Fish assemblages and spawning in the northern Murray Darling Basin

Effects of discharge and temperature in two regulated rivers
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Fish assemblages and spawning in the northern Murray Darling Basin, Australia

Introduction

The hydrological regime of rivers influences the structure and composition of freshwater fish assemblages at both local (Schlosser 1985) and regional (Horwitz 1978; Poff & Allan 1995) spatial scales. Many studies have demonstrated changes in fish assemblages and populations following flooding (Agostinho et al. 2004; Cech et al. 2007; Bailly et al. 2008), but characteristics of low flow can also affect the abundances of fish species (Jowett et al. 2005). The effect of flow regimes on fish assemblages is highlighted by assemblage changes associated with flow regulation imposed by the building and operations of dams (Martinez et al. 1994; Penaz et al. 1995; Drastik et al. 2008; Duan et al. 2009). However, some authors have found river hydrology to be of little influence on fish assemblages within regulated rivers themselves (Grows 2008; Humphries et al. 2008).

Understanding how river flows affect fish species and assemblages is important for the development of ecological theory, for the management of water resources and conservation of fish species in regulated rivers. There is an increasing body of evidence that movement (Dudley & Platania 2007; Crivelli et al. 2008; Hay et al. 2008), spawning (King et al. 2009), feeding (Knight et al. 2008), growth (Peterson & Jennings 2007; Sammons & Maceina 2009) and recruitment (Nunn et al. 2003; Cattaneo 2005; Nunn et al. 2007; Zeug & Winemiller 2008) in a variety of fish species is positively associated with increases in river discharge.

Experimental manipulation of stream flows, through specific water releases from dams aiming to restore elements of the natural flow regime, demonstrate that the adverse effects of river regulation on fish communities and aquatic food webs can be reduced (Weisberg and Burton 1993; Travnichek et al., 1995; Cambray et al. 1997; Molles et al. 1998). As a result of the 1994 Council of Australian Governments (COAG) Water Reform Framework for Australia, a comprehensive package of water reforms was announced. For regulated rivers, the New South Wales State Government under the Water Management Act 2000 resolved that environmental flow rules should be adopted in order to enhance environmental quality, while reducing diverted volumes of water by no more than an average of ten percent. Freshwater fish were selected as one of the environmental indicators that were examined to assess the effectiveness of the environmental flows (Chessman and Jones 2001). To comprehend and assess how fish may respond to improved flow regimes through environmental flow management an understanding is required of how dynamics in river hydrology affect fish communities in the regulated rivers. Grows (2008) found weak relationships between adult fish assemblages and flow modification in the regulated rivers of the Murray Darling Basin in Australia and suggested that future studies which aim to define the role of river hydrology on fish assemblages in regulated rivers should focus spawning and recruitment processes. In this study we test the influence of river discharge and temperature on fish spawning patterns over three summer periods and on adult fish populations over a decade within two regulated rivers.

Materials and methods

Study sites

The two study river, the Gwydir and the Namoi, are tributaries of the Darling River in the north of the Murray Darling Basin (Figure 1). Four study sites were selected on each river, ranging from 22 km to 300 km downstream of two irrigation supply dams: Copeton Dam on the Gwydir River (29°54’15.24”S, 150°55’04.94”E) and Keepit Dam on the Namoi River (30°52’42.84”S, 150°29’29.90”E). The Gwydir River has been regulated since Copeton Dam was completed in 1976 and the Namoi River, regulated since the Keepit Dam was completed in 1961. Site selection was based on the presence of run or riffle habitat, including areas of slack waters.
Both rivers are typically comprised of long (up to 3 km), deep (up to 5 m) and slow flowing pools connected by relatively short (up to 60 m) and shallow (0 to 1.5 m) riffle or runs. Elevations through the study area range from 400 m at upstream sites to 220 m at downstream sites. Average annual rainfall is approximately 800 mm at eastern sites to 600 mm at western sites. The dominant riparian tree species in the catchment were river red-gums (Eucalyptus camaldulensis) and weeping willows (Salix babylonica). River sediments comprised a mixture of approximately 60% sand, 30% clay and 10% silt.

The flows in both rivers have been altered as a result of river regulation since construction of the dams. The median annual flow in both rivers has been reduced by more than 50%, from 170 x 106 m³ to 80 x 106 m³ in the Gwydir River and 517 x 106 m³ to 209 x 106 m³ (Arthington 1995). The reduction in median flows occurred across all months in both rivers with the exception that the median monthly flow in the Gwydir River is greater in September under regulated conditions than would have occurred naturally, from 5.4 x 106 m³ to 6.0 x 106 m³ (Thompson 1993). Although monthly median discharge has been reduced seasonal patterns in both rivers have generally maintained their natural distribution, however, the flow peak that would have naturally occurred in August now occurs in September in the Gwydir River. Flood flows (those that are exceeded 10% of the time) and freshes (flows exceeded 10% to 30% of the time) have been reduced due to the effects of the irrigation dams and water extraction (EPA 1997). Moderate (flows exceeded 30% to 70% of the time) and low flows
(flows exceeded the remainder of the time) are greater in both rivers, particularly, during the summer irrigation periods.

**Data collection**

Mean daily river discharge was obtained from New South Wales Office of Water hydrological gauging stations situated between the most upstream and downstream sites on each river. A gauging station was located within 30 km of each fish sampling site (Figure 1). Water temperature for the first 12 months of the study was taken from temperature thermistors at the hydrological gauging stations. For the remainder of the study water temperature for each river was estimated by averaging daily temperatures from individual temperature recorders deployed at each site.

Adult fish were sampled annually from 1999 to 2001 and 2005 to 2008 in the Austral spring, summer or autumn. Adult fish were sampled by boat electric fishing using a boat-mounted (7.5 kW Smith-Root Model GPP 7.5 H/L) gear. Two anodes were suspended in front of the boat and two cathodes were mounted along the sides. The unit was operated at between 500 and 1000 V, 3-15 A pulsed DC at 120 Hz with a 30-40% duty cycle, depending on the conductivity and temperature of the water. Between 4 and 12, two-minute shots (replicate samples) of electric fishing was done at each site on each sampling occasion, depending on site access. Fish observed but not caught (which could be readily identified) were also recorded. This method of adult fish sampling has been used extensively for State and Federal Government programs (Harris and Gehrke 1997; MDBC 2004).

Fish larvae were collected using active and a passive methods at each site, on each sampling occasions to maximise the number of species sampled. Passive sampling involved nets to sample drifting fish as described by Humphries et al. (2002). During the initial larval sampling occasion, nets consisted of a 0.5mm mesh, with a 500mm diameter opening tapered to a 90mm cod end, total length 1500mm. Mesh size was changed to 1mm for the final two years of sampling to reduce net clogging and increase the volume of water filtered. This increase in mesh size was assumed not to affect the catch rates of either fish larvae or large (>1.5mm) eggs. Nets were set tethered to a metal stake in flowing water up to 1.0 m deep, with the top of the net just below the water surface. Water flow in the sampled river sections was considered turbulent and therefore well mixed. Due to the mixing it was assumed that the fish larvae would be equally distributed throughout the water column. During the first sampling season, three nets were deployed at each site; this was reduced to two nets for the remainder of the study due to resource constraints. Nets were set two to one hours before sunset and collected the following morning just after dawn. A mechanical flow meter in each net's entrance estimated volume of water filtered by each net. Samples were preserved in 70% ethanol after anaesthesia in benzocaine solution.

Active sampling was conducted using sweep-net electric fishing (SNE) described by King and Crook (2002). SNE was operated at 400-500 volts, pulsed DC at 30Hz and 12% duty cycle using a Smith-Root LR-24 backpack electric fishing machine with a 15-cm anode ring used to increase the voltage gradient necessary to effectively collect small fish. A 25 cm x 30 cm plastic frame fitted with a tapered 0.5 mm mesh net was attached to the anode pole to collect fish. Each sample targeted slack waters, with the operator moved upstream for one minute with three replicates collected at each site on all sampling occasions. Sampled fish were anaesthetised in benzocaine solution and preserved in 70% ethanol.

Fish larvae were sampled seven times during the austral spring and summer in each of the 3 sampling seasons. In the first sampling season, from October 2005 to late February 2006, samples were collected every three or four weeks. In the latter two seasons sampling took place every four weeks, between August and February the following year. Fish sampled by drift nets and with SNE were measured (standard length) and identified to species according to Serafini & Humphries (2004). Samples were also searched for *Macquaria ambigua* and *Bidyanus bidyanus* eggs, which were
identified according to descriptions provided by Koehn and O’Conner (1990) and SKM (2004). Fish were considered larvae if their standard length was less than the maximum size of metalarvae recorded in the literature (Table 1). It is recognised that a small proportion of fish classified as larvae using this method would actually be early juveniles.

Age of larvae was estimated using methods described by Secor et al. (1991) on sagittal otoliths. All larvae of Retropinna semoni, Melanotaenia fluviatilis and Maccullochella peelii were aged. All Tandanus tandanus larvae in samples containing less than 50 individuals were aged, however, in samples with a greater number 50 individuals were randomly selected and aged. The daily increment deposition for fish larvae have been verified for M. peelii (Dongchun Lou, personal communication), T. tandanus (Dongchun Lou, personal communication) and R. semoni (Tonkin et al. 2008). Validation of the formation of daily increments in larval M. fluviatilis has yet to be established. However, Humphrey et al. (2003) has confirmed the periodicity of increment formation in a cogeneric species, eastern rainbowfish (Melanotaenia splendida splendida). The spawning date of individual larvae of the aged species was estimated by subtracting their estimated age from the date of capture for the final two sampling seasons.

Statistical analysis

The relationship between the individual larval abundances of the seven most common fish species and environmental conditions was examined using permutational analysis of variance (PERMANOVA) (Anderson et al, 2008). PERMANOVA is an analysis of variance using permutation procedures to obtain probability values. It is suitable for any multifactorial ANOVA design, allowing for all pairwise multiple comparisons by permutation. The average and coefficient of variation of temperature and river discharge, calculated over a three week period prior to fish capture, were used as covariates in a statistical model with site nested in rivers to describe spatial variation and sampling occasion nested in years to describe temporal variation. These analyses are univariate and PERMANOVA rather than classical analysis of variance was used because the null distribution of the test statistic in PERMANOVA is produced by permutation, thus avoiding the usual normality assumptions of ANOVA, which are hard to justify for densities due to the prevalence of zero values in the data. Euclidean distance was used in the analysis of each fish species with 9999 randomisations of the data. Sweep-net electrofishing data were converted to fish caught per minute and drift net data were converted to larvae per megalitre per prior to analysis.

Differences in the composition of adult fish assemblage between rivers and among years were tested using two-way analysis of similarities (anosim), a non-parametric method based on rank similarities among all samples (Warwick et al. 1990, Clarke 1993) in the PRIMER-e software package (Clarke and Gorley 2006). This technique compares the similarity among samples within years or rivers with the similarity among samples between the same treatments. The test uses a randomisation procedure to establish a sample variance for the test statistic in which the observed value is compared with simulations under a null hypothesis. Fish abundance data were converted to catch per hour, averaged across replicates, log transformed and range standardised before analysis. One thousand randomisations of the data were done for each comparison using the Bray-Curtis distance (Bray & Curtis 1957). Data were ordinated with non-metric multi-dimensional scaling (nMDS) using the Bray–Curtis dissimilarity coefficient. Where significant differences between years or rivers were identified, species that contributed to those differences were identified using similarity percentages (SIMPER) analysis (Clarke, 1993).
Results

River discharge and temperature

The maximum daily discharges recorded in the Gwydir and Namoi rivers between 1998 and 2008 were 1296 and 2210 m3 s\(^{-1}\), respectively, in mid 1998 (Figure 2). In December 2000 a similar flow was recorded in only the Namoi River. Four smaller peaks of greater than 428 m3 s\(^{-1}\), sufficient to result in over-bank flooding, were recorded in the Gwydir River between 1999 and 2008. Over-bank flooding occurred for a maximum of five consecutive days. In contrast, no peaks sufficient to cause over-bank flooding were recorded in the same period in the Namoi River. The flows in both rivers during the larval fish sampling period (2005-2008) were smaller, with a maximum flow of approximately 46 m3 s\(^{-1}\) in both rivers in the first 2 summers. The last sampling season had different flows between rivers. A maximum of 58 m3 s\(^{-1}\) was recorded in the Gwydir River, while river discharge in the Namoi River had 3 peaks greater than 58 m3 s\(^{-1}\) yet the river also dried to a series of pools at times. In contrast, the Gwydir River flowed continuously during the larval study period. None of the river flows in the 3 years of the larval study in either the Namoi or Gwydir Rivers were large enough to spill out onto the floodplain in the river sections studied.

Figure 2. River flows in the Gwydir and Namoi Rivers from June 1998 to June 2008. Dots indicate dates of adult fish sampling and dashed line indicates flows estimated to cause over-bank flooding.
The maximum average daily water temperature in each river for every year was recorded in summer during mid February; the maximum recorded was 31°C in the Gwydir River in February 2006 (Figure 3). Water temperature range during summer was between 25 and 30°C. The lowest average daily water temperature was from mid July of each year during winter (outside of the sampling season) with the lowest temperature, 8°C, recorded in the Gwydir River in 2007. Temperatures at the start of larval sampling period in each year averaged 12.5°C and generally increased till February in the following year.

![Gwydir River Temperature Graph](image)

![Namoi River Temperature Graph](image)

Figure 3. Temperatures recorded in the Gwydir and Namoi rivers during the larval fish component.

**Fish species**

A total of fifteen species of fish were collected during the study, four alien species and eleven native species (Table 1). Two species, *Galaxias olidus* and *Perca fluviatilis*, were only caught as larvae and were only caught in the Namoi River. The seven most abundant fish species present as larvae in, and common to, both rivers were *Cyprinus carpio*, *Gambusia holbrooki*, *Hypseleotris spp.*, *M. peelii*, *M. fluviatilis*, *R. semoni* and *T. tandanus*. Pelagic eggs of *M. ambigua* or *B. bidyanus* eggs were not collected during the study. Larvae were collected for all adult fish species, although only one *Leiopotherapon unicolour* larvae and seven *M. ambigua* larvae were collected and only from the Namoi River.
Table I. Abundances of adult and larval fish caught over the study period. Alien species are denoted with an asterisk following the species name

<table>
<thead>
<tr>
<th>Species name</th>
<th>Maximum larval length (mm)</th>
<th>Total abundance of adult fish in the Gwydir River</th>
<th>% occurrence among Gwydir River sites and times</th>
<th>Total abundance of fish larvae in the Gwydir River</th>
<th>Total abundance of adult fish in the Namoi River</th>
<th>% occurrence among Namoi River sites and times</th>
<th>Total abundance of fish larvae in the Namoi River</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bidyanus bidyanus</td>
<td>10.3</td>
<td>1</td>
<td>3.6</td>
<td>69</td>
<td>4</td>
<td>15.4</td>
<td>0</td>
</tr>
<tr>
<td>Carassius auratus *</td>
<td>18.0</td>
<td>38</td>
<td>35.7</td>
<td>10</td>
<td>33</td>
<td>57.7</td>
<td>26</td>
</tr>
<tr>
<td>Craterocephalus stercusmuscarum</td>
<td>8.2</td>
<td>115</td>
<td>39.3</td>
<td>5</td>
<td>14</td>
<td>26.9</td>
<td>30</td>
</tr>
<tr>
<td>Cyprinus carpio *</td>
<td>15.5</td>
<td>413</td>
<td>100.0</td>
<td>287</td>
<td>654</td>
<td>100.0</td>
<td>385</td>
</tr>
<tr>
<td>Galaxias olidus</td>
<td>20.0</td>
<td>0</td>
<td>0.0</td>
<td>0</td>
<td>0</td>
<td>0.0</td>
<td>18</td>
</tr>
<tr>
<td>Gambusia holbrooki *</td>
<td>13.4</td>
<td>20</td>
<td>21.4</td>
<td>82</td>
<td>13</td>
<td>15.4</td>
<td>99</td>
</tr>
<tr>
<td>Hypseleotris spp.</td>
<td>15.7</td>
<td>131</td>
<td>39.3</td>
<td>679</td>
<td>718</td>
<td>46.2</td>
<td>2054</td>
</tr>
<tr>
<td>Leiopotherapon unicolour</td>
<td>20.0</td>
<td>16</td>
<td>17.9</td>
<td>0</td>
<td>39</td>
<td>53.8</td>
<td>1</td>
</tr>
<tr>
<td>Macquaria ambigua</td>
<td>15.9</td>
<td>37</td>
<td>64.3</td>
<td>0</td>
<td>77</td>
<td>73.1</td>
<td>7</td>
</tr>
<tr>
<td>Maccullochella peeli</td>
<td>11.9</td>
<td>154</td>
<td>100.0</td>
<td>58</td>
<td>90</td>
<td>96.2</td>
<td>79</td>
</tr>
<tr>
<td>Melanotaenia fluviatilis</td>
<td>16.1</td>
<td>201</td>
<td>78.6</td>
<td>202</td>
<td>296</td>
<td>80.8</td>
<td>178</td>
</tr>
<tr>
<td>Nematalosa erebi</td>
<td>20.0</td>
<td>1013</td>
<td>75.0</td>
<td>5</td>
<td>1825</td>
<td>100.0</td>
<td>16</td>
</tr>
<tr>
<td>Perca fluviatilis *</td>
<td>18.6</td>
<td>0</td>
<td>0.0</td>
<td>0</td>
<td>0</td>
<td>0.0</td>
<td>47</td>
</tr>
<tr>
<td>Retropinna semoni</td>
<td>22.0</td>
<td>275</td>
<td>64.3</td>
<td>594</td>
<td>169</td>
<td>57.7</td>
<td>687</td>
</tr>
<tr>
<td>Tandanus tandanus</td>
<td>17.2</td>
<td>17</td>
<td>42.9</td>
<td>175</td>
<td>2</td>
<td>7.7</td>
<td>776</td>
</tr>
</tbody>
</table>

The adult fish assemblage structure was significantly different between rivers (R = 0.16, P = 0.02) but not between years (R = 0.05, P = 0.22). Two fish species, *M. fluviatilis* and *M. ambigua*, were identified by SIMPER analysis to contribute greater than 10% to the Bray-Curtis differences between the Namoi and Gwydir Rivers. These two species were more abundant in the Namoi River, however, the average abundances of the remaining fish species were generally similar between the two rivers (Table 1). The low R value for the differences between rivers and the overlap of sites within and between rivers in ordination space (Figure 4) suggests that their fish fauna was very similar. The most abundant fish species in each river was *Nematalosa erebi* followed by the alien species, *C. carpio*. The least abundant species in both rivers were *B. bidyanus* and *T. tandanus*. 
Fish spawning

Two types of fish spawning occurred in the Namoi and Gwydir Rivers. Five of the most common species had larvae collected over the spring/summer (August to February) period in each year, including *G. holbrooki*, *Hypseleotris* spp., *M. fluviatilis*, *R. semoni* and *T. tandanus* which suggests protracted spawning (Figs 5 and 6). By contrast, *C. carpio* and *M. peelii* only spawned over a relatively short period, mainly in spring of each year. The abundance of fish larvae for each species differed among sampling occasions between and among years. The estimated age of hatching for the four species also supported the protracted spawning for *M. fluviatilis*, *R. semoni* and *T. tandanus* as hatching occurred in the winter, spring and summer seasons (Figure 7). The estimated age of hatching of *M. peelii* supported a single spawning in both rivers (Figure 7).
Figure 5. Species caught with sweep-net electric fishing along with temperature and flow. Black bars below dates indicate periods over which larval fish sampling occurred.
Figure 6. Species caught with drift netting along with temperature and flow. Black bars below dates indicate periods over which larval fish sampling occurred.
Figure 7. Estimated date of spawning/hatching from daily increment measurements.
Relationships of fish spawning with temperature and flow

In general, there were no significant sources of spatial or temporal variation in the PERMANOVA models for the larval abundances of any fish species. The larval abundances of the majority of fish species were not generally related to river discharge or temperature (Table 2). However, the abundances of larvae of *G. holbrooki* were positively related to average temperature and discharge, *Hypseleotris* spp sampled using electric fishing and drift nets were positively related to average water temperature and *R. semoni* was negatively related to river discharge (Figure 8).

<table>
<thead>
<tr>
<th>Sampling method</th>
<th>Species</th>
<th>Mean temperature (°C)</th>
<th>CV of temperature</th>
<th>Mean discharge (ML/d)</th>
<th>CV of discharge</th>
</tr>
</thead>
<tbody>
<tr>
<td>Drift net</td>
<td><em>C. carpio</em></td>
<td>0.1</td>
<td>2.8</td>
<td>1.2</td>
<td>0.8</td>
</tr>
<tr>
<td></td>
<td><em>Hypseleotris</em> spp.</td>
<td>4.9</td>
<td>0.1</td>
<td>1.2</td>
<td>1.0</td>
</tr>
<tr>
<td></td>
<td><em>M. peelii</em></td>
<td>0.1</td>
<td>0.2</td>
<td>0.5</td>
<td>0.2</td>
</tr>
<tr>
<td></td>
<td><em>R. semoni</em></td>
<td>0.6</td>
<td>0.1</td>
<td>0.3</td>
<td>0.3</td>
</tr>
<tr>
<td></td>
<td><em>T. tandanus</em></td>
<td>0.3</td>
<td>0.0</td>
<td>0.7</td>
<td>0.8</td>
</tr>
<tr>
<td>Electric fishing</td>
<td><em>C. carpio</em></td>
<td>1.3</td>
<td>0.2</td>
<td>0.6</td>
<td>1.0</td>
</tr>
<tr>
<td></td>
<td><em>G. holbrooki</em></td>
<td>10.2</td>
<td>0.2</td>
<td>32.9</td>
<td>0.0</td>
</tr>
<tr>
<td></td>
<td><em>Hypseleotris</em> spp.</td>
<td>14.0</td>
<td>2.9</td>
<td>3.4</td>
<td>2.8</td>
</tr>
<tr>
<td></td>
<td><em>M. fluviatilis</em></td>
<td>2.4</td>
<td>0.3</td>
<td>0.4</td>
<td>1.0</td>
</tr>
<tr>
<td></td>
<td><em>R. semoni</em></td>
<td>0.1</td>
<td>0.3</td>
<td>5.3</td>
<td>1.9</td>
</tr>
</tbody>
</table>
Discussion

The abundance of larvae in the Namoi and Gwydir rivers was not related to river hydrology between 2005 and 2008 for any fish species. The spawning of five fish species was protracted over spring and summer periods and in general, larval abundance did not appear to be related either to river flow or water temperature. By contrast, the spawning of *M. peelii* and *C. carpio* was relatively short and appeared to occur once each year, the abundance of larvae for these two species was also unrelated to either temperature or river flows. The lengths of the annual spawning period of the fish species sampled in this study are generally supported by other studies the rivers of the Murray-Darling Basin (e.g. Humphries et al. 2002; King et al. 2003). The lack of a relationship between larval abundance variation in the majority of species and river hydrology is also supported by Humphries et al. (2008).
The relationships between river hydrology and spawning and recruitment, however, may differ between fish species in a river. Two fish species sampled as adults in the Namoi and Gwydir Rivers, *M. ambigua* and *B. bidyanus* are thought to have a strong flooding requirement for successful spawning and recruitment (Lloyd et al. 1989; Humphries et al. 1999; Schiller & Harris 2001; King et al. 2009), while temperature has also been suggested to be of equal importance in recruitment success (Roberts et al. 2008). Eggs of neither species were collected in either the Namoi or Gwydir rivers over the three-year study. This absence of eggs may suggest that the flows in these rivers were not large enough to wet the floodplain, to stimulate spawning. King et al. (2009) and Ebner et al. (2009) suggested that while *M. ambigua* and *B. bidyanus* are quite flexible in their spawning requirements and can spawn under flood and within channel habitats, their spawning activity can be greatly enhanced during flood conditions. One future area of study would be to release sufficient water in a managed release from either of the dams on these regulated rivers in order to produce significant over-bank flooding and observe the spawning response of these two fish species.

The adult fish assemblages were not significantly different between seven sampling seasons from 1999 to 2008 and although significantly different between rivers, the similarity of the adult fish assemblages between rivers is high. The Gwydir River over the first five sampling seasons had many more flows required to cause over-bank flooding compared to the Namoi River. These results suggest that if there is a relationship between adult fish assemblage structure and river flow it plays a minor role in the regulated Namoi and Gwydir Rivers. This result is similar to that found by Growns (2008) and Humphries et al. (2009) who demonstrated that faunal composition in regulated rivers in the Murray-Darling basin was weakly influenced by river hydrology.

Five fish species in this study were commonly caught using drift nets, a method that samples flowing waters. Two of these species, *M. peelii* and *T. tandanus*, were caught almost exclusively using drift netting, suggesting that water movement is an important component in the dispersal of these two species compared to other fish species. The relationship between flow and the dispersal for *M. peelii* has been demonstrated previously in the south of the Murray-Darling Basin by several authors including Gilligan & Schiller (2003), Koehn & Harrington (2005) and Humphries (2005). There is limited literature demonstrating the use of flow by *T. tandanus*. The apparent importance of river flow for the dispersion of these five species indicates the importance of maintaining adequate levels of river flow in these two rivers and throughout the spawning season.

In summary, there is little evidence that spawning and recruitment of fish is related to river hydrology in the two regulated rivers sampled. However, the lack of spawning of *M. ambigua* and *B. bidyanus* in these two rivers may suggest an effect of the current river management due to a lack of over bank flows caused by river regulation. The lack of association between altered river hydrology and fish spawning and assemblages either suggests that the fish are not affected by river regulation or that other potential influences on fish ecology in the MDB, such as overfishing, pollution or altered land use, have a greater influence than altered flow regimes. Additionally, the lack of a response of fish to river hydrology maybe because the regulation of these two rivers has resulted in the elimination of fish species that normally respond to river hydrology.
References


Craig M. Ellsworth & Torrey J. Tyler & Scott P. VanderKooi 2010 Using spatial, seasonal, and diel drift patterns of larval Lost River suckers Deltistes luxatus (Cypriniformes: Catostomidae) and shortnose suckers Chasmistes brevirostris (Cypriniformes: Catostomidae) to help identify a site for a water withdrawal structure on the Williamson River, Oregon. Environ Biol Fish (2010) 89:47–57
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