Ecological condition of central Australian arid-zone rivers

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Abstract Australian arid-zone rivers are known to be ecologically variable and go through “boom and bust” cycles based on highly variable and unpredictable flow regimes. They are facing increasing pressure from land and water resources development and, whilst they are considered to be still in relatively good condition, no studies have yet been carried out to verify this. Such baseline studies are crucial if we are to assess any ecological changes in response to development and management interventions. The ecological condition of four of these endorheic rivers (Georgina, Diamantina, Cooper-Thomson and Bulloo) flowing into the Lake Eyre and Bulloo Basins in central Australia was assessed using several criteria (level of human influence, habitat condition, water chemistry and aquatic macroinvertebrate composition). Using criteria based on the level of human influence, most of the sites were assessed to be relatively unimpacted (reference) condition. The most discernible and widespread impact was riparian and bank damage by stock access. However, the level of this impact was considered to be only moderate.

Most aquatic macroinvertebrates found in the area are considered to be opportunistic and tolerant of a wide range of environmental conditions, but with their life histories known to be linked to flow conditions. Their trophic guild was dominated by collectors and predators. The AusRivAS modelled observed to expected values of macroinvertebrate composition indicated that there were differences in ecological condition between sites (e.g. different waterholes) and between times (e.g. seasons and years). Overall, 75% of sites were assessed to be good condition with the remainder being mildly impaired.

Water chemistry of the sites was characterised by high spatial and temporal variability with low conductivity and alkaline pH, relatively high turbidity, total nitrogen and total phosphorus, and wide-ranging dissolved oxygen. Given the high variability in water quality and ecological condition within a catchment, there was little evidence of any overall difference in these factors between the catchments. However, given that the hydrology of each river system is distinctly different, one might expect some differences in ecological structure and function at finer scale. Periods of hydrological isolation (e.g. to allow natural dryouts) as well as the maintenance of natural connectivity (e.g. instream, overbank and floodplain wetting) are both necessary for the maintenance of ecological integrity of these systems.

Keywords Arid-zone rivers; Australia; ecological condition; habitat; macroinvertebrates; relatively unimpacted; water quality

Introduction

The central arid rivers of Queensland have highly variable and unpredictable flows (Puckridge et al., 1998) and are characterised by a large network of river and creek channels, wetlands and riparian areas, and overflows. This provides a far larger area for riparian-water interaction than would be the case for a system dominated by a single large river channel. It has been suggested that the “channel country” rivers support a high diversity of biota and ecological processes because of a broad spectrum of conditions over time across large floodplains (Kingsford et al., 1999). The smaller lakes, swamps and claypans tend to be species rich and, whilst the larger lakes and riverine waterholes tend to be relatively depauperate in species, abundance is often high (serving as a significant food source) (Timms, 1999). These larger, frequently inundated or permanent waterbodies also served as important refuges. High levels of productivity tend to occur in the shallow margins and stable isotope studies indicate that algae growing in the littoral margins of waterholes are a major source of food for other organisms (Bunn and Davies, 1999). Local flora and fauna are adapted to the flow variability, often with “boom and bust” responses to...
changes in flow condition and so the maintenance of diversity and health would require a wide range of inundation frequencies (Cottingham, 1999).

The study of arid rivers has received relatively little attention in Australia. Their ecology has largely been pieced together from a limited number of local investigations (Cottingham, 1999) and there is concern that pressure to develop land and water resources (e.g. irrigated agriculture and water extraction) is getting greater. A scientific forum on river condition and flow management of the “Western Rivers” recommended that ecological monitoring should be undertaken to confirm the state of the environment and to assess any ecological changes in response to water resource development and management interventions (Cottingham, 1999).

In this paper, we present some results from the monitoring activities carried out as part of the Monitoring River Health Initiative and the First Australia-wide Assessment of River Health sub-programs of the National River Health Program. The assessment of ecological condition of central Australian arid endorheic rivers flowing into the Lake Eyre and Bulloo Basins was based on data that were collected for 30 sites comprising 72 samples, between 1997 and 1999. The catchments assessed were the Georgina, Diamantina, Cooper-Thomson and Bulloo (Figure 1).

**Methods**

In this study, assessment of ecological condition is based on aquatic macroinvertebrates as biological indicators of river health as well as on water chemistry and habitat variables. The sampling methods for all the variables are standardised and are those adopted by the National River Health Program. They are described in detail (DNR, 1997). Macroinvertebrate sampling was undertaken with a standard dip net (250 µm mesh, 300 × 300 × 300 mm triangular frame, 650 mm bag depth) on a 1.4 m handle. Each sample was collected over a standard 10 m stream length from each habitat at each site. Sampling was stratified across different habitat types (riffles, edge, sandy/rocky bed and macrophytes) because each habitat is known to support a different community of macroinvertebrates. Macroinvertebrates were then live-picked in the field for up to 60 minutes and all samples

![Figure 1 Map of Australia showing the four catchments in Queensland (from left: Georgina, Diamantina, Cooper-Thomson and Bulloo)](225)
were preserved in 70% methyl-alcohol. The preserved macroinvertebrate samples were enumerated and identified in the laboratory. As a rapid assessment protocol, macroinvertebrates were generally identified to the family taxonomic level. Site, habitat and water quality information was also collected at each site and entered into standard field sheets.

Alone, the values of the various biotic metrics and indices calculated for a site cannot give an indication of its ecological health. This can only be judged by comparing a score with an appropriate standard that is known to be in good ecological condition. In this study, standards were set based on the range of values observed at sites within the catchment where there were no identifiable sources of degradation. These sites are termed “reference sites” and, for the purposes of this analysis, were considered to be in good ecological condition. Nine criteria relating to obvious impact sources were addressed for each biological sampling site (Table 1). Pass or fail assessments were made using the professional judgement of biologists and district hydrographers who had personal knowledge of the sites. Those sites that passed all criteria, and thus had no identified impacts, were considered to be reference sites.

Several metrics were calculated from macroinvertebrate data in order to assess the ecological condition of sites. These were total taxonomic richness (ie. the total number of taxa collected in a sample or at a site), the SIGNAL Index (Chessman, 1995), the functional feeding groups and the AusRivAS (Australian Rivers Assessment System) model output of O/E taxa score. The AusRivAS models use physical characteristics of sites to predict the aquatic macroinvertebrate fauna that would be expected to occur if the sites were in relatively unimpacted (reference) environmental condition (Simpson et al., 1997; Simpson and Norris, 2000). Comparison of the macroinvertebrate taxa predicted to occur by AusRivAS with the taxa that were observed to occur in a sample enables an assessment of the condition of the site with respect to an unimpacted or “reference” condition. The ratio of observed

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<th>Table 1</th>
<th>Selection criteria used to determine reference site condition</th>
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<td><strong>Reference condition selection criteria</strong></td>
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<tr>
<td>No intensive agriculture within 20 km upstream.</td>
<td>Intensive agriculture is that which involves irrigation, widespread soil disturbance and use of agrochemicals. Dryland grazing does not fall into this category.</td>
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<td>No major extractive industry (current or historical) within 20 km upstream. This includes mines, quarries and sand/gravel extraction.</td>
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<td>No major urban area (&gt; 5000 population) within 20 km upstream. If the urban area is small and the river large, this criterion can be relaxed.</td>
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<tr>
<td>No significant point source waste water discharge within 20 km upstream. Exceptions can again be made for small discharges into large rivers.</td>
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<td>No dam or major weir within 20 km upstream. Sites within the ponded area of impoundments also fail. Sites failing this criterion automatically fail the overall assessment.</td>
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<td>Seasonal flow regime not greatly altered. This may be by abstraction or regulation further upstream than 20 km. Includes either an increase or decrease in seasonal flow.</td>
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<td>Riparian zone of natural appearance. Riparian vegetation should be intact and dominated by native species.</td>
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<tr>
<td>Riparian zone and banks not excessively eroded beyond natural levels or significantly damaged by stock. Stock damage to the stream bed may be included in this category.</td>
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<td>Stream channel not affected by major geomorphological change. Geomorphological change includes bank slumping, shallowing, braiding and unnatural aggradation or degradation.</td>
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Results and discussion

Most of the sites sampled fulfilled “reference site” criteria (which were based on the level of human impact). The most widespread impact at these sites was generally riparian and bank damage by stock access. This is not surprising given that grazing is the predominant land-use in these catchments. However, the level of this impact was considered to be only moderate.

Seventy-four taxa (mostly families) of macroinvertebrates were recorded from the Queensland section of the Georgina, Diamantina, Cooper-Thomson and Bulloo Rivers region with Copepoda, Palaemonidae, Chironomidae (Chironominae and Tanypodinae), Corixidae and Caenidae being the most widespread and abundant taxa collected. This number of taxa equates to about two hundred species, which is quite diverse for rivers in such a harsh environment. About 168 higher level taxa (mostly families) are currently known to occur in Queensland and so the four catchments contain about 44% of the State’s total taxa. Eighteen taxa were collected from only single sites. Some families which are nationally widespread (e.g. Atyidae) are rather uncommon in these catchments. The one species of this family (Caridina thermophila) found here is confined to the upper Thomson River near Muttaburra. Cottingham (1999) reported 215 species, including over 80 species of microcrustacea from the Western Rivers wetlands. He stated that there was a decline in species richness in dry years when salinity increases due to evaporation.

The taxon richness of individual habitat samples ranged from 4 to 29 with edge habitat having the highest average taxon richness and sand/silt pool beds the lowest (Figure 2). The edges have been found to have high levels of algal productivity, analogous to a “bath-tub ring” (Bunn and Davies, 1999). High primary production along the shallow margins is expected to support high levels of macroinvertebrate productivity.

Although abundance data from this study have yet to be analysed, Puckridge et al. (1998) found that as the relative permanence of waterbodies increased, macroinvertebrate abundance decreased. They suggested that less permanent waterbodies supporting the
greatest populations of macroinvertebrates are vital to episodic fish and waterbird breeding. The number of EPT (Ephemeroptera, Plecoptera, Trichoptera) at a site ranged from 0 to 4. No Plecoptera (stoneflies) were recorded in the area. Most of the taxa were those considered to be tolerant of a wide range of environmental conditions (Figure 3) but their life histories are known to be linked to flow conditions. An example of the latter is the tadpole shrimp (*Triops australiensis*) which requires a period of desiccation before the eggs undergo development, with adults occurring a few weeks after rain has fallen and created suitable habitats (Williams, 1980). The trophic structure of the macroinvertebrate fauna was dominated by collectors and predators.

Site condition based on taxonomic richness, SIGNAL index and the AusRivAS O/E taxa scores indicated that the edge habitat was in better condition than the sandy/silty pool beds. All these indices varied between sites and seasons. Condition based on the O/E scores for the autumn edge samples are shown in Figure 4. Generally, they had higher values following the wet (autumn) season than after the drier (spring) season. Overall, AusRivAS O/E scores indicated that 75% of samples were in good condition with the remainder mildly impaired. This is somewhat expected given the low level of development in the area.

Water chemistry of the sites was characterised by low conductivity (52–620 µScm⁻¹) and generally alkaline pH (6.7–9) with wide-ranging values for dissolved oxygen (3.3–14 mgL⁻¹), turbidity 4–1000 NTU), total nitrogen (0.3–3 mgL⁻¹) and total phosphorus (0.03–0.85 mgL⁻¹). These values were recorded during baseflow conditions and variability is expected to be even greater when high flows are considered. This provides further evidence of the high variability of environmental conditions in the system. Most of the water quality parameters recorded are well above the generic values stated in ANZECC Guidelines and, given that the current water quality index is based on this, the overall values are low (Figure 5). As these high baseflow values in western rivers are considered to be natural (McNeil *et al.*, 2000), it is recommended that local or regional water quality guideline values and indices be derived for better assessment. This recommendation applies also to the habitat condition index.

Habitat condition was assessed to be generally good, although the index was lower than expected. As in the case of water quality indices, low habitat values reflect the generic nature of the guideline. Some impacts were detected in riparian condition and channel condition due to poor bank stability. The main contributor to these impacts was stock access. This was particularly noticeable during the dry season.

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**Figure 3** Proportion of taxa having different tolerances to environmental condition, based on the SIGNAL index (Chessman, 1995). Tolerant taxa are those in SIGNAL grades 1–3, sensitive taxa are those in grades 8–10 and other (moderate) taxa are in grades 4–7.
Although there were some differences between catchments (e.g. Georgina having some higher salinities), the high variability and overlap in parameters and condition within each catchment suggested no significant difference between them (Figures 5, 6 and 7). However, significant differences may exist at higher resolution (e.g. macroinvertebrate composition at the species level and ecological processes). Periods of hydrological isolation (e.g. to allow natural dryouts) as well as the maintenance of natural connectivity (e.g. instream, overbank and floodplain wetting) are both necessary for the maintenance of ecological integrity of these systems.
Conclusions

The ecological condition of central Australian rivers (Georgina, Diamantina, Cooper-Thomson and Bulloo) flowing into the Lake Eyre and Bulloo Basins was assessed using several criteria. The most discernible and widespread impact was riparian and bank damage by stock access. However, the level of this impact was considered to be only moderate. Most of the macroinvertebrate taxa collected from the area were those considered to be opportunists and tolerant of a wide range of environmental conditions but with their life histories and dynamics known to be linked to flow conditions. Macroinvertebrate, water chemistry and habitat data suggested that sites in the area were generally in good condition but there was spatial and temporal variation. Any landuse and water resource development in the area should take into consideration this variability and the ecological linkages so that biodiversity and ecological processes are not adversely affected.

Figure 6 Ordination of edge habitat macroinvertebrate composition. Georgina (001), Diamantina (002), Cooper-Thomson (003) and Bulloo (011)

Figure 7 Ordination of water quality data. Georgina (001), Diamantina (002), Cooper-Thomson (003) and Bulloo (011)
Acknowledgements
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References