Food resource variability in an Australian dryland river: evidence from the diet of two generalist native fish species

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Abstract

To examine how food resource availability links with natural variation in primary productivity in the Moonie River SW Queensland, the diets of two native Australian fish species (*Nematalosa erebi* and *Macquaria ambigua*) were examined from fifteen waterholes in February, May and September 2006. *N. erebi* diets reflected strong ‘boom and bust’ patterns of food consumption, with high levels of benthic (non-filamentous) algae during boom (flow) times, moving to higher levels of filamentous algae and detritus during bust (no flow) periods. *M. ambigua* diets were primarily dominated by aquatic insects in all sampling periods. While there was no clear ‘boom to bust’ pattern in relation to flow, *M. ambigua* secondary prey consumption revealed a compensatory switch between high energy prey (crustaceans) during more productive periods with terrestrial insects during less productive periods. The ability of both

species of fish to switch from high to low levels of food quality under a variable environmental background allows them to persist through both high productive and low productive periods. This interaction between native biota and variable 'boom' and 'bust' conditions and how changes to the natural hydrology will affect it is an important consideration of any future water resource development plans.

Additional Keywords: dryland rivers, Murray-Darling Basin, stomach contents, generalist feeding behaviour.

Running Head: Temporal variation of dryland fish diets

Introduction:

Two-thirds of the world's land mass is semi-arid, arid or hyper-arid (Davies 1994) and dryland rivers drain one-third of the world's land area (Walker *et al.* 1995), including large areas of Australia, Africa, Asia, America and parts of Europe. In Australia, more than 90% of the 3.5 million kilometres of river channels (measured at the 1:250,000 scale) are lowland rivers and most of these are characterised as dryland systems (Thoms and Sheldon 2000).

Dryland rivers are influenced by varying hydrological (Gibling *et al.* 1998; Kingsford *et al.* 1998; Marshall *et al.* 2006), geological (Magee *et al.* 1995; Liu and Dorn 1996; Gibling *et al.* 1998; Tooth 2000) and climatic (Tooth 2000; Roshier *et al.* 2001) conditions creating highly variable spatial and temporal flow regimes (Puckridge *et al.* 2000; Balcombe *et al.* 2006). As a result, dryland rivers are subject to contrasting periods of high and no flow, which correspond to 'boom' and 'bust' ecosystem processes within the aquatic environment (Kingsford *et al.* 1999; Arthington *et al.* 2005; Balcombe *et al.* 2006). During high flow and flood events ('boom'), floodplain and channel waterholes become connected stimulating production on the newly inundated floodplain (Kingsford *et al.* 1999; Balcombe *et al.* 2007). Native fish, in particular generalist feeders, opportunistically feed on these newly available food resources (Balcombe *et al.* 2005). This increased interaction between the river and its floodplain suggests a lateral dependence on ecosystem production *i.e.* the Flood Pulse Concept (Junk *et al.* 1989; King *et al.* 2003; Balcombe *et al.* 2007) during high flow events.

As floodwaters recede, lateral and longitudinal connectance is disrupted returning the river to a series of typically highly turbid floodplain and channel waterholes ('bust') which act as refugia (Cook *et al.* 2002; Balcombe *et al.* 2005; Bunn *et*

al. 2006). In turbid systems, it is during these ‘bust’ periods that benthic production is limited to a thin, littoral, photic band of algal production which may ultimately support large populations of higher trophic organisms within the waterhole (Bunn *et.al* 2003). Phytoplanktonic production may also contribute significantly to the aquatic food webs in these isolated waterholes (Bunn *et.al* 2003; Balcombe *et al.* 2005). This local, in-stream production suggests a dependence on autochthonous inputs as proposed by the Riverine Productivity Model (Thorpe and Delong 1994). Therefore, from ‘boom’ to ‘bust’, fluctuating sources of aquatic production may ultimately influence the temporal availability, nutritional quality and variety of food resources in dry-land rivers.

Fish diet analysis provides an insight into the sources (allochthonous or autochthonous) of food resources in a river and the abundance and type of prey available (Pouilly *et.al* 2003). In a temporal context, the analysis of fish diets can reveal changes in food availability within and across wet and dry periods. Balcombe *et.al* (2005) found the stomach contents of fish and the source of prey items in Cooper Creek, western Queensland, Australia, to be highly variable between flood and dry seasons. Kennard (1995) however, found little temporal variation in stomach contents across an eight month period in isolated floodplain wetlands of the Normanby River. However, the degree to which conclusions from dietary studies can be applied to spatially different regions is largely unknown (Pusey *et al.* 2000). With that in mind, spatial analysis of fish diets can reveal variation in feeding behaviour at a number of scales (AusRivAs 2006) and is important for assessing the impact of abiotic disturbance upon the aquatic environment (Pusey *et al.* 2000). Jeffree and Williams (1980) concluded that pollution caused an observed change in the dietary composition of *Mogurnda mogurnda* (purple-spotted gudgeon) (a generalist feeder) between two branches of the Finnis River, Northern Territory, Australia. Similarly, Baumgartner

(2007) used diet analysis to determine differences in feeding behaviour and prey density upstream and downstream of a weir on the Murrumbidgee River, New South Wales, Australia.

Nematalosa erebi (Günther, 1868) (bony bream) is arguably the most widespread of Australia's freshwater fishes (Pusey *et al.* 2004) and it plays an important role in many aquatic food webs (Medeiros 2004). Literature (*reviewed in* Pusey *et al.* 2004) suggests that *N. erebi* is primarily a detritivore/algivore with broad dietary analysis revealing 57.3% of the diet was detritus with algae representing 14.7%. However, this broad analysis does not reflect temporal variation in diet composition. Balcombe *et al.* (2005) found that *N. erebi* in Cooper Creek fed entirely on plant matter when it was available and principally on zooplankton when it was not. Therefore, in dryland systems, *N. erebi* may exhibit temporally variable diets from 'boom' to 'bust' periods.

Macquaria ambigua (Richardson, 1845) (yellow belly) is an indiscriminate, opportunistic carnivore (Baumgartner 2007; Pusey *et al.* 2004) with the ability to influence aquatic food webs due to its high trophic status. Literature (*reviewed in* Pusey *et al.* 2004) suggests the diet of *M. ambigua* varies according to habitat type, locality and time of year with fish (63.8%) dominating the diet composition, and crustaceans (27.6%) and aquatic insects (~6%) also making significant contributions. Baumgartner (2007) noted that *M. ambigua* had a high potential for temporal diet change to accommodate seasonal changes in resource availability, while Balcombe *et al.* (2005) found that *M. ambigua* diet varied in composition between wet ('boom') and dry ('bust') periods. Furthermore, Collins and Anderson (1995) reported that *M. ambigua* accumulate large fat reserves during 'boom' periods which they later utilise during 'bust' conditions. Therefore, the generalist feeding behaviour of *M. ambigua*

may be a response to changes in resource availability across ‘boom’ and ‘bust’ conditions.

This paper tests two hypotheses: (1) that benthic algae dominates the diet of *Nematalosa erebi* during wet periods and is absent from the diet following prolonged periods of dry conditions and/or no flow as algal biomass becomes depleted. (2) That the diet of *Macquaria ambigua* is dominated by high energy foods (fish and decapod crustacea) during wet periods and by lower energy food resources following prolonged periods of dry conditions and/or no flow as high quality food becomes scarce. This study was conducted as part of a broader research project investigating dryland fish assemblages in the Moonie River in the upper Murray Darling Basin, Australia.

Methods

STUDY AREA

The Moonie River, is a dryland system situated east of St George in south-west Queensland, Australia (*Fig. 1*). The river is 525 km long and drains an area of 14870 km² (Department of Natural Resources, 1999). It is a tributary of the Barwon River in the Murray-Darling Basin, Australia's largest river system.

The Moonie River catchment has a semi-arid climate, with an average rainfall of 500-600 mm year⁻¹ and mean annual pan evaporation of 1800-2200 mm year⁻¹ with considerable annual variation in temperature and inter-annual variation in rainfall (Bureau of Meteorology, 2007). The Moonie is a rainfall-runoff, as opposed to groundwater, fed river and as rainfall tends to occur as sporadic large-scale events, the hydrology of the river is typified by frequent periods without flow punctuated by unpredictable but well-defined flow events. The river flows for only 35 per cent of the time at Nindigully gauge, and as such, exists for much of the year as a series of unconnected waterholes (Department of Natural Resources and Water, 2007).

The average annual streamflow discharge is 27.0 m³ sec⁻¹ at Nindigully and 37.3 m³ sec⁻¹ at Fenton. The maximum recorded no-flow spell for the system is 13 months at Nindigully gauge in 1979 and 1980 (Biggs *et al.* 2005), whilst the 100 year modelled maximum no flow spell is approximately two years (Department of Natural Resources and Water, unpublished data). Turbidity in the Moonie River is high and variable (range 113 to 3904 NTU, mean 688 NTU, Department of Natural Resources and Water, unpublished data), governed by local geology, rainfall events and landuse, and limits in-stream primary productivity in the system (*sensu* Bunn *et.al* 2003).

Inputs from streams upstream of Alton (Fig. 1), can contribute to major flooding of low-lying areas following local heavy rainfall (BOM, 2007). During large flow events significant amounts of overland flow can occur between the downstream sections of the Moonie, Weir and Macintyre Rivers, inundating large floodplain areas south of Nindigully (Department of Natural Resources, 1999).

The Moonie River is subject to moderate water regulation, with a number of weirs and off-channel storages. There is also a significant number of sites where water is pumped for unregulated stock and domestic use.

FIELD AND LABORATORY METHODS

Fish were collected from fifteen waterholes (Fig. 1) in February 2006 while the river was connected following a summer flood peak, which occurred in December 2005 and again from the same waterholes in May and September 2006 during periods of zero discharge (Fig. 2). Diet analysis was conducted on small to medium bodied fish (30 – 150mm standard length), which were chosen specifically for a separate study. Fish were sampled using 6, 9 and 12 m seine nets of 8 mm square mesh and three fyke nets per waterhole set over a 20 hr period with 8 m long wings spanning 10 m which were positioned parallel to the bank (for description of methods see Arthington *et al.* 2005). Fish collected by active methods (seines) were preferentially used for dietary analysis, however it was necessary to include fyke-caught specimens to increase sample sizes (*N. erebi*, 24; *M. ambigua*, 14). Fish from fyke nets were only used if they had similar stomach fullness to those caught in the seine nets and did not contain intact fish and or prawns (which would indicate feeding within the nets). Fish were killed by immersion in ice slurry upon capture, placed into plastic bags and frozen where they were stored until laboratory analysis.

In the laboratory, stomachs (digestive tracts) were removed for dietary analysis. For yellowbelly, which have a true stomach, this was the oesophagus to stomach section and for bony bream (no true stomach), the entire tract was removed. Stomachs were dissected and food items were identified and placed into broad categories as described by Pusey *et al.* (2004), chosen to represent the major food items preyed upon by each species. For *N. erebi* these were detritus, filamentous and non-filamentous algae) and *M. ambigua* (crustaceans, fish, aquatic insects, terrestrial insects and detritus). Each set of gut contents were pressed to an even thickness (2 mm for *M. ambigua*; 0.5 mm for *N. erebi*) and visually scored over 35 mm² graded graph paper with the relative volumetric contribution of prey items to the total gut content measured in the number of graph squares covered (Hyslop, 1980; Balcombe *et al.* 2005). Allotted squares were summed for each diet category and expressed as the percentage total dietary contribution per site for each fish species.

DIET ANALYSIS

Unidentified food items were omitted from all diet analyses. The broad diets of the two fish species were summarised using frequency histograms for each individual sampling time to visualise diet variability for each species. Schoener's index, T, was used to calculate dietary overlap among each pair of sampling times to verify changes through time in prey consumption. T was calculated: $T = 1 - 0.5 \sum |P_{x_i} - P_{y_i}|$; where P_{x_i} is the total proportion of the food item in sampling period x_i ; and P_{y_i} is the total proportion of the food item in sampling period y_i (Balcombe 2002). T varies between 0 and 1, where 0 indicates, no overlap and 1, identical diets. Values of $T \geq 0.60$ is considered to represent high similarity, hence, biologically significant overlap (Balcombe 2002; Pusey and Bradshaw 1996). Multivariate patterns in diet composition

across sites and times were plotted using non-metric multidimensional scaling (MDS). These plots were constructed from a Bray-Curtis similarity matrix of $\log_{10}(X+1)$ transformed diet data, using Primer-E version 5 for Windows (Clarke and Warwick 2001). One-way analysis of similarity (ANOSIM) was used to test for differences in fish diets through time (sampling periods) using the same Bray-Curtis similarity matrices.

Results

Nematalosa erebi

Diet analyses were performed on 14 fish from five sites in February, 24 fish from five sites in May, and 23 fish from eight sites in September (Table 1.). It was not possible to capture *N. erebi* from all 15 sampling sites on each sampling trip due to low capture rates in many cases.

Diets showed considerable temporal variation with benthic non-filamentous algae representing 86% of the total food consumed during February (wet) and later reduced to 2% of the diet in September (dry) (Fig. 3). The filamentous algal component of the diet was almost absent in February yet had increased to 32% in September (Fig. 3). Detritus in the diet of *N. erebi* increased from 18% in February to 66% in May and September (Fig. 3). Schoener's Dietary Overlap confirmed temporal feeding variability of *N. erebi* captured in the Moonie River with dietary differences between February and May ($T = 0.47$), and February and September ($T = 0.16$) sampling periods. *N. erebi* diets showed some similarity between May and September samples ($T = 0.68$).

Analysis of similarity revealed significant differences in the diets of *N. erebi* between sampling periods (global $R = 0.569$; $p = 0.02$) with pair-wise comparisons between February and September ($R = 0.941$; $p = 0.001$), and May and September ($R = 0.380$; $p = 0.012$) showing significant differences. However, there was not a significant pair-wise difference between February and May diets ($R = 0.256$; $p = 0.09$). These results were visible in the MDS ordination, which showed no overlap between February and September diets. The diets from these months were separately grouped along axis 1, while May diets were interspersed between the two (Fig. 4).

Macquaria ambigua

The diets of 15 fish from seven waterholes in February, 12 fish in May from seven waterholes, and 6 fish from five waterholes in September were analysed (Table 1.). As with *N. erebi* we were unable to capture *M. ambigua* from all 15 sampling sites per sampling trip due to low capture rates.

Schoener's Dietary Overlap revealed marginal temporal diet variation between May and September sampling periods ($T = 0.57$), however there was high diet overlaps among the other sampling times (February/May, $T = 0.67$; February/September, $T = 0.81$). During all three sampling periods aquatic insects represented at least 50% of the diet of *M. ambigua* (Fig. 5). Detritus was consistently consumed across all times, although never contributed more than 12% of the dietary volume on any sampling period. In addition to aquatic insects, there was also a secondary major food source consumed by *M. ambigua* on any sampling occasion. Crustaceans formed this secondary component in both February and September, while these were replaced by terrestrial insects in May. February diet samples contained a higher number of prey categories than May and September (five categories in February and only three in both May and September; Fig. 5).

Analysis of similarity revealed no significant differences between sampling periods (Global $R = -0.053$; $p = 0.74$). These results were confirmed visually in the MDS ordination where no spatial clumping was observed for all sampling trips on either of the two axes (Fig. 6).

Discussion

The diet of *N. erebi* in the Moonie River conformed broadly with other studies (Medeiros 2004; Pusey *et al.* 2004; Balcombe *et al.* 2005) feeding exclusively on algae and detritus. Contrary to Balcombe *et al.* (2005) who found *N. erebi* fed consistently upon zooplankton under varying hydrological conditions in another dryland river (Cooper Creek), no zooplankton were sampled in the stomachs of juvenile *N. erebi* in the Moonie River. It is evident that changes in the processes which govern resource availability from 'boom' to 'bust' have a significant effect on the temporal diets of *N. erebi* in the Moonie River. Results support the hypothesis that benthic algae dominates the diet of *N. erebi* during wet periods and is absent from the diet following prolonged periods of dry conditions and/or no flow as algal biomass becomes depleted. This can be further refined as temporal changes in diet were characterised by progressive decrease in the proportion of non-filamentous algae present from the high proportion in the wet period to near absence as the system dried to isolated waterholes. This loss of non-filamentous algae was compensated first by an increase in the proportion of detritus consumed and then by feeding upon filamentous algae. The dominance of non-filamentous algae when the system is wet may represent the true dietary preference of *N. erebi* under favourable conditions (Balcombe *et.al* 2005). Patterns of dietary shift suggest that *N. erebi* will feed primarily on non-filamentous algae and in its absence or as it is depleted they will move to secondary food sources such as detritus (Balcombe *et al.* 2005). Non-filamentous algae has been identified as an abundant and energy rich food resource in dryland rivers in wet conditions (Bunn *et al.* 2003). Utilisation of this high quality food during 'boom' wet phase conditions is in accordance to predictions of the Flood Pulse Concept (Junk *et.al* 1989). These apparent preferences may further be explained by the typically low nutritional status

(Kahlert *et al.* 2002) and/or poor digestibility (Peterson *et al.* 1998) of many species of filamentous algae. Thus the observed changes may reflect decreasing availability of non-filamentous algae as the preferred food for bony bream as the Moonie system moves from boom to bust conditions. Clearly detritus and filamentous algae are not primary food sources, given that both of these sources were observed to be widely available in the system but were not always heavily utilised as food by *N. erebi*.

The diet of *M. ambigua* in the Moonie River was also in general agreement with the literature (Cadwallader 1977; Pusey *et al.* 2004; Balcombe *et al.* 2005) confirming this fish as a generalist, opportunistic carnivore. High dietary variation within sampling periods resulted in no strong pattern of change between ‘boom’ and ‘bust’ periods for *M. ambigua* based upon dietary overlap metrics, largely as a result of the high contribution of aquatic insects in all sampling periods. While Pusey *et al.* (2004) reported that higher energy foods such as fish and large crustaceans represent the major dietary components of *M. ambigua* in dryland rivers, these prey items were only found in low proportions in this study. This may reflect the observation that both fish and decapod crustacean abundance is low in the Moonie River compared to other dryland river systems in Queensland (e.g. Arthington *et al.* 2005, Marshall *et al.* 2006, NRW, *unpublished data*). Instead, potentially lower energy foods such as aquatic insects were dominant with detritus making the only other consistent contribution to the diet in all three sampling periods. Aquatic insects may represent a temporally abundant and readily consumed source of energy which *M. ambigua* opportunistically fed upon. Balcombe *et al.* 2005 found similar results in the adjacent Cooper Creek where *M. ambigua* were shown to feed primarily on abundant zooplankton in both ‘boom’ and ‘bust’ conditions.

Clearly this species did exhibit an obvious generalist feeding strategy in relation to temporally available food resources. This was evidenced by the diets of *M.*

ambigua in May, where high energy foods, such as crustaceans and fish (Balcombe *et al.* 2005) were absent from the diet (Fig. 5) resulting in the opportunistic predation of terrestrial insects to meet their dietary needs. When put into the context of temporally unpredictable dryland environments, this opportunist feeding is characteristic of *M. ambigua* (Pusey *et al.* 2004). Diet switching from higher to lower energy prey as food resources decline is a common strategy used by generalist fish to persist through lean periods (Lobon-Cervia and Rincon 1994; Balcombe *et al.* 2005; Balcombe and Humphries 2006).

Several dietary studies (*e.g.* Luczkovich *et.al* 1995; Mrigoux and Ponton 1998; Grutter 2000; King 2005) have shown fish feeding to be gape limited, often changing with ontogeny whereby the range of potential prey and prey sizes consumed increases to meet increasing metabolic demands as fish grow. It is important to note that the results of this study relate to individuals that were constrained to pre-defined size range, many of which were relatively small bodied. The dominance of aquatic insects in the diet of *M. ambigua* may be attributed to this constraint. However, Arumugam and Geddes (1996) found the diet of larval *M. ambigua* to increase rapidly from gape limited size dependant to large size selective predation. There was thus, no evidence to support the hypothesis that the diet of *M. ambigua* is dominated by high energy foods (fish and decapod crustacea) during wet periods and by lower energy food resources following prolonged periods of dry conditions and/or no flow as high quality food becomes scarce.

This study further reinforces the generalist feeding nature of two common and abundant dryland river fish species despite their contrasting trophic positions. *N. erebi* feeds at the lowest trophic level (algae and detritus) yet still consumes sufficient resources to meet its energy requirements by switching between different algal types and detritus. *M. ambigua* sits at the highest trophic position in the waterholes, but is

also able to persist under varying environmental conditions by switching foods from various trophic levels, from detritus through to aquatic and terrestrial insects and fish and crustaceans. The ability of these fish to persist in a naturally highly variable hydrological environment is assisted by their dietary plasticity. As such this study has added to our knowledge of dryland river fish assemblages and particularly in the northern Murray-Darling Basin, where little research exists on fish resource acquisition. The duration that these fish can persist under bust conditions without decreasing either individual or population fitness is unknown. Water resource development ultimately interferes with the natural ‘boom and bust’ cycles of waterhole productivity largely driven by the hydrological regime (Arthington *et al.* 2005; Balcombe *et al.* 2006). Given the pressures placed upon dryland river systems by water resource development, it would be beneficial to focus future research efforts on the physiological and ultimately population effects of increased durations of food resource limitation on these fish assemblages.

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References:

- Arthington A.H., Balcombe, S.R., Wilson G.A., Thoms, M.C. and Marshall J. (2005). Spatial and temporal variation in fish assemblage structure in isolated waterholes during the 2001 dry season of an arid-zone floodplain river, Cooper Creek, Australia. *Marine and Freshwater Research* **56**, 25-35.
- Arumugam, P.T. and Geddes, M.C. (1996). Effects of golden perch (*Macquaria ambigua* (Richardson)) larvae, fry and fingerlings on zooplankton communities in larval-rearing ponds: An enclosure study. *Marine and Freshwater Research*, **47**, 837-844.
- AusRivAs Home. (2006). AusRivAs Website. (Gail Ransom, CRC Freshwater Ecology.) Available at: <http://ausriv.as.canberra.edu.au/index.html>. (1st July 2006). [Verified 1 July 2006].
- Balcombe, S. R. (2002). Resource use by *Hypseleotris* (Pisces: Gobiidae) in the littoral macrophytes of a floodplain billabong. PhD Thesis, Department of Environmental Management and Ecology, LaTrobe University, Albury/Wodonga, Australia.
- Balcombe, S.R., Bunn, S.E., Arthington, A.H., Fawcett, J.H., McKenzie-Smith, F. J. and Wright, A. (2007). Fish larvae, growth and biomass relationships in an Australian arid zone river: links between floodplains and waterholes. *Freshwater Biology* **52**, 2385-2398.
- Balcombe, S. R., Bunn, S. E., Davies, P. M. and McKenzie-Smith, F. J. (2005). Variability of fish diets between dry and flood periods in an arid zone floodplain river. *Journal of Fish Biology* **67**, 1552–1567.

- Balcombe, S.R. and Humphries, P. (2006). Diet of the western carp gudgeon (*Hypseleotris klunzingeri* Ogilby) in an Australian floodplain lake: The role of water level stability. *Journal of Fish Biology* **68**, 1484-1493.
- Balcombe, S.R., Arthington, A.H., Foster, N.D., Thoms, M.C., Wilson, G.G. and Bunn, S.E. (2006). Fish assemblages of an Australian dryland river: abundance, assemblage structure and recruitment patterns in the Warrego River, Murray-Darling Basin. *Marine and Freshwater Research* **57**, 619-633.
- Baumgartner, L.J. (2007). Diet and feeding habits of predatory fishes upstream and downstream of a low level weir. *Journal of Fish Biology* **70**, 879-894.
- Biggs, A.J.W., Power, R.E., Silburn, D.M., Owens, J.S., Burton, D.W.G. and Hebbard, C.L. 2005. Salinity audit – Border Rivers and Moonie catchments, Queensland Murray-Darling Basin. QNRM05462. Department of Natural Resources and Mines, Queensland.
- Bunn, S.E., Davis, P.M. and Winning, M. (2003). Sources of organic carbon supporting the food web of an arid zone floodplain river. *Freshwater Biology* **48**, 1-17.
- Bunn, S.E., Thoms, M.C., Hamilton, S.K. and Capon, S.J. (2006). Flow variability in dryland rivers: ‘boom’, ‘bust’ and the bits in between. *River Research and Application* **22**, 179–186.
- Bureau of Meteorology (2007). Queensland Flood History (Bureau of Meteorology, Commonwealth of Australia: Canberra) : Available at:
<http://www.bom.gov.au/hydro/flood/qld> [Verified 4th June 2007].
- Cadwallader, P. L. (1977). J.O. Langtry’s 1949–50 Murray River Investigations. *Fisheries and Wildlife Paper, Victoria*. **13**.
- Clarke, K. R. and Warwick, R. M. (2001). Change in Marine Communities: An Approach to Statistical Analysis and Interpretation, 2nd edn. (Plymouth: Primer-E Ltd.)

- Collins, A. L. and Anderson, T. A. (1995). The regulation of endogenous energy stores during starvation and refeeding in the somatic tissues of the *M. ambigua*. *Journal of Fish Biology* **47**, 1004-1015.
- Cook, B.D., Bunn S.E. and Hughes, J.M. (2002). Genetic structure and dispersal of *Macrobrachium australiense* (Decapoda: Palaemonidae) in Western Queensland, Australia. *Freshwater Biology* **47**, 2098-2112.
- Davies, P. E., 1994. National River Process and Management Program Monitoring River Health Initiative. River Bioassessment. Manual Version 1.0. Department of the Environment, Sport and Territories, Canberra.
- Department of Natural Resources (1999). Overview of Water Resources and Related Issues: The Moonie River Catchment. Department of Natural Resources, Brisbane, Australia.
- Department of Natural Resources and Water (2007). Annual Report 2005-2006, Water Resource Plans. Department of Natural Resources, Brisbane, Australia.
- Gibling, M.R., Nanson, G.C. and Maroulis, J.C. (1998). Anastomosing rivers sedimentation in the Channel Country of central Australia. *Sedimentology* **45**, 595–619.
- Grutter, A.S. (2000). Ontogenetic variation in the diet of the cleaner fish *Labroides dimidiatus* and its ecological consequences. *Marine Ecology Progress Series* **197**, 241-246.
- Hyslop, E.J. (1980). Stomach contents analysis – a review of methods and their application. *Journal of Fish Biology* **17**, 411–429.
- Jeffree, R.A. and Williams, N.J. (1980). Mining pollution and the diet of the purple spotted gudgeon *Mogurnda mogurnda* Richardson (Eleotridae) in the Finniss River, Northern Territory, Australia. *Ecological Monographs* **50**, 457–485.

- Junk, W.J., Bailey, P.B. and Sparks, R.E. (1989). The flood pulse concept in river-floodplain system. Proceedings of the international Large River Symposium. D.P. Dodge, *Special Publications of Fisheries and Aquatic Sciences* **106**, 110-127.
- Kahlert, M., Hasselrot, A.T., Hillebrand, H. and Pettersson, K. (2002). Spatial and temporal variation in the biomass and nutrient status of epilithic algae in Lake Erken, Sweden. *Freshwater Biology* **47**, 1191-1215.
- Kennard, M.J. (1995). Factors influencing freshwater fish assemblages in floodplain lagoons of the Normanby River, Cape York Peninsula: a large tropical Australian River. Unpublished Master of Philosophy Thesis, Griffith University, Brisbane, Queensland.
- King, A. J. (2005). Ontogenetic dietary shifts of fishes in an Australian floodplain river. *Marine and Freshwater Research* **56**, 215–225.
- Kingsford, R.T., Boulton, A.J. and Puckridge, J.T. (1998). Challenges in managing dryland rivers crossing political boundaries: lessons from Cooper Creek and the Paroo River, central Australia. *Aquatic Conservation: Marine and Freshwater Ecosystem* **8**, 361–378.
- Kingsford R.T., Curtin A.L. and Porter J.L. (1999). Water flows on Cooper Creek determine ‘boom’ and ‘bust’ periods for waterbirds. *Biological Conservation* **88**, 31–248.
- Liu, T. and Dorn, R.I. (1996). Understanding the Spatial Variability of Environmental Change in drylands with Rock Varnish Microlaminations. *Annals of the Association of American Geographers* **86**, 187–212.
- Lobon-Cervia, J. & Rincon, P. A. (1994). Trophic ecology of red roach (*Rutilus arcasii*) in a seasonal stream; an example of detritivory as a feeding tactic. *Freshwater Biology* **32**, 123–132.

- Luczkovich, J.J., Norton, S.F. and Gilmore, G.R. Jr. (1995). The influence of oral anatomy on prey selection during the ontogeny of two percoid fishes, *Lagodon rhomboides* and *Centropomus undecimalis*. *Environmental Biology of Fishes* **44**, 79–95.
- Magee, J.W., Bowler, J.M., Miller, G.H. and Williams, D.G.L. (1995). Stratigraphy, sedimentology, chronology and paleohydrology of Quaternary lacustrine deposits at Madigan Gulf, Lake Eyre, South Australia. *Palaeogeography, Palaeoclimatology, Palaeoecology* **113**, 3–42.
- Marshall, J. C., Sheldon, F. Thoms, M., and Choy, S. (2006). The macroinvertebrate fauna of an Australian dryland river: spatial and temporal patterns and environmental relationships. *Marine and Freshwater Research* **57**, 61–74.
- Medeiros, E.S.F. (2004). Trophic ecology and energy sources for fish on the floodplain of a regulated dryland river: Macintyre River, Australia. PhD Thesis, Faculty of Environmental Sciences, Griffith University, Brisbane, Australia.
- Mérigoux, S. and Ponton, P. (1998). Body shape, diet and ontogenetic diet shifts in young fish of the Sinnamary River, French Guiana, South America. *Journal of Fish Biology* **52**, 556–569.
- Peterson, C.G., Vormittag, K. A. and Maurice, V.H. (1998). Ingestion and digestion of epilithic algae by larval insects in a heavily grazed montane stream. *Freshwater Biology* **40**, 607–623.
- Pouilly, M., Lino, F., Bretenoux, J. G. and Rosales, C. (2003). Dietary-morphological relationships in a fish assemblage of the Bolivian Amazonian floodplain. *Journal of Fish Biology* **62**, 1137–1158.

- Puckridge, J.T., Walker, K.F. and Costelloe, J.F. (2000). Hydrological persistence and the ecology of dryland rivers. *Regulated Rivers: Research and Management* **16**, 385-402.
- Pusey, B.J. and Bradshaw, S.D. (1996). Diet and dietary overlap in fishes of temporary waters of southwestern Australia. *Ecology of Freshwater Fish* **5**, 183-194
- Pusey, B.J., Arthington, A.H. and Read, M.G. (2000). The dry-season diet of freshwater fishes in monsoonal tropical rivers of Cape York Peninsula, Australia. *Ecology of Freshwater Fish* **9**, 177-190.
- Pusey, B.J., Kennard, M.J., Arthington A.H. 2004. Freshwater fishes of North-Eastern Australia. (Collingwood: CSIRO Publishing.)
- Roshier, D.D., Whetton, P.H., Allan, R.J. and Robertson, A.I. (2001). Distribution and persistence of temporary wetland habitats in arid Australia in relation to climate. *Australian Journal of Ecology* **26**, 371-384.
- Thoms, M. C. and Sheldon, F. (2000). Lowland rivers: an Australian perspective. *Regulated Rivers Research and Management* **16**, 375–383.
- Thorp, J.H. and DeLong, M.D. (1994). The Riverine productivity model: An heuristic view of carbon sources and organic processing in large river ecosystems. *Regulated Rivers Research and Management* **16**, 375-383.
- Tooth, S. (2000). Process, form and change in dryland rivers: a review of recent research. *Earth-Science Reviews* **51**, 67–107.
- Walker, K., Sheldon, F. and Puckridge, J.T. (1995). A perspective on dryland river ecosystems. *Regulated Rivers: Research and Management* **11**, 85–104.

Tables:

Table 1. Number of *N. erebi* and *M. ambigua* analysed per water hole in the Moonie River for February (Feb), May, and September (Sep) with n representing the total number of fish analysed per sampling period.

Figures:

Figure 1: Map of Moonie River catchment showing its position in eastern Australia and the location of our 15 study sites.

Figure 2: Graph of mean daily discharge ($\text{m}^3 \text{sec}^{-1}$) from November 2005 to November 2006 at Nindigully Gauging Station, Moonie River.

Figure 3: Percent diet contribution (▣, detritus; ■, filamentous algae; and □, non-filamentous algae.) of *N. erebi* (see Table 1) in the Moonie River for February (n=14), May (n=24), and September (n=23) in 2006.

Figure 4: Two-dimensional MDS ordination of the diet of *N. erebi* in the Moonie River for sites analysed in February (▲), May (●) and September (□) in 2006.

Stress = 0.01.

Figure 5: Percent diet contribution (▣▣, crustaceans; ▤, fish; ▥, aquatic insects; ■, terrestrial insects; and ▦, detritus) by volume for *M. ambigua* (see Table 1) in the Moonie River for February (n=15), May (n=12), and September (n=6) in 2006.

Figure 6: Two-dimensional MDS ordination of the diet of *M. ambigua* in the Moonie River for sites analysed in February (▲), May (●) and September (□) in 2006.

Stress = 0.08.