Dryland River Refugia

CRC FOR FRESHWATER ECOLOGY

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What is in this Newsletter?

This is the second Newsletter to be produced by the Cooperative Research Centre for Freshwater Ecology Dryland River Refugia Project. The project, which commenced in 2001, has sampled three river systems (Cooper Creek, Warrego River and the Border Rivers) over three years. This newsletter summarises some of the results from the Cooper and Warrego catchments. Future newsletters will compare the data collected from all three catchments.

The Dryland River Refugia Project has involved researchers from the Centre for Riverine Landscapes at Griffith University, Queensland Department of Natural Resources, Mines and Energy, University of Canberra, Murray-Darling Basin Freshwater Research Centre – Goondiwindi Laboratory and the New South Wales Department of Infrastructure, Planning and Natural Resources.

The major aim of this project is to determine the importance of waterholes as refugia for aquatic organisms in dryland river catchments. We aim to determine the relationship between biodiversity and the physical attributes of individual waterholes as well as their spatial and temporal pattern of connectivity in the landscape. We also propose to identify the biophysical processes that sustain biodiversity and ecosystem health in dryland river refugia. This information will enable us to predict the likely impacts of water resource development, as well as changed floodplain and riparian management, on biodiversity and ecosystem function in dryland river refugia. It will also assist us in identifying key environmental flow and land management criteria to restore dryland rivers where altered flow regimes and changed land management have affected connectivity and other key biophysical processes.

Photo by Jon Marshall QNRME

Binya Waterhole, October 2002

Photo by Jon Marshall QNRME

Sampling Red Waterhole near Binya, October 2002

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The Project so far...

Three rivers (Cooper Creek, Warrego River and Border-Rivers) were selected from the northern rivers of the Murray-Darling Basin and the rivers of the Lake Eyre Basin. They provide a unique set of variables for understanding the physical and biological process related to sustaining key aquatic refugia in dryland rivers. The region offers rivers with the full range of impacts from both water resource development and land management changes. The Border-Rivers region is subject to high levels of water resource development and intensive cropping and grazing. The intensity of both impacts decreases as you move into the Warrego River and further west into the Cooper Channel Country of south-west Queensland. The principal outcomes from the project, relating to understanding how changes in hydrology and land management can influence the biological and physical processes and integrity of refugia, will be directly transferable to other parts of Australia with semi-arid and arid landscapes.

Waterholes on rivers in all three cathments across the gradient have now been sampled on at least two occasions. This provides information on spatial and temporal changes in refugia function. In 2004 the Dryland River Refugia project will focus more on processes such as recruitment.

Photo by Jon Marshall QNRME

Red Waterhole near Binya, Oct 2002

Sites on the Warrego River

Fifteen sites have been sampled on the Warrego River. These sites are distributed across four "reaches" (see Table and Map of sites). Waterholes were sampled in October 2001 and again April 2002. A subset of sites, those in the Binya reach, were sampled again in September 2002 and May 2003. At each site samples were taken of microscopic algae, large and small aquatic invertebrates, fish and turtles. Samples were also taken for water quality parameters and experiments undertaken to determine the productivity of the waterholes.

Thurulgoona Reach: Thurulgoona Homestead, Thurulgoona and Noorama Waterholes
Binya Reach: Binya, Red, Mirage Plains and Tinnenburra Waterholes
Glencoe Reach: Glencoe, Woggannorah, Rocky and Key Waterholes
Quilberry Reach: Sanford Park, Sanford Park Lagoon, Quilberry and Clear Waterholes

Patterns of Waterhole Permanence

Steve Hamilton: Michigan State University, USA
Martin Thoms: University of Canberra & Stuart Bunn: Griffith University

Which waterholes constitute refugia?
Are these refugia static over space and time?
How permanent are waterholes?

Dryland rivers such as the Cooper and Warrego typically experience flow pulses only occasionally and, in the protracted intervals between flows, the aquatic animals reside in isolated waterbodies that function as refugia. In the Cooper Creek, such refugia occur as several hundred isolated, relatively deep segments of channel. To explore aspects of the permanence of these waterholes, 15 were sampled during their isolation phase in April and October 2002 for major solutes and naturally occurring stable isotopes of water ($\delta^{18}O$ and δD), and in April we also sampled smaller pools and pumped ground water on the floodplain. Fractional water loss by evaporation was estimated from the increase in the concentration of conservative ions or salts such as sodium (Na^+) and chloride (Cl^-) and independently from $\delta^{18}O$ using a model of evaporative fractionation.

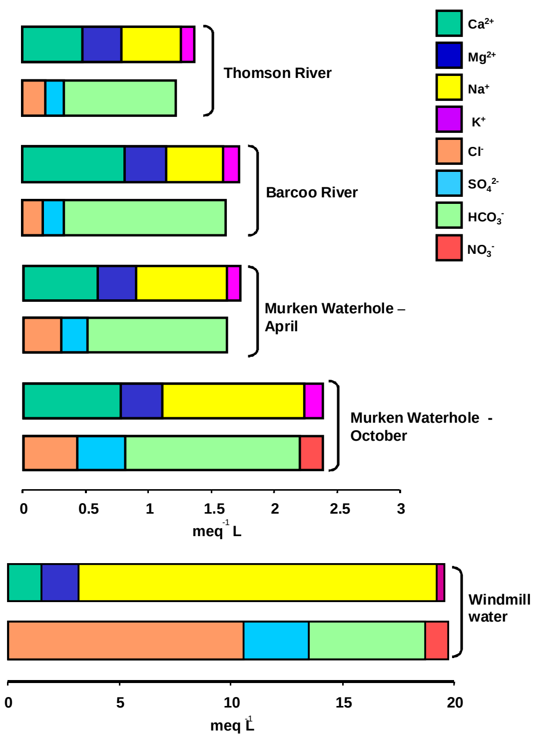


Figure 1. Bar charts showing the major ion chemistry of the Thomson and Barcoo rivers (sampled when flow had nearly ceased in April 2002), a representative waterhole (Murken Waterhole) in April and October 2002, and windmill-pumped groundwater from near Windorah (note different scale).

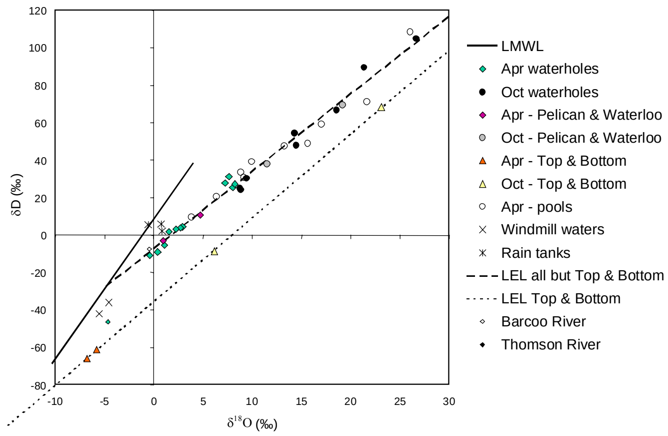


Figure 2. Stable isotope ratios of water in the waterholes (April and October 2002) as well as in floodplain pools, windmill-pumped groundwaters, rivers, and rain tanks in their vicinity (April only). Local evaporation lines (LEL) are based on regressions for the waterholes and pools. A distinct LEL was fit to Top and Bottom waterholes.

The major solute chemistry and isotope hydrology results obtained from these 15 waterholes demonstrate that, between flows, evaporative water loss is the predominant control of water level in the waterholes. Surface waters are effectively isolated from inputs of deeper ground water (Figure 1 and 2).

Estimates of fractional water loss rates were combined with data on basin shape and size to estimate evaporative loss rates ranging from 0.94-5.0 m yr^{-1} (mean, 2.1); during that time pan evaporation averaged 2.5 m yr^{-1}. Only 4 of 14 waterholes had rates greater than the pan evaporation. Extrapolation of those estimated evaporative loss rates indicated that the waterholes would dry to 10% of their bankfull volumes in 6-23 months, although these estimates are for 2002, a year when pan evaporation rates were about 18% higher than the long-term mean. This variation in persistence times is due to variation in both evaporative loss rates and waterhole shape and size.

These persistence times show the importance of flow pulses in sustaining aquatic waterholes as refugia. Complete drying of waterholes could become more common if future water withdrawals reduce the frequency and intensity of river flows to the point where they occur less often than annually.

Aquatic Plants of Dryland River Waterholes

Glenn McGregor: Qld Natural Resources, Mines & Energy

How is aquatic biodiversity (including plant diversity) partitioned in space and time among refugia?

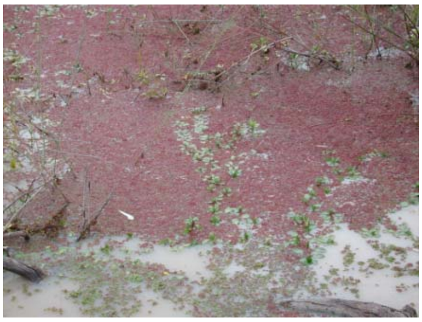
Plants of Dryland River Waterholes

Aquatic plants, through photosynthesis, provide the primary source of production in most aquatic systems and thus provide the energy to support aquatic food webs i.e. zooplankton, macroinvertebrates, fish, waterbirds.

In order to capture the biodiversity of aquatic plants present at each waterhole, a range of community types was sampled including phytoplankton (microscopic algae which are free-floating in the water column), benthic diatoms (microalgae which grow on the substrate), macroalgae (large algae, visible with the naked eye which grow on the substrate), and aquatic macrophytes (vascular plants).

Aquatic Macrophytes

Aquatic macrophytes are rare in both the Cooper and Warrego, being recorded in <20% of all waterholes sampled. Those recorded included sedges growing on the banks of waterholes such as *Cyperus* spp. and *Scirpus* spp., trailing grasses and marginal aquatic plants with most of their leaves at or just below the surface such as *Pseudoraphis spinescens* and *Ludwigia peploides sp. montevidensis* and floating plants such as *Azolla pinnata*.



Azolla pinnata and *Ludwigia peploides* in Thurulgoon Waterhole – Warrego River October 2001

Cyperus sp. (on the banks) and *Ludwigia pepoloides* in Shed Waterhole – Cooper Creek April 2001

Benthic Diatom Diversity

Diatoms are single celled microscopic algae characterised by their siliceous cell wall. They include planktonic forms and forms which may attach to a number of substrates including rocks, woody debris, sand, mud and aquatic plants. They have been widely used as indicators of environmental change due to the large number of species (globally > 10 000) and characteristic range of habitats and environmental tolerances. For this study, benthic diatoms from both hard (woody debris) and soft (waterhole sediments) substrates were sampled.

Benthic diatom species richness was high with a total of 253 species collected. At the waterhole level the number of species varied between 10 and 30, with the highest number, 66, at Warranee (Cooper) in September 2001 and 74 at Binya (Warrego) in April 2002. Combined number of species (taxa) for both hard and soft substrates for the Cooper and Warrego are shown in Figure 1. The number of species was about twice as high on hard substrates than soft, possibly related to substrate stability.

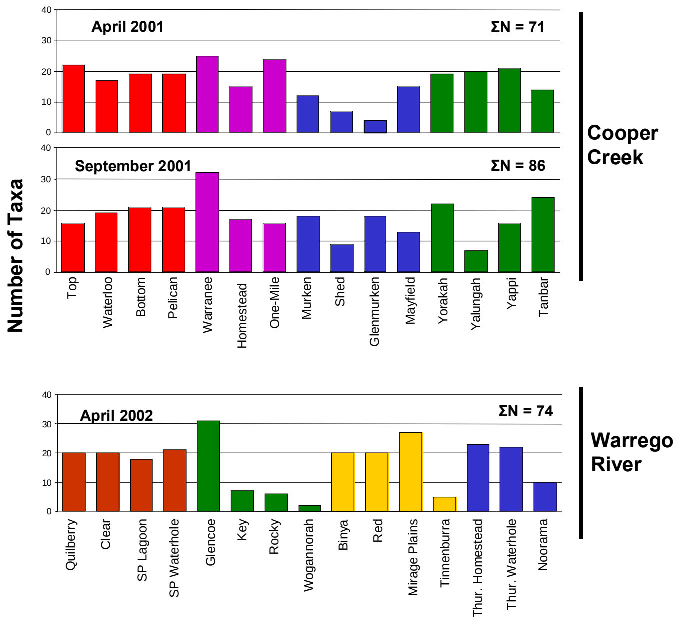


Figure 1. Number of species (taxa) collected from waterholes sampled on the Cooper Creek (April and September 2001) and Warrego River (April 2002).

Phytoplankton Diversity within Cooper Creek

Phytoplankton

Phytoplankton production in dryland river systems is regulated by hydrologic processes, which determine their transport along the system and within each water hole, and by the prevailing light climate that determines the dosage of light available to the algae. When flows cease and dryland rivers become a series of disconnected waterholes, the influence of hydrology diminishes, and the phytoplankton communities resembles those of shallow lakes.

Dryland waterholes are generally highly turbid and this limits light penetration through the water column to 30 cm. Under these light limiting conditions, phytoplankton taxa which are able to actively alter their position in the water column to maximize their exposure to light have a competitive advantage over those who are passively entrained in the water column. This is evident by the numerical dominance of mobile algae which such as *Euglena*, *Phacus*, *Trachelomonas* and *Campylomonas*, and by vacuolate cyanobacteria such as *Anabaena* and *Anabaenopsis.* In comparison to the benthic sampling, diatoms were poorly represented in the plankton. This reflects a reduction in water column mixing when flow ceases and the river becomes a series of disconnected waterholes.

Phytoplankton species richness and abundance was low at most waterholes in both the Cooper and Warrego catchments compared to published accounts of river phytoplankton. In general less than 10 species were recorded at most waterholes at each sampling occasion. There were however some exceptions. Both species richness and total abundance in Yappi waterhole, Cooper Creek in April 2001 was significantly higher than in other waterholes sampled. This included a marked increase in the diversity of green algae such as *Monoraphidium* and *Scenedesmus*, and colonial cyanobacteria such as *Aphanocapsa* and *Merismopedia.* This increase in phytoplankton abundance may have been associated with a large number of water birds roosting at Yappi in the months prior to sampling. A bloom of the cyanobacterium *Anabaena spiroides* dominated the phytoplankton in Murken waterhole, Cooper Creek in September 2001. Concentrations were high, exceeding 200 000 cells mL^{-1} and a blue band of phycocyanin (a photosynthetic pigment) was evident along the shoreline, indicative of decomposing cyanobacterial cells. The taxonomic composition for the Cooper Creek sites in April and September 2001 is shown in Figure 2.

The results of this study provide a valuable contribution to our knowledge of river phytoplankton, which in comparison to lake phytoplankton is poorly known.

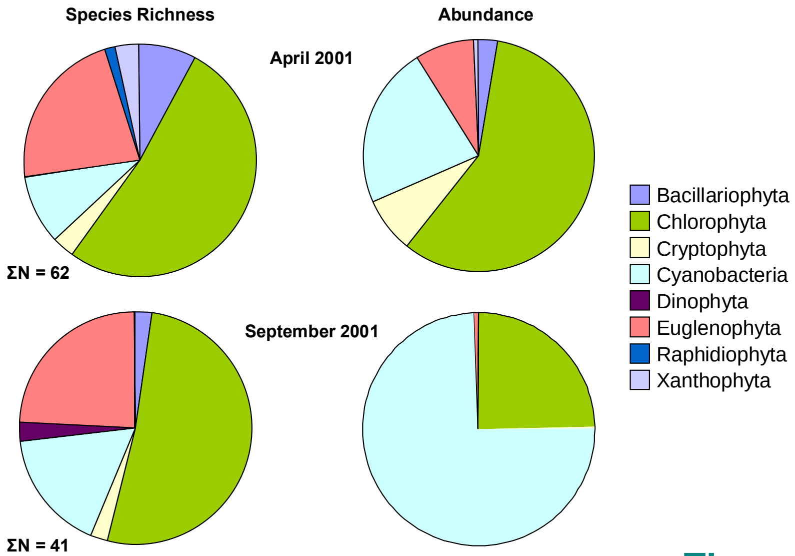


Figure 2. Taxonomic composition of phytoplankton samples from waterholes sampled on Cooper Creek in April 2001 and September 2001.

Murken Waterhole, Cooper Creek September 2001

Shoreline Scum of Phycocyanin

The next stage of the project

The next phase of the study will examine how much of the observed patterns in the various algae communities can be explained by water quality and other environmental variables measured at each waterhole.

Fish Diversity: Cooper and Warrego Waterholes

Angela Arthington & Stephen Balcombe: Griffith University
Glenn Wilson: MDFRC, Northern Laboratory

How is aquatic biodiversity partitioned in space and time among refugia?

Diversity between the Catchments

The Cooper Creek fish assemblage is comprised of 14 species, of which 12 are native, while the Warrego River assemblage consists of 10 native and three exotic species (Figure 1 and Table 1). Cooper Creek and Warrego River fish assemblages are quite similar with seven shared species and a further three ecologically and closely related pairs of species (yellowbelly, rainbowfish and ambassids). The only fish species in the Warrego not represented by a closely related species in the Cooper is the introduced common carp. The introduced goldfish does, however, have similar feeding habits but a much lower reproductive output, hence, not such a noted impact on the environment. The Cooper assemblage is more distinctive than the Warrego with four species not found in the Warrego (the Cooper Creek and silver tandans, and the Barcoo and Welch's grunter).

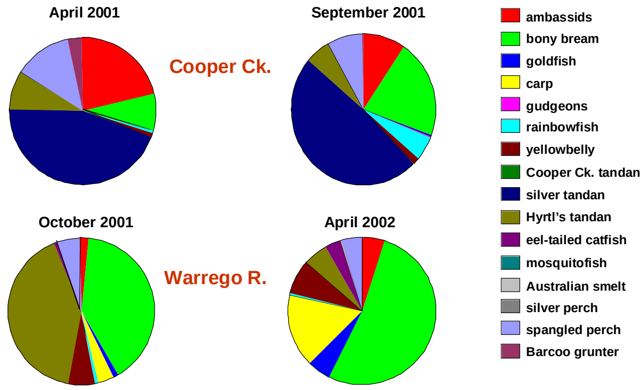


Figure 1. Percentage of different taxa collected from the Cooper Creek and the Warrego River across the different sampling occasions.

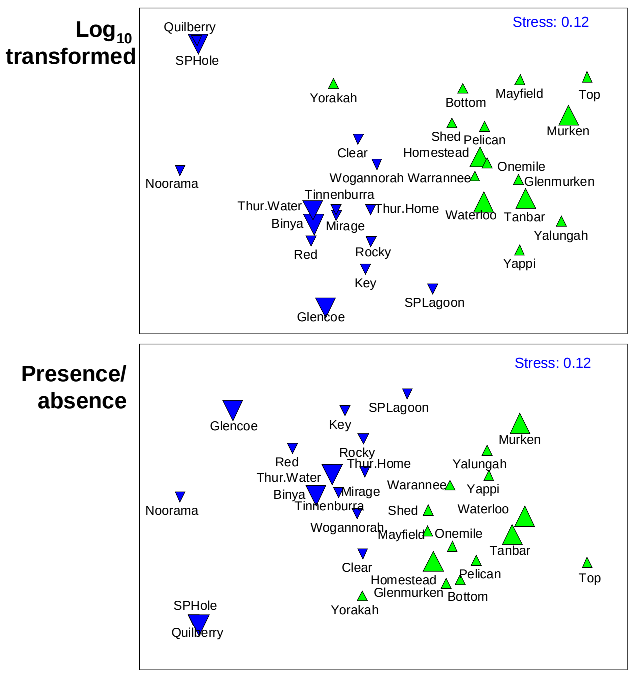


Figure 2. Ordination diagram of species assemblage data and presence/absence data for sites sampled on the Cooper Creek and Warrego River. Sites closer together are more similar in terms of fish assemblage composition.

Common name	Scientific name	
Northwest ambassis	*Ambassis* sp.	Cooper only
Cooper Creek tandan	*Neosiluroides cooperensis*	
silver tandan	*Porochilus argenteus*	
Barcoo grunter	*Scortum barcoo*	
desert rainbowfish	*Melanotaenia splendida tatei*	
Lake Eyre yellowbelly	*Macquaria* sp.	
Welch's grunter	*Bidyanus welchii*	
bony bream	*Nematolosa erebi*	Shared species
carp gudgeons	*Hypseleotris* spp.	
Hyrtl's tandan	*Neosilurus hyrtlii*	
Australian smelt	*Retropinna semoni*	
spangled perch	*Leiopotherapon unicolor*	
goldfish *	*Carassius auratus*	
mosquitofish *	*Gambusia holbrooki*	
silver perch	*Bidyanus bidyanus*	Warrego only
yellowbelly	*Macquaria ambigua*	
eel-tailed catfish	*Tandanus tandanus*	
olive perchlet	*Ambassis agassizii*	
crimson-spotted rainbowfish	*Melanotaenia fluviatilis*	
common carp *	*Cyprinus carpio*	

Table 1. Fish fauna of the Cooper and Warrego catchments, species names and common names. Introduced taxa are marked with an asterix.

Multivariateordination can be used to compare waterholes based on their similarity in fish assemblage composition. When sites are plotted in "ordination space" similar sites plot closer together. Figure 2 shows the distinct assemblages between the Cooper Creek (green symbols) and Warrego River (blue symbols).

Differences in Abundance

Cooper Creek waterholes support greater numbers of fish than Warrego waterholes. The total catch from 3 fyke nets with an average set-time of 19 hours is often greater than 500 fish in the Cooper, while catches are generally below 150 fish in the Warrego. The difference is particularly strong after flooding. Fish surveys during April 2001 in the Cooper and April 2002 in the Warrego both followed flood events. The massive response in some Cooper waterholes was evident with 8 out of 15 waterholes having a total catch greater than 1000 fish, with the maximum catch about 46000 (Figure 3). In the Warrego 4 out of 15 waterholes had catches greater than 100 fish, with a maximum of 300. It is not clear why there is such a profound ecological response after a flood event in the Cooper. This may be explained in part by the higher primary productivity in Cooper Creek waterholes compared to Warrego productivity levels. In general, Cooper Creek fish assemblages are more variable in abundance than the Warrego assemblages, which probably reflects the much more variable flow pattern of the Cooper.

Photo by Jon Marshall QNRME

Processing fish caught at Murken Waterhole, Cooper Creek, October 2002

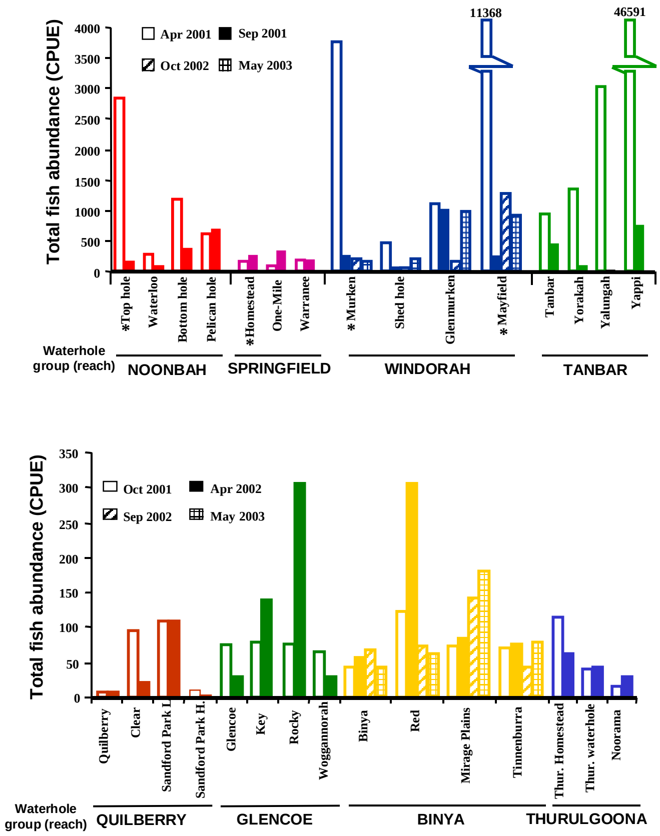


Figure 3. Total fish abundance (CPUE) for Cooper Creek (top) and and the Warrego River (bottom) across the four different sampling occassions.

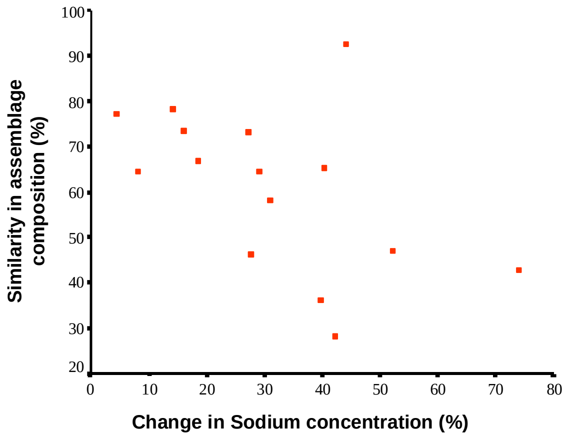


Figure 4. Relationship between change in waterhole volume (as indicated by percent change in sodium concentration) for each waterhole and change in assemblage composition for each waterhole between the April 2001 and September 2001 sampling occassions on Cooper Creek.

Why the large difference in catches between April and September in Cooper Creek? It is possible that the loss of water volume mainly through evaporation is a major cause of decreased fish abundance. As water levels recede there is less space and food available for fish and they also become more vulnerable to predation. When a measure of similarity (of the fish assemblages) for each waterhole between the two sampling periods is plotted against the change in water volume between the two sampling periods (Figure 4) there is a definite trend of greater change in fish assemblages between April and September for waterholes with the greatest loss of volume.

Macroinvertebrate Diversity within Waterholes

Fran Sheldon: Griffith University
Jon Marshall: QLD Natural Resources, Mines & Energy

Diversity of the Larger Taxa

Samples collected from the Cooper Creek and Warrego River were sorted to obtain the abundance of four 'large' macroinvertebrate taxa present within the rivers These were:
Notopala sublineata: the 'river snail'
Thiara balonnensis: the 'sculptured snail'
Corbiculina australis: the 'fingernail clam'
Macrobrachium australiense: the 'river prawn'

There are obvious differences in the proportion of each of these taxa between the Cooper Creek and Warrego River and also between sampling times on Cooper Creek (Figure 1). The three molluscs, *Notopala sublineata*, *Thiara balonnensis* and *Corbiculina australis* were noticeably absent from the Warrego with only the river prawn (*Macrobrachium australiense*) being collected.

Historical collections suggest both snails and also the clam were were once present within the Warrego system and thoughout the Murray-Darling Basin. The cause of their decline is unclear but reflects patterns found in other regions of the Murray-Darling Basin.

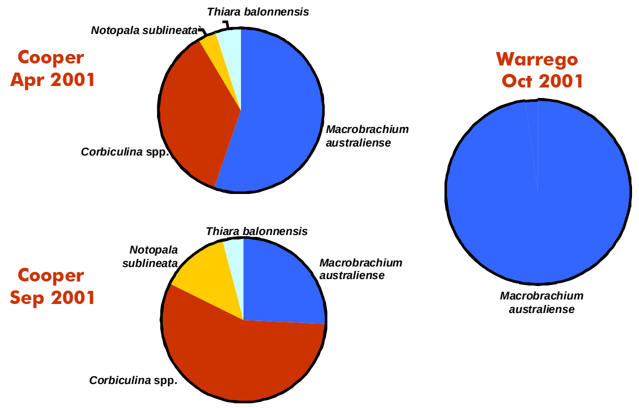


Figure 1. Large macroinvertebrate taxa distribution between the Cooper Creek (April and September 2001) and the Warrego River in October 2001.

Macrobrachium australiense (freshwater prawn)

Macroinvertebrates in the Cooper Creek

70 different macroinvertebrate taxa were collected from 87 samples from the Cooper Creek between April 2001 and May 2002. Insects were the dominant group with the most taxa and individuals (see Figure 2). Of the insects, the Diptera, which includes a range of flies (not bush flies), biting midges and non-biting midges, comprised the greatest abundance but only 30% of the number of species (richness). The Coleoptera (or beetles) comprised 37% of the total insect richness while Odonata (dragonflies) comprised 24% (see Figure 3). Molluscs (such as snails and clams) comprised 14% of the total invertebrate abundance and 10% of the total richness while Crustaceans (shrimps and yabblies) comprised only 4% of the abundance (see Figure 2).

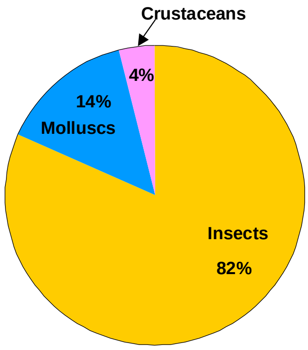


Figure 2. Abundance of macroinvertebrate groups across all sites sampled on the Cooper Creek in April 2001.

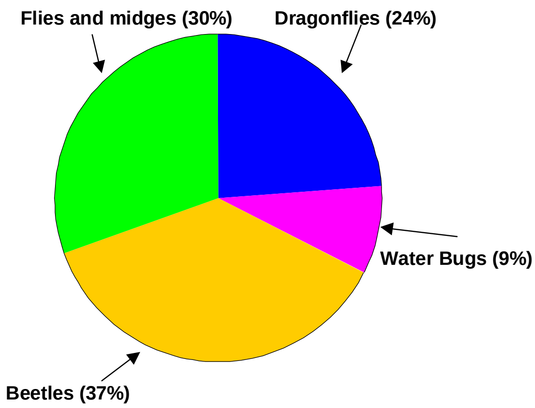


Figure 3. Richness (number of species) of major Insect groups across all sites sampled on the Cooper Creek in April 2001.

Cooper Assemblage: Differences in Space and Time

Richness (number of species) and abundance patterns of invertebrates for each waterhole in April 2001 are shown in Figure 4. Within each reach there were waterholes with high abundance and richness and some with lower abundance and richness. Overall, the waterholes in the Tanbar reach had lower abundances than the others.

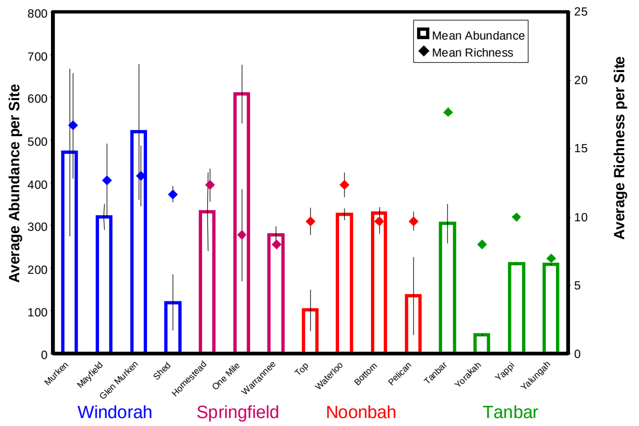


Figure 4. Average Abundance (bars) and average Richness or number of species (points) for samples collected from each waterhole on the Cooper Creek in April 2001.

When the waterholes at Windorah were examined over a two year period the shifts in abundance and richness associated with flows and floods are evident (Figure 5). Higher abundances were observed in April 2001 after the large floods of early 2000 and again in May 2003 after the in-channel flows earlier that year for Murken, Mayfield and Glen Murken waterholes. Lower abundances are evident in both September 2001 and October 2002, during a dry period. Shed waterhole showed a different pattern with higher abundances in October 2002.

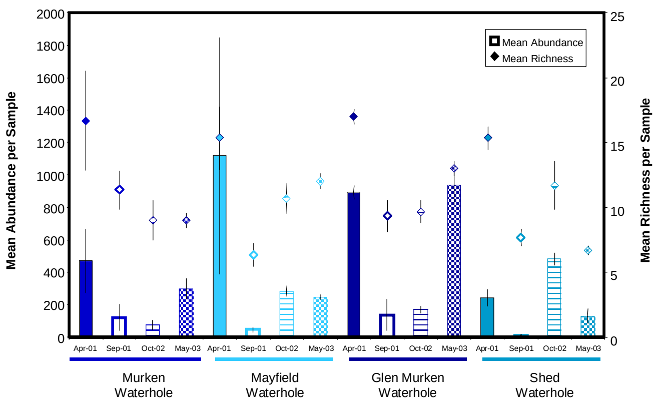


Figure 5. Average Abundance (bars) and average Richness or number of species (points) for samples collected from waterholes in the Windorah reach on the Cooper Creek in April 2001, September 2001, October 2002 and May 2003.

Multivariate ordination can be used to compare waterholes based on their similarity in invertebrate assemblage composition. When sites are plotted in "ordination space" similar sites plot closer together. Figure 6 shows the distinct assemblages between the reaches sampled on Cooper Creek (Windorah, Noonbah, Springfield and Tanbar) and between the different sampling occasions at Windorah (April 2001, September 2001, October 2002 and May 2003). The error bars are standard errors from three replicate composite samples; note that only single samples were collected for Yalungah, Yorakah and Yappi waterholes in the Tanbar region. The position of the centroids (points) and their error bars suggest greater variation in assemblage composition between waterholes than within. The four sampling occasions at Windorah suggest that at each sampling time all four waterholes shared a similar pattern of change in assemblage composition indicated by similar trajectories through ordination space (Figure 6).

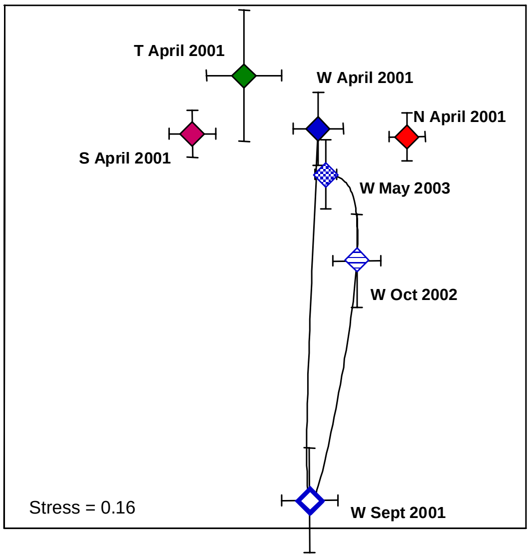


Figure 6. Ordination diagram of species assemblage data for sites sampled on the Cooper Creek in April 2001 (solid points) and sites sampled again in the Windorah reach in September 2002, October 2002 and May 2003. T=Tanbar reach, S=Springfield reach, W=Windorah reach, N=Noonbah reach.

Photo by Jon Marshall QNRME

Murken Waterhole at Windorah, October 2002

Turtle Populations and the Impacts of Fishing

Arthur Georges, Melissa White &Fiorenzo Guarino: University of Canberra

Which waterholes are important for turtles? How do turtle populations vary in space and time?

Waterholes in the deserts of far western Queensland are an unusual phenomenon. More unusual however, is the occupation of these waterholes by fully aquatic turtles, otherwise known to scientists as the Cooper Creek turtle, *Emydura macquarii emmotti* (Figure 1). The Cooper Creek turtle is one of the largest species of Chelid (side-necked) turtle in Australia, specimens of up to 8kg in mass and over 40cm long have been recorded. Despite their large size, this species of turtle does not grow continuously; in fact they utilize a boom and bust strategy to survive in arid environments. During drought times they sit out and starve, relying on fat reserves accumulated during previous boom periods when food was more plentiful. Because of this stop-start feeding regime these turtles are slow growing and typically do not reach sexual maturity until about 15 years of age. By virtue of their slow realized growth rates and the late onset of sexual maturity, they are particularly sensitive to environmental perturbations.

Recruitment of juvenile Cooper Ck turtles is poor. Foxes, pigs and rats readily predate upon nest sites. Also, embryos that successfully hatch and reach the waterhole from the nest site have similarly low levels of survivorship due to high levels of predation from fish, raptors and waterbirds. High survivorship levels afforded by adult turtles typically offset the poor survivorship of eggs and hatchlings. However, this balance in births and deaths has, in some waterholes of the channel country, been pushed out of equilibrium via illegal fishing (gill netting or drum trapping). The fishermen's aim is to catch the much sought after yellowbelly, *Macquaria ambigua*. Yet, in doing so they also trap and drown non-target vertebrates like turtles, as by-catch.

Figure 1. The Cooper Ck turtle, *Emydura macquarii emmotti*.

One of the most common forms of illegal fishing is the drum trap. Drum traps come in arrange of dimensions but typically they resemble the one in the picture below (Figure 2). The drum trap like many other traps is baited with an attractant, then thrown into the water and after many hours or some days later is pulled and the catch removed. Turtles, like fish, are attracted to the bait but unlike fish the turtles die by asphyxiation within a few hours of entering the trap. This is because turtles are air breathing and can only hold their breath for about 3 hours at 28^{0}C. The second most common method of illegal fishing takes the form of gill nets set across waterhole channels. Both forms of fishing kill turtles.

Figure 2. Illegal drum trap found in the Longreach region used for illegal netting. These items were found hidden on the banks of a waterhole.

Female turtles are most frequently captured in drum-traps and gill nets. Turtles in these life-history stages are sensitive to exploitation. The impact of low adult survivorship on population dynamics of turtles is highly destructive. Evidence from other studies has shown that light harvesting pressure as low as 10% could result in a 50% reduction in the population of adult turtles within 15 years. For example, the consequences of killing a female turtle are severe as this is equivalent to about 2,500 eggs, which she would potentially lay in her lifetime. Many of the turtles killed through illegal fishing are 80-100 years old.

In our study, we inadvertently sampled waterholes that have undergone three different fishing histories: (1) those that have rarely been fished; (2) those that were fished up until 15 years ago; and (3) those that are currently fished. Waterholes that have had no fishing history have a healthy adult component to population size structure (Figure 3). Likewise, populations that had previously been netted for fish (up until about 10-15 years ago) had similar size distributions to those that were never fished but differed in that they had fewer large adults and a greater proportion of sub-adults and juveniles than the unfished sites (Figure 4). The turtle populations in these waterholes are recovering and are on the up swing and are expected to attain a stable population state in years to come. Waterholes that are presently fished typically had fewer individuals than the other categories and tended to have a size distribution skewed to the left (Figure 5). The modal size class was 125mm as opposed to 250mm in the previously fished sites and unfished classes. The low proportion of adults brought about by fishing pressure indicates a population in decline.

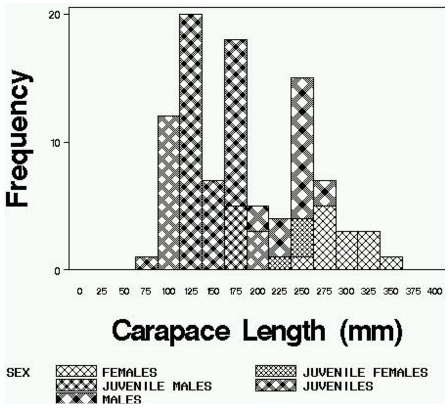


Figure 5. Typical size distribution of a population of Cooper Ck turtles in a waterhole where illegal fishing practices are currently conducted—it supports an unhealthy adult turtle population.

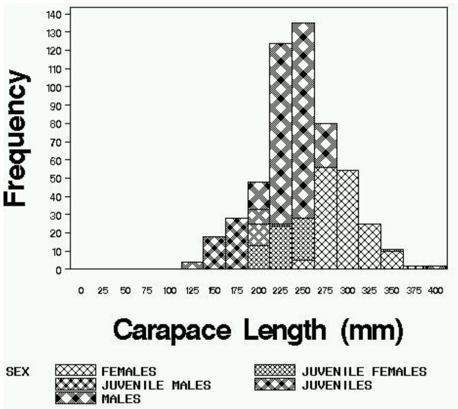


Figure 3. Typical size distribution of a population of Cooper Ck turtles in a waterhole that has had no history of illegal fishing– it supports a stable adult turtle population.

Waterholes with good road access or those close to town centres tend to be more susceptible to illegal fishing than those further away from towns, or with poor vehicle access and or on private land. There is also variation between landholders who either allow or do not allow fishing. Turtles have also suffered mortality from a small minority of drop-line fishermen who react aggressively towards turtles that steal bait. Some fishermen have been observed cutting the line and releasing the turtles, whilst a small minority of others have been observed killing the turtles.

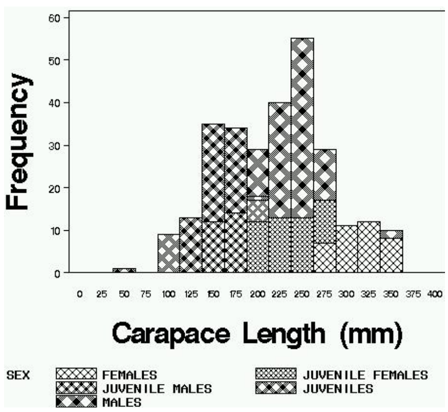


Figure 4. Typical size distribution of a population of Cooper Ck turtles in a waterhole where illegal fishing was stopped ca. 15years ago –it supports a large number of sub-adults which is a good sign for the future showing that a turtle population can recover over a period of 15 plus years.

Photo by Jon Marshall QNRME

Mayfield Waterhole at Windorah, October 2002

Productivity in Dryland Rivers

Christy Fellows, Nerida Beard & Stuart Bunn: Griffith University

What are the physical, chemical and biological processes that sustain refugia during dry periods?

In the last newsletter, we described how benthic algae (the algae that live attached to the sediment on the water hole bottoms) are an important part of the foodwebs in Cooper Creek water holes. The rate of production of organic carbon by benthic algae through the process of photosynthesis is therefore one factor that influences the amount of food that is available to aquatic animals in the water hole. We reported on the results of field sampling conducted in April 2001 over a total of 15 waterholes on four reaches of the Cooper Creek system and showed that benthic algal production was strongly related to light penetration in the water. A second field trip was conducted to Cooper Creek in September 2001. The same sampling methods were also employed in the Warrego River in October 2001 and April 2002, in 15 waterholes on the Quilberry, Glencoe, Binya and Thurulgoona reaches.

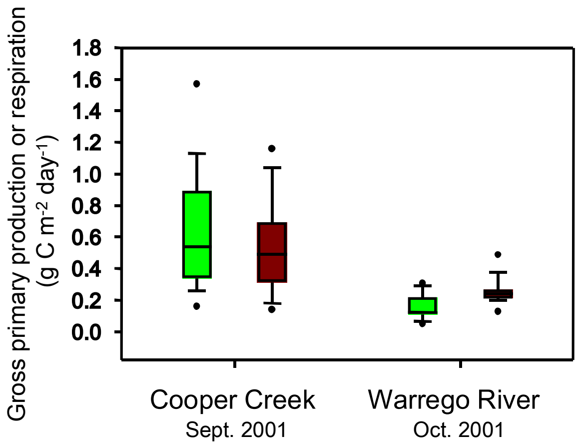
Photo by Jon Marshall QNRME

Photo by Jon Marshall QNRME

Glen Murken Waterhole at Windorah, Oct 2002

Warrego waterholes support lower rates of benthic algal production

A comparison of the results from Cooper Creek September 2001 and the Warrego River October 2001 show that the waterholes of the Cooper Creek system overall have higher rates of benthic algal primary production and respiration (the process that algae and other organisms carry out to generate energy which consumes organic carbon and oxygen and produces carbon dioxide) than the Warrego River waterholes (Figure 1 below).



Cooper Creek > Warrego for both GPP and R ($p = 0.001$, $p = 0.002$)

Figure 1: Comparison of Cooper Creek and Warrego River benthic algal production and respiration. Primary production (GPP) is shown in green and respiration (R) is shown in red.

Rates of both benthic production and respiration measured at Cooper Creek waterholes were more than twice as great as those measured at the Warrego River. Benthic production at Cooper Ck waterholes ranged from 0.2 to 1.6 grams of carbon produced per square metre per day, with an average production across the 15 waterholes of 0.7. In contrast, rates in Warrego River waterholes ranged from 0.05 to 0.3 grams of carbon produced per square metre per day with an average of 0.2. Respiration rates in the Warrego averaged 0.5 grams of carbon consumed per square metre per day in comparison to Cooper waterholes with an average of 1.2.

Why is benthic algal production lower in Warrego waterholes?

Factors such as light and nutrient availability, consumption by animals, and physical disturbance can all influence rates of algal production. Levels of light penetration and nutrients are fairly similar between Cooper Creek and Warrego River waterholes, and so we are looking at other factors that might be causing the low rates of production in the Warrego River. Two possibilities are the slope of water hole banks and the density of bottom-feeding fish.

Waterhole morphology

The *photic zone* is the area of the submerged 'ring' around the banks of the waterhole that receives enough light to enable benthic algae to carry out photosynthesis. Algal production is considered negligible where light intensities are lower than 1% of the light at the surface. The depth at which the 1% light point occurs is referred to as the *photic* depth (Figure 2a). This depth is a function of waterhole turbidity (amount of sediment in the water), with smaller photic depths in waterholes with higher turbidity.

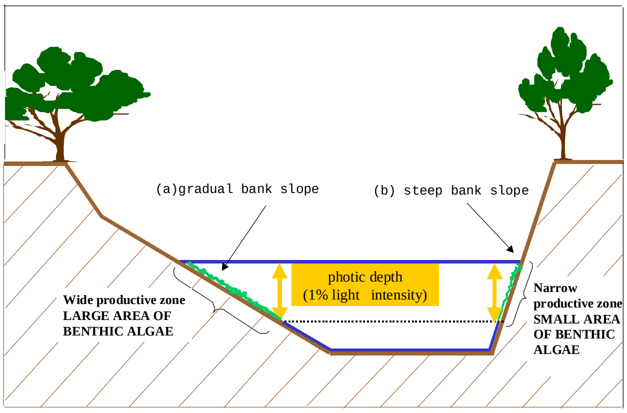


Figure 2: (a) Area in photic zone available for algal production is large due to gradual bank slopes. (b) Area in photic zone available for algal production is small due to steep bank slopes.

The slope of waterhole's banks influences the photic zone width. When slopes are shallow, a larger area of waterhole bank lies within the photic zone, and production could be expected to be higher due to higher light availability (Figure 2a). If the slopes are steep, the width of the 'ring' around the waterhole is small (Figure 2b). In this way, differences in waterhole morphology may be influencing rates of primary production in the Warrego River if waterhole banks are steeper there than in the Cooper waterholes.

Influence of carp

The feeding habits of fish may also have an effect on primary production. Carp (*Cyprinus carpio*), an exotic species present in the Warrego River but not in Cooper Creek, are bottom feeders. Through their feeding habits, carp disturb and resuspend sediments and this action may reduce benthic production by physically disrupting benthic algal colonies and increasing turbidity.

The next stage of the project

Phase 2 of this project (2003-2005) will investigate differences in benthic algal production by conducting carp-exclusion experiments, detailed within-waterhole slope surveys and whole-waterhole production measurements.

Photo by Jon Marshall QNRME

Mirage Waterhole at Mirage Plains, October 2002

Photo by Jon Marshall QNRME

Tinnenburra Waterhole at Tinnenburra, October 2002

Photo by Jon Marshall QNRME

Algal Scum at Mirage Waterhole, Mirage Plains, Oct 2002

Summary so far....

Identification of Refugia

• Between 2001 and 2003 the Project team sampled waterholes on the undeveloped Cooper Creek, Lake Eyre Basin, and the Warrego River, Murray-Darling Basin. Between 2002 and 2003 waterholes in the highly developed Border Rivers, Murray-Darling Basin were sampled.

• The geomorphic character of waterholes in the Cooper and Warrego and Border Rivers systems has been determined by both standard survey techniques and GIS processing. Preliminary analysis suggests some distinctive differences between main and satellite waterholes. Sites in the Cooper also appear to be more variable in physical character than those in the Warrego.

• Although the presence of true aquatic macrophytes is rare in dryland rivers this project has highlighted a high diversity of freshwater algae in dryland river waterholes: including more than 120 diatom taxa and 65 phytoplankton taxa.

• The recorded diversity of freshwater invertebrates in dryland river waterholes is not outstanding but typical of other dryland river waterholes. The main finding is the high abundance of molluscs (both bivalves and gastropods) in the waterholes of the Cooper system and the paucity of this group in the Warrego and Border Rivers. Another difference is the presence of aytid shrimps in the Murray-Darling Rivers while the palaemonid prawn dominates in Cooper Creek waterholes. See Dryland River Refugia Newsletter No. 1.

• Along with those freshwater mussel species expected in the study area (*Velesunio ambiguus* and *Velesunio wilsonnii*) the Dryland River Refugia Project has discovered at least two undescribed species of freshwater mussel in the genus *Velesunio* within waterholes of the Cooper Creek catchment. At present their distribution may well be limited to the Cooper Channel country. See Dryland River Refugia Newsletter No. 1

Photo by Steve Hamilton MSU

Cooper Creek Turtle at Tanbar, April 2002

• Of the fish fauna, a higher diversity of native species (11) was recorded in the Cooper Creek where very few exotic taxa were found. The rare Cooper Creek tandan was collected only in the northern portion of the Cooper study reach. In comparison, waterholes of the Warrego River in the Murray-Darling Basin supported fewer native taxa but a greater percentage of exotic species such as carp. The Border Rivers catchment supported fewer native species on average than the Warrego River and exotic species represented a higher proportion of total numbers.

• In the Cooper, turtles (*Emydura macquarii)* are locally abundant but have a patchy distribution. Of all waterholes sampled only two mature populations were identified and interestingly these two populations occurred in waterholes protected from fishing and netting.

• The Cooper has a higher degree of endemism and diversity compared with the Warrego for most taxonomic groups. The turtles are an exception, however, with the highest genetic diversity in the Warrego.

• Temporal shifts in composition of some taxonomic groups appear to relate to degree of waterhole persistence, as determined by water isotopes and chemistry.

Photo by Steve Hamilton MSU

Nardoo on the Cooper Floodplain, April 2002

Photo by Jon Marshall QNRME

Sampling at Red Waterhole, Binya, October 2002

Connectivity and Dispersal

• Waterholes seem to be permanent features of the landscape, relative to life histories of biota. The location of long-term refugia for turtles is not likely to change and these refugia are very few in number. It is currently uncertain as to whether waterholes vary in importance over time for other taxonomic groups.

• Genetic markers in both invertebrates and fish have been used to measure patterns of connectivity between waterholes in both the Cooper and the Warrego. Most taxa show little dispersal between drainages and there are clear barriers to dispersal – e.g. Lake Eyre. In contrast, populations of some taxa are highly connected within drainages. For example, the freshwater prawn *Macrobrachium australiense* shows distinct differentiation for populations between drainages with high levels of similarity within drainages.

• In contrast, there is evidence of limited dispersal in mussels at the catchment scale. Turtles also show restricted dispersal within catchments, especially in the Warrego. There is also restricted dispersal in snails and these appear to be poor recolonizers.

• There appears to be little evidence of restricted dispersal among satellite and main waterholes within reaches. The snail *Notopala* may be an exception.

Processes Sustaining Refugia

• Water isotope chemistry and Na^+ and Cl^- data suggest that waterholes are largely sustained by surface flows, though some are more persistent than we might predict, given high evaporation rates.

• The Dryland Refugia project has measured the production of benthic algae across a range of waterholes to determine why some waterholes are more productive than others. Cooper waterholes appear to be more productive than Warrego sites and a key objective of Phase 2 will be to determine the factors that underpin this difference.

• Algal production in the Cooper is also highly variable – in part due to turbidity. Productivity appears to increase as pools recede during dry spells.

• Previous work on the Cooper suggests that benthic algae are the most important source of organic carbon for aquatic animals in waterholes. Phytoplankton also were a significant primary source for some consumers. The trophic base of food webs in the Warrego and Border Rivers is yet to be resolved, using stable isotopes and diet analysis. Preliminary data on the Warrego suggests that, with the exception of freshwater mussels, phytoplankton are not major contributors to the food web.

Next Newsletter

In our next newsletter we will:
(a) present more data from the temporal Cooper Creek and Warrego River field work, the largely undisturbed systems
(b) present initial data from the Border Rivers field work, the disturbed system
(c) continue to explore what features of waterholes underlie the observed patterns in biodiversity
(d) explore what processes sustain refugia

Photo by Steve Hamilton MSU

Freshwater mussel shells at Tanbar, April 2002

Photo by Steve Hamilton MSU

Pelicans at Tanbar, April 2002

Newsletter prepared by Fran Sheldon, CRCFE Griffith University. F.Sheldon@griffith.edu.au

Cooperative Research Centre for Freshwater Ecology

Improving Australia s Rivers

Healthy rivers are essential for the future of Australia's landscape and its people. Yet many rivers are being damaged by unsustainable practices, resulting in poor water quality, degraded habitats and declining biodiversity. Understanding how our river systems work is essential if we are to manage them in a sustainable way.

The Cooperative Research Centre for Freshwater Ecology (CRCFE) is a world-class research centre specialising in river system ecology, river restoration and sustainable river management. It provides the latest ecological knowledge needed to manage rivers in a sustainable way. A core part of the CRCFE's work is to communicate this knowledge while working with other scientists, water managers, policy makers and the community.

The CRCFE's 200 staff and students are based in Adelaide, Brisbane, Canberra, Melbourne and Sydney; as well as in three regional laboratories: the Murray-Darling Freshwater Research Centre in Albury, the Lower Basin Laboratory in Mildura and the Northern Laboratory in Goondiwindi.

The CRCFE's research addresses four key themes in water resources management:

- Environmental Flows (Program A)
- Restoring River Systems (Program B)
- Conserving Biodiversity (Program C)
- Assessing River Health (Program D)

Key questions

- Can we improve river systems through better management of water releases?
- How does flood harvesting and flow regulation affect river – floodplain ecology?
- How can we best rehabilitate disturbed river systems?
- What biodiversity still remains in our river systems and how is it regulated?
- How can we best measure river condition to evaluate management actions?

The research required to address these questions is often beyond the resources and skills of individual researchers. The CRCFE brings together some of Australia's best freshwater scientists from many different disciplines and organisations to work in teams. This collaborative, multidisciplinary approach enables the CRCFE to play a leading role in water resources management as a provider and broker of knowledge.

Further information

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