Fishway assessment for the Pinjarra Weir

Prepared by

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Background and aims

The construction of fishways may be an effective means to allow passage of fishes of otherwise impassable artificial barriers; such as water supply dams, gauging stations and road culverts. From a south-western Australian perspective, such barriers not only impede the passage of fish that often migrate upstream in rivers but can also create unnatural lentic habitats that are often favoured by feral species (such as the Eastern Gambusia). Fish move (or migrate) for a number of reasons including for feeding, to spawn in upstream reaches to offset the downstream movement of eggs and larvae, or as juveniles recruiting into a population.

To date, there have been five fishways constructed in south-western Australia: one on Bennett Brook (Beatty & Morgan 2002); two on the Margaret River (see Morgan & Beatty 2004, 2007, Beatty et al. 2007); one on the Goodga River (see Morgan & Beatty 2006); one on the Hotham River (see Morgan & Beatty 2004, Morgan et al. 2005) (Figure 1). Recently, a more formal prioritisation process for further fishway construction in the state is being prepared by the authors for the Department of Water.

Figure 1: Major fishways of Western Australia.
The Pinjarra Weir is located on the Murray River (Figures 2 and 3) and was constructed in 1895 as a means to create a potable water supply by limiting the upstream tidal influence. However, although still useful for town irrigation purposes, the increase in salinisation of the Murray River due to upstream land-clearance now renders the river unsuitable for drinking water supply.

As with other weirs on rivers of the south-west (e.g. the Goodga River (Morgan & Beatty 2006) and Margaret River (Beatty et al. 2007)) the Pinjarra Weir was believed to represent a barrier to upstream movement of fishes due to anecdotal evidence of seasonal increases in fish abundances below the weir. As the weir is located in the section of the Murray River that is tidally influenced it therefore potentially impacted on both estuarine (e.g. Black Bream) and freshwater fishes.

In order to effectively demonstrate the need for a fishway on a perceived barrier, a monitoring program is required to first determine whether it poses a barrier to fish movements. If this is demonstrated, a monitoring program should also enable an appropriate fishway to be designed and constructed that caters for those specific species that are blocked and operates during spawning migrations.

The overall aim of the project is to determine the degree to which the Pinjarra Weir inhibits the migration of various fish species in the Murray River, through:

1. Determining the fish species richness and abundance both upstream and downstream of the weir utilising a number of methods including set nets, seine nets, fyke nets and electrofishing.

2. Comparing physico-chemical properties of specific sites, such as, pH, temperature, conductivity, salinity, turbidity, oxygen and flow.

3. Determining whether fish move over the weir from downstream of the weir to upstream and from upstream of the weir to downstream. This will be achieved with the use of replicate fyke nets set for a period of 24h which will allow for both upstream and downstream movement.

4. Using these results, make recommendations for the appropriateness of a fishway at the site.
Figure 2: The Murray River and location of Pinjarra Weir. Sourced from GoogleMaps

Figure 3: Sampling of the Pinjarra Weir (clockwise from top left) fyke nets below Pinjarra Weir, on the weir, and opposite the boat ramp downstream of the weir.
Methodology

Sampling times and monitoring environmental variables

Sampling occurred on three occasions in September (26/9/07) and November (27/11/07) 2007 and February (13/2/08, 20/2/08) 2008 to allow for a seasonal comparison of the impact of the weir on fish movements.

Daily discharges and stage heights were obtained for the Murray River was obtained from the Department of Water.

Cross-sectional depths, flow rates and fall over the weir were determined on each sampling occasion using a hand-held flow meter. The mean water temperature, dissolved oxygen, conductivity and pH were taken on each sampling occasion at the Pinjarra Weir.

Fish monitoring protocol

Movements and densities

On each sampling occasion, four sites downstream, one site upstream, and the weir wall itself was monitored for fish movements using fyke nets for up to three 24 h periods. In addition, the densities of fish were estimated immediately downstream and upstream of the weir using a 10 m seine net. Fyke nets were set both facing downstream and upstream to capture fish moving upstream and downstream, repeatedly (Figure 3). Fyke nets were checked every 24 h. All fish captured were identified, measured for total length (TL, mm) and released immediately. Similarly, all freshwater crayfish captured in the nets were identified, sexed, orbital carapace length measured (OCL, mm) and released. The relative percentage of the river that was blocked by the fyke net was determined and the actual catches of fish on each sampling occasion were adjusted to account for total number of fish that passed this section of the river. Subsequently, mean upstream and downstream movements were determined for each species on each sampling occasion. Length-frequency analysis of fish and freshwater crayfish was undertaken and histograms for upstream and downstream movements were plotted for each species in each month.

Parasite examinations

During the study, an ectoparasitic copepod was observed on Freshwater Cobbler (Tandanus bostocki). It was identified by Marina Hassan at Murdoch University's Fish Health Unit as Lernea sp. (Lernaeidae (anchor worms)), and is most likely to be Lernea cyprinacea L., which is an introduced parasitic copepod often found on the skin and gills of freshwater fish. However, within Western Australia it has only been reported on fish in the Canning River (Hassan et al. in press). During sampling, all fish were superficially externally examined for this parasite and incidence (number of parasites per host) of infection recorded.

Results and Discussion

Discharge and environmental variables

Average water temperatures downstream of the Pinjarra Weir ranged from 14.9°C in September to 30.7°C that was recorded on the bottom of the water column (in the saline tidal wedge) in February (Table 1). Conductivity of the river was generally slightly saline on the surface ranging from 3616 µS/cm at the surface immediately below the weir in February 2008 to 6907 µS/cm further downstream at the boat ramp during the same month. This increase in surface salinity during this month was probably due to a degree of mixing of the fresher surface water flow with the saline tidal wedge that was present during this time.
(Table 1). For example, the salinities at the bottom of the water column at the boat ramp and immediately below the weir were 45733 and 43900 µS/cm, respectively (Table 1). However, during the spring although this part of the river is still tidally influenced, it appeared that at the time of sampling in November, the salt wedge was not present below the Pinjarra weir as indicated by the similar salinities at the surface and bottom of the water column (Table 1).

**Table 1:** Environmental variables in the Murray River downstream of the Pinjarra Weir during the study. N.B. the tidal saline wedge present during the February 2008 sampling as indicated by the sharp increase in the salinity and temperature at the bottom of the water column.

<table>
<thead>
<tr>
<th>Site</th>
<th>Date</th>
<th>Depth (m)</th>
<th>Temperature °C</th>
<th>Conductivity (µS/cm)</th>
<th>pH</th>
<th>Dissolved oxygen (ppm)</th>
<th>Turbidity (NTU)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boat Ramp</td>
<td>25/9/2007</td>
<td>0.5</td>
<td>14.9</td>
<td>4013 (1.41)</td>
<td>8.46 (0.03)</td>
<td>9.58 (0.09)</td>
<td>10.31 (0.9)</td>
</tr>
<tr>
<td>Boat Ramp</td>
<td>27/11/2007</td>
<td>0.5</td>
<td>24.83 (0.08)</td>
<td>4100 (4.24)</td>
<td>7.44 (0.01)</td>
<td>7.80 (0.07)</td>
<td>2.26 (0.16)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10m below weir</td>
<td>13/2/2008</td>
<td>0.5</td>
<td>24.8 (0.2)</td>
<td>3616 (284)</td>
<td>7.48 (0.02)</td>
<td></td>
<td>4.06 (0.3)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1.5</td>
<td>30.2 (0.1)</td>
<td>43900 (393)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Boat Ramp</td>
<td>13/2/2008</td>
<td>0.5</td>
<td>26.8 (0.1)</td>
<td>6907 (229)</td>
<td>7.54 (0.02)</td>
<td></td>
<td>4.47 (0.38)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2</td>
<td>30.7 (0.4)</td>
<td>45733 (502)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Key flow characteristics of the Pinjarra weir during sampling in November 2007 and February 2008 are presented in Table 2. It can be seen that the drop over the weir and average water velocities on the eastern side of the weir were less than those in the middle and on the western edge (Table 2). The falls over the weir during February sampling were also greater (~25%) than those during the November sample and the weir effectively 'drowns out' during winter (i.e. the fall becomes negligible) as shown in Figure 4. The greatest average velocity of the water flowing over the weir was 1 m/sec during the November sampling. It is important to note that during the September sampling these measurements were not taken and this velocity would probably increase (and the fall decrease) with greater discharge during winter/spring (see photos in Figure 5).

Table 2 demonstrates that the fall over the weir is slightly greater on the western bank as are the water velocities when compared with the eastern bank. It also demonstrates that the height of the fall over the weir increased during the lower flow period in February.

**Table 2:** Key flow characteristics recorded at the Pinjarra Weir during sampling in November 2007 and February 2008. N.B. The width of the weir lip (where the average lip velocities were taken) is 0.58 m.

<table>
<thead>
<tr>
<th>Date</th>
<th>Location on weir</th>
<th>Drop over weir</th>
<th>Av velocity on lip (m/sec)</th>
<th>Av velocity of fall (m/sec)</th>
</tr>
</thead>
<tbody>
<tr>
<td>27/11/2007</td>
<td>Eastern edge</td>
<td>0.3</td>
<td>0.76</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Middle</td>
<td>0.48</td>
<td></td>
<td></td>
</tr>
<tr>
<td>13/02/2008</td>
<td>Eastern edge</td>
<td>0.4</td>
<td>0.22</td>
<td>0.25</td>
</tr>
<tr>
<td></td>
<td>Middle</td>
<td>0.6</td>
<td>0.35</td>
<td>0.55</td>
</tr>
<tr>
<td></td>
<td>Western edge</td>
<td>0.53</td>
<td>0.32</td>
<td>0.52</td>
</tr>
</tbody>
</table>
Figure 4: Discharge in the Murray River at Pinjarra showing the stage height where the Pinjarra Weir is effectively drowned out.
Figure 5: Pinjarra Weir in September 2007 (top) and February (2008). N.B. the fall over the weir being far greater during the summer sampling time.
Species captured in the Murray River at the Pinjarra Weir

Estuarine species

A total of seven estuarine species were captured during the study (Figure 6). Loneragan et al. (1986) previously recorded 43 species of fish in the Peel Harvey estuary; with 20 (of 35 species occurring in at least five samples) being recorded at a site further downstream in the Murray River: ~5km from the mouth of the Inlet. This suggests that although large numbers of estuarine species enter the lower reaches of the Murray River, many of those may not penetrate upstream as far as the Pinjarra Weir. However, the limited sampling times in the current study means that other species not captured in the current study may also move (at least seasonally) as far up as the tidal limit at the Pinjarra Weir.

Based on both seasonal upstream and downstream density estimates and also upstream and downstream movement patterns adjacent to the Pinjarra Weir a number of estuarine species were clearly impeded by the weir. Most obviously impeded species were the Western Hardyhead, Whitebait and Blue-spot Goby (Figures 7, 8, 9). This was particularly evident by the large increase in density of the Western Hardyhead and Whitebait in February 2008 with both species being either virtually (Western Hardyhead) or totally (Whitebait) absent from immediately above (either density or migration sampling) the weir at this time (Figures 7 and 8). Furthermore, these two species were never recorded moving over the weir during the fyke netting that took place on to of the weir wall. Thus the weir appears to severely limit the upstream movement of these estuarine species in the Murray River and may impact on their levels of recruitment.

Notably, Western Hardyhead is known to penetrate great distances upstream in the Murray River similar to the Blue-spot Goby and therefore the weir does not reduce the overall distribution of these species in the Murray River (Morgan & Beatty 2005). However, the seasonal increase in the densities of these species below the weir in summer (period of greatest tidally influence), would undoubtedly increase levels of predation by e.g. birds and this may negatively impact on their populations in the lower section of the river.

The Blue-spot Goby was recorded in considerable density above the weir in September and this species and the South-west Goby were the only species that were recorded actually moving over the weir during February (Figure 10). Therefore, the Weir probably has least overall impact on these two estuarine species and their upstream migration over this small barrier would be aided by the morphological adaptation that they have, i.e. fused pelvic fins used for climbing (‘sucking’ onto walls).

The recreationally important Black Bream is anecdotally seasonally abundant immediately below the weir and in the current study was only recorded below the weir (Figure 11). This confirms that the species is at least seasonally impeded by the weir (noting that it moves upstream to spawn during late spring and early summer in south-western Australia (Sarre & Potter 1999)).

Therefore, for the fishway to effectively allow Black Bream to move upstream over the Pinjarra Weir, any fishway needs to operate during flow reduced periods in summer (see Figure 5 for the appearance of the weir during February), and should provide adequate depth to enable passage of this relatively large, deep bodied species (see Design Considerations).

Although the Sea Mullet was only recorded below the Pinjarra Weir during the current study, it is anecdotally present upstream of the weir. This species spawns in deepwater off the coast (Thomson 1963) and uses estuaries and rivers as a nursery ground (Orr 2000). It is a relatively good swimmer (and is known to jump out of the water) and therefore would
be able to at least seasonally pass over the weir. However, during the low flow summer and autumn periods when the drop over the weir is greatest, the weir would at least reduce the ease of (or prevent) upstream passage of this species.

Sea Mullet captured downstream of the Pinjarra Weir.
Figure 6: Fishes captured during the study at the Pinjarra Weir.
Figure 7: Upstream and downstream movements of Western Hardyhead (left) and densities (top right) at various locations around the Pinjarra Weir on the three sampling occasions. Bottom right shows the length-frequencies of a sub-sample of fish captured during the different sampling times.
Whitebait

Figure 8: Upstream and downstream movements of Whitebait (left) and densities (top right) at various locations around the Pinjarra Weir on the three sampling occasions. Bottom right shows a photo of the high densities of Whitebait below the weir in February 2008.
Blue-spot Goby

Figure 9: Upstream and downstream movements of Blue-spot Goby (left) and densities (top right) at various locations around the Pinjarra Weir on the three sampling occasions. Bottom right shows the length-frequencies of a sub-sample of fish captured during the different sampling times.
Figure 10: Upstream and downstream movements of South-west Goby (left) at various locations around the Pinjarra Weir on the three sampling occasions. Right shows the length-frequencies of a sub-sample of fish captured during the different sampling times.
Figure 11: Upstream and downstream movements of Bream at various locations around the Pinjarra Weir on the three sampling occasions.
Native freshwater species

Four native freshwater species were captured during the study. These species are all known from sites upstream in the Murray River and its tributaries. However, in the Hotham and Williams Rivers, in the upper catchment of the Murray, only the Western Minnow occupies those salinised sites with the Nightfish and Western Pygmy Perch generally occupying fresher sections of the Murray River and its tributaries in the Darling Scarp. All of these species are known to undergo upstream migrations as part of their breeding cycle; often into small tributaries from the main channel (Beatty et al. 2006).

The Freshwater Cobbler is the largest of the freshwater endemic fishes of the south-west and is known to occupy main channels of the many of the major rivers; including in sections of salinised rivers such as the Blackwood River (Morgan et al. 1998, 2003, Beatty et al. 2006). The species is known to move upstream between pools during spring and summer in other systems in the south-west (Beatty et al. 2006). In the current study, the species was recorded moving in the river both upstream and downstream of the weir (it was not recorded in the density estimates probably due to its nocturnal nature) (Figure 12). The weir would undoubtedly prevent the upstream movement of this species in this section of the river. As with the Black Bream, any potential fishway construction should be designed to allow the passage of this species during times of lower flow (i.e. summer).

The study found that the Western Minnow appeared to be generally impeded from moving upstream over the weir as suggested by the large densities below the weir and it not being recorded upstream of the structure on any occasion (Figure 13). Of all the freshwater species recorded in the study, however, this species is believed to have the greatest ability to move over barriers due to its apparent superior swimming and jumping ability (observed to leap ~50 cm, authors unpublished data) and would likely be able to at least seasonally move over the weir.

The Western Pygmy Perch was captured in relatively high densities and moving both upstream and downstream below the weir but was never recorded at the upstream sites (Figure 14). Therefore, although the species exists further upstream in the river and its tributaries, it appears that the weir prevents the species moving upstream in this section of the river. Only two Nightfish were captured during the study; both below the weir. As with the Western Pygmy Perch, the species would not be able to move over the weir.

Therefore, construction of an appropriately designed fishway would aid in the upstream movement of these freshwater species; the majority of which are currently (at least seasonally) impeded by this structure.
Figure 12: Upstream and downstream movements of Freshwater Cobbler (left) at various locations around the Pinjarra Weir on the three sampling occasions. Right shows the length-frequencies of a sub-sample of fish captured during the different sampling times.
Figure 13: Upstream and downstream movements of Western Minnow (left) and densities (top right) at various locations around the Pinjarra Weir on the three sampling occasions. Bottom right shows the length-frequencies of a sub-sample of fish captured during the different sampling times.
Western Pygmy Perch

Figure 14: Upstream and downstream movements of Western Pygmy Perch (left) and densities (top right) at various locations around the Pinjarra Weir on the three sampling occasions. Bottom right shows the length-frequencies of a sub-sample of fish captured during the different sampling times.
**Feral fish**

Two feral species were recorded during the study; the Eastern Gambusia and the Goldfish. The Eastern Gambusia was recorded in the greatest densities immediately upstream of the weir during February (Figure 15). It was also recorded moving upstream and downstream in the November and February below the weir. This species is known from throughout the upper Murray catchment and is highly tolerant of salinity being recorded in 58 ppt (Morgan & Beatty 2004). It is a native of North America being introduced into W.A. in the 1930’s for the purpose of mosquito control. However, it is a very aggressive species and fin-nips native fishes (Gill *et al.* 1999). It generally favours slow-flowing lotic or lentic environments; such as those created above artificial barriers. It is generally a poor swimmer and has not been known to readily utilise the fishways in south-western Australia; probably due to its general avoidance of turbulent flows.

This study represents the first known record of the Goldfish from the Murray River (Figure 16). However, Morgan *et al.* (2004) recorded them in the nearby Serpentine River and also the Harvey River. Its presence is most likely due to the deliberate (or accidental) aquarium release and the biology of a wild population has recently been described from the Vasse River (Morgan & Beatty 2007). It is an omnivorous benthic feeder and has the potential to exacerbate algal blooms by re-suspending nutrients during its feeding and also via the effects of its digestive system on cyanobacteria (Kolmakov & Gladyshev 2003). The species was not recorded above the weir in the current study; there is therefore the potential for the upstream spread of the species should it utilise a potential fishway on the Pinjarra Weir. However, additional more intensive sampling should be conducted upstream of the weir to determine whether the species is already present.
**Eastern Gambusia**

![Image of Eastern Gambusia](image)

**Figure 15:** Upstream and downstream movements of the feral Eastern Gambusia (left) and densities (top right) at various locations around the Pinjarra Weir on the three sampling occasions. Bottom right shows the length-frequencies of a sub-sample of fish captured during the different sampling times.
Goldfish

Figure 16: Upstream and downstream movements of the feral Goldfish at various locations around the Pinjarra Weir on the three sampling occasions.
Disease

The introduced parasitic copepod *Lernea cyprinacea* was found on 84 individual fish from two species, however all but one case of infection was on the Freshwater Cobbler (Figure 17). The other host was a single individual of the South-west Goby. Of the infected Freshwater Cobbler, 66 individuals had one parasite, 16 had two and one fish had three. Most infections occurred on or behind the dorsal fin, however, they were also recorded the pelvic and pectoral fins, on the operculum, around the cloaca, on the chin and around and in the mouth. It is worth noting that the species often attaches to gills (which were not examined).

![Image](https://example.com/image1)

**Figure 17:** Parasitic copepod *Lernea cyprinacea* on the dorsal fin of Freshwater Cobbler captured below the Pinjarra Weir.

Although *L. cyprinacea* has been introduced into eastern Australia, it has only recently been reported in Western Australia (Hassan et al. in press). Hassan et al. (in press) reported *L. cyprinacea* on four native fish species Western Minnow, Western Pygmy, Nightfish and the Freshwater Cobbler, as well as on introduced Goldfish, Eastern Mosquitofish and One-spot Livebearers (*Phaloeceros caudimaculatus*). With the exception of the latter species, each was found within our study area near the Pinjarra Weir, so it is surprising that none was found on these other species. However, the presence on the South-west Goby represents the first report of this species as a host for *L. cyprinacea* and this study also extends the range of this introduced parasite in W.A. The most likely source of introduction of this species into the river is via infected Goldfish that were released from an aquaria or fish pond.
Conclusions and recommendations

- The Pinjarra Weir blocks upstream tidal influence in the Murray River.
- The study has shown that the Weir totally or partially prevents (at least seasonally) the upstream movement of estuarine species, particularly – Black Bream, Western Hardyhead, Whitebait, Blue-spot Goby, Big-headed goby, and possibly Sea Mullet.
- Four native freshwater fishes were also recorded in the study; with at least three of these are totally or seasonally inhibited by the weir.
- However, although blocked by the weir from freely moving upstream in this section of the Murray River, a number of these species do exist and reproduce well upstream (some as far as the wheatbelt) such as: the two gobies, Western Hardyhead, Freshwater Cobbler, Western Minnow, Western Pygmy Perch, and Nightfish.
- Nonetheless, an appropriately designed fishway constructed on the Pinjarra Weir would allow upstream colonisation of a number of estuarine species (including Black Bream) and allow mixing of populations already upstream to those downstream.
- This would potentially enhance recreational fishing opportunities and increase the ecological connectivity of the lower Murray River.
- The specific swimming abilities of these species have not yet been precisely determined although the authors have field data relating to other fishways that should be incorporated in the design of the Pinjarra Weir fishway.
- An investigation into the distribution, prevalence and environmental tolerance (particularly salinity tolerance of this supposedly freshwater parasite) of the introduced parasite *Lernea cyprinacea* should be conducted in the Murray River to complement a similar investigation of the parasite in the Canning River.

Scoping study considerations

A scoping study is required that needs to consider specific design/s of the fishway, full costings, and include community and stakeholder consultations. The following should be included in the scoping study process:

- Large body species (Black Bream and Freshwater Cobbler) need to be able to negotiate the fishway during times of low flow.
- Therefore, the fishway would need to be designed to function for as long as possible (i.e. summer ↑ tidal).
- If the fishway design successfully caters for these two large species, then it should allow the passage of the smaller bodied species that generally migrate during periods of higher flows.
- Vertical slot design is likely to be the preferred design option as it can allow deeper resting pools and therefore allow larger and slow moving fish to move between baffles and negotiate the fishway (see conceptual photo below).
- Vertical slot design will necessitate the ‘notching’ of the weir (likely to be ~10cm although will depend on the overall design) at the fishway exit to ensure the fishway functions during lower flow periods.
- In terms of ease of site access for construction of a potential fishway, the western bank of the river would be more suitable; however, this would require a slightly increased height of construction of the eastern bank.
- A post-construction monitoring program (conducted over the period of at least one year) would be required to demonstrate the effectiveness of the fishway.
- A vertical slot fishway would also require a simple, but ongoing maintenance program (likely to involve monthly cleaning) to be implemented to ensure it remains clear of debris and algae.
- An inclusive consultation process needs to occur to ensure the project considers the opinions and suggestions of a wide range of stakeholders. This will enhance the
profile of the project and ensure it has the support of the local community and
government departments and therefore increase its success and long-term
sustainability.

An imposed impression of a vertical slot fishway situated on the western bank at the Pinjarra Weir.
REFERENCES


