Issue 6
December 2011

On TRaCK

Tropical Rivers and Coastal Knowledge

Remote sensing captures animal impacts on waterholes

In 2009 TRaCK researchers began working with the Kowanyama Land Office in the Mitchell Catchment on the western side of Cape York to try to better understand the influence of large animals on waterholes in the area.

The agency had a developing wetlands management program which included the exclusion of stock from some local waterholes due to concerns about water quality. They had begun to develop an aerial photo and horses monitoring program, but were looking for new ways to monitor whether the waterholes were changing over time, if they were considered healthy, and the impacts of large mammals, particularly pigs and cattle, on local water bodies.

Some waterholes in the area have been used to water cattle as far back as the 1920s and have become quite degraded with serious pugging, infill and loss of aquatic vegetation.

Dr Tim Jardine, Dr Neil Pettit and Research Assistant Dominic Valdez formed a partnership with the agency and began on-ground water quality measurements of basic variables such as pH levels, nutrients, turbidity as well as aquatic vegetation at nine perennial waterholes around Kowanyama.

They also set up time-lapse and motion sensitive cameras at the study sites to monitor animal visitation around the waterholes and the rise and fall of water levels and changes in wetland plant cover.

At the time a fence to exclude stock had been erected at one of the sites – Crayfish Hole - and pig exclusion was completed the following year.

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Photo courtesy of the Kowanyama Photo Archive

Progression of aquatic vegetation across a lagoon in the Mitchell River Catchment

In this issue

Photo Andrew Brooks

Australian Government

Department of Sustainability, Environment, Water, Population and Communities

National Water Commission

Fisheries Research and Development Corporation

In 2007 TRaCK received major funding for its research through the Australian Government's Commonwealth Environment Research Facilities initiative; the Australian Government's Raising National Water Standards Program; Land & Water Australia; the Fisheries Research and Development Corporation; and the Queensland Government's Smart State Innovation Funds.

This year TRaCK has received funding from the National Water Commission to undertake targeted projects as part of a 'synthesis and adoption' year to ensure research findings are relevant and more widely available.

TRaCK brings together leading tropical river researchers and managers from Charles Darwin University, Griffith University, The University of Western Australia, CSIRO, James Cook University, Australian National University, Geoscience Australia, Environmental Research Institute of the Supervising Scientist, Australian Institute of Marine Science, North Australian Indigenous Land and Sea Management Alliance, and the governments of Queensland, the Northern Territory and Western Australia.

Foreword

TRaCK Chair John Childs
Chair of the Daly River Management Advisory Committee

Welcome to the sixth issue of *On TRaCK*.

From the beginning, TRaCK has focused on developing a knowledge base and helping people make good and sensible decisions about the use of river and coastal resources in northern Australia.

The research findings coming to the fore now, and the stories contained in this edition are an expression of our understanding of the interactions between land and water and how those resources influence one another.

As the story on aquatic insects shows, we now have a much better understanding of food chains in a biological sense. And as the story on water use demonstrates, it's also important to understand people's use of those resources , because it highlights the fact that any impacts on biological biodiversity will also affect the community's ability to interact with those resources.

One of the important issues is that we are still learning how to do regional development well. In the past people have spotted a resource that they might be able to exploit, and they have then benefited from those resources. But if northern Australia is to sustainably and viably develop, we need to ensure those natural resources benefit the broader community in a regional sense.

A key lesson for many research consortiums is that researchers need time to interact after they have completed their work with people who are interested in applying the research. TRaCK's research program is not just about what the scientists have discovered, it's also a chance for interplay between the researchers and people in the community with experience, knowledge and motivation who will benefit from and contribute to the work.

All public good research programs should have at least a year to tease out the benefits and application of the ideas developed and how they might be utilised. I commend the National Water Commission for having the vision to support a synthesis and adoption year for TRaCK, because the research outcomes will benefit immeasurably from this process.

We're now much more capable of doing research in a participatory way with the community and others with an interest in water resources. People who have worked with researchers and the TRaCK program now have an idea of how that can be done and done well.

The benefit of having done participatory, interactive research with communities over an extended period of time is the creation of experience, knowledge and relationships that can be used by the consortium in the next phase of research under the National Environmental Research Program. The continuity of this process is crucial to developing programs that are of lasting benefit to regional communities.

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Meanwhile, Dr Doug Ward began using satellite imagery to look for changes and patterns in plant cover and turbidity in the waterholes at a catchment level that could be identified from space.

"Remote sensing was really being used on two levels in this project – firstly through analysis of the satellite imagery, but also on-ground with the use of time-lapse cameras that recorded animal activity around the waterholes at certain times throughout 2009 and 2010," Dr Ward said.

"Remote sensing has always interested me because it's a really useful way to observe what's happening in the environment over time.

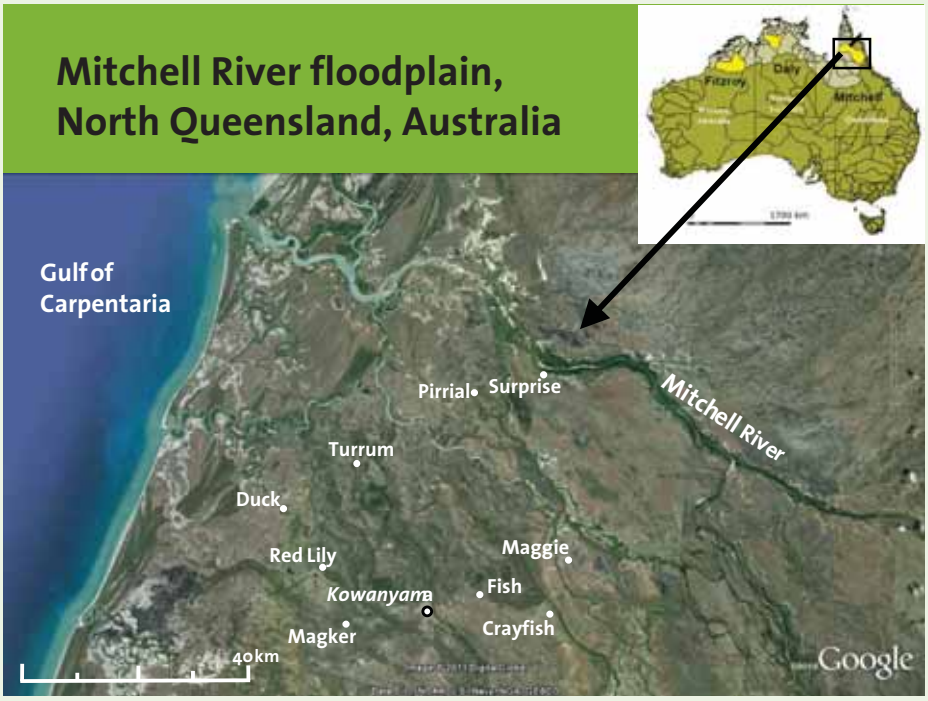
"There is an archive that allows you to look at an entire series of information, so you can go back to the 80s, pick a large water body, and monitor the changes that occurred in that waterhole every 16 days (using the Landsat TM satellites) for many years, and that can create a very powerful time series.

"We use it to answer ecological questions by relating the satellite imagery to on-ground measurements. We can monitor, in a surrogate way, what's happening with the water quality of the waterholes."

Kowanyama Land Office had also used historic aerial photos to monitor morphological changes to the South Mitchell River estuary, which they knew had changed radically since the 1920s.

What did the satellite imagery show?

The researchers divided the freshwater aquatic habitats in the area into two categories: rivers; and lakes, swamps, floodplains and waterholes. They found that after flood events, the rivers became very turbid due to the amount of sediment flowing into them, but quickly cleared up, while the water bodies on the floodplains followed the same process, but turbidity dramatically increased again towards the end of the dry season.



Nine perennial waterholes in the Mitchell Catchment were studied to monitor the effects of large animals on refugial waterholes

"When it becomes very hot and dry a lot of those systems contract to very small waterholes, and the imagery shows a dramatic increase in waterhole turbidity, while the riverine systems remain relatively clear," Dr Ward said.

"Turbidity is a measurement of the scatter of light by particles. It affects the amount of light that can get into a water body, and light drives the whole photosynthesis process of algae in the water, which supports aquatic life.

"Having high turbidity reduces the productivity of the water body and is considered an 'undesirable' state by the local community in this area and scientists.

"Post flood, aquatic vegetation cover in the floodplain water bodies is very high, particularly in shallow water.

"But as the season goes on the water conditions in the waterholes become more turbid and the growth of aquatic vegetation drops off, while in the main river channels, the vegetation cover doesn't really change that much."

What did the on-ground research show?

Generally water bodies in northern Australia exist in two stable states: they can be turbid with high nutrients and limited aquatic vegetation, or clear with low nutrients and lots of vegetation.

Dr Jardine learnt from working with the Kowanyama Land Office and staff that the local community prefers its waterholes in the second state, because there are aquatic plants that are highly valued including lotus and water lilies.

"Part of it is aesthetics but there's also functional appeal as well – when the waterholes are in this condition it's easier to harvest those plants and other aquatic resources like crayfish," Dr Jardine said.

The researchers sampled three times, in August and October 2009, and June 2010. The last sample was taken after the river systems had been reset by the floods.

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A series of time lapse photographs which show decreasing water levels and aquatic vegetation cover at Crayfish Hole from the end of the wet season through to the end of the dry season

Photos courtesy of Tim Jardine

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"Our on-ground measurements showed that water quality generally deteriorates as the dry season progresses and the water bodies become shallower, while the motion sensitive cameras showed that animal activity around the waterholes definitely increases as the dry season progresses because fewer and fewer places are available for them to get water," Dr Jardine said.

"It's highly likely that this increased activity contributes to the decrease in water quality, and a lot of the animals also feed on the remaining aquatic vegetation in the water.

"The last sample was interesting because what we found is that floods actually homogenise these waterholes.

"By the end of the dry season they're very different in terms of their nutrient levels, aquatic vegetation cover and turbidity, whereas if you go back after the floods all the waterholes are fairly similar across those areas.

"It appears that when a waterhole gets reconnected to the river, it effectively resets it.

"You could extrapolate from this that the negative impacts caused by animals the previous dry season are in effect 'washed away', however we're not entirely sure yet if that's actually happening and whether these waterholes are progressively degrading over time, even with seasonal flooding."

The Kowanyama Rangers

The Kowanyama Rangers are part of the Kowanyama Aboriginal Land and Natural Resources Management Office, which has been operating since the late 1980s as an Indigenous owned and controlled land management agency.

Manager Viv Sinnamon said the community was concerned about Crayfish Hole, or Yiymanthuw as the locals know it, which is an important source of crayfish and other aquatic resources.

"It was one of those situations where humans compete with animals for aquatic resources, and the lagoon was becoming very degraded," Mr Sinnamon said.

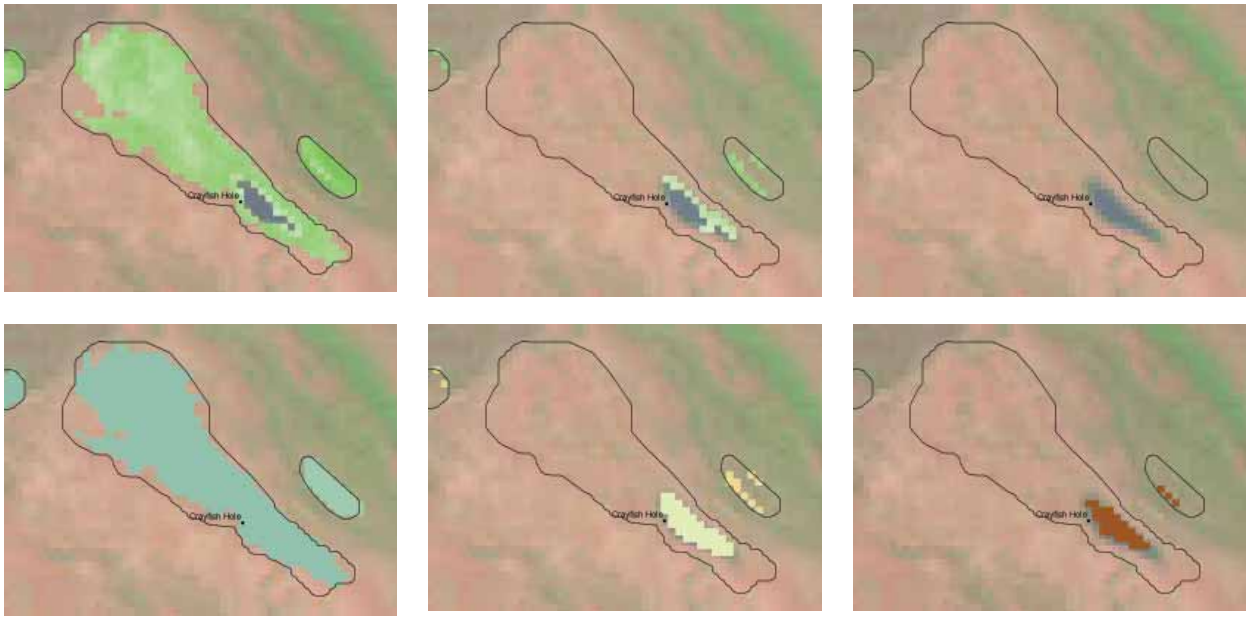
"It had a lost a lot of its aquatic vegetation, which is what sustains the crayfish, and the population had basically crashed. The lagoon has also shallowed over time with infill by sediment.

"As part of our wetlands management program, we consulted with a local cattle company to see if we could fence off the lagoon and monitor it to see how it would respond to the exclusion of large animals.

"Our first effort in 2009 involved fencing off the lagoon from cattle and horses. Horses are particularly bad because they're able to wade right out into the middle of the lagoon up to their chest, stick their head underwater and eat the lily bulbs and seed cases.

Aquatic vegetation sustains local crayfish populations, which are hunted by people and animals

Photo courtesy of the Kowanyama Photo Archive



A series of satellite images showing decreasing aquatic vegetation cover (top row) and increasing turbidity (bottom row) as the dry season progresses

"In 2010 we put pig mesh in, and we've been able to stop the larger animals getting in there but we've had to shoot some pigs because they've been really persistent in getting under the fence."

Mr Sinnamon says that as a very busy land management agency, the Kowanyama Land Office has to strategically choose projects that complement existing programs.

"We decided to join with TRaCK because they had some cameras that we hadn't heard about. We've had a lot of trouble getting a picture of what's happening in remote areas with the use of traps - bower birds tend to take the rods out, while toads predominate in the smaller traps, and goannas in the larger traps," Mr Sinnamon said.

"Dr Jardine and his team installed a camera at Crayfish Hole and were able to get some really good time lapse photographs which proved an excellent resource in terms of monitoring visitation to the lagoon by feral animals and domestic stock, water levels and progression of aquatic vegetation.

"Because we were able to leave the cameras on site we ended up with an incredible amount of data during the period when we wouldn't have been able to access the site.

"Since this project with TRaCK we've decided to invest in ten Reconyx cameras to capture remote sensing images.

"Privacy is an issue so it's important to properly engage with the community so that they know what's going on, otherwise there could be a sense that people are losing their privacy in the bush.

"Data management is also an issue because the cameras capture a lot of images which we are using for promotion, monitoring and reporting but you do need a long-term plan to manage and store the data.

"The two positive outcomes from our association with TRaCK and our involvement in this project are that we became aware of new technology which we've taken on board, and we have increased our network of scientists.

"Some TRaCK researchers are now part of our technical advisory group for the wetlands management program, as independent experts value-adding to the knowledge of local Aboriginal people as Traditional Owners of Mitchell River delta country."

Key lessons

Dr Ward says one of the most surprising things in northern Australian environments is the amount of water disappearing from the beginning to the end of the dry season.

"Many people are surprised to learn that up to 90% of the surface water that falls during the wet season disappears between March and October," he said.

"Towards the end of the dry season, the refugial water holes that are left play a critical role in sustaining populations of biota, fish and other species before the onset of the next wet season.

"That has implications for land managers in the context of climate change, because we anticipate that things are going to get a lot drier in some parts of Australia.

"What we've learnt from other parts of Australia and the world is that modifying flood events or reducing the amount of floodwater running over the landscape influences the quality and amount of water left in refugial water bodies.

"Floods are an essential part of the landscape in northern Australia, because they replenish and allow fish and other biota to move out of the smaller water bodies and main river channels, to forage in different freshwater environments.

"And throughout the dry season, the conservation, management and maintenance of refugial water bodies is really important because they provide the only source of biota before the onset of the next wet season.

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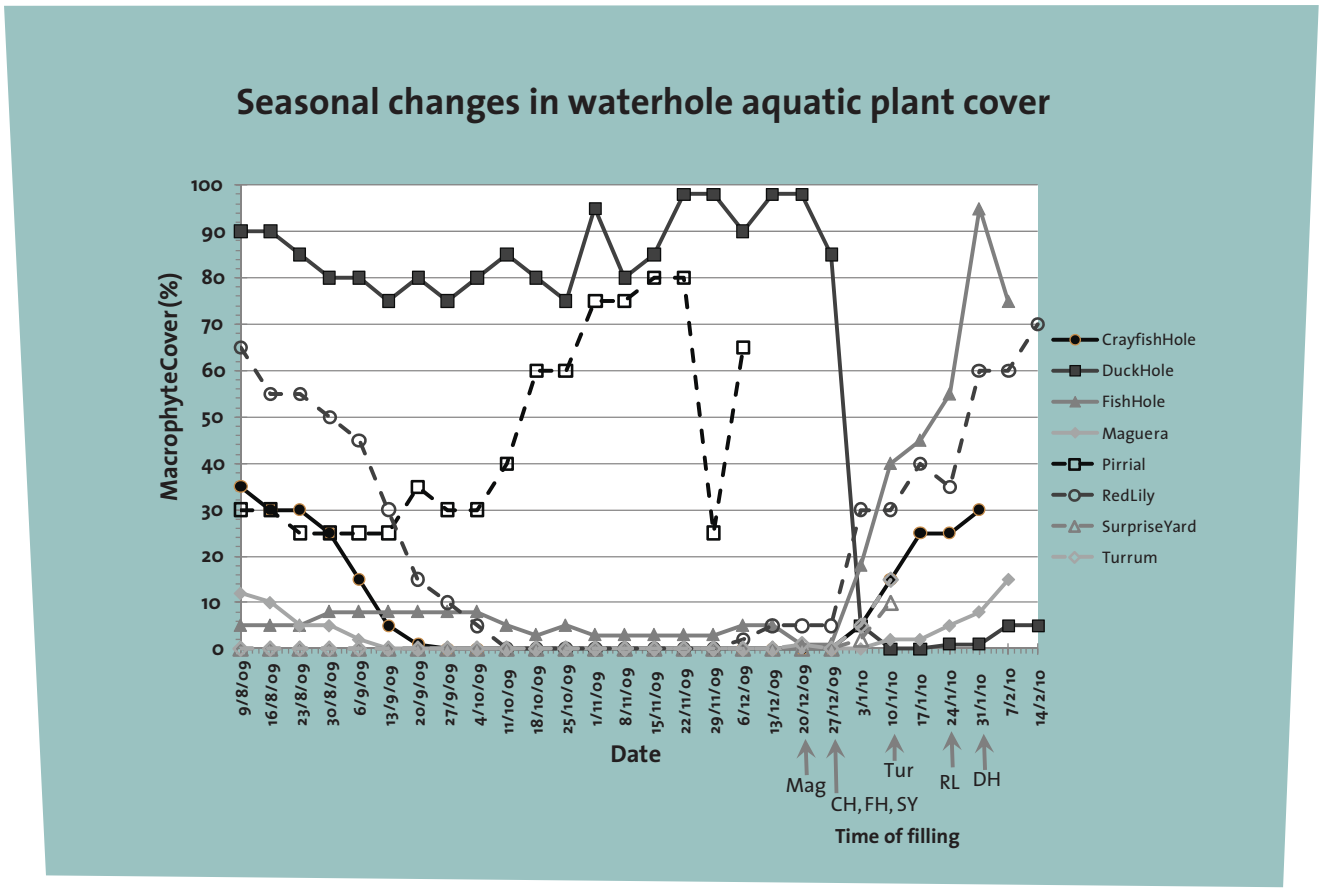

Aquatic vegetation cover decreases as more animals visit refugial waterholes, turbidity increases, and the remaining vegetation is eaten

"There needs to be a lot of consideration in conservation planning methods for identifying where these refugial water bodies are, and then appropriate management actions to maintain them in reasonably good condition.

"One of the management actions may be to fence them off, but there are other actions that can be taken. As we've learnt with other TRaCK research, ensuring the basic hydrology of the area is maintained is critical.

"Everyone has an intuitive sense that these exclusion zones work but nobody really knows exactly how they work, how long it takes and what the precise benefits that you gain are."

Viv Sinnamon says the monitoring results from Crayfish Hole show improved water quality and a slight increase in the density of aquatic plants, but it will take a while for the aquatic vegetation to fully recover.

"I agree with Dr Ward that fences are a small part of managing higher priority areas with cultural and economic values – it's a small part of the overall picture," Mr Sinnamon said.

It's hoped that analysis of satellite imagery from the years before 2009 will show if there are any emerging patterns at a catchment scale from a larger time series.

The use of waterholes by pigs and cattle is an issue across dry land Australia, not only in northern Australia, but also in the interior. Dr Jardine says there have been some very impressive results from exclusion tests where waterholes have rebounded to pristine conditions, but it's very difficult to synthesise the findings and a lot of them are anecdotal.

"Hopefully this project has contributed some findings that have a little more scientific rigour behind them, and we are hoping to develop projections about how waterholes might improve as a result of excluding large animals," Dr Jardine said.

What is remote sensing?

Remote sensing involves using different types of instruments remotely to monitor various aspects of the surface of the earth. It can be done from a satellite, from an aircraft, or from ground-based instruments like loggers or cameras, which are left at a site to log data remotely, and later picked up.

Remote sensing covers many different areas but is most commonly associated with the imagery that's captured by satellites or aircraft.

In 1972 NASA set up the Earth Resources Technology Satellite, which was eventually renamed 'Landsat', to conduct observations of the earth. Various incarnations of the Landsat satellite have since captured millions of images, acquiring nearly 40 years of data which depict changes in the landscape every 16 days.

As a free resource, this important record provides scientists with the opportunity to compare on-ground findings with catchment-scale optical images.

Photo Peter Novak

The wet season is when cherabin are thought to be most abundant

Freshwater prawns focus of new study

Cherabin, a type of freshwater prawn, are a big source of food for local communities across northern Australia and are also sought after by recreational fishers for use as bait. Cherabin can grow bigger than saltwater prawns and are found in freshwater habitats in the tropical Indo-Pacific region including northern Australia.

While a lot is known about similar species in an aquaculture setting (an estimated 30,000 tonnes of cherabin are harvested each year in more than 30 countries), very little is known about its ecology and life history in a natural setting.

Anecdotal evidence suggests that cherabin stocks in some rivers in northern Australia are in decline, and people are worried about how this might impact on the overall ecology of the habitats where they are found.

Last year Charles Darwin University PhD student Peter Novak began designing a research project plan that would investigate these issues.

"My research aims to address knowledge gaps about the ecology of wild cherabin, which means looking at changes in abundance over time, gender ratios, breeding times and cycles, and the development of juveniles," Peter said.

Anecdotal evidence suggests cherabin undergo a massive upstream migration, from the estuary to freshwater reaches over a few weeks in the wet season.

"Cherabin are large-bodied animals, so I am particularly interested in the migration of juveniles upstream because I suspect this large movement of biomass means they are a big contributor to upstream food webs," Peter said.

"It's highly likely this migration provides a significant "foodweb subsidy" to the upstream freshwater environment from estuarine and marine ecosystems, as the juveniles will be carrying biomass derived from the marine and estuarine environments to the freshwater reaches.

"This is what we call ecosystem connectivity. There's a link between the ocean and freshwater environments, so if this migration were to change through things like lower water levels or dams , it could have a signifcant impact on the upstream freshwater ecology."

In terms of their importance to local communities, work has been done around the Fitzroy River in Western Australia that shows that cherabin are one of the more important species that are harvested by local communities. Around the Daly River in the Northern Territory, they are still harvested, but species like freshwater turtle are much more important.

"In the Daly Catchment cherabin are probably more important to recreational fishers who catch them to eat and for use as bait. They have been heavily harvested and we think this could have exerted significant pressure on stock levels," Peter said.

"We've got five sites on the Daly channel itself, starting just below the Daly Crossing and working our way further upstream. We also have sites in three of the tributaries – the Katherine River, which is a major tributary into the Daly, the Ferguson River, which is an ephemeral system, and the Edith River which is a permanent river.

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Photo Michael Douglas

Cherabin found on field trips are counted, weighed, measured and sexed

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"To collect the life history information, I'm going out every month and setting more than 20 traps at each site in the afternoon, then picking them up in the morning.

"We count, weigh, measure and determine the sex of the cherabin caught in the pots, which will begin to give us a picture of changes in abundance at these particular sites over the year.

"I'd had fairly low catch rates up until the beginning of the wet, when they're supposed to become more abundant. On my last trip in November I recorded a three to four-fold increase in the catch rate at most sites."

Peter says new catch limits in the Northern Territory will reduce the impact of fishing pressure on cherabin stocks.

"You're only allowed to have three cherabin pots per person with a maximum of six pots per boat, and you can only retain ten cherabin per person with a maximum of 30 per boat," he said.

The research on the life history of wild cherabin and their contribution to connectivity will be applicable to other large tropical rivers in Northern Australia with similar catchments and flows.

"TRaCK aims to gain baseline information on how freshwater ecosystems in northern Australia work so that future management and development decisions can be made based on sound science. This research will certainly contribute to the bigger picture," Peter said.

Peter began collecting data in September and will continue on a monthly basis until at least September 2012. He needs volunteers to go out with him on each field trip. If you are interested in taking part, please contact the TRaCK office at Charles Darwin University on (08) 8946 7444.

The project is part of the North Australia Hub's work on river connectivity and biodiversity, under the National Environmental Research Program.

Photo Guillaume Puig

A fully-grown male cherabin

Photo J. Clark

Graphic flutterer (*Rhyothemis graphiptera*)

Northern Australia's unique aquatic biodiversity must be protected

Most people who have travelled to northern Australia will agree that the lush vegetation and extraordinary wildlife of the wet-dry tropics are a highlight among the country's stunning natural landscapes.

With the largest intact savanna ecosystem and greatest concentration of free-flowing rivers in the world, it's not surprising that northern Australia contains more than half the continent's rich biodiversity.

The region's inland tapestry of aquatic habitats is home to a host of species including freshwater prawns and crabs, migratory birds, brightly coloured spotted scats and freshwater sawfish - many of which are found only in northern Australia.

Dr Bradley Pusey has been working with more than 30 researchers from the Tropical Rivers and Coastal Knowledge (TRaCK) research hub to pull together knowledge about northern Australia's freshwater biodiversity.

"We've been doing research across the north for some time, but the formation of TRaCK really signalled critical mass in terms of having a whole group of researchers from different disciplines working in collaboration to build our knowledge in this area," Dr Pusey said.

"What that research has shown is that the north's aquatic biodiversity is nationally significant and incredibly rich. It's got at least 30 per cent of the country's biodiversity in 17 per cent of the land mass, or well over 50 per cent if you include the 105 species of freshwater fish."

Dr Pusey says maintaining the connectivity of river systems is a key feature of healthy freshwater aquatic habitats.

"If there is one clear lesson from the history of development in the south, it is that we need to be cautious about a conventional development pathway for the north, because once ecosystems are degraded, it is costly and difficult to turn back the clock," he said.

"We have our large network of free-flowing rivers to thank for this rich biodiversity. Elsewhere in the world, many rivers are dammed or fragmented and freshwater biodiversity is declining as a consequence.

Photo D. Wilson

Green tree frog (*Litoria caerulea*)

"Half of northern Australia's freshwater fish rely on access to the sea to breed, so there are important lessons in this research about interfering with river flows and connectivity."

Dr Pusey also said there are significant threats to northern Australia's biodiversity including the spread of invasive species such as mimosa, rubber vine, pasture grasses and feral animals; pollution from abandoned mines; unrestrained stock access; altered fire regimes; and saltwater intrusions as a result of climate change.

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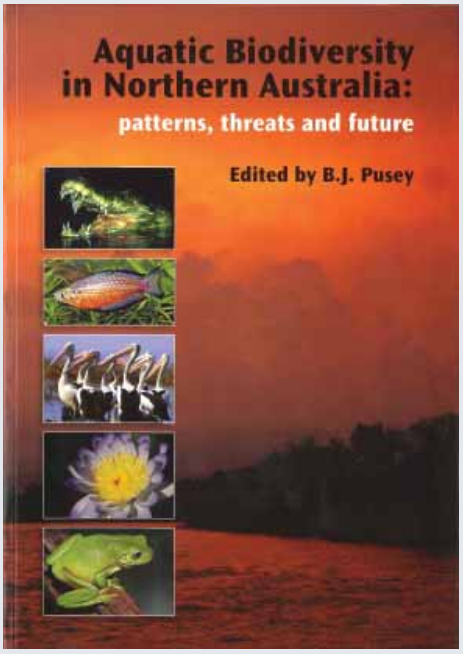
Spotted scat
(*Scatophagus argus*)

Photo Brad Pusey

Aquatic Biodiversity in Northern Australia: patterns, threats and future is available for sale online at www.cdupress.cdu.edu.au



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"We know that the wetlands of northern Australia are internationally significant for migratory birds and important breeding grounds for the iconic barramundi, but many of these wetlands are little more than a metre above sea level," he said.

"Even the most conservative estimates indicate sea level rises will push saltwater into these freshwater environments, so we need to take steps now to preserve areas with high conservation values.

"While most of the existing threats are mostly low level and relatively diffuse, we cannot afford to ignore them because this will invariably lead to further and more widespread degradation.

"For example with buffalo control there have been successes in terms of returning areas to their original state. It's possible to stop these environments from passing irreversible thresholds with sensible planning and appropriate management actions.

"I think there's a very bright future ahead for northern Australia if we approach it in a considered manner, taking advantage of the information that's been gathered over the years.

"If we want to protect these areas people need to recognise that they are significant - not just for Australia, but globally - and it's a matter of devoting significant resources to maintain them into the future."

How can we protect northern Australia's freshwater aquatic biodiversity?

1. Prioritise and protect high value aquatic ecosystems
2. Address current threats before it is too late
3. Explore development options and their consequences carefully
4. Improve planning processes to secure environmental water allocations and community confidence in water management
5. Improve the information base required to secure adequate environmental water allocations and maintain the connectivity of river systems
6. Increase public awareness and engagement.

Mouth almighty with eggs
(Glossamia aprion)

Photo Brad Pusey

Freshwater sawfish
(Pristis microdon)

Photo D. Wilson

Water use in northern Australia

Traditional Owners were hired as research assistants to conduct interviews with their communities

New research from TRaCK has brought together data on expenditure and water use patterns in households and industry across the Daly and Mitchell river catchments.

The research began as a way of exploring what was happening with people across the landscape, and aimed to draw together the findings from three related research areas. These research areas covered:

1. The size of tropical Australia's socio-economic systems, including population, tourism figures, and growth projections.
2. The types of socio-economic activities including average incomes, number of children per family, proportion of the Indigenous population, and the main sectors of employment in each of the focus catchments.
3. The interactions between the different sectors of socio-economic activity and how these relate to water use and the economy.

A survey was conducted in the Daly and Mitchell catchments, with data collected from 510 households. Most data was collected via a mail-out survey, although within the Indigenous communities Traditional Owners were hired as research assistants to conduct interviews to ensure proper representation of Indigenous people.

The questionnaire analysed how much was spent each week on items such as food and petrol, which was used to gauge how much people were spending and where people did most of their shopping.

JAMES COOK UNIVERSITY AUSTRALIA

Socio-economic activity and Water use in the Tropical Rivers Region
Resident survey

TRaCK Tropical Rivers and Coastal Knowledge

Household occupant information

1. What is the name of the town or community that you live in? _____
   If you do not live in a town, please tell us the name of the town or community that is closest to you
2. How many people 'normally' live in your house (including yourself)? _____
   Please fill in number. If the number of people changes from week to week, then please give us an 'average' number
3. How many of those people are Aboriginal or Torres Strait Islanders? _____
   Please fill in number

People in the Mitchell and Daly catchments were surveyed on their household expenditure and water use

TRaCK researcher Natalie Stoeckl says responses were captured from about eight per cent of the total Indigenous population and six per cent of the non-Indigenous population in the Daly River Catchment, while in the Mitchell River Catchment there were responses from about 30 per cent of Indigenous residents and 18 per cent of non-Indigenous residents.

"To the best of our knowledge no-one's ever collected data on people's expenditure patterns or water use that allows one to look at similarities or differences between Indigenous and non-Indigenous households in Northern Australia," Professor Stoeckl said.

"The ABS collects data in their household expenditure survey every five years, but they don't collect data in remote areas once populations drop below a certain density, and they don't have a flag identifying people as Indigenous so you can't differentiate between Indigenous and non-Indigenous expenditure.

"Many anthropologists (and economic anthropologists) have documented Indigenous spending, and many standard economists have documented non-Indigenous spending, but the reason why this research is important is because it draws the two together and allows them to be compared.

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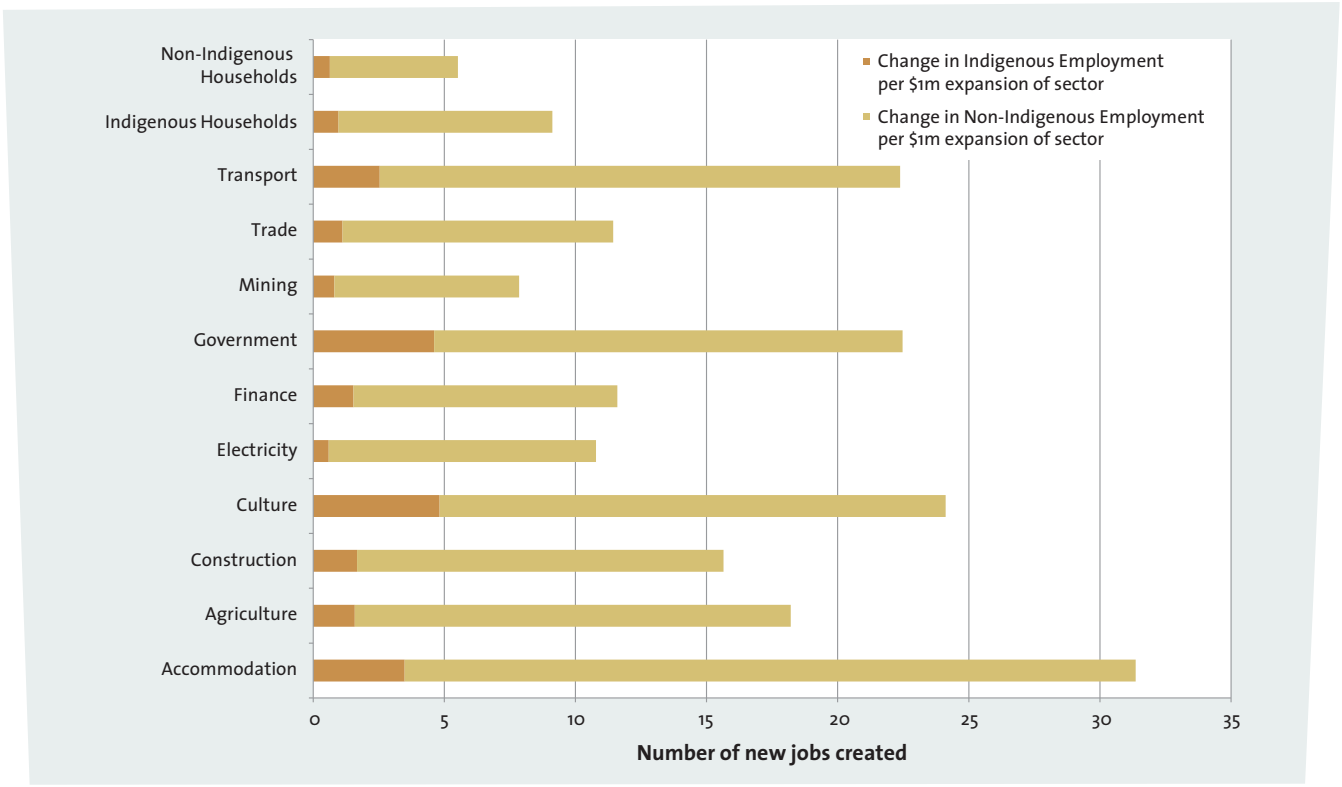
Employment multipliers were used to estimate the number of local jobs that would be created through the expansion of various sectors.



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"The models have many underlying assumptions, so the results should not be taken literally, but they do provide a guide as to where development may be concentrated to achieve the most growth in regional incomes or employment, or to reduce pressure on water resources."

Indigenous people spend a greater proportion of their weekly budget on food

The survey showed that Indigenous respondents were spending between 30 to 40 per cent of their income each week on food and beverages, in contrast to the ABS average of around 20 per cent.

"We attributed this to the fact that often their income is very low and prices tend to be relatively high in remote area shops, so they need to spend a large proportion of their budget on the basics," Professor Stoeckl said.

Non-Indigenous people use water in their garden, while Indigenous people use it to stay cool

"The water use patterns across the Indigenous and non-Indigenous communities were quite interesting," Professor Stoeckl said.

"Non-Indigenous people were found to be using a lot more water in their gardens than Indigenous people and so their daily water use was higher. There were huge differences between dry season and wet season water use.

"One of the interesting findings was that particularly in the Mitchell Catchment, water use inside the houses was higher among Indigenous households than non-Indigenous households.

"The anecdotal evidence suggests that in many of those communities people cannot afford to use air conditioning, or they don't have air conditioners, so they use water to cool down in summer, for example by having more showers."

Household water use is far lower than industrial water use

"There were notable differences between Indigenous and non-Indigenous household water use, but when you incorporate data from the Australian Bureau of Statistics about industrial water use, the water used by industry and businesses is so much higher that the difference between various households is not all that relevant," Professor Stoeckl explains.

"The ABS data is reported at a state-wide level, which means it is nowhere near as precise as we would like it to be, so we used 'location quotients' which are used in regional economics to try to determine how much water is being used at a catchment level.

"It was a fairly crude assessment but where we were able to compare our estimates with other published data they looked fairly plausible, and these estimates showed that the agricultural sector draws the largest amount of water from the system across northern Australia.

"The type of agriculture that is being undertaken is also important, so for example irrigated agriculture requires more water than grazing."

Income versus employment

While some industries may generate a lot of income or government revenues at the regional scale, they don't necessarily generate a lot of local jobs per dollar invested.

Professor Stoeckl says people focused on regional development need to consider whether they are interested in creating local jobs or creating state and Federal revenues.

"When we generated some employment multipliers which looked at the number of new jobs created from a million dollar expansion of various sectors, the area that came out on top in terms of creating local jobs was the accommodation sector, with an estimated 30 new jobs created," said Professor Stoeckl.

"In contrast, if you were to have an equal expansion in the mining sector, you would only get about seven or eight new jobs created.

"That doesn't mean there wouldn't be fly-in fly-out workers, or that places like Townsville or Perth or Sydney wouldn't benefit, but in terms of the jobs that are created for people that live locally, the benefits are going to be much smaller."

According to the research, the accommodation, culture and recreation, government (administration, health and education), and transport sectors were most likely to bring benefits in terms of local employment, while the mining, electricity, trade (retail and wholesale) and finance sectors were least likely to create local jobs.

Professor Stoeckl says this may be in part because industries like the mining sector are very capital intensive, investing in things like machinery which is imported from elsewhere, while the accommodation sector is much more likely to spend money on people or locally produced goods and services.

Generating future development scenarios

"A water use input/output model was used to simulate various scenarios which showed the effect on incomes, employment and water demand if a particular sector experiences growth of ten per cent," Professor Stoeckl said.

"What was interesting was that if you put money into the non-Indigenous sector, the money mainly stayed within that group. For example if a local shopkeeper earned a lot of money, they would use the extra money to employ more staff, who in turn spent more money on local services, so the money kept circulating around within the non-Indigenous community.

"But that money didn't have the opportunity to move to Indigenous households and that's primarily because there were so few Indigenous people working in the shops that they weren't actually getting the jobs or the benefits of extra growth.

"With so few Indigenous businesses, Indigenous people were not really seeing the benefits of extra regional expenditure. There were no physical links or financial avenues by which money could go from the non-Indigenous sector to the Indigenous sector – it was completely separate.

"But we called it an 'asymmetric divide' because it was quite the contrary if you put money into the Indigenous sector. In this case, it flowed almost instantaneously to the non-Indigenous sector, in shops or on housing."

Professor Stoeckl believes these findings indicate that the potential benefits of regional development for non-Indigenous people far exceed the benefits for Indigenous people in northern Australia.

"What we can learn from this, in conjunction with other research, is that if the development is detrimental, affecting stream flows and impacting upon the wild resources which many of these Indigenous communities rely on, then it's possible that the net effect of that development on Indigenous communities could be negative," Professor Stoeckl said.

"It cannot be assumed that economic development through traditional sectors is going to generate a net benefit for Indigenous people."

The research from this project is now feeding into one of the synthesis and adoption projects led by Associate Professor Francis Pantus, **Decision support tools for tropical river catchments**. A software package more specifically configured to evaluate management strategies for the Daly River catchment will allow water planners to interrogate different scenarios in water allocation planning.

Professor Stoeckl is working with other TRaCK researchers (Dr Sue Jackson, Dr Mark Kennard, and Associate Professor Francis Pantus) on a paper that will use information generated from other TRaCK projects about the value of wild resources and about the impact of water extraction on stream flows and fish habitat, to try to draw inferences about the impacts of various types of development on Indigenous households. She is also involved in a Northern Australia Water Futures Assessment project collecting data about the values people associate with water resources.

The project report, *Socio-Economic Activity and Water Use in Australia's Tropical Rivers*, can be found on the TRaCK website under Publications.

Natalie Stoeckl

Natalie Stoeckl is an Economics Professor at James Cook University in Queensland and has always had an interest in environmental economics. Before university, Natalie spent three years on a prawn trawler and many years running a silvicultural business.

Much of her course work while studying for an undergraduate degree and PhD from the Australian National University, and a Masters from James Cook University, focused on non-market valuation techniques that are often used in economics to try to estimate the economic value of environmental resources.

Professor Stoeckl became involved with TRaCK after doing a scoping project in 2006 looking at the social and economic values associated with tropical rivers in northern Australia. She was attracted by the opportunity to work with people from other disciplines, all contributing their expertise to TRaCK's body of research.

Aquatic insects rely on healthy riparian zones

Not a lot is known about the movements of aquatic insects and their contribution to the productivity and biomass of northern Australia's tropical rivers.

Very few researchers have looked at what happens to these bugs during the wet season, partly due to the challenges of conducting field work at this time of year, and possibly because of a lingering belief that nothing much emerges during heavy rainfall.

TRaCK researcher Erica Garcia set out to study the movements of aquatic and terrestrial insects in and out of three Northern Territory rivers at different times of the year, to better understand the interchange between the aquatic and terrestrial environments.

"We chose three rivers in the same catchment that vary in hydrological connectivity, and which all eventually flow into the Daly River: the Cullen, Ferguson and Edith rivers," Dr Garcia said.

"The goal was to work in one of TRaCK's three focus catchments, with three representative river types that we could access throughout the year, because researchers really hadn't ventured out much in the wet season.

"The Edith is perennially flowing for the most part although for one of our sampling periods it had actually stopped flowing but there was still a lot of water.

"The Ferguson is seasonally intermittent, meaning it mostly holds water year-round, but it becomes disconnected pools in the dry season, while the Cullen goes completely dry.

"Other TRaCK researchers were looking at the longitudinal movement of fish and insects up and downstream in these rivers, but my focus was the lateral fluxes, meaning the movement of insects between the river and the riparian zone."

From water to land and back again

Research happening in other parts of the world shows that when there are large differences in the productivity of two adjacent ecosystems, for example a desert island and the sea, there is often movement of food resources from the high productivity ecosystem to the low productivity one.

In the wet-dry tropics there are big differences in the seasons, and corresponding periods of productivity. For this reason, the rivers are often more productive than the surrounding savanna in the dry season.

"Higher productivity systems can 'subsidise' lower productivity systems. In this research I was looking at aquatic insects as a possible subsidy because as larvae they live in rivers and then they metamorphose and become flying adult insects that may be important food items for birds, mammals, reptiles and terrestrial insects," Dr Garcia said.

"We really wanted to see if this was the case in the Daly Catchment too, because obviously this is important for water managers in determining how much water needs to stay in the system."

Three different trapping methods

Dr Garcia examined the insect movements using three different trapping methods. Five malaise traps, which are similar to small tents, were set up for 24 hours at different distances away from the river and used to capture flying insects.

"The first trap was within a metre of the river's edge, then 5, 10, 15 and 20 metres away, plus one more that was out in the savanna, about 100 metres away from the river," Dr Garcia said.

The carbon signature of spiders sampled showed that at certain times of the year, river food sources were very important

Photo Michael Douglas

"This method was used to see how far aquatic insects were coming out of the river into the riparian zone and whether they made it into the savanna, and conversely, how close terrestrial insects were getting to the river.

Light traps were also set for one hour, about an hour after sundown, and were always within one metre of the river's edge.

"I wanted to observe if there was movement of terrestrial insects from the riparian zone and/or savanna into the river and if the amount of insects entering the river changed thoughout the year. For this I used pan traps, which are big trays that float on the river's surface," Dr Garcia said.

"The pan traps were left on the river for 24 hours at a time to catch what we call 'invertebrate rain'.

"I used these different trapping methods because the light traps, for example, would only attract certain types of insects, so I wanted to use a variety of traps to get an appreciation of the whole insect community and what was really happening with them.

Soap was used to break the surface tension of the water in the light traps, causing insects to fall in and drown

Photo Michael Douglas

"We collected insects 8 times over a 15 month period so we could capture a good amount of data, and we were particularly trying to capture the transitions between the seasons in late wet/early dry, then the heart of the dry, then the late dry/early wet, and the middle of the wet.

"The two sets of wet season data were really quite variable in terms of the intensity of the rainfall."

Using carbon and nitrogen stable isotopes to determine food sources

Dr Garcia was also interested in determining the critical time in terms of terrestrial ecosystem dependence on aquatic ecosystems.

"I wanted to know roughly when the rivers were an important source of food for terrestrial animals in the form of aquatic insects for spiders, bats, and birds, and we used carbon stable isotopes to measure this. The carbon signature of an organism can tell you if that animal is mostly eating food from the river or from land or even if it is eating a mixture of both," Dr Garcia said.

"The carbon signature of riparian spiders in the Edith and Cullen rivers showed they were much more dependent on river food sources than land-based food sources during the first wet season sample, but for the Ferguson this was true in the late dry and dry to wet transition seasons."

Insects are a major food source in the river and on the land

Despite the different flow regimes of the three rivers, the pan traps showed that the peak of invertebrate rain for all three systems happened during the transition from the wet to dry season in May.

"That particular peak for invertebrate rain coincided with the carbon stable isotope signature results which showed that land-based food sources were an important source for fish at this time," Dr Garcia said.

"That's quite a nice pairing, that when lots of terrestrial insects are falling into the river that's also when fish are feeding on them."

The malaise traps showed different patterns for each river. Typically when these types of trials are done most insects (aquatic and terrestrial) are found in the trap that's closest to the river because aquatic insects tend not to move too far away from the river, while terrestrial insects don't show a consistent pattern.

"I only found that classic pattern at one of the rivers – the Ferguson. At the Edith River there were mo Ferguson re insects out in the savanna trap, 100 metres away," Dr Garcia said.

The peak times for when insects were emerging from the rivers varied but never occurred during the dry season which is when most studies are conducted.

"For the Ferguson the peak was the wet to dry season sampling, but for the Edith it was in the wet season. These results certainly have something to do with the pattern of flow in the different rivers," Dr Garcia said.

"In general there were more insects in the Ferguson River, and that could be because of its hydrological connectivity. Varied river conditions tend to increase the diversity of insects.

"There were only two times that I used light traps at the Cullen River, and at one of those times during the wet season we found the most insects of any of the rivers.

"That was surprising because the Cullen River goes completely dry, so the lesson there is that even though it doesn't have water all the time, when it does have water it's contributing a lot to the ecosystem."

Riparian zones are important for the movement of insects

"All three of the rivers we studied had a good riparian zone, meaning they hadn't been cleared for cattle grazing or other uses," Dr Garcia said.

"This is important information because there is a lot of discussion now around clearing more land in the Daly Catchment to support different industries, so we need to think carefully about how this is done.

"In other studies, for example in North America, they have found that when you lose the riparian zone around rivers, you lose that exchange between the terrestrial and aquatic environments.

"Without trees and plants there's no place for the aquatic insects to emerge from the stream, and have a safe place to wait to dry their wings so they can fly away."

This research will inform future work about the importance of riparian zones, which species rely on aquatic and terrestrial insects for survival, and which times of the year are most important. It also adds to the body of work being done by TRaCK which demonstrates the importance of wet season flows in maintaining healthy ecosystems throughout the drier months.

Malaise traps were used to capture flying insects
Photos Michael Douglas

Pan traps were used to catch 'invertebrate rain'

Synthesis and adoption year

Governments have invested in a number of initiatives focused on improving our knowledge of northern Australia's rivers and water resources. The largest coordinated investment has been through TRaCK, and the outcomes from the first phase of research are already influencing water planning and management in the north.

This year TRaCK has received funding from the National Water Commission to undertake 'synthesis and adoption' with selected projects to share research findings and ensure they are relevant, build awareness of the tools and products being developed, and seek feedback on the products to improve useability.

Discussions with end users from a range of government agencies identified the following as suitable projects for synthesis and adoption based on information needs and the availability of knowledge.

1. TRaCK Digital Atlas and river classification tool
2. Decision support tools for tropical river catchments
3. Indigenous enterprises and water planning
4. Indigenous engagement in water research
5. Monitoring river health in the wet-dry tropics
6. Environmental flows tool for the wet-dry tropics

More information about these projects is available on the TRaCK website at

www.track.gov.au/synthesis-adoption.

On TRaCK
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About TRaCK

TRaCK was established in 2007 as a research hub under the Commonwealth Environment Research Facilities Program to provide the science and knowledge that governments, communities and industries need for the sustainable use and management of Australia's tropical rivers and estuaries.

The research consortium is led by Charles Darwin University, CSIRO, Griffith University, the North Australia Indigenous Land and Sea Management Alliance and the University of Western Australia.

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