralka Ranger explained that the program is essential to ensuring cultural continuity.

"That is the most important—the ranger program as a structure for learning, for passing on the cultural values."

The program also reinforces key social and community principles by distinguishing both gender roles and aged-based ones, thereby reflecting existing cultural conventions. At its inception, the program was staffed by male rangers, but the role of female rangers has grown considerably since then.

"In terms of the men and women, some of the projects are together, some are separate. It is good to have both. They worked together doing lots of work around the ranger station— the women doing the nursery and cleaning up, the men doing other jobs like cutting the lawn," said one homeland-based Yirralka Ranger.

Female Yirralka Rangers making soap at Baniyala ranger station.

Living in the homeland

Many of the rangers work in the homelands where they are also Traditional Owners. Community elders say that to be truly settled in one place, you also need to work there. This allows rangers to not only look after their home, but to fulfil ongoing cultural obligations and foster relationships with family.

"I have a purpose to stay here. My family is here, I have a good job, a good environment," said one homeland-based Yirralka Ranger.

"When you are living in the big townships, there are a lot of negative things happening, and personally I prefer living here in the homeland. Living in the homeland gives us more freedom, and a healthy country is a healthy life," said another homeland-based Yirralka Ranger.

A key aspect of the benefits the ranger program brings comes from this local residence. Formal education and training, opportunities to travel, and future employment opportunities also broaden social skills, including the ability to interact cross-culturally.

"We need to know how to work with people who are not respecting the Yolngu law. We have to look at visitors, what they need, what kind of people they are," said a former Head Ranger.

Governance and cooperation

Contemporary Yolngu political life reflects both local autonomy and regional cooperation. A ranger steering committee provides opportunities for locals to gain experience in governance, planning and strategic decision making, while governance by elders in homeland communities reflects local independence. The benefits of improved confidence and pride, as well as the origins of the program, help cement local feelings of independence.

"Whoever—people, community, leaders—they see and support it [the program]. Wherever the rangers come up with ideas, the facilitators help us. They help us, but we built it," said one homeland-based Yirralka Ranger.

Future implications

It's clear the benefits derived from the Yirralka Rangers, though often interconnected, are far-reaching. Maintaining and improving these benefits will help the rangers to continue their valuable work and keep their communities happy and healthy. A full understanding of the values of Indigenous ranger programs can also help governments to better design policy and make smarter investments in Indigenous communities in future.

A day in the life of Yirralka Rangers and their love for the job is highlighted in a new documentary, 'Let's care for this country'. The film is co-directed and co-written by the Yirralka Rangers and the Blue Mud Bay community of Baniyala and is intended for a wider audience. It highlights the importance of the ranger program to the community, the diversity of Ranger roles, participation in traditional Yolngu practices, and the beauty of the country they live and work in. The film is free from https://vimeo.com/133308877

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EDITION 38

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