Tropical Rivers and Coastal Knowledge

Northern Australia Aquatic Ecological Assets

Summary Report – Assessing the Likely Impacts of Climate Change and Development

TRaCK – *Research to support river and estuary management in Northern Australia*

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, the Environmental Research Institute of the Supervising Scientist, Australian Institute of Marine Science, North Australia Indigenous Land and Sea Management Alliance, and the Governments of Queensland, the Northern Territory and Western Australia.

Disclaimer

This report was jointly funded by the National Water Commission and the Department of Sustainability, Environment, Water, Population and Communities.

Copyright

Citation

Close, P.G., Dobbs, R. and Davies, P (2012). *Summary Report – Assessment of the likely impacts of development and climate change on aquatic ecological assets in Northern Australia*. A report for the National Water Commission, Australia. Tropical Rivers and Coastal Knowledge (TRaCK) Commonwealth Environmental Research Facility, Charles Darwin University, Darwin.

Technical Report Citation

Close, P.G., Wallace, J., Bayliss, P., Bartolo, R., Burrows, D., Pusey, B.J., Robinson, C.J., McJannet, D., Karim, F., Byrne, G., Marvanek, S., Turnadge, C., Harrington, G., Petheram, C., Dutra, L.X.C, Dobbs, R., Pettit, N., Jankowski, A., Wallington, T., Kroon, F., Schmidt, D., Buttler, B., Stock, M., Veld, A., Speldewinde, P., Cook, B.A., Cook, B., Douglas, M., Setterfield, S., Kennard, M., Davies, P., Hughes, J., Cossart, R., Conolly, N. and Townsend, S. (2012). Assessment of the likely impacts of development and climate change on aquatic ecological assets in Northern Australia. A report for the National Water Commission, Australia. Tropical Rivers and Coastal Knowledge (TRaCK) Commonwealth Environmental Research Facility, Charles Darwin University, Darwin. ISBN: 978-1-921576-66-9. 561pp

Images and layout

Front cover image – *Water lilies in a northern Australian wetland.* Image: Ian Dixon
Back cover images – Top: *Plumed Whistling-ducks.* Image: TRaCK; Bottom: *Yellow Water Lagoon in Kakadu National Park, NT*. Image: John Baker and DSEWPaC.

Design and layout – First Class in Graphic Design, Darwin.

Aquatic ecosystems in Northern Australia

Northern Australia hosts a range of high value aquatic ecosystems, including, estuaries, rivers, lakes and wetlands. These ecosystems have important intrinsic and cultural values, and among other things, provide clean water, food and recreational activities for people. Climate related changes in rainfall, run off and sea level, together with future development and expansion of agricultural, urban and industrial land use represent significant risks to these high value aquatic ecosystems. The systems support high biodiversity and many species of aquatic plants and animals that are found nowhere else. It is important that these valuable assets be sustainably managed and protected so that they provide ongoing value to both human activities and ecological requirements.

What is being done to inform the protection and sustainable development of water resources?

The Northern Australia Water Futures Assessment (NAWFA) is an Australian Government initiative to provide the information required to assist in the protection and sustainable development of northern Australia's water resources, which is consistent with the National Water Initiative. This project, one of a number under the NAWFA, aimed to assess the likely impacts of possible development and climate change on northern Australian aquatic ecosystems.

A variety of biota rely on natural patterns of river flows. Image: TRaCK.

Irrigated agriculture on the Daly River floodplain, NT. Image: Michael Douglas.

Development and climate change impacts on aquatic ecosystems in northern Australia

This project has provided water planners and managers with additional information on the possible impacts of future development and climate change scenarios on aquatic ecosystems in northern Australia. This new knowledge will be incorporated into the decision making process for future water management plans, to ensure that potential impacts resulting from development and climate change can be managed more effectively.

This project addressed seven key tasks:

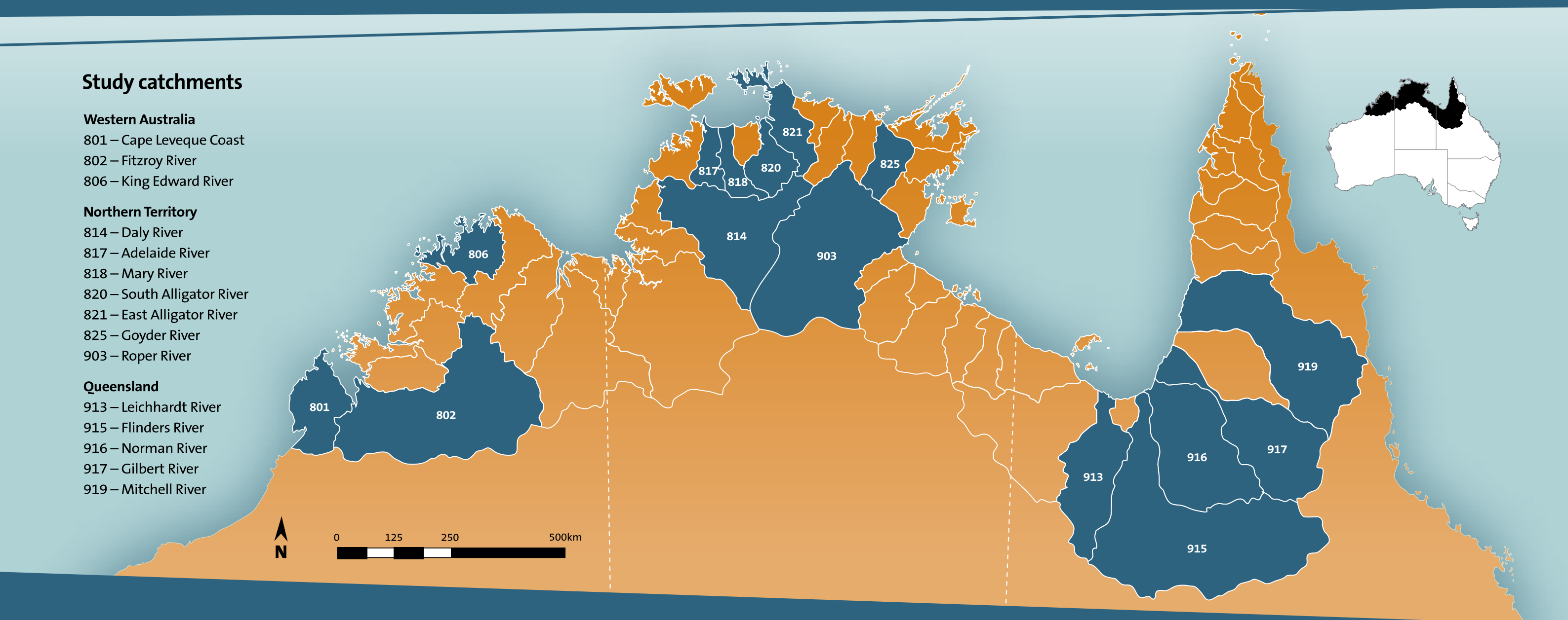
1. Describe the ecology and hydrology of northern Australian aquatic assets
2. Identify the major human related factors impacting upon the assets and their relationship to future development and climate change risks
3. Assess the impacts of these threats on landscape connectivity
4. Identify key ecological thresholds in terms of ecological water requirements, ecosystem function and habitat use by key biota
5. Describe the relationships between assets and their social and cultural values
6. Recommend management strategies and monitoring frameworks to report on environmental change
7. Identify specific knowledge needs and future investment priorities

Where was the research undertaken?

The geographical area considered by the project stretches more than 3,000 km, from Broome in the west to Cairns in the east. This area includes three drainage divisions (Timor Sea, Gulf of Carpentaria and the part of the North-east Coast Drainage Division, north of Cairns) and 64 river basins. The Project focussed on 15 catchments identified by jurisdictions as likely to experience hydrological change due to water resource development or climate change.

Climate, landscape and groundwater connections vary over the 1.25 million km^2 NAWFA region. A diversity of river systems exist, including those that flow year-round, and others that cease to flow for varying lengths of time during the dry season.

Below: NAWFA study region and focus catchments (blue) used in this project.



A number of groundwater basins occur across northern Australia, which have important interactions with some surface water systems, most notably the contribution of groundwater to perennial flows.

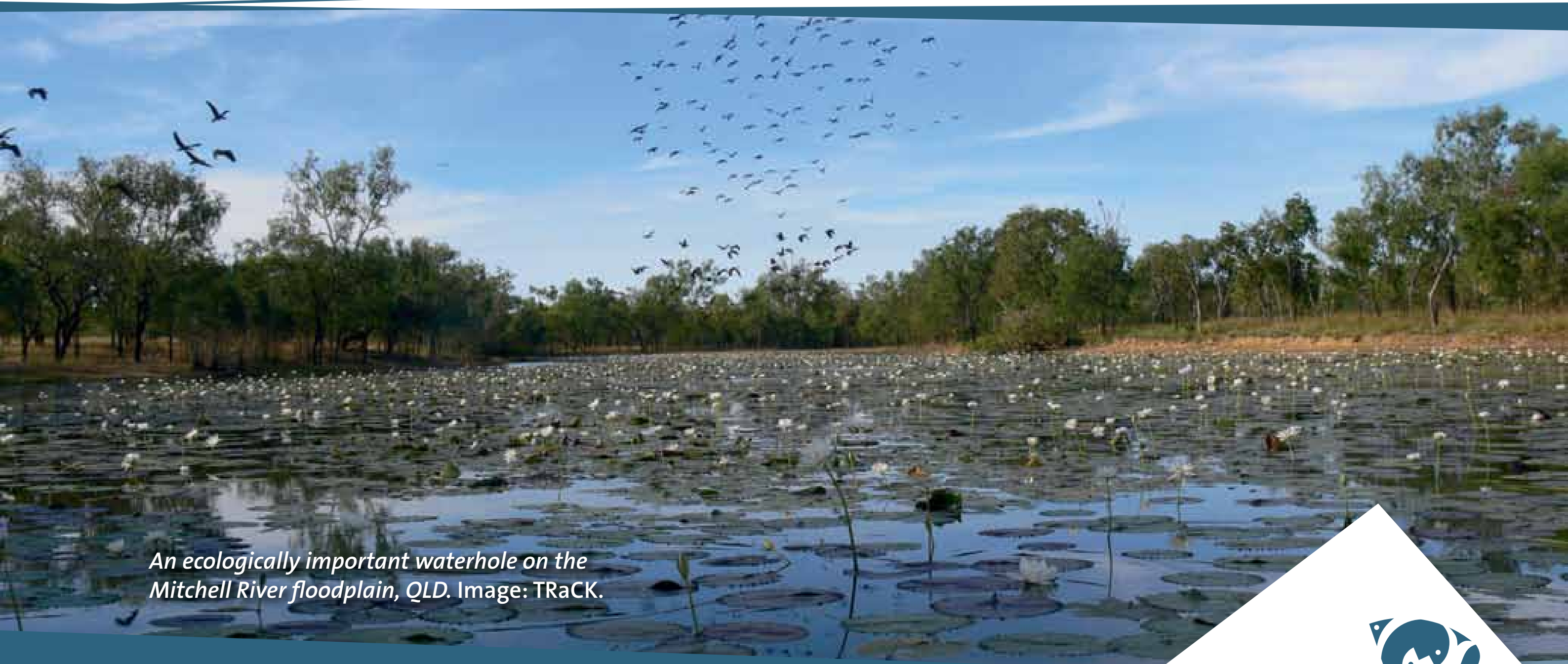
Northern Australia is generally characterised by low relief landscapes. River flows in the central to western regions are typically constrained in rocky channels, flanked by a succession of relatively small, discontinuous floodplains. In comparison, rivers draining to the Gulf of Carpentaria flow through extensive alluvial floodplains for much of their length. To the east of the Great Dividing Range (i.e. the northern North-East Coast Drainage Division) steep coastal escarpments abut a narrow coastal plain and the rivers tend to be much shorter and steeper than those found elsewhere in northern Australia.

Northern Australia's climate is characterised by highly seasonal, summer-dominated rainfall, high temperatures and high evaporation rates. Mean annual rainfall is highly variable (range 400 – 4000 $mm.year^{-1}$) and a large proportion of the study area is considered to be water limited. Stream flow in northern Australia is considerably more seasonal and has a higher inter-annual variability, than do other world rivers of the same climate type. Although there are notable exceptions, few rivers in the region are regulated and levels of catchment disturbance remain relatively low.

The Kimberley region of Western Australia is remote and waterways in the region have typically low levels of disturbance. The region is rich in natural resources and mining activities represent a significant potential for increased water resource use, increased infrastructure and concentration of populations.

The Northern Territory includes a diverse range of waterways in both remote and developed catchments. Groundwater discharge is an important feature of some catchments, maintaining river flow throughout the dry season. Demands on Northern Territory water resources from mining, pastoral diversification and tourism represent significant threats. Climate change, particularly sea level rise, also threatens the lower reaches of many river basins.

In north western Queensland, rivers flowing to the Gulf of Carpentaria are seasonally connected to each other via the Gulf Plains, an ecologically important floodplain system which spans the entire coastal region of the Gulf of Carpentaria. In times of high rainfall, there is overflow between catchments although for most of the year the catchments are hydrologically isolated. Most



An ecologically important waterhole on the Mitchell River floodplain, QLD. Image: TRaCK.

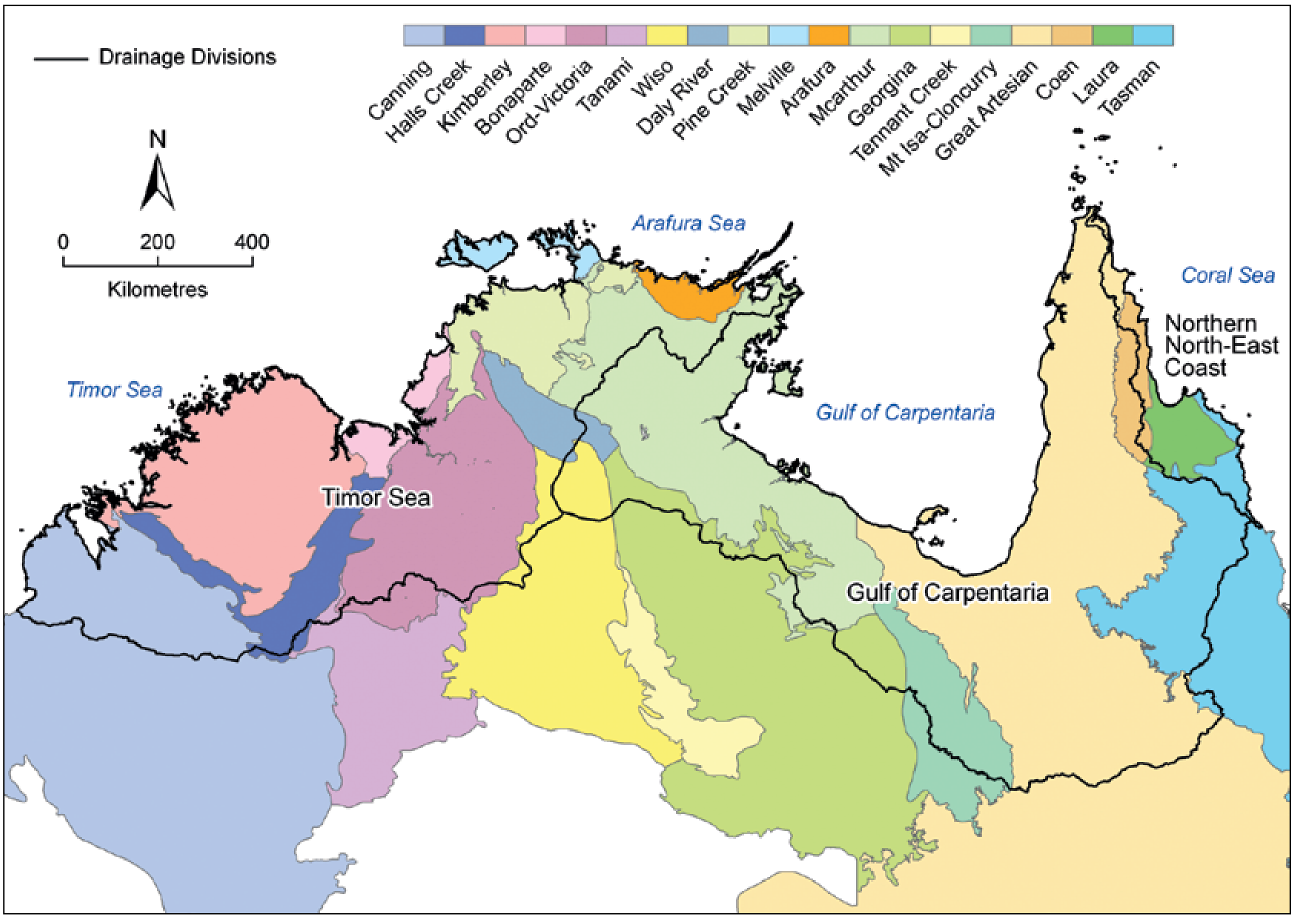
aquatic habitats are intermittent, despite significant groundwater influence. Primary industries in the catchments include pastoralism and mining. Increased development of the water resource to support expansion of the mining industry represents a significant potential risk that requires careful management.

Water dependent plants and animals in northern Australia are diverse and many are found nowhere else. The region also has a long history of Aboriginal occupation, particularly associated with waterways, and culturally important sites are numerous. Biodiversity and cultural assets in Northern Australia are closely linked and have adapted to the unique landscape, climate and riverflows. Changes to river flows, landscapes and aquatic habitats due to climate change and development demands are likely to impact the unique biodiversity values of the region.

Climate and development impacts on surface-groundwater interactions

Groundwater provides an important contribution to many northern Australian waterways. There are a number of groundwater basins across the region and their contribution to surface water varies from maintaining permanently watered wetlands, to maintaining year-round river flows.

Across northern Australia, more than 90% of annual rainfall and runoff typically occurs during the wet season and during this period groundwater recharge occurs via a combination of diffuse infiltration of rainfall, floodplain inundation and leakage from streams and rivers. Estimates of recharge rates range between <1 mm yr^{-1} and >200 mm yr^{-1}; with the lowest rates in the most arid regions (e.g. much of



Groundwater basins that underlie the drainage divisions of northern Australia.

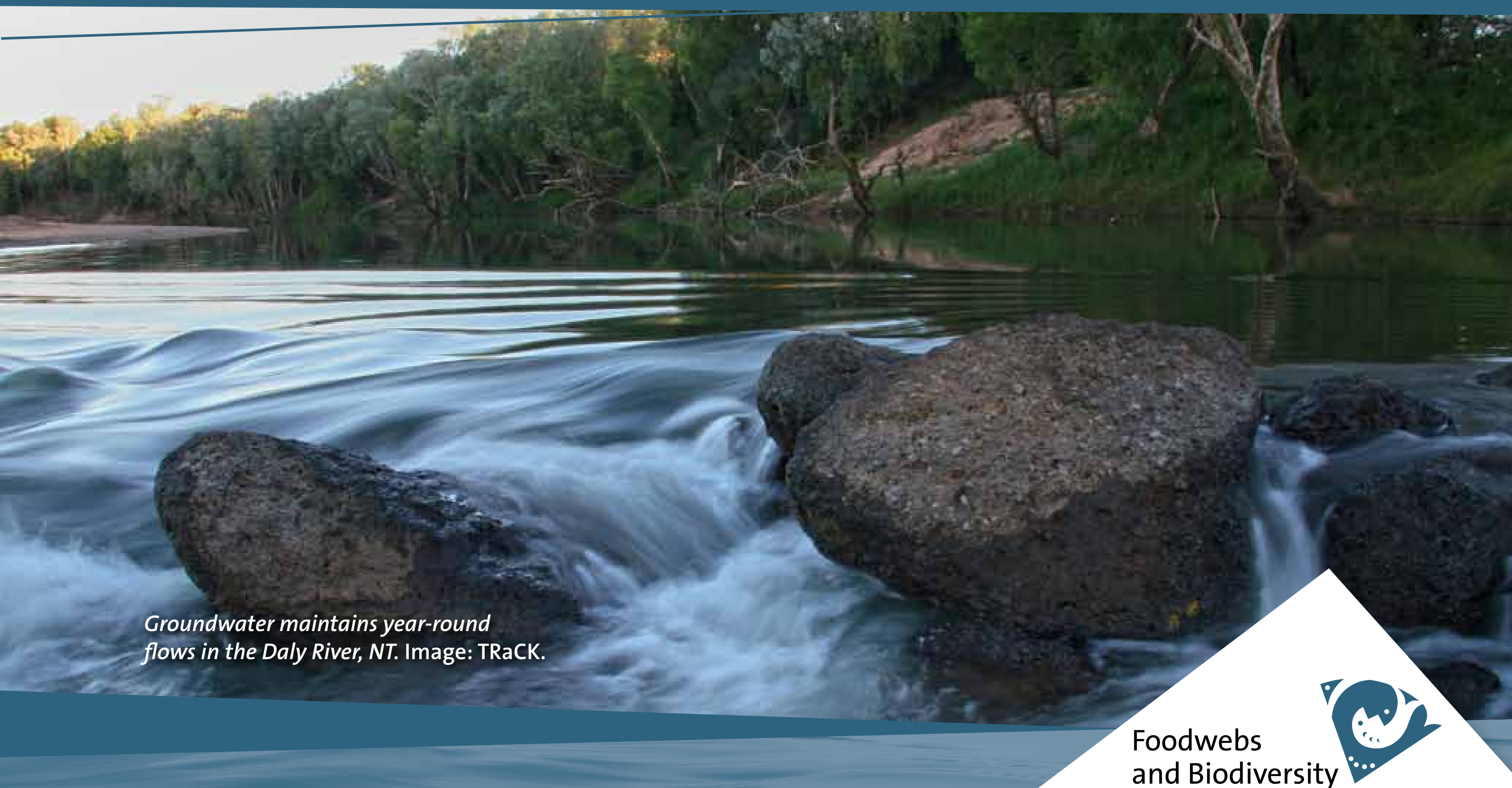
the Flinders-Leichhardt region) and the highest rates generally associated with wet-tropic climates and more permeable soils.

During the dry season, river flows recede rapidly and the majority of surface water features cease to flow, and may either dry completely or form a chain of disconnected waterholes. There are, however, several iconic perennial rivers such as the Daly River and Roper River (NT), the Fitzroy River (WA) and many of the rivers on Cape York peninsula (QLD) that rely on significant groundwater input through the dry season.

Predicted changes in annual groundwater recharge due to climate change vary from +39% to -5%. The impacts of climate change on groundwater dependent ecosystems will be more immediate in those which are fed by shallow, local, unconfined aquifers (e.g. the Flinders-Leichhardt, Mitchell and Kimberley regions) and, conversely, delayed in systems fed by deep, regional aquifers (e.g. the Daly and Fitzroy regions). In some areas with significant levels of current groundwater extraction (e.g. the Darwin Rural Area), groundwater levels are likely to continue to decline despite increases in diffuse recharge, and these declines may threaten a number of groundwater dependent ecosystems in the area.

Development impacts on groundwater have been estimated in very few locations. The greatest impact from development is expected in catchments with a high degree of groundwater-surface water connectivity, such as the Daly River. Development is most likely to have significant impacts in parts of aquifers that are furthest from the rivers. This is because groundwater extraction in these areas cannot be mitigated through increased leakage from the rivers.

Water resource development on the Ord River, WA. Image: Paul Close.



Groundwater maintains year-round flows in the Daly River, NT. Image: TRaCK.

Foodwebs and Biodiversity

Despite a broad general knowledge of the locations of significant groundwater discharge to rivers and streams in northern Australia, there remain fundamental knowledge gaps around the nature of interactions in complex geological environments, and how these systems will respond to potential future climate change and increased water resource development.

Climate and development impacts on river flows

Stream flow in northern rivers is extremely seasonal with the vast majority (> 90%) of annual flow occurring during the wet season (November to April). Aquatic ecosystems dependent on these flows are well-adapted, responding to both wet season high flows and the long dry season low flows. Nevertheless, there is a general lack of quantitative information on the relationships between flow and specific flora and fauna in northern Australia and this makes it difficult to predict the ecological consequence of flow changes. In a selection of focus catchments, the impact of a variety of climate change and development scenarios on high and low flows were examined. High and low flows are important drivers of floodplain and in-stream ecosystem structure and processes in northern Australia.

In general, predicted changes to the high and low flow characteristics of most northern rivers under future climate scenarios are quite large and likely to have significant consequences to aquatic biota.

Low flows under dry climate change scenarios are likely to be altered significantly. Some areas are likely to experience considerable increases in the duration of low and zero flows, which may have major ecological impacts. Combining climate change with development pressures can exacerbate changes to low flow conditions.

Flooding is an important factor that sustains many environmental assets by providing connectivity across the floodplain and facilitating migration. Under dry climate change scenarios, flood frequency can be reduced greatly and this may have impacts on provision of habitat and breeding grounds. Under wet climate change conditions, flooding may become much more frequent and this could have both positive and negative impacts depending on the flow requirements of different species.

The implementation of additional development water entitlements in Queensland can exacerbate the climate

Wet season flows inundate a tropical floodplain river. Image: TRaCK.

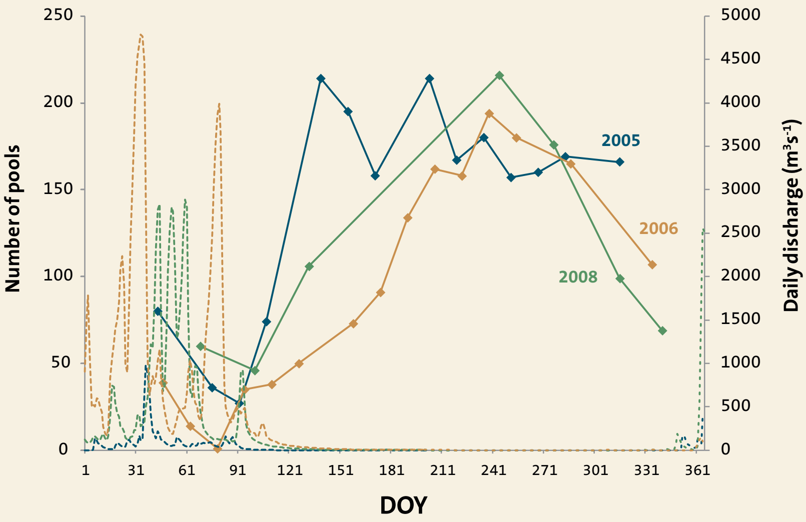
impact, but the relatively modest development water requirements reported for NT and WA developments did not usually add much further impact on high and low river flows.

In-stream pools as ecological refugia

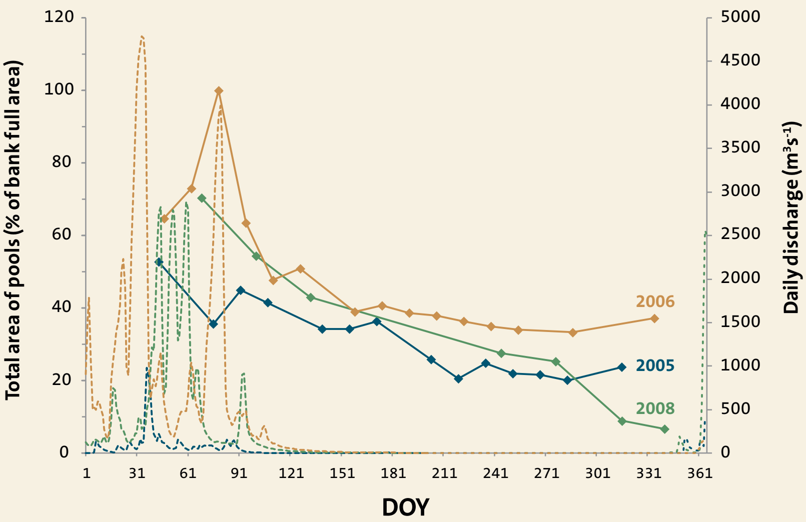
In-stream pools form critical refuges for many aquatic biota during the long dry season when many rivers cease to flow. The relationship between flow and the formation of in-stream pools is therefore important in understanding and predicting how changes to river flows from climate change and development may impact aquatic biodiversity and socio-cultural assets of permanent waterholes. Using remotely sensed (LiDAR, LandSat and Ikonos) data, pool size and numbers were estimated in several catchments across northern Australia (Fitzroy, Mitchell and Daly catchments) in which isolated river pools form during the dry season.

There are reasonably good relationships between pool number, total pool area and flow, but the relationships are quite different for each river. In the Fitzroy River the preceding wet season affects the rate at which pools form in the early dry season, but the late dry season pool number is insensitive to wet season flow. This implies that groundwater is the primary source of base flow in this river at this time. Both the Fitzroy and Mitchell Rivers showed a decline in pool numbers by the end of the dry season. This may be due to the disappearance of small pools, which cannot be sustained by groundwater flow at this time. Many more pools form in the Fitzroy and Mitchell rivers than in the Daly River. This is because (i) flows are much lower for longer in the two former rivers and (ii) there is a greater groundwater contribution in the Daly River. Most of the pools in all three rivers are relatively small (~ 200 to 600 m in length) and the number of small pools generally increases as the dry season progresses.

October 2005 Ikonos image clearly showing pools (left) and the same image with the identified pools from LandSat analysis overlain (right).



The development of pools in the Fitzroy River, WA during three years. Also shown is the daily discharge (dashed lines) during the same three years.



The seasonal change in total pool area in the Fitzroy River, WA during three years. Also shown is the daily discharge (dashed lines) during the same three years.

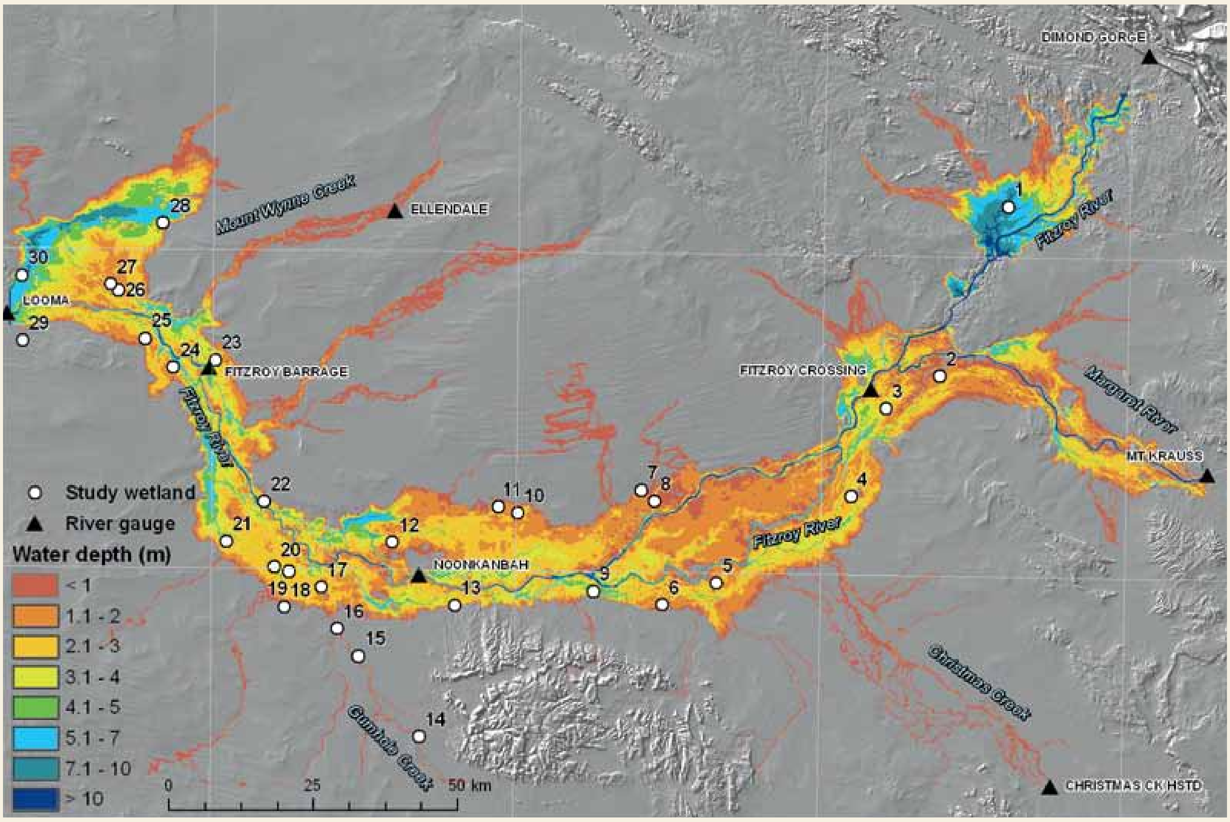
While some of these relationships may be useful for setting ecologically acceptable low flows, additional information on the response of key aquatic biota to pool characteristics is needed to quantify these thresholds.

River floods and wetland connectivity

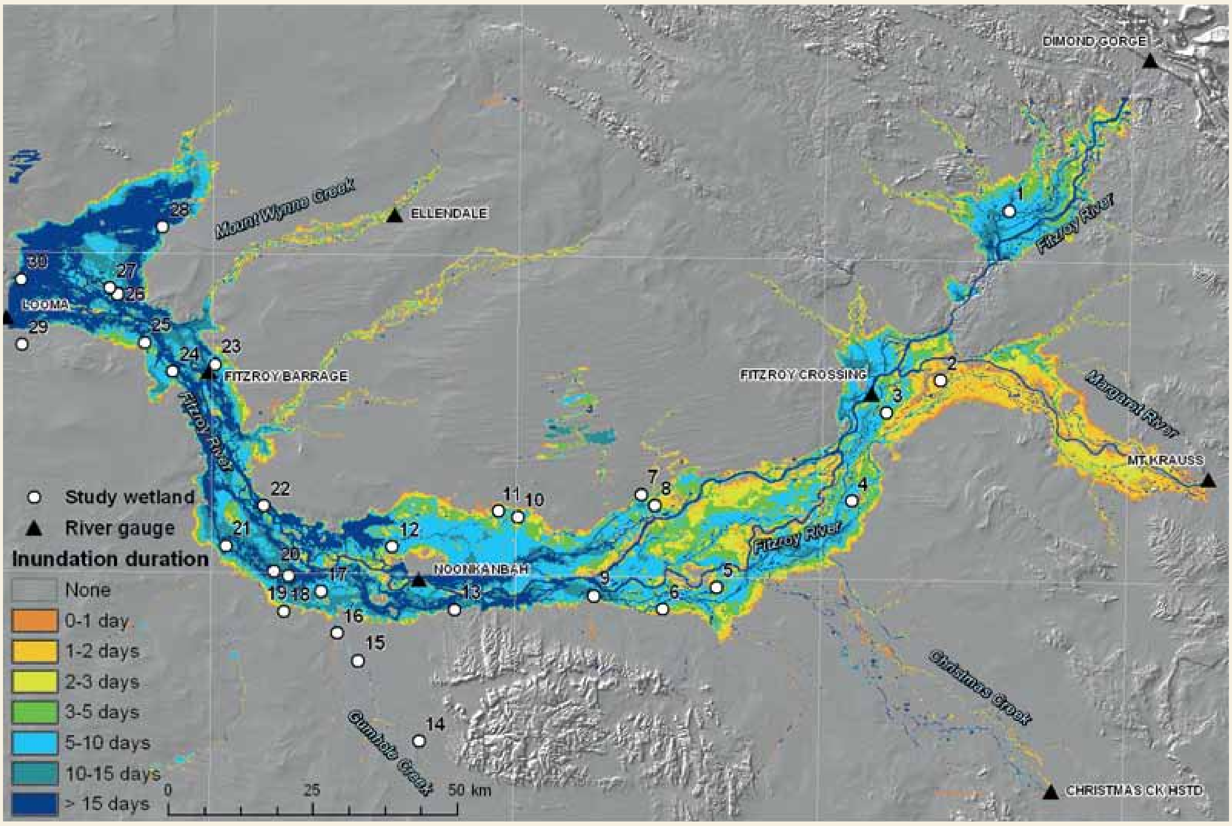
Flood flows provide opportunities for the off-stream floodplain wetlands to be connected with the main channels of floodplain river systems, and these 'flood pulses' are thought to be the major determinant of the high biodiversity of floodplains. A hydrodynamic model of the Fitzroy River catchment was used to quantify the timing, frequency and duration of the connectivity for 30 floodplain wetlands and the main river channel. Wetland connectivity was calculated for three floods of different sizes with annual return intervals (ARI) of 1.5, 3 and 14 years.

The duration of wetland connectivity ranged from 1 to 40 days per flood and was not only related to distance from the main river channel, but also the topography between the wetland and river. Some wetlands connect in relatively small and frequent floods and others only connect in much larger, less frequent floods. Wetlands in the lower part of the floodplain tend to have greater connectivity because of the longer duration of inundation in this area.

Understanding the relationships between flow magnitude and the connectivity of floodplain wetlands will be useful to future studies on (i) movement and recruitment patterns of fish during floods (ii) wetland habitat characteristics and (iii) biodiversity of individual wetlands.

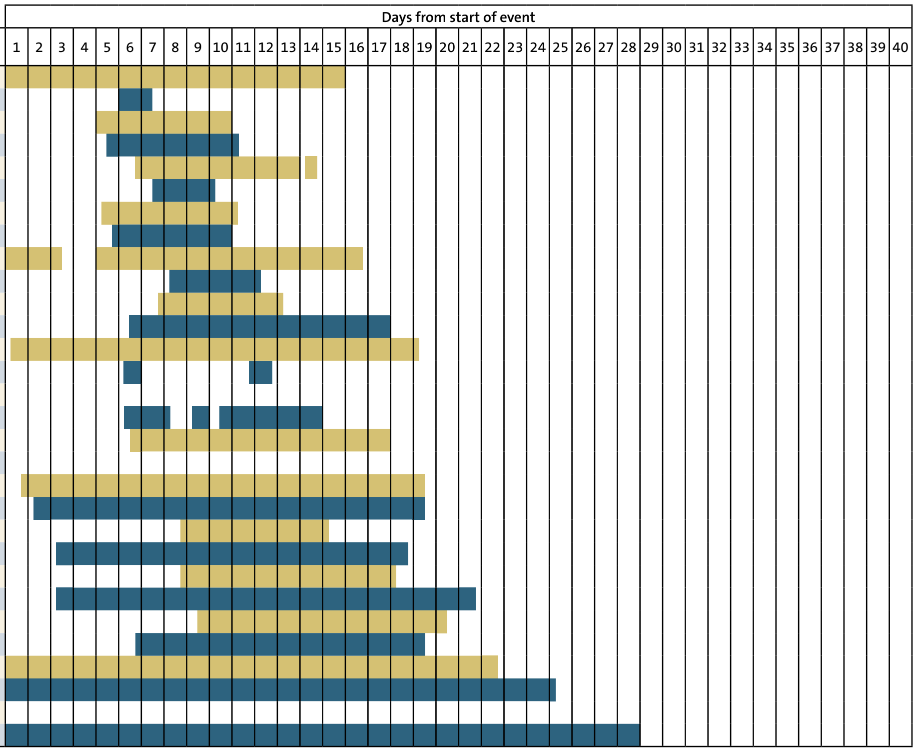


Simulated inundation area and maximum inundation depth across the Fitzroy River floodplain during a flood with a 14 year ARI (February-March 2002).



Simulated inundation duration across the Fitzroy River floodplain during a flood with a 14 year ARI (February-March 2002).

ID	Wetland	Duration (days)	Distance (km)
1	Duck Hole	15.3	5.7
2	Lilyhole Billabong	1.5	8.6
3	Coorie Billabong	6.0	4.5
4	Jillyardie Waterhole	5.8	4.9
5	Pelican Billabong	7.8	5.1
6	Sevenmile Billabong	2.8	4.0
7	Patersons Dam	6.0	15.8
8	Quanbun Billabong	5.3	12.9
9	Red Billabong	14.3	1.9
10	Mallallah Swamp I	4.0	14.1
11	Mallallah Swamp II	5.5	12.7
12	Sandy Billabong	11.5	6.9
13	Balwynah Pool	18.0	3.1
14	Gumhole Billabong	1.8	42.3
15	Peaceful Lagoon	0.0	0.0
16	Duckhole Billabong	7.3	12.1
17	Goosehole Billabong	11.5	4.8
18	SandHill Swamp	0.0	0.0
19	Backhouse Waterhole	17.8	5.5
20	Slaughter Hole	17.3	7.0
21	Quonga Waterhole	6.5	8.6
22	Broken Wagon Pool	15.5	0.9
23	Troys Lagoon	9.5	1.7
24	Ligligin Waterhole	18.5	2.8
25	Ninemile Pool	11.0	3.1
26	Yallamungie Pool	12.8	3.6
27	Camballin Floodplain	22.0	7.8
28	Le Lievre Swamp	24.5	23.4
29	Lake Daley	0.0	0.0
30	Upper Liveringa Pool	28.3	5.4



Predicted timing and duration of connectivity of wetlands to the Fitzroy River during the flood of February-March 2002 (ARI 14 years).

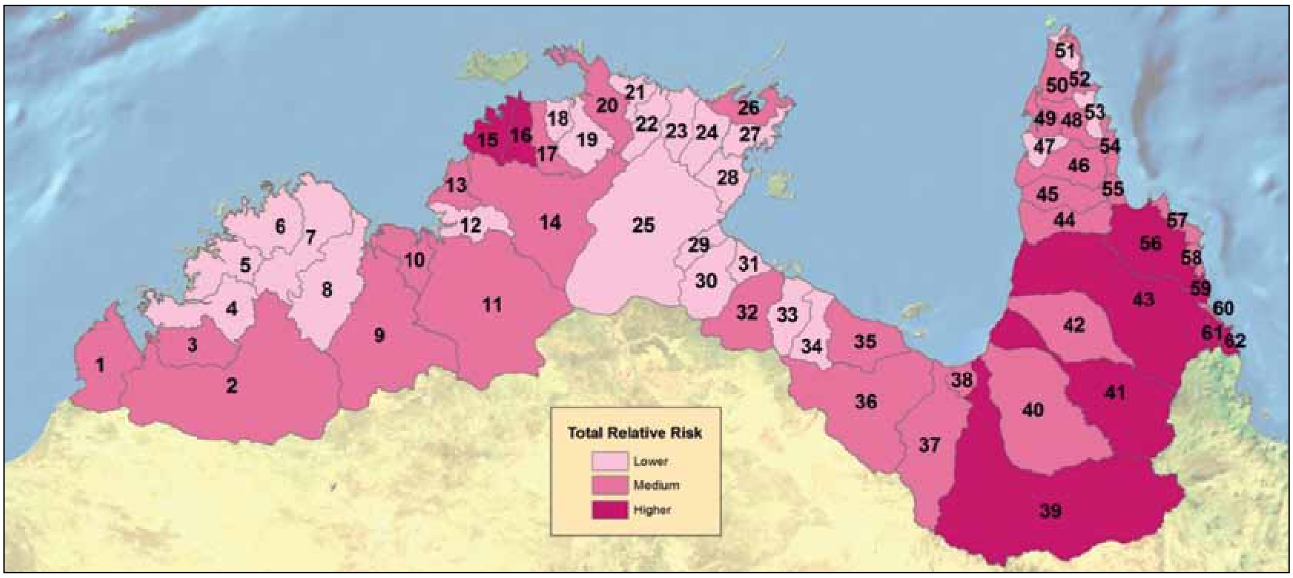
Likely impacts of climate change and development

The likely impacts of climate change and development on a variety of assessment endpoints were quantified using a spatially-explicit Relative Risk Model (RRM). The model included high-resolution sub-catchment and species biodiversity data across the entire NAWFA area as well as the 15 focus catchments. Multiple assessments were undertaken to predict the potential impacts of a variety of threats (land use; potential sea level rise impacts; mining, and; river disturbance) on a range of aquatic habitat types (waterways, wetlands and riparian vegetation). The potential risks facing these habitats from the identified threats were assessed in terms of their effect on flow regimes, water quality, extent and health of riparian vegetation and biodiversity.

The regions at high risk from the threats assessed in this study were: the Finniss, Adelaide, Flinders, Gilbert, Daintree, Normanby, Mulgrave-Russell, Barron and Mitchell rivers. Grazing of natural vegetation was identified as the greatest threat followed by river disturbance and sea level rise. Water quality

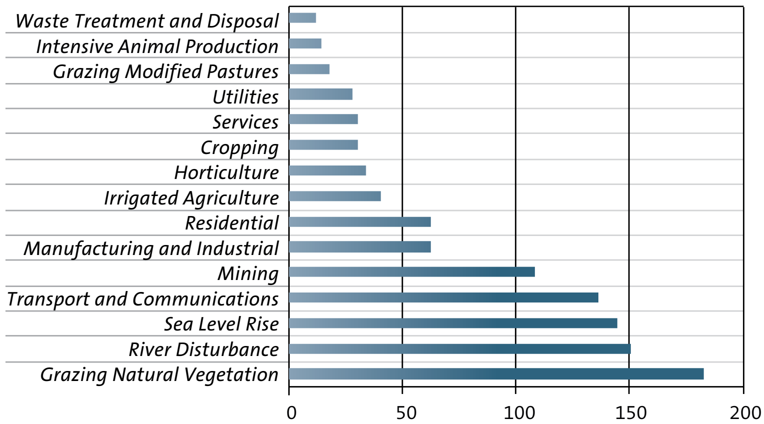

Image: Michael Douglas.


Image: Ian Dixon.



Total relative risk shown as higher, medium or lower for the 62 risk regions (catchments).

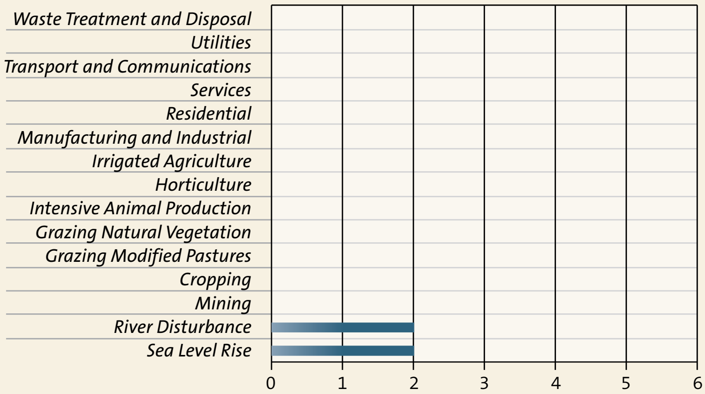
in northern Australian waterways was identified to be at significant risk from the threats identified above. Regions with the highest total risk to water quality were the Finniss, Adelaide, and Barron rivers. Interestingly, the maintenance of flow regimes was identified as having the lowest potential risk from the threats identified above. Regions with the highest total risk for maintenance of riparian vegetation included the Finniss, Mitchell and Flinders rivers. Regions with the highest total risk for maintenance of biodiversity were the Finniss and Adelaide rivers, and Jacky Jacky Creek.



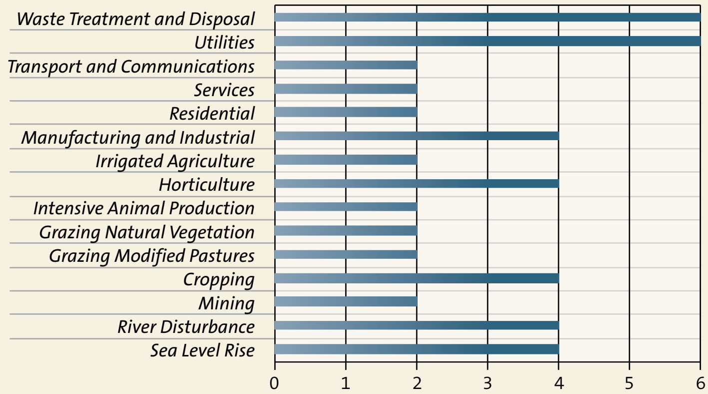
Sum of threats for each threat included in the RRM for the 62 risk regions (higher numbers indicate greater threat).

Uncontrolled cattle represent a significant risk to rivers in QLD. Image: TRaCK.

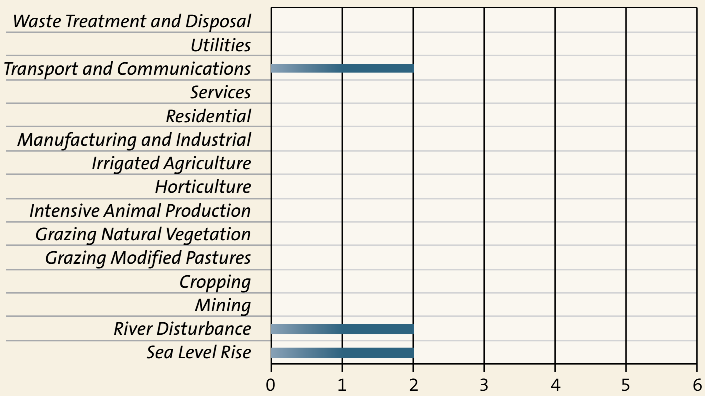
King Edward River



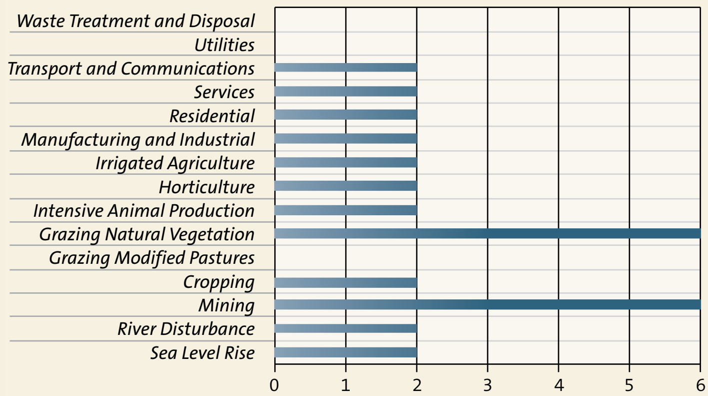
Finniss River



Goyder River

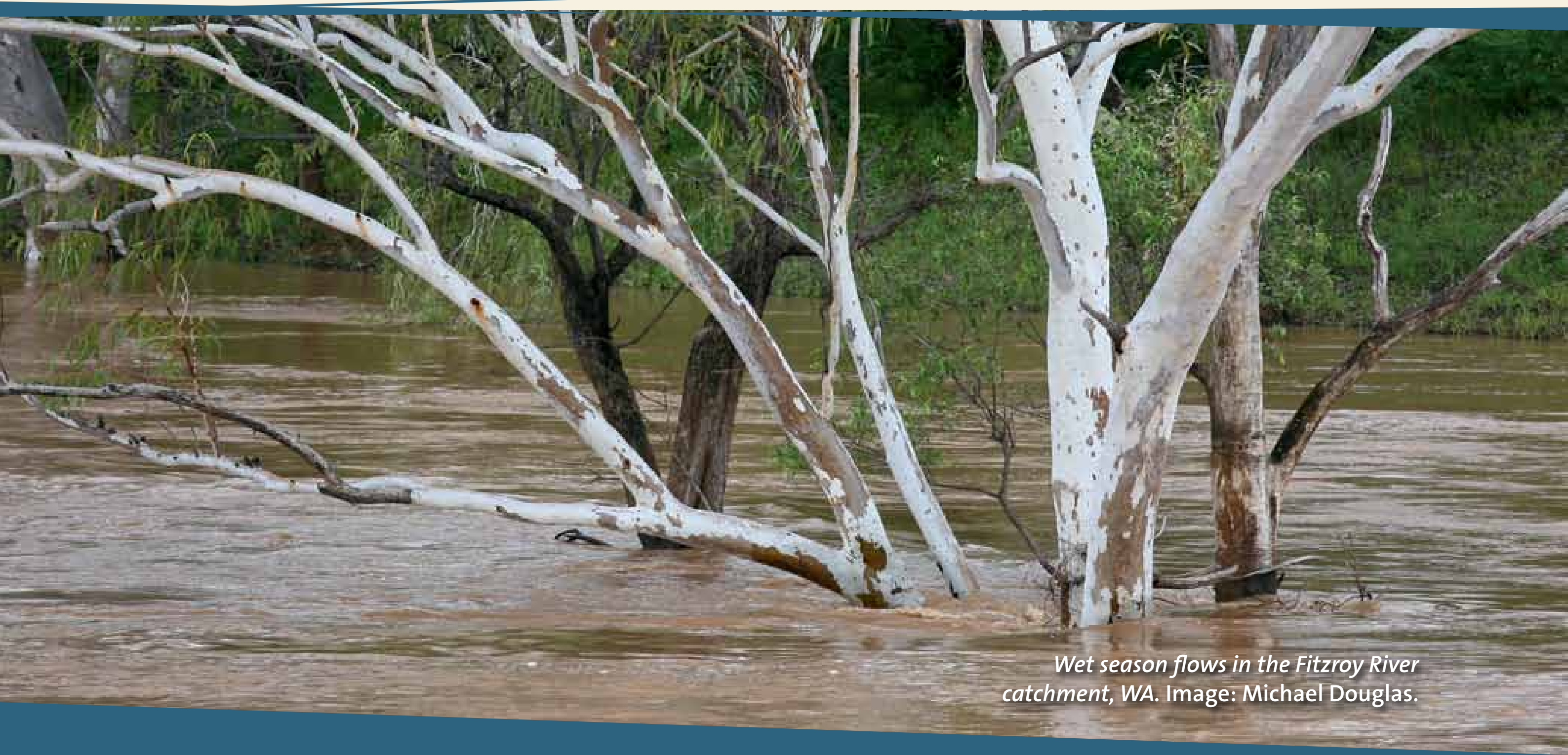


Mitchell River



Risk profiles for catchments identified as having low risk (higher numbers indicate greater risk).

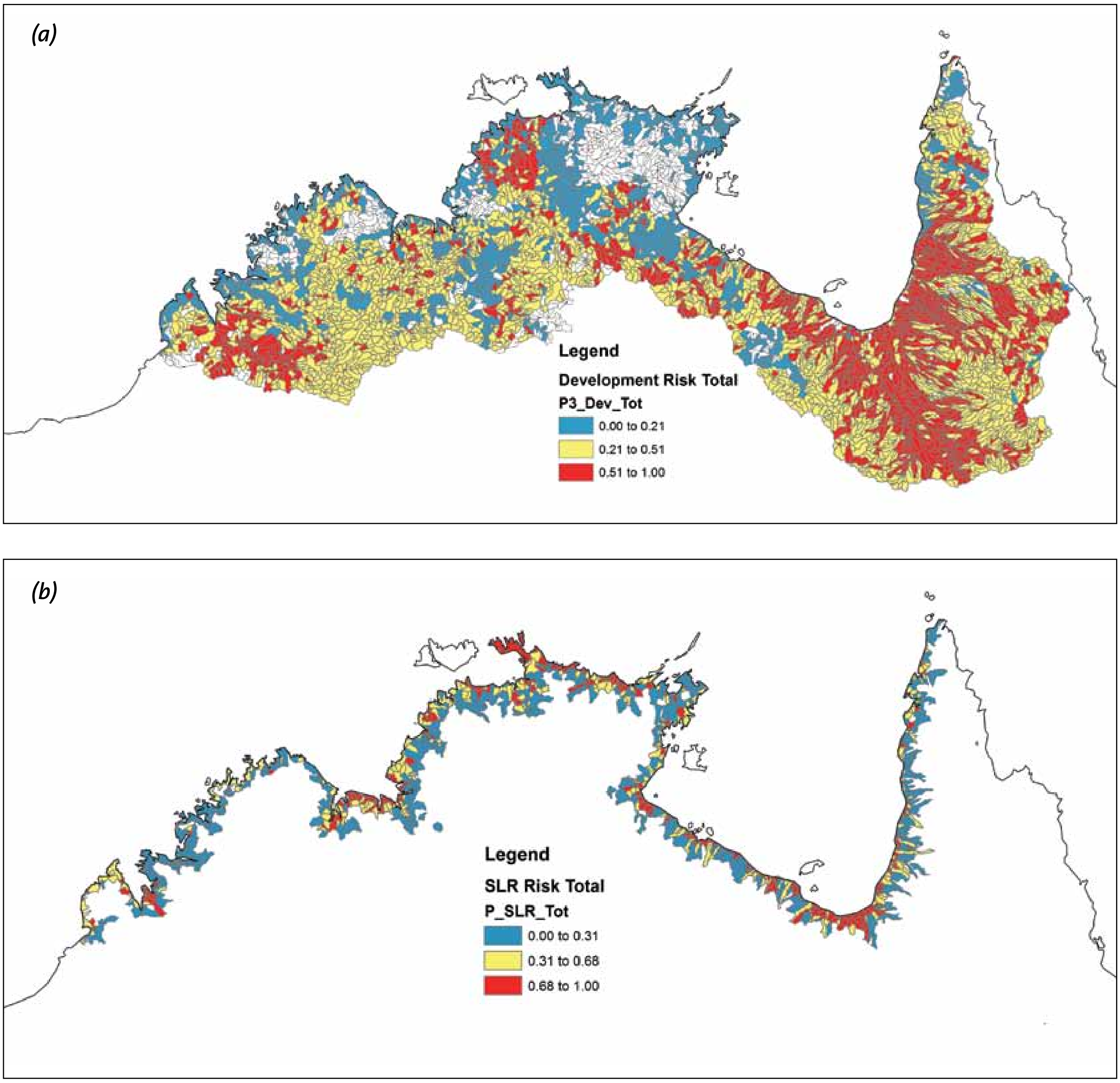
Risk profiles for catchments identified as having high risk (higher numbers indicate greater risk).



Wet season flows in the Fitzroy River catchment, WA. Image: Michael Douglas.

Risk profiles were also generated for each of the 15 focal catchments. The Finniss, Adelaide and Mitchell rivers were identified as those at most risk from climate change and development. Conversely the risk regions with the lowest risk scores are the King Edward and Goyder rivers.

The overall risk to aquatic ecosystems from development is about five times greater than that from a projected 1m sea level rise. Basins with aquatic ecosystems most at risk from current development comprised clusters in the southern Gulf of Carpentaria (Qld) and the Adelaide River basin close to Darwin (NT). In contrast, basins at least risk from current development comprise clusters in remote Arnhem Land (NT), the South and East Alligator River basins in Kakadu National Park, and the Moyle River basin. The basin most at risk from sea level rise is Mornington Inlet, being a small low-lying coastal catchment in the southern Gulf of Carpentaria.

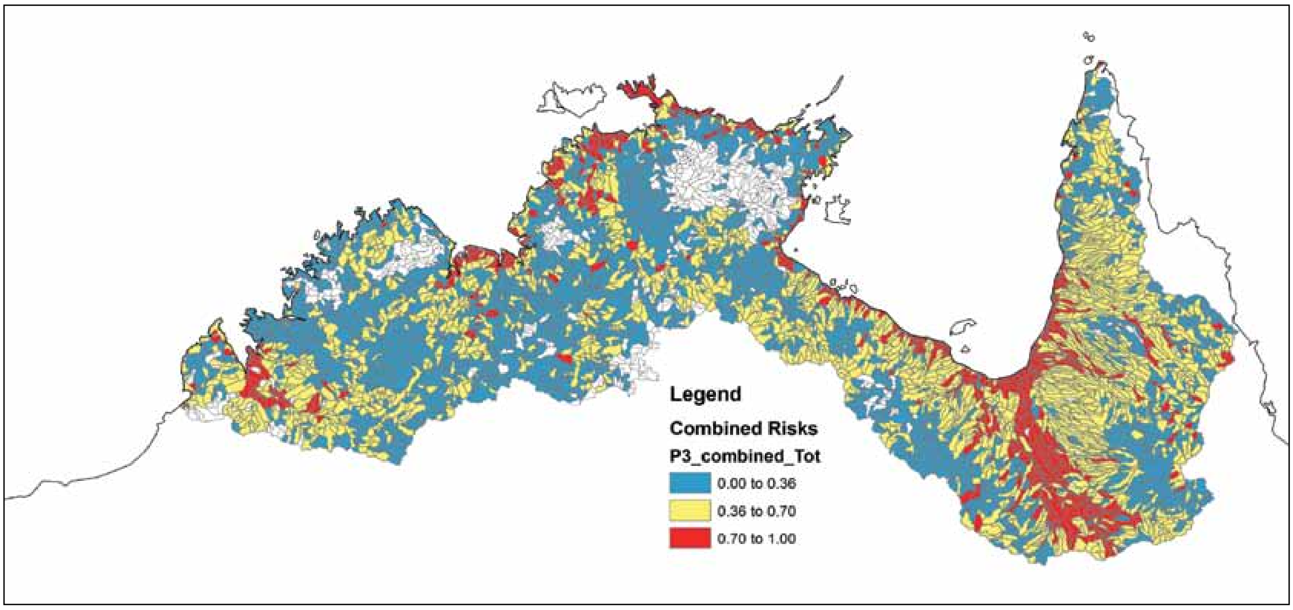


Total risk from (a) development and (b) 1 m rise in sea level (blue indicates low risk and red indicates high risk).

Four broad regions were identified as being at high risk from combined development and sea level rise: the Ord-Pentecost basins (WA); the Finniss-Adelaide-Mary-Roper basins (all around Darwin, NT); Joseph-Bonaparte Gulf; basins in northern Arnhem Land (NT); and basins in the southern GoC-western Cape York (Qld) region.

The overall risk from development to High Conservation Value Aquatic Ecosystems (HCVAE's) was 23 times greater than a projected 1m rise in sea level. For this study, HCVAE99 assets were the subcatchments most likely (99th percentile, or top 1%) to contain aquatic ecosystems that met at least one of the six HCVAE criteria. The Adelaide River basin had the greatest development risk to HCVAE99 assets, followed by the adjacent Mary River basin. The Mornington Inlet basin had the highest sea level rise (SLR) risk to HCVAE99 assets.

An analysis of risk to biodiversity from a projected 1m SLR identified about 10% of sub-catchments where at least one species of turtle is predicted to occur, and about 18% of subcatchments where fish



The combined total risks to equatic ecosystems from development and a 1m sea level rise (blue indicates low risk and red indicates high risk).

and waterbirds occur, will be affected by a 1m SLR. The mean risk to waterbird species is about three times greater than that for both turtles and fish, presumably because many water bird species are heavily reliant on shallow coastal wetland habitats such as tidal mudflats.

Important biological and ecological thresholds

Conceptual relationships and critical thresholds of habitat use by key fauna, as well as thresholds for vital ecosystem processes were identified based on review, synthesis and analysis of current data and knowledge.

Habitat Connectivity

Rivers are highly connected ecosystems and the distribution, reproductive biology and movement characteristics of freshwater fauna reflect this. Changes in connectivity between estuaries and their upstream river and floodplain habitats may significantly interfere with breeding and recruitment, impacting populations along the entire river length and resulting in flow-on effects to commercial and recreational fishing industries. The importance of connectivity was examined using genetic databases available for northern Australian fish populations.

Evidence clearly suggests that habitat-linkages are critical for population connectivity. Salt water intrusion, increasing water temperatures and changes to river flows associated with climate change are likely to alter the distribution, abundance and suitability of habitats in many tropical rivers.

Water Temperature

Water temperature is arguably the most important water quality parameter, directly influencing habitat suitability as well as modifying a wide variety of physical, chemical and biological processes. The maximum recorded water temperature from northern Australia is 44°C, although mean daily water temperatures rarely exceed 33°C. Based on laboratory experiments, the maximum thermal tolerance for a variety of fish and crustacea was approximately 39°C, with a range from 33°C - 42°C. In general the thermal tolerance of species considered in these analyses was greater than the water temperatures usually found in northern Australian waters. Given the over-riding effect of even short-term elevated temperatures in determining environmental outcomes this does not preclude temperature being a major driving force in tropical aquatic communities.

Image: Brad Pusey.

Image: TRaCK.

Ecosystem productivity

Australian tropical floodplains are generally considered highly productive ecosystems with seasonal flooding supplying fresh water and nutrient rich sediments to both river channels and downstream estuaries. Seasonal changes in water levels and associated increases in aquatic and floodplain primary production usually produce a corresponding shift in the nature of the dominant primary producers. Regional variation in hydrological regimes, particularly the degree of flood plain inundation, strongly influences the nature of primary productivity. Many of the drivers and triggers for primary productivity in northern Australian aquatic ecosystems are system specific. Nonetheless, the magnitude, duration, rate of rise and timing of peak flows are likely to be key drivers of riverine, floodplain and estuarine productivity.

Hydrological regimes

Impacts of climate change and development on natural hydrological regimes are many, varied, persistent, interactive and difficult to reverse. Development impacts often have clear and direct effects on the timing and rates of rise and fall of water flow. Devegetation and water regulation alter the frequency, duration, and rates of rising and falling flow. They can also alter groundwater rates of recharge and discharge, and duration of base flow. There are few examples in northern Australia where naturally intermittent or ephemeral streams have become perennial due to water regulation. With increasing water resource development, and the expansion of mining activities, these effects may become more widespread in the future. The most significant impact of water supplementation of naturally intermittent waterways appears to be the proliferation and spread of aquatic weeds and macrophytes. It is likely that the presence of permanent water and deeper pools will facilitate the movement of estuarine fish species further upstream. The presence of these species would likely impact resident aquatic fauna, both indirectly through their effect on local food sources, and directly through predation and competition, resulting in changes to assemblage structure.

Groundwater maintains river flows and waterholes throughout the dry season. Image: Danielle Warfe.

Invasive plant species

Globally, aquatic ecosystems are considered to be highly vulnerable to invasion by alien plants. Weeds have been found to have negative impacts on the environment, the economy and Indigenous cultural values. In northern Australia, five species are listed as Weeds of National Significance (WoNS) because their impacts on natural and agricultural systems are so severe: giant sensitive tree, olive hymenachne, cabomba, salvinia and rubber vine. Other weeds that have serious impacts on northern Australia's aquatic ecosystems, include para grass, water lettuce and gamba grass. Increased CO_2 levels and temperatures associated with climate change are likely to increase the growth and geographical distribution of invasive weed species. Other impacts of climate change may limit the spread of weeds in some habitats, for example, rising sea levels will reduce the availability of freshwater habitats for some weed species. Species distribution models offer a potentially useful management tool to identify environmental conditions where weed species may establish and survive.

Based on the review of key biological and ecological thresholds the following relationships were identified between seasonal flow characteristics and key ecological values.

Season: DRY

- River base flow, cease to flow events, and groundwater levels are the key flow components of the dry season.
- The duration and timing of disconnection, the rate and variability of winter base flow and the persistence and level of groundwater discharge have the greatest impact on ecological values.
- Flow components support a wide range of biological values, and maintain ecological integrity and vital ecosystem processes such as reproduction and migration.

Mitchell-Lawley Rivers Region, WA.
Image: Cathy Zwick and DSEWPaC.

Season: DRY-WET Transition

- The onset of flows and floods at the commencement of the wet season are the key flow components during this transition.
- The duration, timing and magnitude of flow have the greatest impact on ecological values.
- Values associated with longitudinal connectivity are important during this transition, with dominant processes including cues for reproduction, and the alleviation of stresses related to the late dry.

Season: WET

- Flood events, peak and total annual flow, and groundwater recharge are the key flow components of the wet season.
- The duration, magnitude and extent of flood inundation, as well as the timing and volume of total wet season flow, and the rate of groundwater recharge, have the greatest impact on ecological values.
- Flow components support a wide range of biological values and extensive aquatic and terrestrial primary productivity. Dominant processes include habitat maintenance, nutrient supply and connectivity: allowing for successful migration/reproduction and appropriate genetic exchange.

Season: WET-DRY Transition

- High flow recession and groundwater dynamics are the key flow components during this transition.
- The magnitude, duration and timing of groundwater discharge affects primary productivity values, whilst the recession of flood and peak flows and groundwater levels affects the persistence of aquatic fauna, which may become stranded on the floodplain or in unviable habitats if flows recede too quickly.

A small permanent stream in the upper reaches of the Mitchell River catchment, QLD. Image: TRaCK.

Image: Michael Douglas

Season: ALL

- Variability, base flow and mean annual flow are key flow components throughout all seasons.

- Variability in seasonal wetting and drying, and in flow parameters such as rates of rise, magnitude and constancy impact ecological values such as species diversity, productivity and habitat structure.

- Base flow perenniality, and the magnitude of mean annual flow increases fish biodiversity due to increased connectivity and productivity.

Management priorities and monitoring options

There is a need for research that links social-cultural values with a more holistic understanding of a healthy ecosystem. By synthesizing a number of different perspectives, integration can improve understanding and also the application or implementation of research knowledge. As part of this project a framework was developed to analyse the interacting effects of development (under different climate change scenarios) on social, environmental and economic indicators in northern Australia. A test-application of the framework highlighted the utility of this approach as a relatively simple and rapid management tool, capable of addressing complex interacting management issues.

A preliminary assessment of existing regional (jurisdictional) management objectives, monitoring and assessment priorities and frameworks, indicated that management agencies have the capacity to report against likely risks associated with climate change and development in Northern Australia.

Reflections on the Hann River, Fitzroy River catchment, WA. Image: Danielle Warfe.

Where to next

This project has provided jurisdictional water planners in northern Australia with new information, techniques, data and knowledge that can be incorporated into management frameworks to address the risks associated with climate change and development to northern Australian aquatic ecosystems. A variety of knowledge gaps and key recommendations were identified by this project. While existing research programs, such as the National Environmental Research Program (NERP), will provide significant benefit to the management of climate change and development risks, many of the specific knowledge gaps and recommendations identified in this project's technical report will remain unanswered without further targeted research and monitoring. These gaps represent significant constraints on the development, implementation and monitoring of management actions. Consequently, these gaps should be explicitly stated within the adaptive management frameworks of relevant water and biodiversity management agencies within each jurisdiction. This will allow opportunities for existing management and monitoring actions to be adapted, enhanced or extended to incorporate new knowledge. This approach will also help to guide any future investment in research and monitoring of Northern Australian aquatic ecosystems and associated ecological values and processes, in line with the knowledge gaps and recommendations noted above.

Further Information

The project was funded as part of the Northern Australia Water Futures Assessment (NAWFA). NAWFA was a multidisciplinary program delivered jointly by the National Water Commission and the Department of Sustainability, Water, Population and Communities, in close collaboration with the Office of Northern Australia and State and Territory government agencies.

This project was developed in collaboration with research partners from TRaCK (Tropical Rivers and Coastal Knowledge **www.track.gov.au**) – a research hub which has drawn together more than 70 of Australia's leading social, cultural, environmental and economic researchers.

The project was lead by The University of Western Australia's Centre of Excellence in Natural Resource Management. The project team included researchers from The University of Western Australia, Griffith University, Charles Darwin University, James Cook University, the Environmental Research Institute of the Supervising Scientist and CSIRO. The project was undertaken in collaboration with the jurisdictions; Department of Water (WA), Natural Resources,

Expansion of irrigated agriculture threatens some waterways in QLD. Image: TRaCK.

Environment, The Arts and Sport (NT) and Department of Environment and Resource Management (QLD).

Contacts

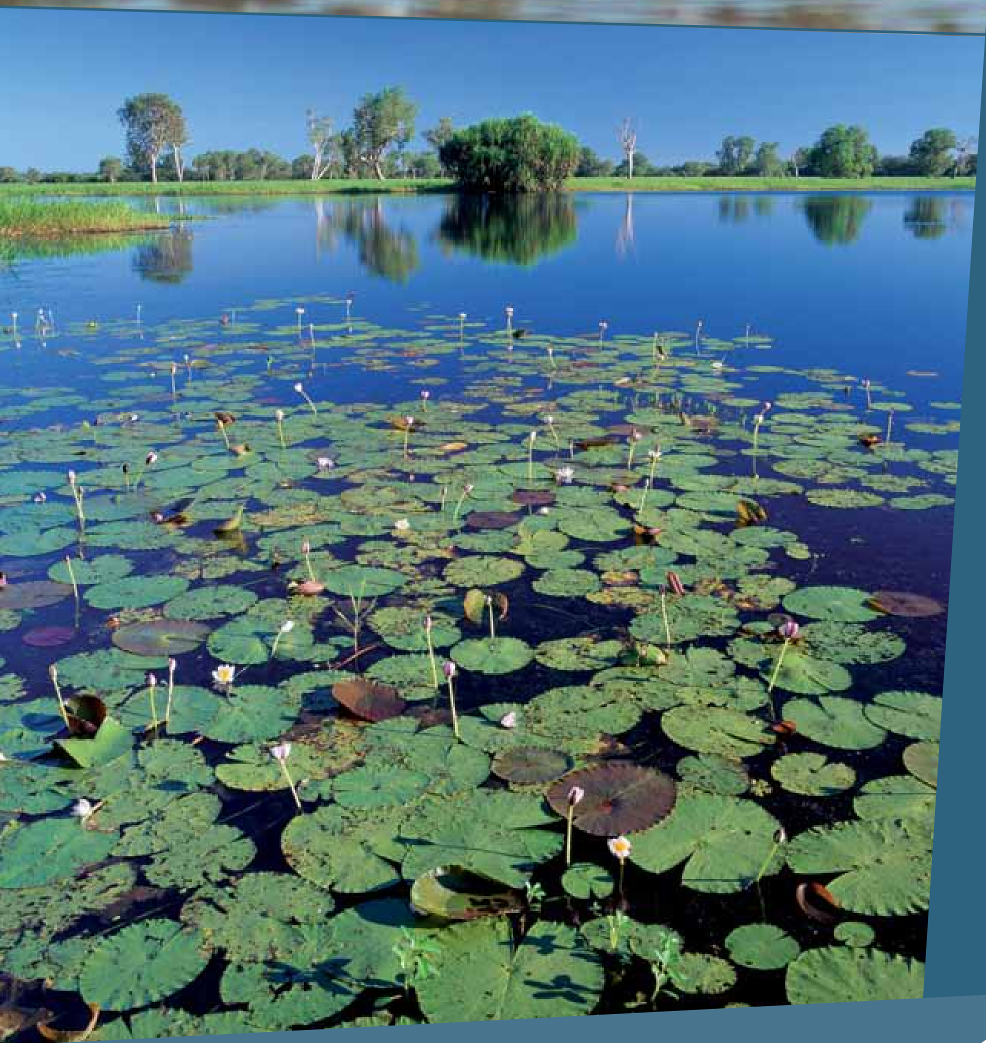
For more information on this project, or to access the full technical report, contact:

Northern Australia Water Futures Assessment
Department of Sustainability, Environment, Water, Population and Communities
email: northern.assessment@environment.gov.au
phone: 1800 218 478
web: www.environment.gov.au

Paul Close
Tropical Rivers and Coastal Knowledge (TRaCK)
The University of Western Australia
email: paul.close@uwa.edu.au
phone: 08 9842 0833
web: www.cenrm@uwa.edu.au

Image: Neil Armstrong

Image: Brad Pusey



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

Australian Government
Department of Sustainability, Environment, Water, Population and Communities
National Water Commission

For more general information about TRaCK

visit www.track.gov.au
email track@cdu.edu.au

TRaCK
Tropical Rivers and Coastal Knowledge