TRaCK
Tropical Rivers and Coastal Knowledge

Indigenous socio-economic values and river flows

A Summary of Research Results: 2008–2010

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National Water Commission
Fisheries Research and Development Corporation

CSIRO

Tropical Rivers and Coastal Knowledge

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

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Tropical Rivers and Coastal Knowledge
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Indigenous socio-economic values and river flows

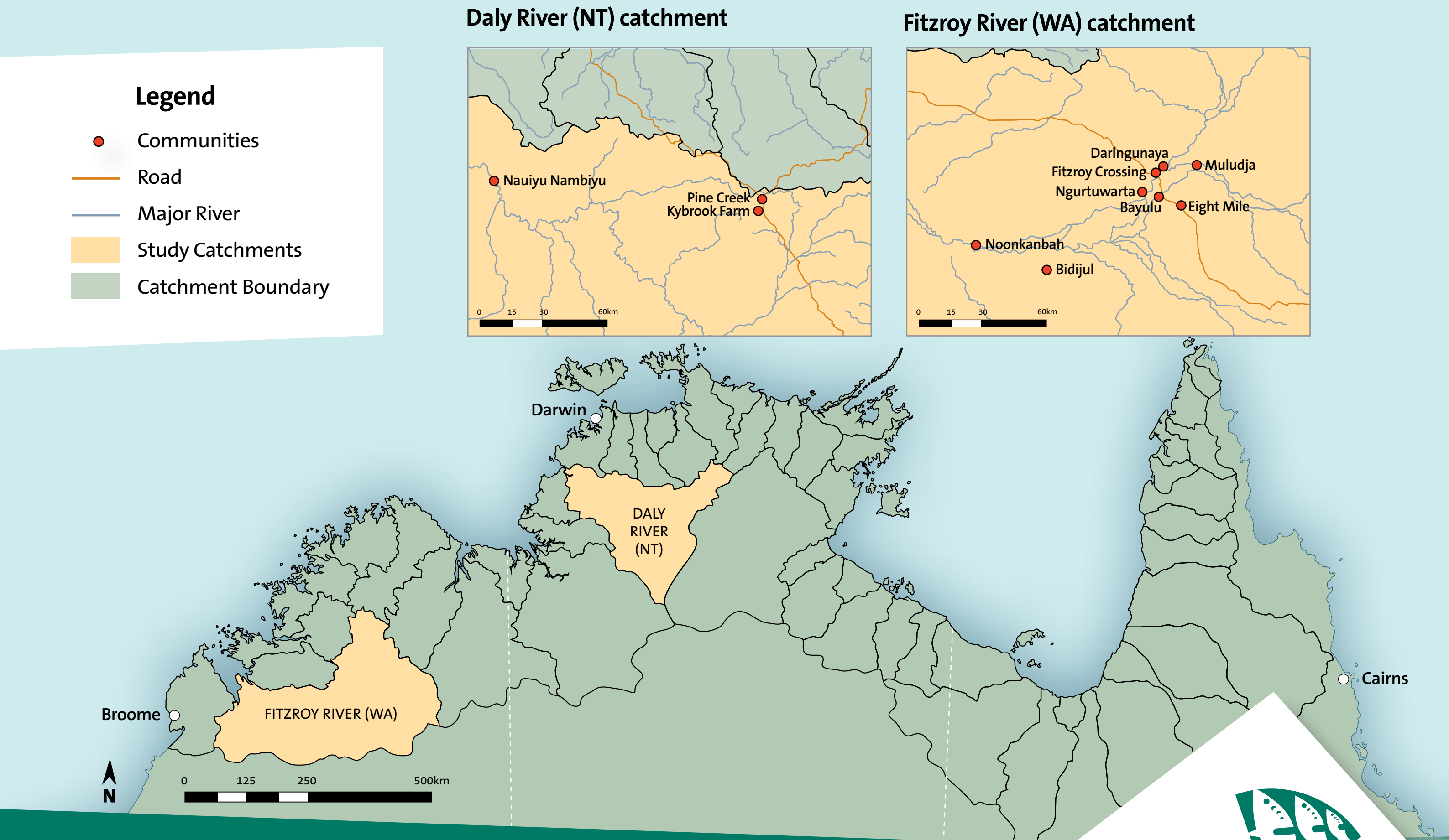
*This booklet is a summary of the final report from the **Indigenous Socio-economic Values and River Flows** project of the Tropical Rivers and Coastal Knowledge (TRaCK) program.*

Australia's tropical rivers account for about 70 per cent of Australia's total runoff. With water becoming an increasingly valuable resource in southern Australia there is growing interest in the water resources of the north, particularly for irrigated agriculture. There is also recognition that tropical river systems sustain important fisheries, and underpin a wealth of other natural and cultural assets valued by society. The sustainable management of water in northern Australia requires good information on our river systems – how they work and how people value and use them.

Australia's tropical rivers hold special significance for Indigenous communities. Indigenous people value rivers in a number of interrelated ways; they provide bush foods and medicines; they are part of a culturally significant landscape; and have the potential to sustain future water-related businesses and employment. Indigenous values associated with rivers tend to be poorly understood by decision-makers, and some are difficult to relate explicitly to particular river flow patterns and to address in water allocation decisions.

The *Indigenous Socio-economic Values and River Flows* project addressed these issues in two catchments, the Fitzroy River of Western Australia and the Daly River of the Northern Territory, over three years (***Figure 1***). The project team combined qualitative and quantitative methods to understand the spatial and temporal pattern of resource use, its social, cultural and economic significance to local communities and their economies, and the eco-hydrological dependencies of the aquatic resources consumed by Indigenous households.

Figure 1
The research team worked in two TRaCK focal catchments – the Daly (NT) and Fitzroy (WA).



Assets and Values

Project aims

The aims of the project were to:

1. Document the significance of water and river systems (including groundwater) to Indigenous communities, particularly to Indigenous belief systems and environmental philosophy.
2. Quantify the direct economic value derived from Indigenous use of wild resources found in, or reliant upon, rivers and wetlands.
3. Assess the social, cultural and economic impacts of changes to flow regime on Indigenous communities.
4. Collaborate with Indigenous land management agencies to develop and trial a participatory monitoring program for flow regime changes and wild resource use.

We wanted to answer the following questions:

Stage 1 Resource and values assessment (Years 1-2)

1. **Where and when do people go fishing, hunting and gathering?**
2. **How often do people fish, hunt and gather?**
3. **What can Indigenous people tell us about the ecology of river flows?**

Stage 2 Economic valuation (Years 2-3)

4. **What is being caught and harvested?**
5. **Who is consuming the harvested plants and animals?**

Stage 3 Impact assessment (Year 3)

6. **What might be the effect of water use decisions on Indigenous values?**
7. **What participatory monitoring methods might suit Indigenous groups?**

Project stages and methods are shown in the diagram below:

Stage 1: Resource and values assessment

- River-use mapping
- Qualitative social research
- Household surveys

(Year 1-2)

Stage 2: Economic valuation

- Quantification of harvested species
- Calculation of replacement value
- Qualitative social research

(Year 2-3)

Stage 3: Impact assessment

- Modelling of flow regimes, and potential flow alterations
- Assessment of impact and cost to Indigenous livelihood
- Social and cultural impacts of flow alteration

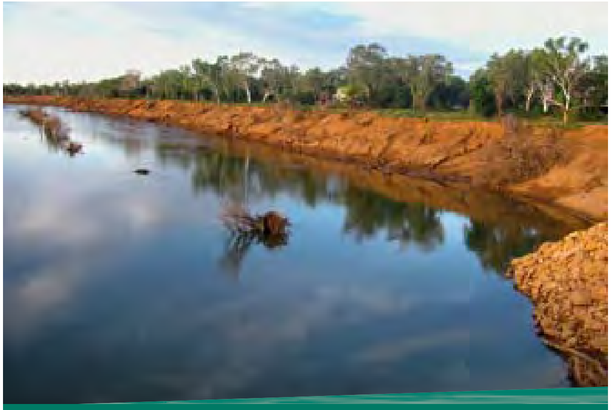
(Year 3)

A significant effort was devoted to recording local ecological knowledge (reproduced in multiple forms including seasonal calendars), and to enhancing local capacity for environmental monitoring.

Who did we work with?

In the Daly River region in the NT the project team worked with the communities of Kybrook Farm and Pine Creek and Nauiyu Nambiyu (Daly River). In the Fitzroy Valley of the Kimberley, residents from the communities of Bayulu, Bungardi, Darlgunya, Junjuwa, Ngurtuwarta, Muludja and Noonkanbah were engaged along the Fitzroy River. Representatives from a number of language groups were involved in the research, including Ngan'gi, MalakMalak and Wagiman speakers from the Daly region and Bunuba, Gooniyandi, Walmajarri and Nyikina-Mangala speakers from the Fitzroy region.

The research team worked closely with the project Steering Committee, which included representatives and specialists from the Northern Territory's Department of Natural Resources, Environment, the Arts and Sport, Western Australia's Department of Water, the Australian National University's Centre for Aboriginal Economic Policy Research, the University of Western Australia and CSIRO. We sought to keep participating communities and local and regional stakeholders updated through regular e-newsletters.



The Fitzroy River at Fitzroy Crossing, Western Australia.

The Daly River at Nauiyu Nambiyu, Northern Territory.

Project e-newsletter updates and brochures were distributed throughout the course of the project.

How did we do the research?

The project involved the following activities:

1. River-use mapping – gathering data on Indigenous resource use.

This information was gathered in small meetings in each community and was used to:

- Create maps of the spatial distribution of resource use to help understand which habitats were most commonly used and how river flows (particularly flooding and drying cycles) might affect those habitats; and
- Contribute to the development of seasonal calendars representing Indigenous ecological knowledge of seasonal change.

River mapping with residents of Ngurtuwarta, Fitzroy River.

River mapping with residents of Bayulu, Fitzroy River.

Documenting species harvested at Muludja Community. Emma Woodward (CSIRO) with June Davis and Helen Malo.

2. Household surveys – quantifying the harvest and consumption of aquatic resources.

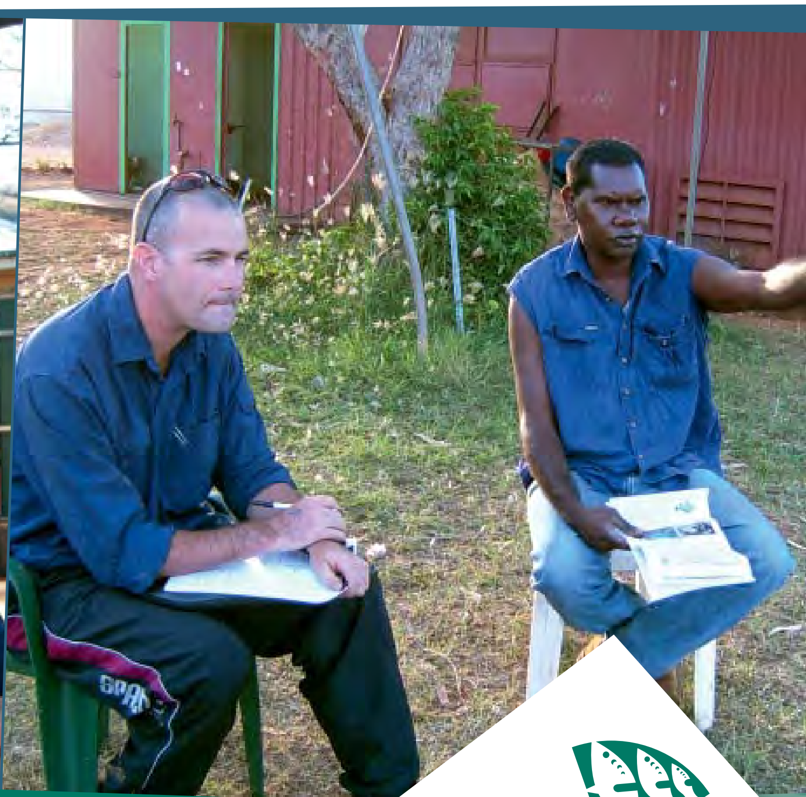
Approximately 20 per cent of households in the selected communities of Nauiyu Nambiyu (NT), Pine Creek (NT), Fitzroy Crossing (WA) and Noonkanbah (WA) were surveyed. Surveys involved fortnightly interviews eight times a year with a senior member of each household. The survey targeted aquatic species and habitats and asked how often people in the household went fishing or hunting, who participated, the location, total harvest, how much the surveyed household consumed, as well as some broad questions on the sharing and use of the harvested species. The surveys began in 2008 and were completed by November 2010.

George Brooking signing off on a household survey that he has just completed with Marcus Finn (CSIRO), Brooking Springs, Fitzroy Crossing, WA.

Pippa Featherston (CSIRO) conducting a household survey with Peter Martin and family, Nauiyu Nambiyu, Daly River, NT.

Below left: Daisy Smith being surveyed by Pippa Featherston (CSIRO) at Bayulu Community, Fitzroy Crossing, WA.

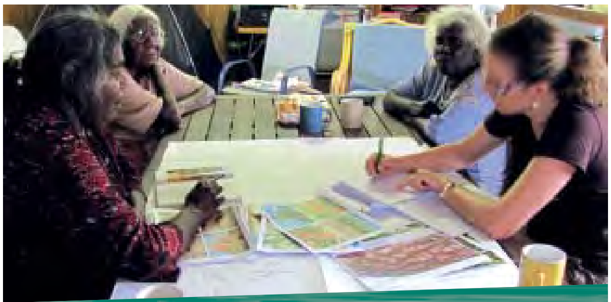
Below right: Marcus Finn (CSIRO) interviewing Roderick Andrews for a household survey, Junjuwa Community, Fitzroy Crossing, WA.



3. Social and cultural studies of Indigenous values.

In collaboration with participating communities, the research team identified a range of research activities and methodologies to reveal the social and cultural value of river systems. These included documentation of local social histories and cultural knowledge, community artworks, seasonal calendars, river mapping, and a photography project with school children and community members. These activities have contributed to a better understanding of the social effects of water-use changes.

Working on a Photovoice project with students at Noonkanbah, Fitzroy Catchment, WA.



Working on the 'Walmajarri words from the river side': Left to Right, Joy Nuggett, Amy Nuggett, Nancy Bangu and Emma Woodward (CSIRO).

Photos and stories from Nauiyu Nambiyu: results of a photography project (Photovoice) with community members, Daly River, NT.

What did we find?

1. *Where and when do people go fishing, hunting and gathering?*

In the **Daly River catchment**, harvesting sites radiate from the Nauiyu community along the Daly River. Additional harvesting sites were indicated along tributaries and low-lying floodplain areas downstream of the community. River-use mapping conducted with residents from Pine Creek and Kybrook Farm showed a cluster of sites around Claravale Crossing at the upstream limit of sites, extending downstream for a substantial distance.

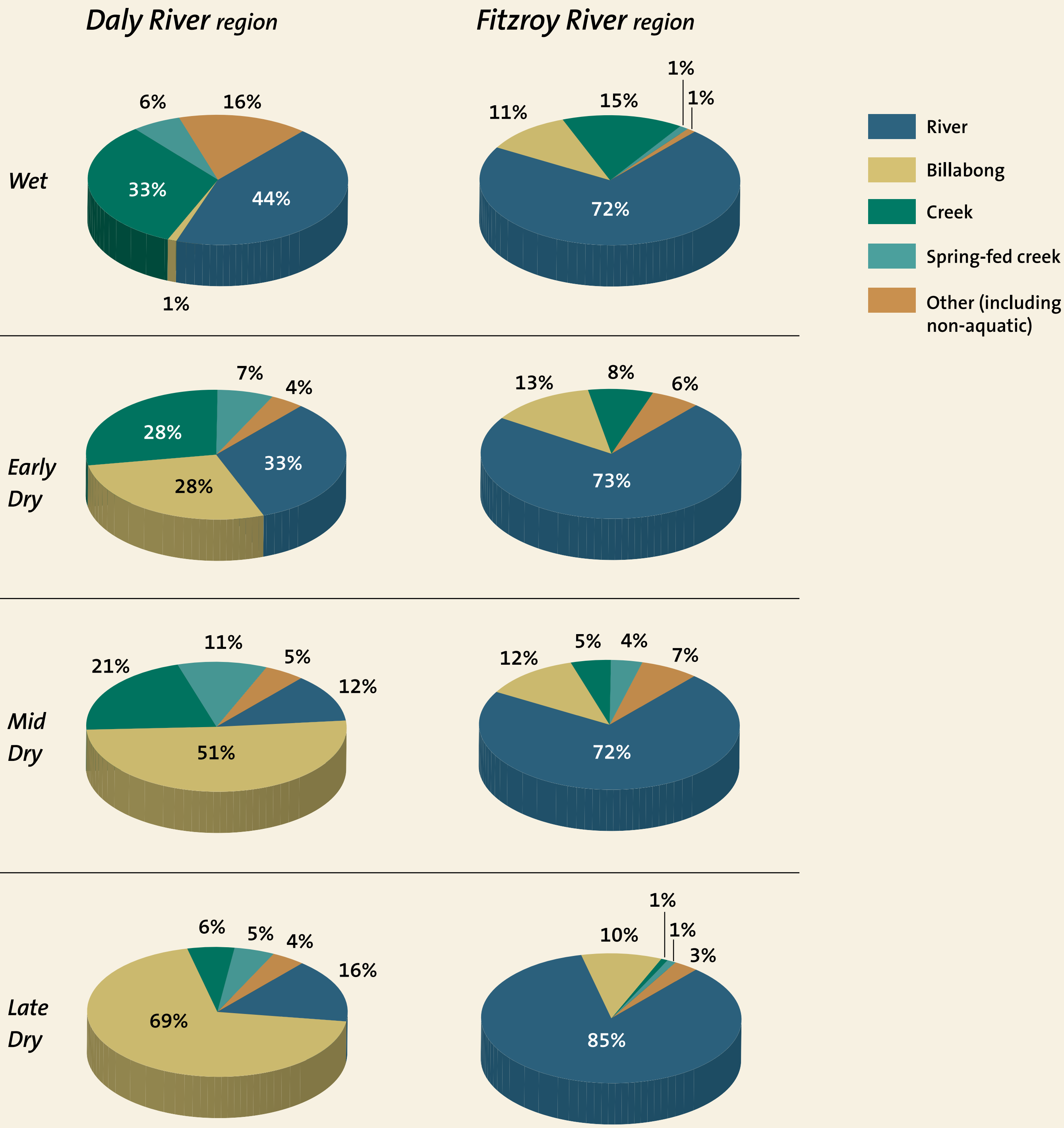
In the **Fitzroy River catchment**, harvesting trips were distributed well upstream and downstream of the Fitzroy Crossing communities where river-use mapping took place. Comparison of river-use mapping data and household survey data suggests that physical access to fishing locations can play a substantial role in influencing where people go and the frequency of the trips undertaken. There are substantial differences in the way survey respondents in the Fitzroy and Daly River catchments use aquatic habitats.

Harvesting activities in the Fitzroy River are largely focussed on use of the main river channel, with visits to the main river channel making up more than 70% of all trips throughout the year. In the Daly, however, harvesting activities showed a clear switch from use of the main river channel during the wet season, to billabongs becoming the focal point of activities as the dry season continued (***Figure 2***). By the late dry season, 70% of all Daly trips are to billabongs, whereas at the same point in time in the Fitzroy, billabongs account for only 10% of trips (***Figure 2***).These differences reflect the accessibility of different aquatic habitats. Whereas the main river channel was accessible to Fitzroy River communities throughout the year, the locations in which our Daly River respondents live tend to become isolated by floodwaters during the wet season, and much of the country they usually visit for harvesting activities is inaccessible.

Molly Yawulminy fishing with a handline at a Daly River billabong during the late dry season.

Fishing at a pool on the Margaret River, a tributary of the Fitzroy River.

Figure 2
Where people hunt and fish in the Daly and Fitzroy River regions.



These differences in flow regimes and accessibility also result in differences in the seasonal pattern of harvesting effort (***Figure 3***). During our household surveys at the height of the wet season in 2009 and 2010 in the Daly River, 45% of respondents mentioned they had not been fishing because “the water is too high”, it is “too boggy” or the river was “running too hard”, compared to a similar response from only 8% of survey respondents in the Fitzroy.

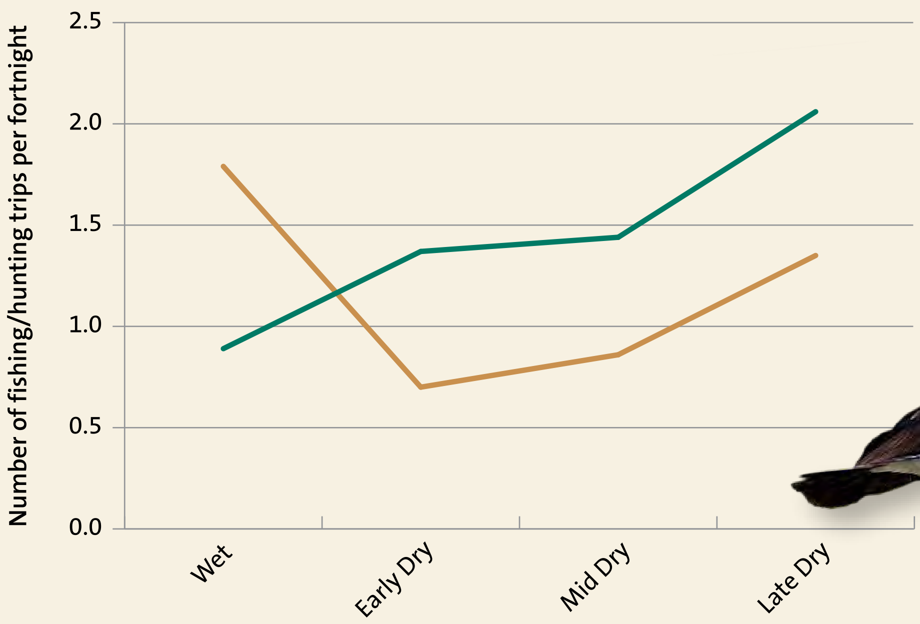
While harvesting locations are also isolated by floodwaters in the Fitzroy catchment, flooding in the Fitzroy and Margaret rivers stays largely within the river channel. This allows our survey respondents, most of whom live within walking distance of the river channel, ready access to the river for fishing during the wet season.

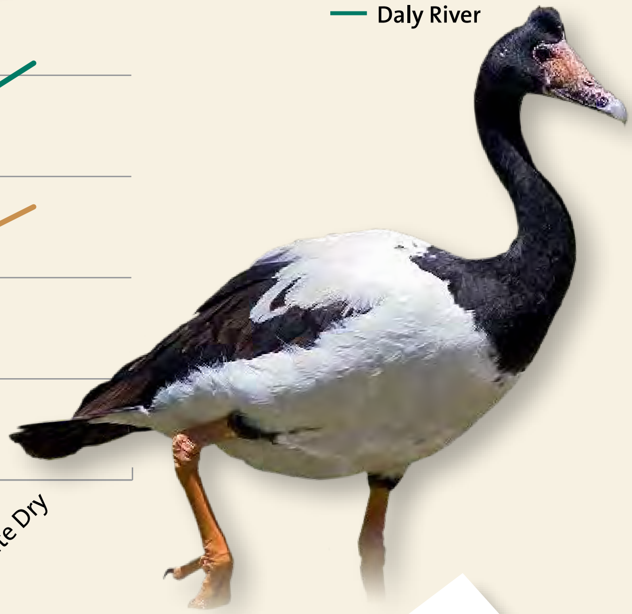
This period in the Fitzroy is also well known as an excellent time to catch Barramundi (*Lates calcarifer*) and Catfish (*Neoarius* spp.) at locations where flooded creeks are running back into the river. Fitzroy River survey respondents often commented on people “going mad for Barramundi” at this time, and so the fishing effort was substantial, as the graph in ***Figure 3*** illustrates.

The plants and animals harvested for customary use are often associated with particular habitats during particular times of the year. For example, Magpie Geese (*Anseranas semipalmata*) and Long-necked Turtle (*Chelodina rugosa*) are often harvested from billabong habitats late in the dry season, when they are found in large numbers. Understanding species-habitat linkages, and knowing which habitats are most commonly used for harvesting activities, can help prioritise the management of valuable areas.

Figure 3

Seasonal patterns of harvesting in the Fitzroy River and Daly River catchments.





Assets and Values

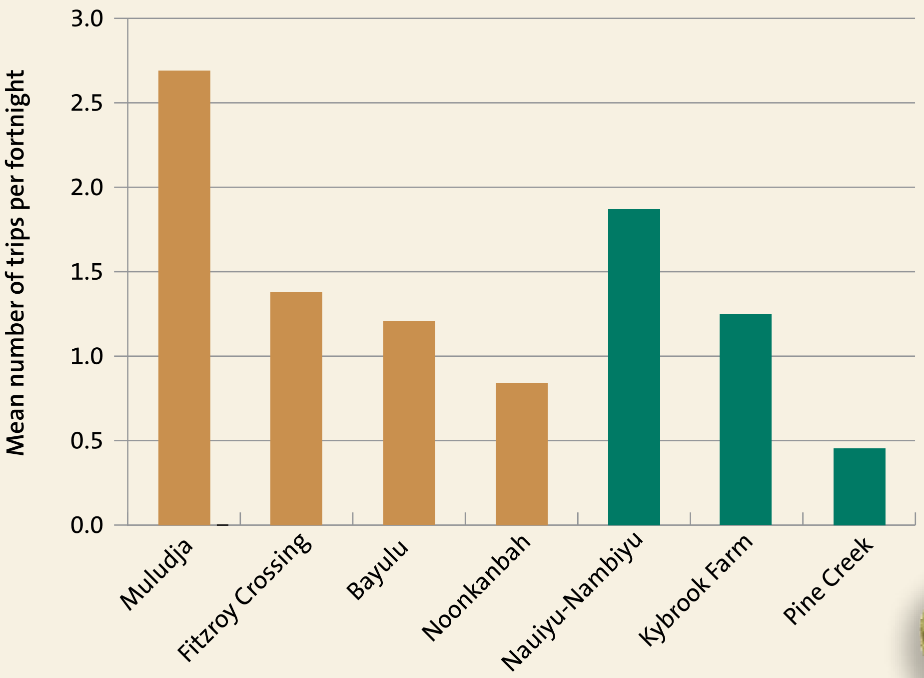
2. *How often do people fish, hunt and gather?*

The frequency of fishing and harvesting trips ranged from 0.49 trips per fortnight for the households that we surveyed in Pine Creek (Daly), to an average of 2.7 trips per fortnight for survey households in Muludja (Fitzroy) (***Figure 4***). Overall, survey households from the Daly River tend to undertake more fishing and harvesting trips (1.52 trips per fortnight) than survey households from the Fitzroy River (1.37 trips per fortnight).

Turtle hunting at a Daly River billabong.

Figure 4

Number of trips undertaken by survey respondents in the Fitzroy River and Daly River catchments.



3. *What is being caught and harvested?*

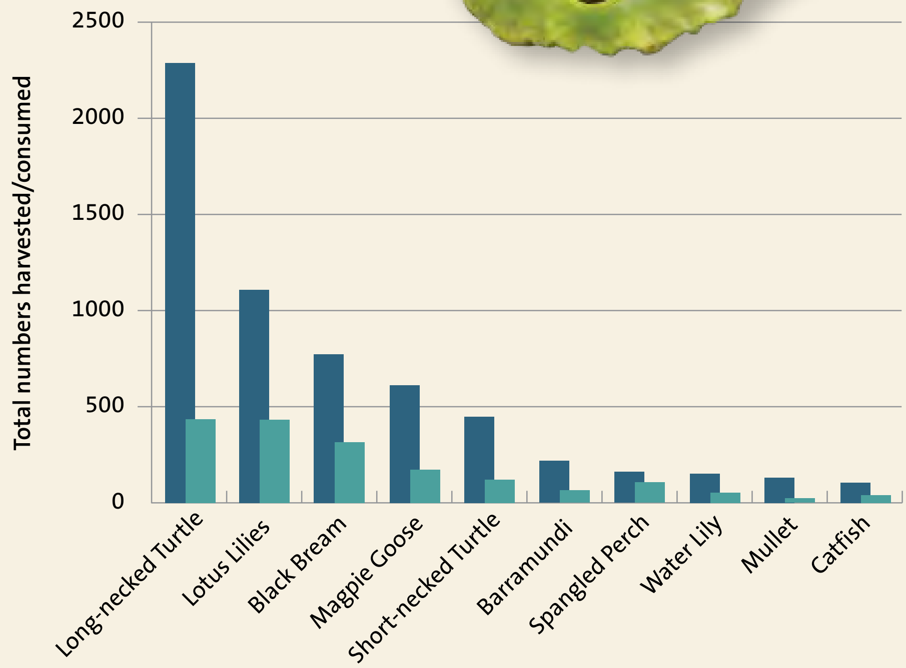
The most commonly caught and harvested species in the Daly River catchment were Long-necked Turtle (*Chelodina rugosa*), Lotus Lily (*Nelumbo nucifera*), Black Bream (*Hephaestus fuliginosus*), Magpie Goose (*Anseranas semipalmata*) and Short-necked Turtle (*Emydura/Elseya* spp.) (***Figure 5***) This dominance of non-fish species reflects the frequent and widespread use of billabong habitat in the Daly catchment.

Right: Lotus Lily** (Nelumbo nucifera)* ***seed pod and flower.

***Below left: Magpie Goose** (Anseranas semipalmata).*

***Below right: Long-necked Turtle** (Chelodina rugosa).*

Figure 5
Daly River – species most commonly harvested and consumed.



Assets and Values

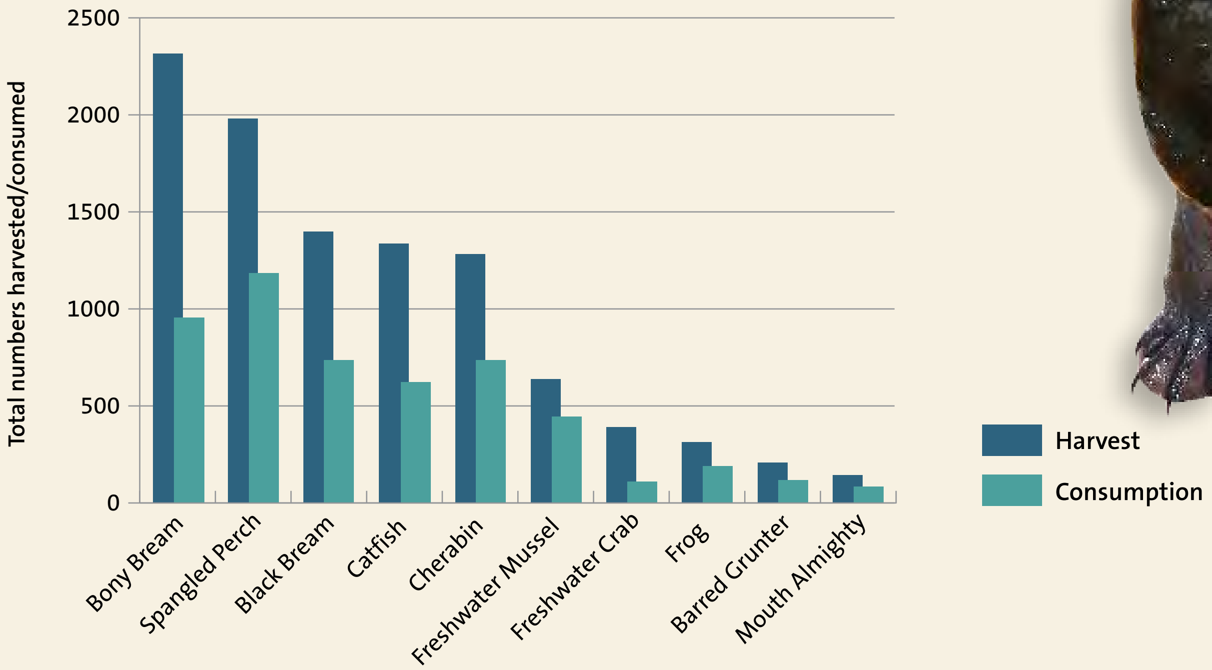
In contrast, four of the five most commonly harvested species in the Fitzroy catchment were fish: Spangled Perch (*Leiopotherapon unicolor*), Bony Bream (*Nematalosa erebi*), Cherabin (*Macrobrachium rosenbergii*), Black Bream (*Hephaestus jenkinsi*) and Catfish (*Neoarius* spp.) (***Figure 6***).

***Right: Long-necked Turtle** (Chelodina rugosa).*

Below: The collection and consumption of Lotus Lily** (Nelumbo nucifera) **by residents of Nauiyu Nambiyu, Daly River, NT.

Figure 6

Fitzroy River – species most commonly harvested and consumed.



Two of these fish species, Bony Bream and Spangled Perch, are small bodied species predominately used as bait for catching other fish. Black Bream and Catfish are two popular food species, and were harvested in relatively high numbers. These results are supported by Toussaint's (2010) qualitative data on fishing in the Fitzroy where Black Bream is "regularly caught if not always actively sought" because they are easily hooked and can be cooked and consumed on the spot. Cherabin, also known as freshwater prawns, are a large-bodied decapod crustacean that is captured from rivers and billabongs.

Above: Spangled Perch
(Leiopotherapon unicolor)

Below left: Cherabin
(Macrobrachium rosenbergii)

Below right: Catfish *(Neoarius* spp.*)*

Bottom: Black Bream
(Hephaestus jenkinsi)

4. *Who is consuming the harvested plants and animals?*

Household consumption of species was always lower than the amount harvested (***Figures 5*** and ***6***). This is because catches were widely shared with others, who may or may not have been involved with harvesting. In particular, Magpie Geese and Long-necked Turtles are harvested by a small number of households and shared around or traded with extended family and friends locally and in surrounding communities. In contrast, smaller species such as Black Bream are often eaten immediately over a camp fire at the site of harvest. Given the important social role of food exchange, it is clear that any changes to water use that have a detrimental impact on key species like turtle may have a wide impact, affecting communities living beyond the areas from which aquatic resources are harvested.

Turtle hunting at a Daly River billabong.

***Right: Black Bream** (Hephaestus jenkinsi)*

Below: Freshwater sawfish** (Pristis microdon) **(left) and the Fitzroy River at Noonkanbah (right)

What can Indigenous people tell us about river flow ecology?

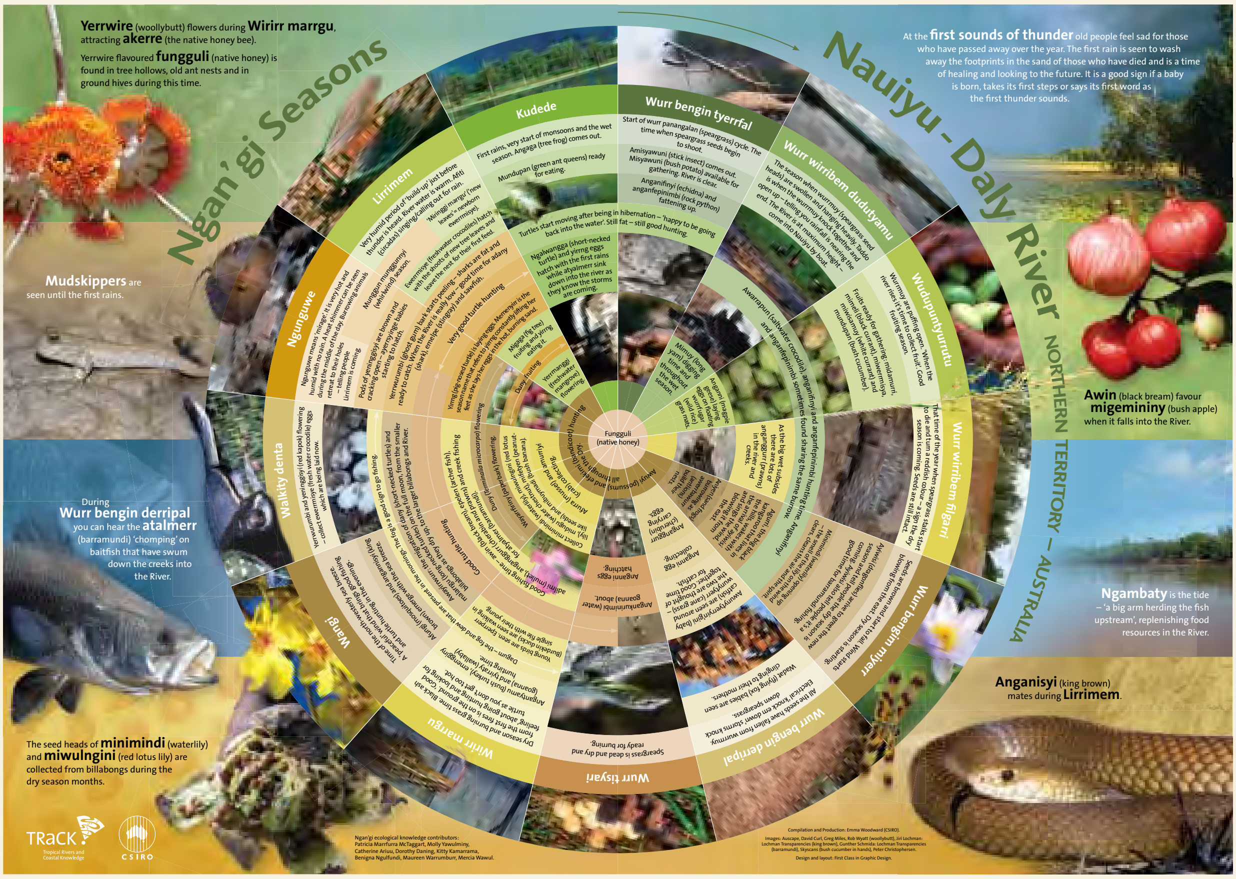
Seasonal calendars were compiled with four different language groups. The calendars are based on Indigenous knowledge of the different plants and animals that are available and harvested in varying quantities throughout the year The calendars depict the ecological cues and indicators that signal people to start hunting or collecting specific resources. In contrast to calendars with seasons that have pre-set dates, like the Gregorian calendar, Indigenous seasons are defined by one or more indicative events, which herald the arrival of a new season (Woodward *et al.* in press).

Climatic and meteorological conditions drive the seasonal cycle of resource availability with river flow conditions triggering some customary harvesting activities, either directly or indirectly. River flows can determine triggers for feeding or movement of species, and these flows are often recognised by those hunting, gathering and fishing as an indicator of the probability of harvesting success. Such examples include the increased capture of Bull Sharks (*Carcharhinus leucas*) during the first muddy or 'dirty' water coming down the river in the pre-wet season storms; the increased harvest of Long-necked Turtles late in the dry season as they aestivate (bury themselves and slow their metabolic processes) in the mud of drying billabongs, and the increased harvest of Magpie Geese during the build-up as they feed on billabongs in preparation for breeding. Frequently, seasonal indicators including fruiting and flowering events are linked to the availability of aquatic species, and will signal to fishers that particular fish or turtle species are in abundance or 'fat' and ready to eat.

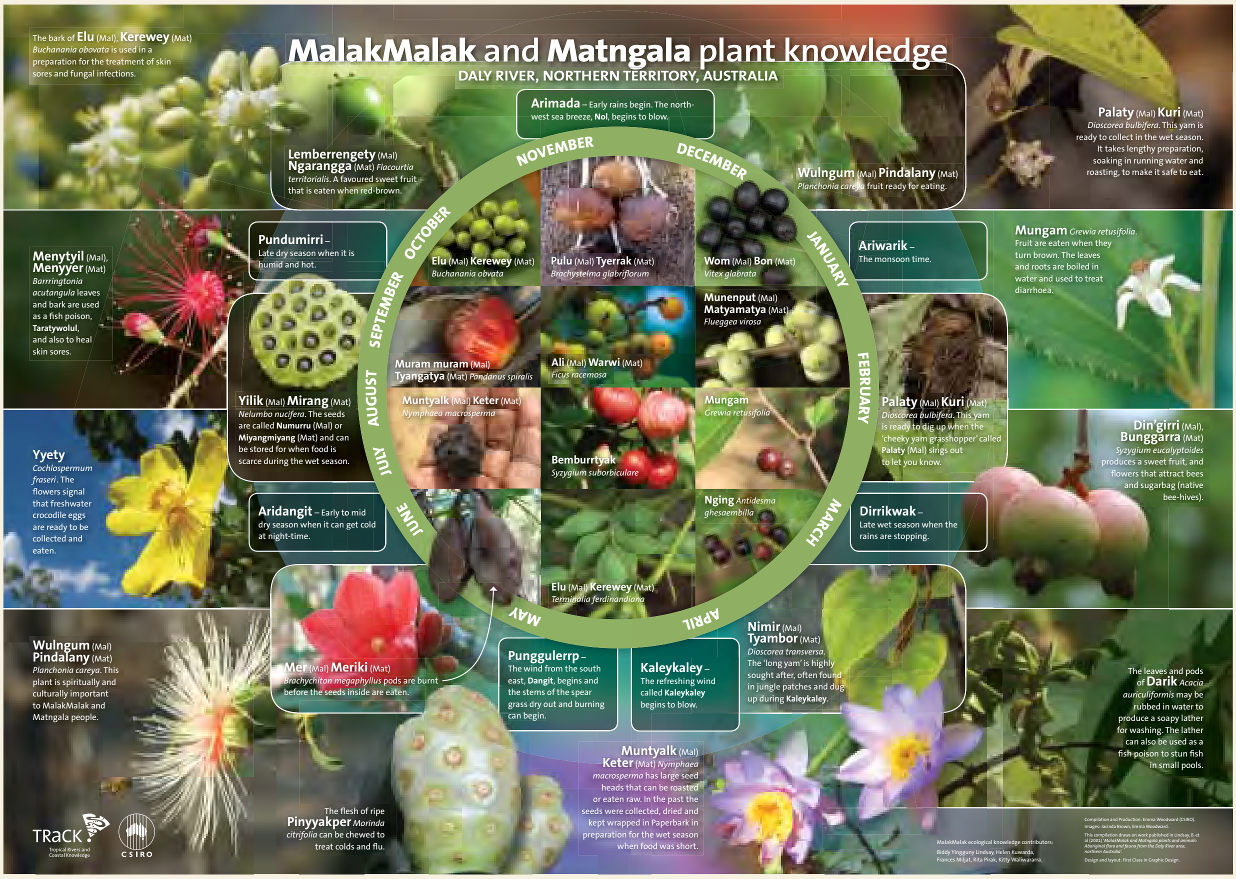
Working on the Ngan'gi Seasons calendar at Nauiyu Nambiyu; L to R Benigna Ngulfundi, Mercia Wawul, Molly Yawulminy (obscured), Catherine Ariuu, Emma Woodward (CSIRO) Maureen Warrumburr and Patricia Marrfurra McTaggart.

Amy Nuggett, Joy Nuggett and Emma Woodward (CSIRO) creating the 'Walmajarri words from the river side' seasonal calendar, Fitzroy Crossing.

Biddy Lindsay and Emma Woodward (CSIRO) with the MalakMalak and Matngala plant knowledge calendar.



Ngan'gi Seasons, Daly River, NT > www.csiro.au/resources/Ngangi-Seasonal-Calendar



MalakMalak and Matngala plant knowledge, Daly River, NT > www.csiro.au/resources/MalakMalak-Plant-Knowledge-Seasons-Calendar

Working on the Gooniyandi Seasons calendar; Helen Malo, June Davis, Mervyn Street with Grandson Jai and Emma Woodward (CSIRO), Muludja Community, Fitzroy Crossing, WA.

Talking through the MalakMalak & Matngala Seasonal Plants calendar; L to R Emma Woodward (CSIRO), Rita Pirak and Biddy Lindsay.

Children playing with the rotating Ngan'gi Calendar at the Merrepen Arts Festival, Daly River.

At the community known as Nauiyu Nambiyu, on the Daly River, knowledgeable Ngan'gi speakers know that as the billabong levels drop during the seasons of *Wirirr marrgu* and *Wangi*, a range of lilies can be accessed along the margins of billabongs and swampy areas. This period can be described as the mid-dry season: burning has started and there is black ash on the ground.

Water dependent species targeted during these seasons include Waterlily (*Nymphaea macrosperma*), Lotus Lily *(Nelumbo nucifera*) and Water Chestnut (*Eleocharis dulcis).* Native Peanut *(Horsfieldia australianum*), found in monsoon vine forests, and Bush Banana (*Marsdenia viridiflora)* are also collected at the same time. With lower water levels, it is much easier to collect mussels and crabs on the exposed edges of billabongs, creeks and springs, and turtle hunting begins. In the Daly River, Waterlilies (*Nymphaea macrosperma*) and Lotus Lilies *(Nelumbo nucifera*) are collected for their seed heads, stems, tubers and roots.

According to the Ngan'gi Seasons calendar compiled during the project, turtle hunting intensifies as the water retracts. The heating and drying experienced over the coming months creates increasing areas of drying billabong margins. This soft mud is searched with crow-bars and feet in an attempt to find hibernating animals. In the seasons of *Ngunguwe* and *Lirrimem*, it is said to be the best time for hunting turtles hiding under the mud. These seasons occur in the late dry season, just before the wet season starts.

Gooniyandi knowledge of flow ecology from the Fitzroy River catchment is tightly linked to observations of wind and rain. Wind direction dictates the strength of winds, and whether the associated 'storm' will bring calm soothing rain which is good for fishing, or potentially destructive rain. People know that when the river flows for the second time (after the first flush) the ripe fruits of *Ficus coronulata* fall into the river, feeding the turtles and fish and fattening them up.

When the rain finishes at the end of the wet season, a change of wind direction brings the *Garrawoorda* wind from the south. At this time the water is high and it is a good time for fishing for Sawfish (*Pristis microdon*). However, as the river channel pools dry up during the season of *Barrangga*, trapped Sawfish and Barramundi will stop biting, and Catfish *(Neoarius* spp.*)* and Black Bream *(Hephaestus jenkinsi)* will run for the bait. At this time, people know they must target the deeper river sections if they want to catch Sawfish or Barramundi. Detailed Indigenous seasonal knowledge, only briefly discussed here, indicates the strong reliance of people's subsistence strategies on healthy aquatic ecosystems.

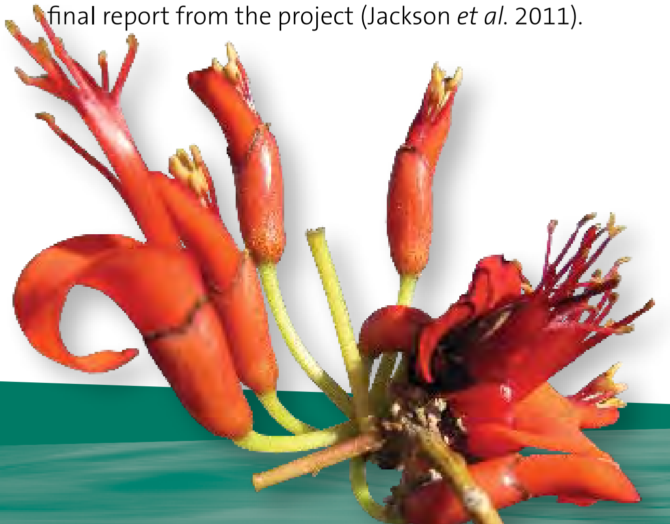
Images: A range of food resources from lillies.

What might be the effect of water use decisions on Indigenous values?

Indigenous people hold distinct cultural perspectives on water relating to identity and custodial management responsibilities to traditional estates. In Indigenous belief systems, water is a sacred and elemental symbol of life and aquatic resources constitute a vital part of the non-market Indigenous customary economy, as much as they inspire everyday experiences.

Consumption of aquatic species contributes to family incomes and diets, and the act of fishing contributes to the maintenance of social networks, thus enhancing the social and cultural wellbeing of Indigenous people. Fish and fishing is of immense importance to Indigenous people in the regions in which the project team worked, as are hunting and gathering activities. These activities allow time with family, a break from the demands of community life, and provide opportunities for families to both teach young people about the country and renew social and environmental connections.

Even if they do not have a market value, some of the economic contributions made by aquatic ecosystems (e.g. from fish obtained for food or plants obtained for arts and crafts) can be measured and their value related to river flows. Non-market valuation is increasingly being undertaken as a means of revealing 'hidden' values and to bring to light the importance of resources or environments not exchanged in market transactions but nonetheless beneficial to human societies (Emerton 2005). Although these methods are increasingly popular, there are numerous limitations that have been well documented in the literature on valuation. The limitations are fully discussed in the final report from the project (Jackson *et al.* 2011).



The Fitzroy River at Fitzroy Crossing.

There are two reasons for attempting to estimate the value of the aquatic species harvested by Indigenous people:

1. To quantify one type of cost that Indigenous people may experience as a result of water use decisions, either at the local or regional scale, and

2. To assist water managers who have limited resources and knowledge to target management action to areas of greatest economic value to Indigenous people.

This project assumed that a principal indicator for assessing the health of a water body is its productivity and the food and other materials sourced from it by Indigenous people. The project therefore focused on quantifying the direct use (subsistence) value of aquatic resources to Indigenous people and, in doing so, to redress the relatively small amount of research into the economic value of the use of wild resources by Indigenous people in Australia (Gray *et al.* 2005; Altman 1987).

The results on Indigenous use of aquatic resources will also serve as a baseline for long term monitoring of changes to water resources in the regions under study.

Replacement value of aquatic resources

The economic value of resources consumed by households was calculated using the replacement goods method (Altman 1987); a standard method used relatively widely. According to this method, the market price of a similar product to that being consumed (a proxy) is used to estimate its value. It is only a partial economic value and does not attempt to account for intangible cultural and social values associated with wild resource harvest which are reportedly significant (Jackson 2006; Toussaint *et al.* 2001).

The valuation nonetheless provides useful information on the likely lower-bound value of Indigenous flow related resource use to the customary economy.

We used shop bought items as proxy values to:

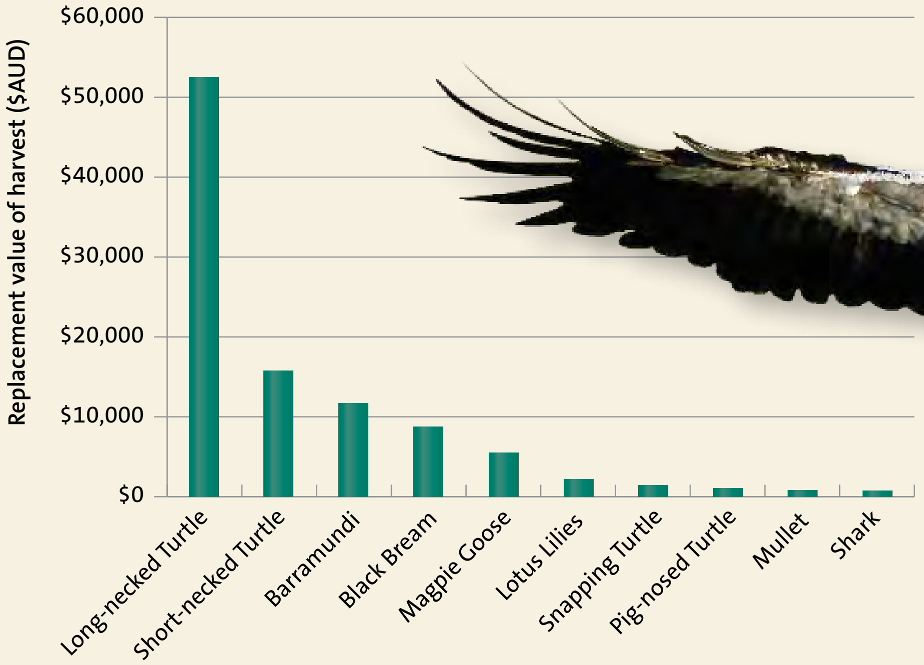
1. Generally reflect the type of food item the species represent (e.g. turtles were given values representing the cost of meat from a shop, fish were given replacement values representing the cost of fish from a shop); and

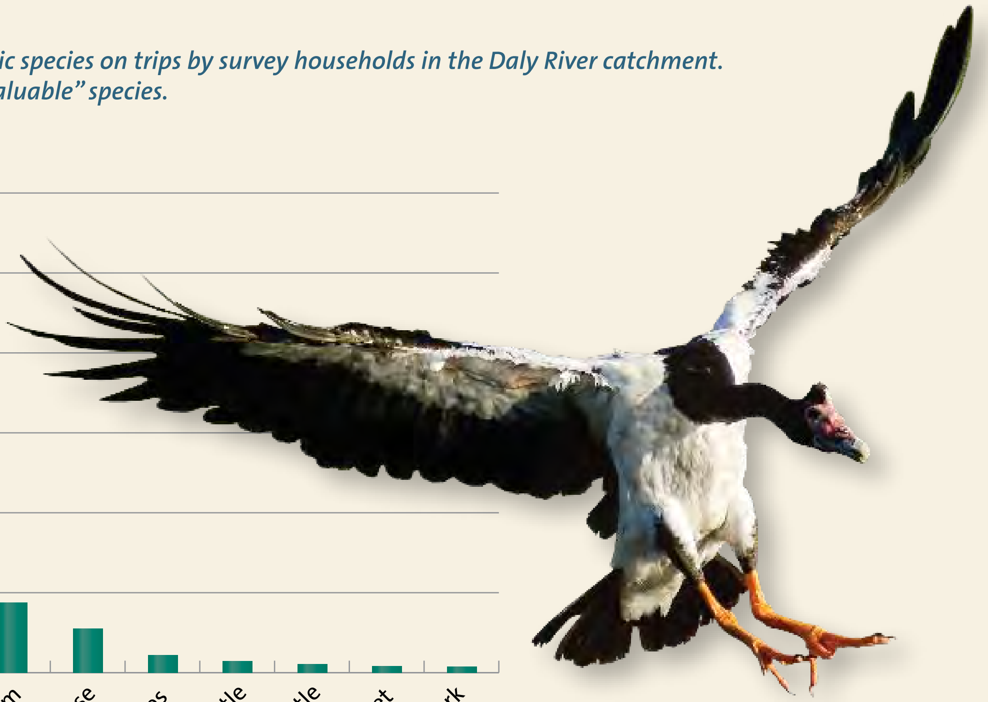
2. Reflect the general preferences for species that were made apparent to researchers through the project.

For example, Pig-nosed Turtle were considered a prized species by Indigenous survey respondents and so were given a more expensive "fillet steak" value. Long-necked Turtle were usually treated as a more general food source, and so were given a less expensive "T-bone steak" value (for a full discussion of the assumptions involved and steps taken in the valuation see the final

Figure 7

Replacement value of **harvested** aquatic species on trips by survey households in the Daly River catchment. This figure only shows the ten "most valuable" species.





report, Jackson *et al.* 2011). The valuation data provided within this report allows the ranking of species by their economic contribution to Indigenous households.

This allows a subset of economically important species to be identified, and their flow requirements assessed, as well as a ranking of the economic contribution harvesting sites make to Indigenous households.

With the exception of the Lotus Lily, the species that made the largest contribution to replacement value in the Daly were also the species that were harvested in the greatest numbers (***Figures 7*** and ***8***). The top five species, with the highest (harvested) replacement value in the Daly River, accounted for 91.6% of the total replacement value.

However, when the replacement value of harvest from the top 5 sites in the Daly River was calculated, they accounted for only 63.9% of the total replacement value. Most of the species harvested in large numbers (and with a high replacement value) in the Daly River were relatively large-bodied species, with the bait species commonly harvested in the Fitzroy River not being harvested in great numbers (***Figure 6***). This can be attributed to the target species and fishing methods utilised. The main harvesting methods for Long-necked Turtle (searching drying billabongs) and Magpie Goose (shooting) do not involve the use of fishing lines and bait.

The five species with the highest replacement value (harvest) in the Fitzroy River accounted for 91.7% of the total replacement value. However, in contrast to the Daly River, the five "most valuable" sites used by survey households in the Fitzroy represented only 29.9% of the total replacement value (***Figures 9*** and ***10***). The Daly River households concentrate their effort on a small number of floodplain sites where large bodied species like Magpie Goose and Long-necked Turtle aggregate.

Figure 8

*Replacement value of aquatic species **consumed** by survey households from the Daly River.*

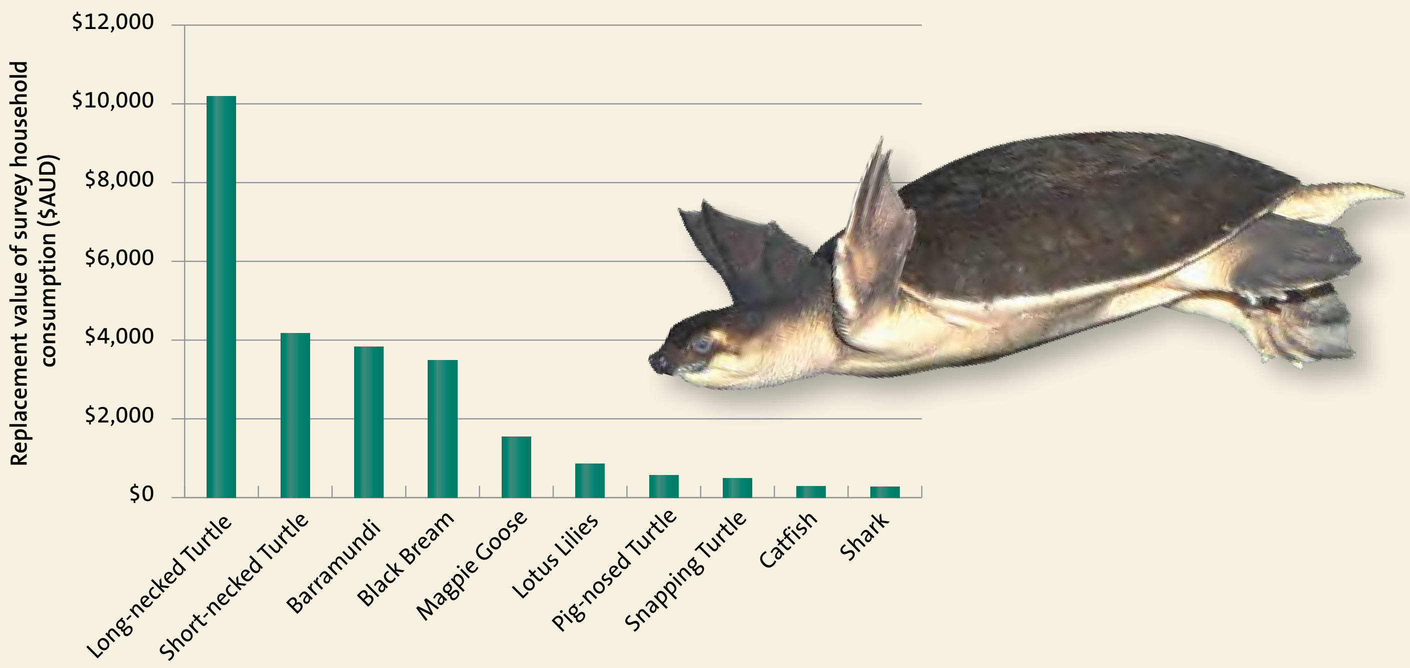


Figure 9

*Replacement value of aquatic species **harvested** in the Fitzroy River catchment. This figure shows only the ten "most valuable" species.*

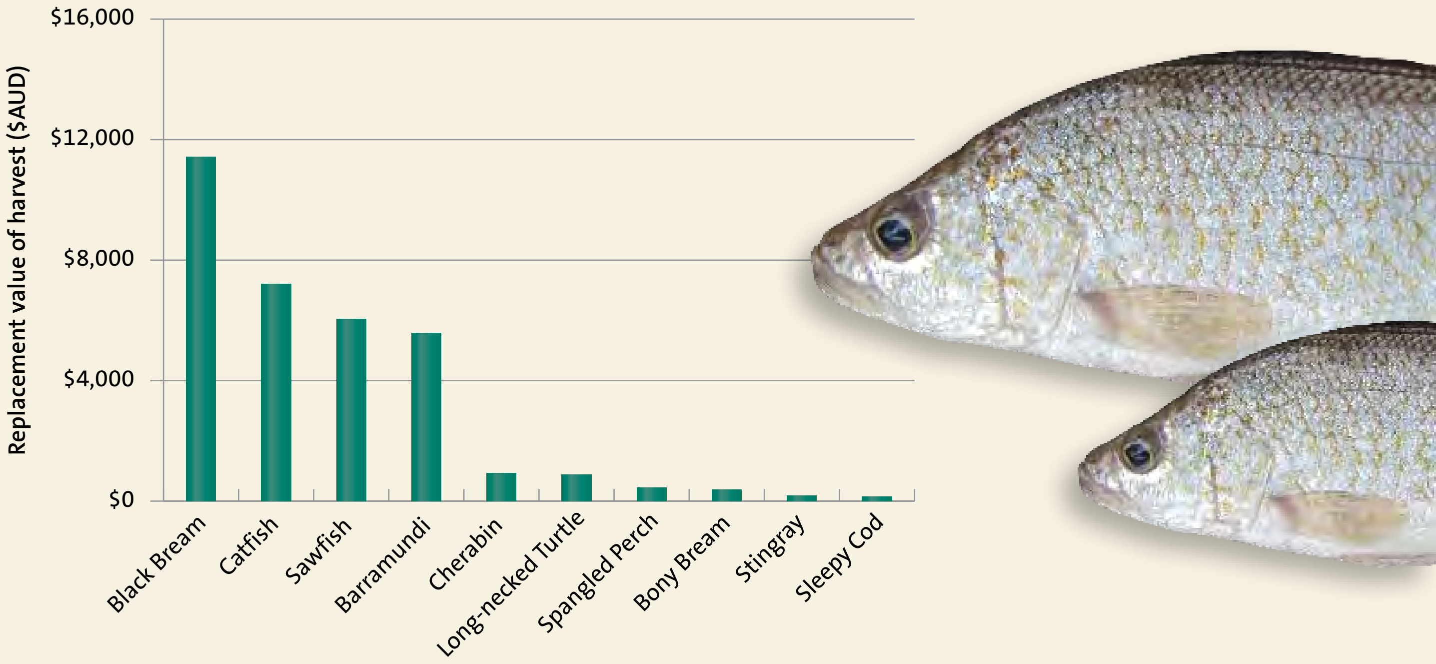
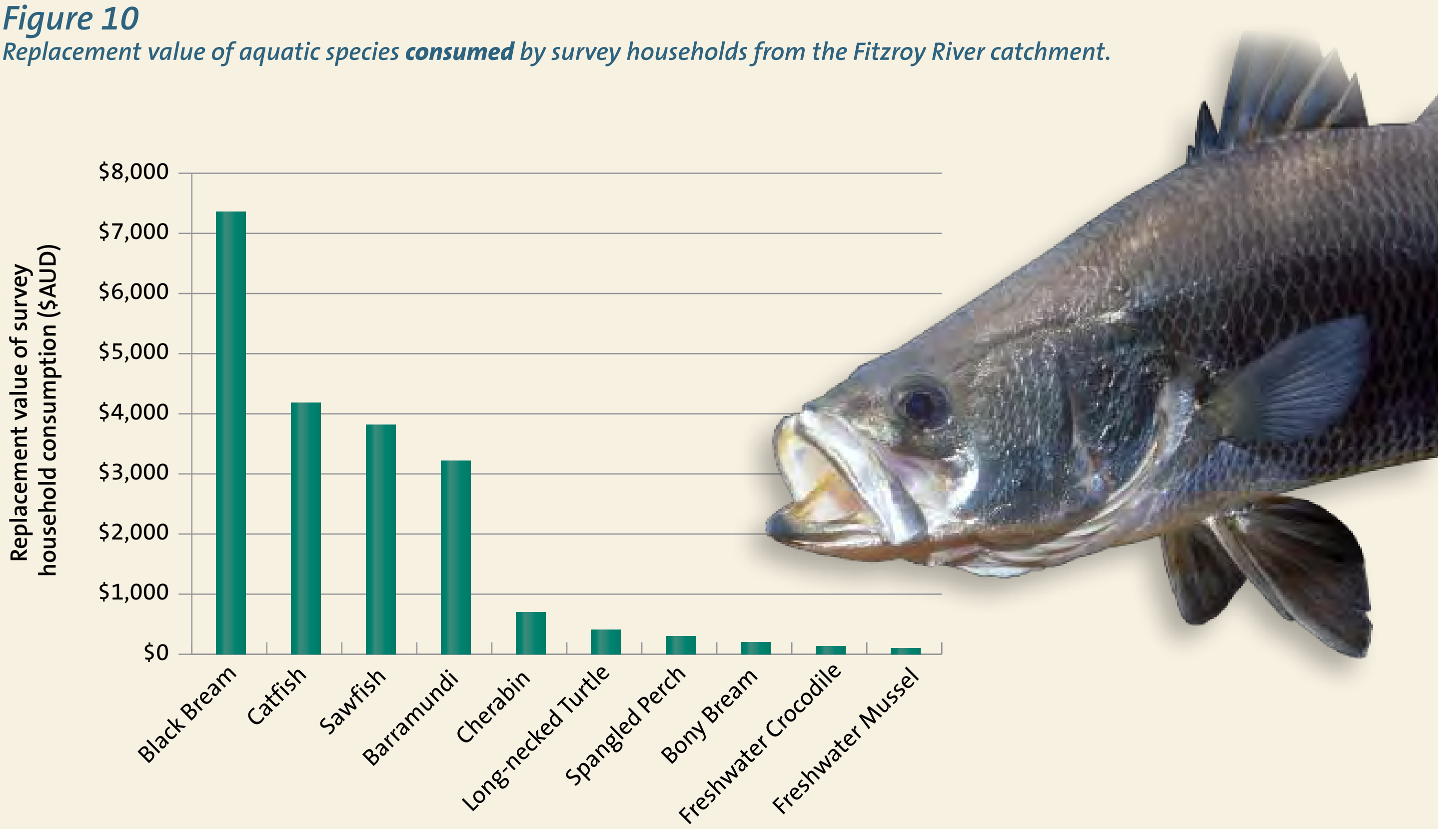


Figure 10

*Replacement value of aquatic species **consumed** by survey households from the Fitzroy River catchment.*



As shown in ***Figure 11***, the customary sector represents a substantial component of the Indigenous economy in our study regions. The value of aquatic resources to surveyed households equates to 5.1% of the median household income in the Daly and 2.9% in the Fitzroy.

It is worth bearing in mind that the economic contribution the customary sector makes to Indigenous households can change depending on the location, and harvest in outstations and remote areas is generally higher than in townships and larger centres (Altman *et al.* 2011). Our focus on aquatic species, the conservative nature of our valuation, and the township-based nature of most of our survey households suggests that the replacement values we have calculated are an absolute lower bound figure.

Harvesting Long-necked Turtles in the Daly River catchment.

Figure 11

The value of aquatic resources in the Daly and Fitzroy river catchments.

	Daly River			Fitzroy River		
	Harvest	Consumption	Household consumption as % median income	Harvest	Consumption	Household consumption as % median income
Top 5 Species	$245.83	$60.66	4.5%	$67.24	$33.26	2.7%
Top 10 Species	$262.11	$67.11	5.0%	$71.62	$35.24	2.9%
All Species	$268.25	$69.17	5.1%	$73.36	$35.92	2.9%

Flow changes and their effects on Indigenous resource use

With the exception of the Freshwater Sawfish (*Pristis microdon*) in the Fitzroy River, which is listed as vulnerable according to national environmental law, all of the species that made a large contribution to replacement value were common and widespread species. Water resource development that reduced the number or distribution of these common species would therefore have an impact on Indigenous livelihoods (Finn and Jackson 2011).

Furthermore, the top 5 species (by replacement value) in the Daly and Fitzroy Rivers have flow linkages that span the entire flow regime. In the Daly, the floodplain billabongs are of critical importance in sustaining the very popular turtle and geese harvested in large numbers during the dry season. So water planners should consider the flow requirements of the harvested species throughout their life cycles.

It is especially important to consider the impacts of dry season water extraction on the ecology of these rivers. Models of current and future water extraction scenarios in the Daly River show that the bulk of impacts to discharge occur during low flows in the mid and late dry seasons (Chan *et al*. 2010); a situation we expect is relevant to other northern catchments.

We also assessed the potential for impact on important Indigenous harvest species during the wet season as well as the dry, as there is some potential for infrastructure projects and capture of higher flows in the future. In 2011, for example, the Western Australian Premier reaffirmed his commitment to pursuing large water capture and transport projects that may well include the Fitzroy River at some time in the future.

Potential low flow impacts

A number of species in our study that substantially contribute to Indigenous household incomes have the potential to be severely impacted by dry season water extraction (Kennard *et al*. 2010).

These species included Black Bream, Barramundi and Mullet in the Daly River catchment, and Black Bream, Barramundi, Bony Bream and Sleepy Cod in the Fitzroy River catchment [The risk assessment of Kennard *et al*. (2010) and quantitative modelling of Chan *et al*. (2010) was conducted using data from the Daly River. We have extrapolated from that data for the species harvested in the Fitzroy.]

Spangled Perch and Catfish in the Fitzroy catchment presented lower levels of risk. The quantitative risk assessment of Chan *et al*. (2010) further shows Barramundi and Black Bream might be substantially impacted by water extraction in the dry season.

According to our valuation of the ten species that contributed most to Indigenous household economies in each catchment, those that are highlighted as being at high-medium risk of late dry season water extraction (Kennard *et al*. 2010) make up 2.2% of median household income in the Daly River, and 3.1% of the median household income in the Fitzroy River. Because we don't have information on the risks to all harvested species, it is difficult to quantify what this level of risk might mean to total replacement value.

Nonetheless, if water extraction resulted in a significant reduction in the harvest of these high risk fish species, the contribution that customary harvest makes to Indigenous households could decline substantially. If, for example, dry season water extraction reduced the Indigenous harvest of those high and medium risk species by 50%, their contribution to the total replacement value we calculated is halved. This would result in our calculated replacement value declining by 11% in the Daly River and 27% in the Fitzroy.

Potential impacts of post-wet season flow changes

While the qualitative risk assessment and modelling undertaken by Chan *et al*. (2010) focused on dry season water extractions, our summary of the life histories and flow requirements of the five species contributing most to replacement value suggests that flows occurring immediately after the wet season may be important to many species harvested heavily by Indigenous households.

There is some potential for alteration of these flows early in the dry season as heavy extraction of water into off-stream storages with declining wet season flows could limit the extent and duration of downstream flooding (Pusey *et al*. 2004) and substantially increase the rapidity of drawdown. Barramundi spawn in saline conditions near the mouths of rivers during the wet season (Staunton-Smith *et al*. 2004). Larvae spend a short amount of time in flooded, saline coastal habitats before moving into freshwater (Keenan 1994). When possible, Barramundi juveniles make their way upstream into freshwater, where they grow faster and have a higher survivability (Milton *et al*. 2008).

Large wet season flows are critical for the maintenance of the flooded coastal habitats used by juveniles, while early dry season flows allow juvenile Barramundi to move upstream into the more productive freshwater habitats. Freshwater Sawfish appear to have a similar life history to Barramundi; pupping in estuaries (Whitty *et al*. 2008), with the juveniles moving upstream and spending their pre-maturity lives in freshwater habitats (Stevens *et al*. 2008).

Water extractions during the drawdown of the wet season may impact the ability of juvenile Freshwater Sawfish to move upstream. This is particularly true of the Fitzroy River, which dries back to a series of disconnected pools in the dry season, and has a human-made barrier (Camballin Barrage) and natural barrier (an upstream rock-bar) along its main channel. While there is the potential to improve fish movement across human-made barriers by using fishways, there is no information available to suggest Freshwater Sawfish use such structures (Doupe *et al*. 2005; Morgan *et al*. 2005).

A significant correlation has been found between late wet season discharge (April) in the Fitzroy River and Freshwater Sawfish recruitment (Whitty *et al*. 2008), suggesting that water extractions affecting discharge over this period will have a clear impact on this species.

The Fitzroy River – Early dry season 2011.

As for Freshwater Sawfish and Barramundi, Cherabin appear to rely heavily on the longitudinal connectivity made available by higher discharge periods.

Cherabin spawn in brackish water near estuaries, and after approximately a month of development (Thanh Huong *et al.* 2010), make their way back upstream to freshwater habitats (Lee and Fielder 1979). Given that marine salinities kill Cherabin larvae (John 2009), and that post-larval and adult Cherabin grow faster in freshwater (Thanh Huong *et al.* 2010), connectivity appears to be a key feature of the productivity of Cherabin populations. This is especially true in many northern Australian rivers that dry to (or close to) disconnected pools later in the dry season. Cherabin have been observed and sampled moving upstream in April in northern Australia (P. Novak, pers. comm.), suggesting that juveniles take advantage of the receding wet season flows to move back upstream to more productive habitats.

Below left: Pippa Featherston (CSIRO) and June Davis on the banks of the Margaret River in the Fitzroy region, WA.

Below right: Bayulu-Gooniyandi Ranger, from left, Nehemiah Barnes, Canian Skeen and Morris Mackie using litmus paper to determinethe pH of a billabong in the Fitzroy region, WA.

Potential impacts of altering wet season floods

Should wet season flows be altered, there would be substantial impacts to some of the key species harvested by Indigenous people in our focal catchments. Long-necked Turtle lay their eggs under water along the edges of seasonally inundated billabongs (Kennett *et al.* 1998). The eggs need to dry, then re-wet for development and hatching (Kennett et al. 1993; Fordham *et al.* 2006).

Long-necked Turtle alone make up 51% of the total value of the harvest in the Daly River catchment, according to the replacement method of valuation. So, any flow alterations or changes to land management that impact Long-necked Turtle are likely to have a substantial effect on Indigenous household incomes. Magpie Goose also depend on floodplain habitat for nesting, and aggregate in vast colonies during the wet season (Brook and Whitehead 2005).

Like Long-necked Turtle, any reduction in the area of inundated floodplain would also effect Magpie Goose populations, and this impact would likely reduce Indigenous harvest rates. While the severity of economic impacts of alteration to wet season discharge is not as clear cut in the Fitzroy River

catchment due to the smaller contribution of Long-necked Turtle and Magpie Goose to harvest, both Barramundi and Freshwater Sawfish have life history stages dependant on wet season discharge. Barramundi populations have been shown to be positively correlated to wet season discharge (Staunton-Smith *et al*. 2004), while Freshwater Sawfish recruitment has been shown to be positively correlated to late wet season (April) discharge (Whitty *et al*. 2008).

Wet season discharge to estuaries is also likely to create extensive brackish water habitats required for the successful spawning and larval development of Cherabin (de Bruyn *et al*. 2004). Reductions in wet season discharge could reduce or remove these brackish spawning habitats, and reduce the Cherabin populations highly valued by Indigenous people. Reductions in wet season discharge would likely reduce the population size and Indigenous harvest of these species, which make up 34% of the total value of Indigenous harvest.

Below: A MalakMalak billabong was one of the sites selected for the participatory monitoring program. Feral pig damage is evident in the late dry season (top) with more extensive disturbance in the wet season (below).

Calculating the reduction in the total value of Indigenous harvest associated with flow alterations is very difficult. The difficulty arises because published information on quantified relationships between all of the species harvested and riverine discharge is not available, although scientific understanding is steadily improving as demonstrated by recent advances in knowledge relating to Freshwater Sawfish and a number of fish species from the Daly River catchment.

Although clear quantification is difficult, knowing the effect of changes to flow regimes on key species harvested by Indigenous people will allow water managers to more readily assess the potential impacts of water management decisions.

Participatory monitoring in the Daly and Fitzroy

A participatory monitoring program with Indigenous communities in the Daly and Fitzroy River regions developed suitable indicators to monitor outcomes for water management plans. The monitoring program was rolled out in two steps over 12 months.

1. Workshops were conducted with each of the four groups to select monitoring sites. A large number of sites were selected because of their significance, as well as the perceived risks to their values. They were sites that "people wanted to keep an eye on". A smaller number of sites were chosen to ensure frequent access and data collection. Information collected at sites included Indigenous knowledge of hydrology, plant and animal species, perceived impacts (e.g. feral pig damage), and the social, cultural, and environmental significance. Indicators were selected to facilitate monitoring of the significant aspects of each site.

2. A range of methods and indicators for monitoring of the sites was tested. Methods were selected based on the indicators selected in the workshops, the perceived utility, and their relative ease of implementation.

Delton Cox and Cainan Skeen of the Bayulu-Gooniyandi Rangers with Marcus Finn (CSIRO) taking a series of photographs at a permanent photo point in the Fitzroy catchment.

Wagiman Ranger, Patrick Huddlestone.

Methods and Indicators

1. **Permanent photo points.**
2. **Measurement of water quality.**
3. **Catch rates and recording of fishing trips.**
4. **Using transects to assess landscape change.**

As each of the monitoring groups chose their own methods and indicators, not all groups shared the same monitoring plans, or tested all available methods. However, there was some consistency amongst the groups, particularly in the use of permanent photo points.

1. Permanent photo points.

Permanent photo points proved to be a quick, consistent and easy-to-replicate way of collecting information on water levels, aquatic and riparian vegetation changes, disturbance by cattle and feral animals, and, in some cases, the characteristics of cultural sites. While the results of the permanent photo points were not quantitative measurements, the photos gave Indigenous research participants the opportunity to view temporal changes at a single point in time. Obvious impacts that could be assessed included weed growth, feral pig damage, and bank erosion.

2. Measurement of water quality.

A range of water quality measurements were taken at a number of sites. The use of water quality as an indicator reflected group perception that it was a legitimate indicator of aquatic health from a western science perspective. A manual water quality kit was used, and limited training in the use of the kit meant that solo application by the groups was difficult. More consistent results could be obtained by using a more automated water quality testing unit that does not require in-field mixing of chemical reagents.

3. Catch rates and recording of fishing trips.

Recording and measuring of fish catches was popular but problematic due to the limited time available.

Fishing, and the subsequent measuring of catch, was done on an opportunistic basis. This meant that other methods (such as photos and water quality) tended to take priority and fishing activity was usually completed “after knock-off”. Ensuring that catching fish and the recording of data was the day’s primary monitoring activity would result in a more adequate implementation of this technique.

4. Using transects to assess landscape changes.

The use of transects for assessing weeds and disturbance by cattle and feral animals was only successful in some communities. The number of younger rangers in a group determined the success of this method. More senior rangers were physically challenged by walking transects across rough terrain.

Two photos of bank erosion on the Daly River, taken 9 months apart from a permanent photo point.

Bayulu-Gooniyandi Ranger Roneil Skeen doing a transect along the billabong’s edge. The transect measured the occurrence of cattle disturbance along the water’s edge.

Results

The results of the individual monitoring programs are reported in group specific reports available from CSIRO.

In summary:

- Permanent photo points were by far the most accepted technique of recording information, and the easiest to implement;
- While the main focus of the monitoring program was a "test of concept", changes were observed at a number of significant sites, resulting in management responses. These changes included extensive feral pig impacts and Noogoora Burr infestations;
- Monitoring methods that were technical and relatively complicated, or were onerous to implement, e.g. walking transects during the "build up", were not well accepted;
- Most groups did not have easy access to computers or the relevant training required for data storage, analysis, report writing and production of publications. Participatory monitoring programs should consider requirements for training, support, and equipment;
- Monitoring programs need to commence with an assessment of capacity, and support and training will need to be provided to ensure the program is a success.

Nehemiah Barnes of the Bayulu-Gooniyandi Rangers and Marcus Finn (CSIRO) using a river monitoring program made using CyberTracker software in the Fitzroy Catchment.

Morris Mackie, Roneil Skeen and Cainan Skeen from the Bayulu-Gooniyandi Rangers with Marcus Finn (CSIRO) 2nd from left, performing an electrical conductivity experiment on a water sample, Fitzroy Catchment, WA.

Conclusion

This project focused on assessing the socio-economic significance of tropical rivers to Indigenous people in two major catchments: the Fitzroy River of Western Australia and the Daly River of the Northern Territory. It is clear that aquatic resources make a substantial contribution to household incomes in regions where average incomes are very low and are essential to daily social and cultural life. The economic contribution, currently unaccounted for in mainstream metrics of Indigenous household economies, provides a means for Indigenous households to supplement their incomes.

Aquatic resources consumed by Indigenous people are not traded in a market and therefore their economic value is difficult to estimate. Their value has been largely unquantified and unrecognised in assessments of environmental flows and other water use decisions. As a result, water resource development may put at risk species that provide a significant contribution to the Indigenous economy. For example, if we made the very general assumption that extensive flow alterations reduced the consumption of aquatic resources by 50%, and all other factors such as effort remained constant, the result could be a 2.5% reduction in household incomes in the Daly River catchment (representing approximately $35.00 per fortnight).

Presumably the use of this water would increase the size of the regional market economy via commercial production, but it is unlikely that more than 0.5% - 1% of these benefits would filter to Indigenous people (Stoeckl *et al.* 2011). So, water resource extraction would likely lead to a decline in the contribution that the combined market and customary sectors make to Indigenous households. Maintaining current Indigenous household incomes would therefore require increased levels of government support. Our quantification of value focuses only on the consumption of aquatic species. If the broader range of productive activities contributing to the customary economy such as hunting, fishing, gathering, art, craft, and caring for country activities (Buchanan *et al.* 2009) were included, the value of the customary sector would be much larger than the figures reported here.

A relatively large proportion (>90%) of the gross replacement value calculated for aquatic species was comprised of a relatively small subset of high value species. Yet this value was distributed across a large number of locations from which species were harvested. This is an important feature to note for water resource management, particularly when attempting assessments of environmental flows.

Below left: Reporting research results back to Daly River communities.

Below right: The research provided opportunities for inter-generational transfer of knowledge.

While a relatively small subset of species will encompass a large proportion of the replacement value, a subset of aquatic sites will not. Scoping for Indigenous values and flow assessments should aim to be spatially inclusive, but can focus on small subsets of key species. Substantial gaps in knowledge remain, ranging from the flow requirements of species harvested by Indigenous people to the relationship between species' population dynamics and Indigenous harvest success. These gaps mean that clear calculations of changes in the replacement value of aquatic species associated with flow alteration scenarios remain problematic.

The research confirms that access to wild species, and the aquatic habitats that support them, is critical to maintaining a vibrant customary economy. Assessing the impacts of water resource development on key species, and allocating or protecting flows to minimise socio-economic impacts, cannot occur effectively without a clear understanding of the Indigenous values associated with aquatic resources, and the flow requirements of supporting these. The scientific determination of Indigenous water requirements will be essential if governments are to fulfil their obligations under the *Native Title Act* to guarantee traditional owners customary rights in water for subsistence. Implicit in the right of customary use is a need to maintain Indigenous people's access to river resources (and so the direct-use value they can derive), an issue that the National Water Initiative (NWI) also seeks to address. As acknowledged by the National Water Commission (2011), the scientific determination of Indigenous water requirements remains a priority for Australian water planning. CSIRO is contributing to this research agenda by conducting research similar to that described here in partnership with the Kowanyama Aboriginal Land Management and Natural Resources Office in the Mitchell River delta of Cape York in Queensland, and in collaboration with Aboriginal organisations in the Murray Darling Basin in New South Wales.

Another requirement of national water policy is to ensure that Indigenous people directly participate in water planning and management. Community-based management efforts such as river monitoring provide one important avenue for participation and representation in water use decisions. The research reported here will provide a baseline for monitoring the effects of water resource development in the Daly and Fitzroy River regions. The methods and approaches trialled will be of assistance to water planners and communities looking to mitigate the negative impacts of increased water use on Indigenous values as well as enhance Indigenous participation in water management.

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