Assessment of the Rushy Creek fishway system, south-western Australia.

Report to:
Department of Water

S Beatty, M Allen, J. Keleher
May 2012
Assessment of the Rushy Creek fishway system, south-western Australia.

Acknowledgements:

This project was funded by the Department of Water, Government of Western Australia. We greatly appreciate the project coordination and development by Krish Seewraj (Department of Water). Many thanks for the unrestricted access to Boathaugh Estate organised by Jill and Colin McGregor. Thanks to Michael Klunzinger for field assistance. The study complied with scientific permits granted by the Department of Fisheries WA, Department of Environment and Conservation WA, and the Murdoch University Animal Ethics Committee.
Summary

- The Rushy Creek rock-ramp fishway system (lower Blackwood River catchment, south-western Australia) was monitored monthly in spring 2010 and was demonstrated to be effective in enabling passage of the Western Minnow and the Swan River Goby.

- In order to further assess its effectiveness and quantify interannual variation in species utilisation of the fishway system, the current project replicated the monthly monitoring of the bypass and spillway fishways during 2011 and also increased the scope to include monitoring of species movements below the dam, and an additional major upstream branch of Rushy Creek.

- Nine species of fish were recorded during the 2011 monitoring including the first records of the native Freshwater Cobbler and Western Hardyhead from Rushy Creek.

- A 138% increase in numbers of fish was recorded on the fishway system in 2011 compared to 2010.

- Passage of fish was relatively even between the bypass (54.4%) and spillway (45.6%) fishways, compared with 2010 when only 30.3% were recorded on the bypass and 69.7% on the spillway. Although the bypass presumably allowed earlier upstream passage of resident species, monitoring fish passage earlier in the year when the bypass begins to operate, but flow rates are less than those recorded in the current study, is still required to determine whether the bypass is, to a degree, superfluous.

- Compared to 2010, substantial increases in upstream and downstream movements on the fishway system were recorded in 2011 for the Western Minnow, Swan River Goby and importantly, the Western Pygmy Perch that was shown to move upstream over the bypass and spillway in October 2011.

- In 2011, significant differences existed in the average upstream movement between the bypass, spillway and site downstream of the dam for the three most abundant fish captured, the Western Minnow, Western Pygmy Perch and Swan River Goby.

- Average upstream movement of each of those three species was also shown to differ significantly between sampling months in 2011.

- Monitoring upstream movements in Rushy Creek at the site below the dam provided valuable information in assessing the functioning of the fishways and suggested that neither the bypass nor spillway allowed passage of the Freshwater Cobbler noting it was recorded moving upstream below the dam in August. However, although the Nightfish, Western Hardyhead and South-west Goby were did not utilise either fishway, these were not detected moving upstream at the site below the dam and therefore may simply not require passage over the dam as part of their lifecycle.

- Greater average flow rates occurred in Rushy Creek (and on the fishways) in 2011 compared to 2010 and they probably contributed to an overall increase in abundance of most species in the system, and in turn passage rates of several species on the fishways. Retro-fitting that was carried out in May 2011 to reduce the height of steps on a major step that existed below both the spillway and bypass may have also contributed to greater passage rates in 2011 compared to 2010.
• The passage of the Western Pygmy Perch over the spillway in October 2010 and both fishways in October 2011 exceeded predictions based on its known $U_{\text{sprint}}$ value, the average flow velocities on the fishways, and their total length. This was attributed to the complex nature of the hydrology on the rock-ramp fishways (i.e. providing rest areas) coupled with its ability to undertake burst (anaerobic) swimming. However, its lack of passage in August and September (during its major breeding period when considerable numbers of larger, mature individuals were recorded in the stream below) in both years suggest the elevated flow rates (with average velocities approximating or exceeding its $U_{\text{sprint}}$ value) on those structures exceeded its swimming ability.

• The additional sampling in the upstream southern branch of Rushy Creek revealed that it provided habitat for the Western Minnow, Western Pygmy Perch, Nightfish, Swan River Goby, and Gilgie. Importantly, numerous burrows of the endemic Engaewa genus of freshwater crayfish were also recorded in the southern branch in the native vegetation site. Although not captured, the species was likely to be $E. \text{ similis}$.

• The study demonstrated that the Rushy Creek bypass and spillway structures were successful in allowing native fish passage and thereby at least partially mitigate the potential impact of the dam on the recruitment and abundance of native fishes in the system.

• To provide additional evidence of the benefits of the bypass channel, it is recommended that monitoring occur at the onset of flow in the bypass to determine whether it is used at that time, particularly by the Western Pygmy Perch.

• A tracking study (using passive internal transponders PIT tags and electronic monitoring stations) could determine the relative proportion of those fish that passed over the bypass and spillway that subsequently move into the upper branches of Rushy Creek.

• Similar bypass and spillway fishway systems should be constructed for other instream dams if they are demonstrated to house native freshwater fishes that are known to undergo spawning migrations.

Motorbike Frogs $Litoria \text{ moorei}$ in the dam on Rushy Creek.
Contents

Summary............................................................................................................................................................................. 3

Contents.............................................................................................................................................................................. 5

Background.......................................................................................................................................................................... 6

Materials and methods......................................................................................................................................................... 6

Results and discussion......................................................................................................................................................... 12

Environmental variables and flow profiles.......................................................................................................................... 12

Overall captures .................................................................................................................................................................... 16

Fishway utilisation................................................................................................................................................................. 19

Population structure and movement patterns...................................................................................................................... 23

Freshwater crayfishes............................................................................................................................................................ 37

Relationship of fish movement to hydrology and swimming performance................................................................. 39

Summary and Recommendations........................................................................................................................................ 40

References.............................................................................................................................................................................. 42
Background

An initial fish survey of Rushy Creek (a tributary of McLeod Creek in the lower Blackwood River catchment, south-western Australia) (Figure 1a) had recorded the presence of relatively common south-west Western Australian endemic fishes including the freshwater Western Minnow (Galaxias occidentalis), Nightfish (Bostockia porosa), Western Pygmy Perch (Nannoperca vittata), the estuarine South-western Goby (Afurcagobius suppositus) and the introduced Eastern Gambusia (Gambusia holbrooki) (Beatty et al., 2008a). Subsequent to that study, a dam and bypass fishway system was constructed in 2009 on Rushy Creek with details of its design, construction and additional background on the Whicher Plan outlined in Seewraj et al. (in press). The Rushy Creek bypass and spillway fishways were subsequently monitored in August, September and October 2010 in order to assess their effectiveness in allowing upstream and downstream passage of fishes in the system (Seewraj et al. in press).

Seewraj et al. (in press) identified that the fishways were at least partially effective in that they facilitated the passage of the Western Minnow; a species known to use the other rock-ramp fishways in south-western Australia (Morgan and Beatty 2004a and b; Morgan and Beatty 2005; Morgan and Beatty 2007a). However, the former study also identified knowledge gaps pertaining to the use of the fishways, including: Are the species that did not readily utilise the fishways moving on mass in the undisturbed channel downstream of the fishway? How much variability in fishway passage occurs between years? Is the southern branch of Rushy Creek upstream of the dam utilised by resident species? Could the monitoring approach be refined to answer these questions? The current study aimed to: assess the functioning of the bypass and spillway fishways on Rushy Creek in 2011 and quantify the spatial and temporal (monthly and interannual) variation in movement patterns and population structure of fishes in the system, determine the flow profiles on the fishways and compare these with upstream passage and known swimming abilities of fishes, and determine the degree of utilisation of the southern branch of Rushy Creek.

Materials and methods

The approach of the current study was largely consistent with those methods deployed during 2010 (Seewraj et al. in press) that quantified movement patterns over the spillway and bypass fishway within Rushy Creek, as well as providing information on the fish and crayfish communities upstream and downstream of the structures. By replicating those methods (with the refinements outlined below), the current study aimed to determine the inter-annual variability in the movement patterns and population structure of the various species. Therefore, surveys were undertaken on three occasions in August, September and October (into early November) 2011 (Figures 1a-c).

On each sampling occasion, fyke nets (11.2m in width, including two 5m wings and a 1.2m wide mouth fishing to a depth of 0.8m, 5m long pocket with two funnels all comprised of 2mm woven mesh), were set facing upstream and downstream at the downstream end of the bypass system (upstream of bypass fishway) and just upstream of the spillway crest (above the spillway fishway) (Figures 1a-c). In order to compare species movements in the unimpeded section of Rushy Creek downstream of the dam with those on the fishways, a downstream site in Rushy creek was also
monitored for upstream movements (Figures 1a-d). The latter downstream site was monitored following the fyke netting on the fishways in each month so as not to bias the captures on the fishways. Prior to the fyke nets being set on the fishways, back-pack electrofishing occurred (Smith Root Model LR25A) in the shallow (<20cm maximum depth) of the upstream crest of both the spillway crest and bypass in order to remove any resident fish that may bias the captures. This was undertaken as the fyke nets were unable to be set precisely at the upstream end of the fishway structures due to lack of depth and excessive flow. Mean upstream and downstream movement was determined for each species in each month at each site. Captures on the spillway were scaled to 100% as the fyke nets only permitted the channel to be partially blocked during high flow.

Spatial and temporal patterns of species densities were determined following the fyke netting at the following sites: in Rushy Creek below the two resting pools, within the two resting pools, in the previously sampled (in 2010) northern tributary of Rushy Creek (above the dam on Boathaugh Estate), and finally two additional sites in the southern major tributary of Rushy Creek above the dam (Figures 1a-c). The latter sites included a site on cleared farmland and also a naturally vegetated site on the upstream neighboring property. A combination of replicate seine netting (10m seine, 2mm mesh width) in the resting pools and also the use of the above back-pack electrofisher at all other sites was used for the density estimates. Three samples were taken from different stream habitats within each location and all fish captured were identified and measured to the nearest 1mm TL, and mean density of fish (fish/m²) was determined for each species, at each site in each sampling period.

A sub-sample (i.e. in the case of large abundances up to a hundred to avoid excessive stress due to prolonged captivity) of all fishes captured at each site on each occasion were identified and measured to the nearest 1 mm total length (TL), and evidence of spawning activity recorded in larger (>60mm TL) Western Minnow (i.e. obvious presence of eggs or exudence of sperm), before being released.

In order to test for differences in average upstream movement of the three major species (in terms of greatest numbers recorded) between the bypass and spillway fishways and also the stream below and whether differences in usage existed between months sampled, ANOVAs were conducted employing General Linear Models. The models were constructed for Western Minnow, the Western Pygmy Perch, and the Swan River Goby (see results for capture numbers):

\[ N_{movement} = \mu + S_i + M_k + S_x M_k + e \]

where \( \mu \) is the overall average upstream movement of the species, \( S_i \) the fixed effect of the ith site, \( M_k \) the fixed effect of the kth month, \( S_x M_k \) is the interaction between the Ith site and Mth month, and e the residual error. Tukey’s post hoc tests were undertaken to determine pairwise differences between the sites and also the months. All data were log+1 transformed prior to analysis and tests were undertaken in SPSS (v18) statistical program.
Figure 1a: Sites sampled in Rushy Creek in 2010 and 2011. N.B. the additional sites in the southern tributary sampled in 2011. Image from Google Maps.
August 2011

September 2011

October 2011

Figure 1b: The Rushy Creek fishway system during sampling in 2011, (clockwise from top left): looking upstream on the bypass, looking downstream on the spillway, looking upstream on the spillway, fyke nets on the spillway exit, exit of the bypass (foreground) and spillway, looking upstream on the spillway (left) and bypass,
Figure 1c: Sites sampled in Rushy Creek during 2011. Clockwise from top left: northern tributary, the juncture of the northern tributary and bypass, the thickly vegetated upstream section of the southern tributary, the lower section of the southern tributary, the downstream site (below the resting pools), the upper section of the bypass.
Figure 1d: Retrofitting the major steps on the bypass and below the spillway that occurred on the 27th May 2011 by Department of Water. Clockwise from top left: step below fishway system before modification (October 2009), step below fishway being modified (May 2011), step below fishway system following modification (September 2011), alternative passage formed around lower step (August 2011), bypass steps before modification, bypass steps after modification (May 2011). Photos K. Seewraj.
Depth-flow profiling of the bypass fishway, spillway fishway and riffle sections downstream of the fishway was undertaken in each month. Each cross-section (five per fishway) or longitudinal (one per fishway) section consisted of up to 15 individual point measurements. Depth-flow profiling was also undertaken on the two largest steps located near the top and bottom of the bypass fishway, three measurements were taken during each sample period. Velocity and depth measurements were made using a hand held flow probe (Global Water FP101). Average velocity was then determined for each fishway in each month and compared with the data collected in Seewraj et al. (in press).

The flow data from 2011 was then entered into the program IDRISI Taiga as vector points relative to each flow readings location on the fishway or bypass. Interpolation of these vector points was then carried out using the TIN module to generate a triangulated irregular network model. The TIN triangulation algorithm is designed for speed of operation. It first divides the set of input data points into sections, and then each section is triangulated. The resulting "mini-TINs" are then merged and a local optimization routine is run during the merge process to ensure that Delaunay criteria are met in the final TIN. To determine the percentage of area on the fishway and bypass over or under 65cm.sec\(^{-1}\) (the \(U_{sprint}\) value for the Western Pygmy Perch as determined by Keleher et al. 2011) the RECLASS module was used. The previous TIN images were reclassified and the pixel values were stored in each image.

**Results and discussion**

*Environmental variables and flow profiles*

Table 1 displays the mean physic-chemical variables of the sites during sampling times in 2011. As with the 2010 sampling, all sites were very fresh (<300µS.cm\(^{-1}\)) and highly oxygenated providing ideal conditions for freshwater fishes and crayfishes. Some differences existed in the temperature on the spillway and bypass fishways no doubt attributed to the upstream lentic (i.e. the dam) and lotic (i.e. the bypass channel) habitats that would have considerably different thermal properties. Average flow velocities were greater on the spillway compared to the bypass in August and September in both 2010 and 2011, but were greater on the bypass compared to the spillway in October of both years (Table 2). Table 2 also clearly demonstrates that there was a considerably greater average water velocity on both the bypass and spillway fishways in all months sampled in 2011 compared with 2010. The increase in velocities between years was proportionally greatest on the bypass in August and September (70 and 82% increase) compared to the spillway in those months (55, 16% increase), however in October, the increase on the bypass and spillway were 34% and 85%, respectively, between 2010 and 2011 (Table 2).

The spatial distribution of flow velocities on the two fishways is further demonstrated in Figures 2 and 3 which show the composite flow profiles of the bypass and spillway fishways interpolated from five cross sections and one longitudinal depth-flow profiles taken from approximately the same points on each fishway on each month in 2011. Both the bypass and spillway fishways were dominated by areas of high flow (>\(\sim\)50cm.sec\(^{-1}\)) in both August and September, however, in October, there is a relative greater reduction in flow rates on the spillway compared to the bypass
in October (Figure 2). This was also reflected in the average velocity on the spillway being less than that on the bypass in October in 2011 and 2010 (Table 2).

Table 1: Mean (±1S.E.) physicochemical variables measured during sampling of the fish system in Rushy Creek in 2011.

<table>
<thead>
<tr>
<th>SITE</th>
<th>Month</th>
<th>Temperature °C</th>
<th>pH</th>
<th>Conductivity µs</th>
<th>NaCl ppm</th>
<th>TDS ppm</th>
<th>DO mg/l</th>
<th>DO %</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Bypass</strong></td>
<td>August</td>
<td>13.4 (0)</td>
<td>262.83 (0.03)</td>
<td>131.43 (0.03)</td>
<td>123.9 (0)</td>
<td>11.16 (0.03)</td>
<td>107.73 (0.33)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>September</td>
<td>16.67 (0.03)</td>
<td>230.27 (0.28)</td>
<td>115.27 (0.03)</td>
<td>110.63 (0.27)</td>
<td>11.59 (0.05)</td>
<td>119.17 (0.26)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>October</td>
<td>24.77 (0.03)</td>
<td>183.2 (0.56)</td>
<td>91.74 (0.11)</td>
<td>91.2 (0.32)</td>
<td>10.53 (1.27)</td>
<td>127.47 (15.48)</td>
<td></td>
</tr>
<tr>
<td><strong>Spillway</strong></td>
<td>August</td>
<td>14.93 (0.07)</td>
<td>252.9 (0.59)</td>
<td>126.77 (0.19)</td>
<td>120.97 (1.03)</td>
<td>9.92 (0.04)</td>
<td>98.73 (0.47)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>September</td>
<td>15.9 (0.1)</td>
<td>233.07 (0.15)</td>
<td>116.27 (0.2)</td>
<td>111.2 (0.85)</td>
<td>9.14 (0.04)</td>
<td>92.47 (0.43)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>October</td>
<td>23.27 (0.09)</td>
<td>186.73 (0.07)</td>
<td>93.35 (0.13)</td>
<td>91.21 (0.07)</td>
<td>8.52 (0.15)</td>
<td>101.87 (0.87)</td>
<td></td>
</tr>
<tr>
<td><strong>Southern tributary bushland</strong></td>
<td>August</td>
<td>15.4 (0)</td>
<td>238.47 (0.68)</td>
<td>119.53 (0.07)</td>
<td>113.67 (0.03)</td>
<td>8.75 (0.08)</td>
<td>89.63 (1.38)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>September</td>
<td>17.03 (0.2)</td>
<td>209.9 (1.6)</td>
<td>105.33 (0.52)</td>
<td>101.26 (0.84)</td>
<td>6.91 (0.11)</td>
<td>305.9 (233.95)</td>
<td></td>
</tr>
<tr>
<td><strong>Southern tributary farmland</strong></td>
<td>August</td>
<td>16.7 (0)</td>
<td>234.47 (0.34)</td>
<td>118.83 (0.29)</td>
<td>113.6 (0.87)</td>
<td>9.52 (0.13)</td>
<td>91.73 (1.99)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>September</td>
<td>16.3 (0.12)</td>
<td>216.37 (0.67)</td>
<td>108.2 (0.25)</td>
<td>103.17 (0.26)</td>
<td>7.09 (0.3)</td>
<td>78.43 (0.55)</td>
<td></td>
</tr>
<tr>
<td><strong>Northern tributary farmland</strong></td>
<td>August</td>
<td>16.7 (0)</td>
<td>234.47 (0.23)</td>
<td>117.3 (0.06)</td>
<td>112.93 (0.12)</td>
<td>9.86 (0.12)</td>
<td>101.53 (1.1)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>September</td>
<td>17.9 (0.66)</td>
<td>202.2 (0.2)</td>
<td>100.6 (0.31)</td>
<td>97.58 (0.14)</td>
<td>8.11 (0.04)</td>
<td>87.93 (0.52)</td>
<td></td>
</tr>
<tr>
<td><strong>Road crossing below dam</strong></td>
<td>August</td>
<td>17.27 (0.03)</td>
<td>185.3 (0.1)</td>
<td>92.65 (0.07)</td>
<td>91.65 (0)</td>
<td>8.76 (0.12)</td>
<td>104.2 (1.1)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>September</td>
<td>23.77 (0.03)</td>
<td>7.32 (0.14)</td>
<td>92.65 (0.07)</td>
<td>91.65 (0)</td>
<td>8.76 (0.12)</td>
<td>104.2 (1.1)</td>
<td></td>
</tr>
</tbody>
</table>
**Table 2:** Mean (±1S.E.) overall average water velocity on the bypass and spillway fishways on Rushy Creek in each month sampled in 2010 and 2011.

<table>
<thead>
<tr>
<th></th>
<th>Bypass</th>
<th>Spillway</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2010</td>
<td>2011</td>
</tr>
<tr>
<td>August</td>
<td>55.23 (6.02)</td>
<td>93.77 (9.54)</td>
</tr>
<tr>
<td>September</td>
<td>37.83 (4.08)</td>
<td>68.86 (6.81)</td>
</tr>
<tr>
<td>October</td>
<td>23.16 (2.88)</td>
<td>31.10 (3.35)</td>
</tr>
</tbody>
</table>

**Table 3:** The area (%) of the spillway and bypass fishways of water velocities exceeding 65cm sec$^{-1}$ (i.e. the $U_{\text{spine}}$ value of the Western Pygmy Perch (Keleher 2011)) on the bypass and spillway fishways on Rushy Creek in each month sampled in 2011.

<table>
<thead>
<tr>
<th>Month</th>
<th>Bypass</th>
<th>Spillway</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>% of Area &lt;65cm/s</td>
<td>% of Area &gt;65cm/s</td>
</tr>
<tr>
<td>August</td>
<td>18.36</td>
<td>81.64</td>
</tr>
<tr>
<td>September</td>
<td>36.01</td>
<td>63.99</td>
</tr>
<tr>
<td>October</td>
<td>71.55</td>
<td>28.45</td>
</tr>
</tbody>
</table>
Figure 2: The flow profiles of the bypass (left) and spillway (right) fishways in August (top), September (middle) and October (bottom) 2011. N.B. the clear reductions in flow rates between the sampling months and the greater area of low flow on the spillway compared to the bypass in October.
Overall captures

A total of nine fish species (four freshwater, three estuarine, two introduced) were recorded during sampling of the Rushy Creek system between August and October 2011 (Figure 3, Tables 4 and 5). This compared to seven species recorded during the sampling that occurred in 2010 (note in addition to those species in Table 4, the Western Mud Minnow was also recorded in fyke netting in 2010). The Freshwater Cobbler (*Tandanus bostocki*) was recorded during 2011; the first time it has been recorded from the Rushy Creek system (see Beatty et al. 2008a; Seewraj et al. in press) and was captured in fyke netting that occurred below the dam. The Western Hardyhead (*Leptatherina wallacei*) was also recorded below the dam in 2011 that was known from McLeod Creek (Beatty et al. 2008), but had not been recorded in Rushy Creek. The introduced Goldfish (*Carrasius auratus*) was also recorded below the dam in 2011 and had not been previously recorded in McLeod or Rushy Creeks, although is known from the Blackwood catchment (Beatty et al. 2008b).

**Figure 3:** Fishes captured in 2011 in Rushy Creek. N.B. those in red are introduced species.
Table 4: Sites sampled in the current study for species densities (fish.m\(^{-2}\)) from the 2010 sampling period. N.B. A = August, S = September, O = October sampling period and S.E. are in parentheses.

<table>
<thead>
<tr>
<th>Site</th>
<th>Native freshwater fishes</th>
<th>Native estuarine fishes</th>
<th>Introduced native fishes</th>
<th>Freshwater crayfish</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Western Pygmy Perch</td>
<td>Western Minnow</td>
<td>Nightfish</td>
<td>Swan River Goby</td>
</tr>
<tr>
<td>Rushy Creek Below fishways</td>
<td>A=0.39 (0.19)</td>
<td>S=1.30 (0.2)</td>
<td>O=0.17 (0.17)</td>
<td>A= 0.35</td>
</tr>
<tr>
<td>Lower resting pools</td>
<td>S= 0.02 (0.02)</td>
<td>O= 0.07 (0.04)</td>
<td>A= 1.63</td>
<td>S= 2.56</td>
</tr>
<tr>
<td>Upper resting pool</td>
<td>O= 0.31 (0.28)</td>
<td></td>
<td>A= 3.13</td>
<td>S= 3.6 (3.2)</td>
</tr>
<tr>
<td>Northern tributary above fishway</td>
<td>A= 0.04 (0.02)</td>
<td>S= 0.01 (0.01)</td>
<td>A= 0.08</td>
<td>S= 0.25 (0.1)</td>
</tr>
</tbody>
</table>
Table 5: Sites sampled in the current study for species densities (fish.m\(^{-2}\)) from the 2011 sampling period. N.B. A = August, S = September, O = October sampling period and S.E. are in parenthesis.

<table>
<thead>
<tr>
<th>Site</th>
<th>Native freshwater fishes</th>
<th>Native estuarine fishes</th>
<th>Introduced native fishes</th>
<th>Freshwater crayfish</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Western Pygmy Perch</td>
<td>Western Minnow</td>
<td>Nightfish</td>
<td>Freshwater Cobbler</td>
</tr>
<tr>
<td>Rushy Creek Below fishways</td>
<td>A= 0.8 (0.24)</td>
<td>S= 0.59 (0.12)</td>
<td>O= 1.2 (0.65)</td>
<td>A= 0.16 (0.13)</td>
</tr>
<tr>
<td>Lower resting pools</td>
<td>A= 0.02 (0.02)</td>
<td>S= 0.16 (0.07)</td>
<td>O= 3 (1.26)</td>
<td>A= 0.72 (0.28)</td>
</tr>
<tr>
<td>Upper resting pool</td>
<td>A= 0.02 (0.02)</td>
<td>S= 0.25 (0.11)</td>
<td>O= 0.22 (0.22)</td>
<td>A= 2.3 (0.8)</td>
</tr>
<tr>
<td>Upstream crest of spillway</td>
<td>O= 0.09</td>
<td>A= 0.01</td>
<td>O= 0.09</td>
<td>A= 0.06</td>
</tr>
<tr>
<td>Upstream crest of bypass</td>
<td>O= 0.55</td>
<td>O= 0.25</td>
<td>O= 0.05</td>
<td>A= 0.04</td>
</tr>
<tr>
<td>Northern tributary above fishway Farmland</td>
<td>A= 0.2 (0.08)</td>
<td>S= 0.06 (0.03)</td>
<td>O= 2.98 (2.65)</td>
<td>A= 0.05 (0.03)</td>
</tr>
<tr>
<td>Southern tributary above fishway Bushland</td>
<td>S= 0.07 (0.07)</td>
<td>O= 0.17 (0.17)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Southern tributary above fishway Farmland</td>
<td>S= 0.06 (0.02)</td>
<td>O= 2.97 (2.52)</td>
<td>A= 1.01 (0.75)</td>
<td>S= 0.51 (0.34)</td>
</tr>
</tbody>
</table>
Fishway utilisation

During the sampling for movement patterns on the bypass and spillway fishways in 2011, a total of 4183 fish were recorded (a 138% increase from 2010). Of these 2275 (54.4%) were captured at the bypass exit and 1908 (45.6%) on the spillway exit. Similar to 2010, the freshwater native species the Western Minnow and Western Pygmy Perch dominated those captures, along with the native estuarine Swan River Goby commonly captured on the spillway (Figures 4, 5 and 6).

On the bypass channel 575 (25.6%) of fishes were moving upstream and 1700 (74.7%) downstream. Of the upstream moving captures, 533 (92.7%) were the Western Minnow, and 38 (6.6%) were Western Pygmy Perch (Figure 5). On the spillway moving upstream, 765 (55.3%) Western Minnows were captured, 400 (28.9%) Western Pygmy Perch, and 211 (15.3%) Swan River Gobies (Figures 5 and 6). There was therefore an increase in the proportion of Western Pygmy Perch moving upstream over the bypass from 2.2% in 2010 to 28.9% in 2011. Furthermore, an increase in the proportion of Swan River Goby moving upstream on the spillway occurred between 2010 (1.8%) to 2011 (15.2%).

Downstream captures on the bypass consisted mostly of the Western Minnow (1311, 77.1%) and Western Pygmy Perch (384, 22.6%). There was therefore a slight increase in the proportion of Western Pygmy Perch moving downstream over the bypass from the 6.6% recorded in 2010. There was also a reduction in the proportion of Nightfish moving downstream from the 4.1% in 2010 to just 0.2% in 2011 (Figures 5 and 6). Downstream movements of on the spillway largely consisted of Western Minnow (272, 51.9%), Western Pygmy Perch (113, 21.6%), and Swan River Goby (127, 24.2%) (Figures 4, 5, 6).

Expansion of the fyke netting program in 2011 to include a site below the dam within Rushy Creek (a key recommendation of Seewraj et al. in press) proved very worthwhile as it resulted in the recording of the Freshwater Cobbler which would otherwise not have been recorded during the density estimate sampling. The Freshwater Cobbler and Western Mud Minnow (the latter recorded in 2010, Figure 4), were not recorded on either the bypass or spillway, or either branch of Rushy Creek in 2011. Therefore, it is assumed that the structures do not allow movement of these species, although the Western Mud Minnow is known from above the bypass.
Figure 4: Mean (+1 S.E.) upstream and downstream movement of fishes recorded at the upstream exit of the bypass fishway and spillway fishway on Rushy Creek during each sampling month in 2010.
2011

G. occidentalis

Bypass fishway

Spillway

Rushy Creek downstream

N. vittata

B. porosa

G. munda

T. bostocki

Figure 5: Mean (+1 S.E.) upstream and downstream movement of fishes recorded at the upstream exit of the bypass fishway and spillway fishway, and below the dam (upstream movement only) on Rushy Creek during each sampling month in 2011.
Figure 6: Mean (+1 S.E.) upstream and downstream movement of the Swan River Goby and introduced Eastern Gambusia recorded at the upstream exit of the bypass fishway and spillway fishway, and below the dam (upstream movement only) on Rushy Creek during each sampling month in 2010 and 2011.
Population structure and movement patterns

The **Western Minnow** was again shown to utilise both the bypass and spillway fishways in large numbers in all months sampled. Western Minnow has a peak spawning period between early winter and mid-spring (Pen and Potter, 1991a; Beatty et al. 2008b). A peak in upstream movements occurred in September 2011 (adjusted average of 380 individuals per night moving upstream) over the spillway although considerable upstream movements continued in October (Figure 5). Similar upstream movement of the species to those on the bypass and spillway was recorded below the dam during October 2011 again suggesting that the structures freely allow the population to negotiate upstream over the dam (Figure 5). There was an overall significant difference (p=0.016) in the upstream movement of the species between the sites (i.e. bypass, spillway, and the site downstream in Rushy Creek), between months (p=0.009) and the interaction of sites with months (p=0.042). Pairwise tests revealed that the average upstream movement of the Western Minnow was significantly different between the spillway and the downstream site (p=0.013), but not between the bypass and the spillway (p=0.199). There was significant differences in the overall average upstream movement between the months of August and both September (p=0.009) and October (p=0.042), but not between September and October.

Length frequency distribution of the Western Minnow in 2010 and 2011 are presented in Figures 7 and 8 and suggest the population is self-maintaining with multiple size cohorts (that would likely correspond to age cohorts). Similar patterns existed in these distributions between the years with juveniles (<60 mm TL) being recorded utilising the bypass and spillway fishways mostly in September (particularly the spillway) and October. Both smaller and larger (>60 mm TL) individuals were recorded moving upstream over both structures and the length-frequency distributions in the resting pools were again very similar to those recorded at the upper section of the spillway again highlighting that the entire population size range could move over the structure in both 2010 and 2011 flow conditions (Figures 7 and 8). It is interesting to note that the juvenile cohort in September 2010 was of slightly smaller size than that recorded in September 2011, possibly as a result of a slightly later breeding event in 2010 compared with 2011. The length-frequency distribution in the resting pools was also similar to that recorded in the stream below those pools in 2011 (Figure 8).

As highlighted by the length-frequency and the density estimates presented in Tables 4 and 5, the Western Minnow was recorded utilising both upstream branches of Rushy Creek and those habitats are undoubtedly key spawning habitats for the species, along with probably the bypass channel itself, and possibly the reservoir. More juveniles were recorded in the Northern tributary in 2010 compared with 2011 (Figures 7 and 8).
Figure 7: Length-frequency distributions of the Western Minnow in Rushy Creek at the sites and months sampled in 2010.
Figure 8: Length-frequency distributions of the Western Minnow in Rushy Creek at the sites and months sampled in 2011.
The study also recorded the presence of a cestode worm in 2011, which was probably the introduced *Ligula intestinalis* (see Morgan 2003) in the Western Minnow population which caused an obvious swelling of the abdomen in infected individuals (see Figure 9). It was found in 4.3% of all Western Minnows captured during the study being most prevalent in August (9.4%) and September (2.0%). *Ligula intestinalis* has also previously been recorded on Western Pygmy Perch and the Swan River Goby elsewhere (Lymbery et al. 2010). Also present was a species of trematode recorded in 2011 (see Figure 9). Both parasites are the subject of ongoing research by the Freshwater Fish Group and Fish Health Unit and more information on parasites of native and introduced freshwater fishes of south-western Australia can be found in Lymbery et al. (2010).

*Figure 9:* (Top) a cestode (probably *Ligula intestinalis*) that was removed from a recently deceased Western Minnow and (bottom) a Western Minnow heavily infested with a trematode.
The Western Pygmy Perch was captured in far greater numbers moving upstream over the bypass and the spillway in 2011 compared to 2010 (Figures 4 and 5), particularly in October. Movement of the species on the bypass was generally in a downstream direction in all three months in both 2010 and 2011 with a most notable large downstream movement occurring over the bypass and spillway in October 2011 (Figures 4 and 5). Negligible upstream movement of the Western Pygmy Perch on the bypass was recorded in 2010 whereas there was upstream movement on the spillway in October 2010 and upstream movements over both the bypass and spillway in October 2011.

Monitoring upstream movements in Rushy Creek at the site below the dam in 2011 provided valuable information in assessing the functioning of the fishways. A large upstream movement of the Western Pygmy Perch was recorded below the fishway in October 2011, which corresponding to the large upstream movement of a wide size range over the spillway and to a lesser extent the bypass at that time. The mode of the juveniles was consistent between the 2010 and 2011 monitoring periods being between 20-25 mm TL (Figures 10 and 11). The Western Pygmy Perch in the Collie River has been shown to breed multiple times during late winter and spring (Pen and Potter 1991b) and the length-frequencies suggest that juveniles and adult individuals were present in October 2010 and 2011 (Figures 10, 11). The species has previously been shown to attain approximately 40-45 mm TL at age one (in the Collie River) and therefore the dominant 20-25 mm cohort in late October in the current study may indicate a relatively early spawning period in the more southerly Rushy Creek (or a very slow growth rate) cf the more northern population in the Collie River. Furthermore, the wide size range (including juveniles) that was recorded moving upstream over both the bypass and spillway fishways in October 2011, and also October 2010 for the spillway, was suggestive of fishway usage for population dispersal rather than solely as part of a spawning migration (Figures 10 and 11). There was also a relatively high abundance of larger individuals of species in the stream below the dam in August and September 2010, and August 2011 (Tables 4 and 5), and although they were recorded in the density sampling not in the fyke netting, may have indicated a congregation associated with a prior (i.e. before the sampling commenced) upstream spawning migration. This therefore suggests that the species was unable to utilise either fishway in August and September possible due to excessive flows (see section below on hydrology and movements).

Although close to significant (p=0.055) there was no overall significant difference in the upstream movement of the species between the sites (i.e. bypass, spillway, and the site downstream in Rushy Creek). However, there was a significant difference between the months (p=0.000). Pairwise tests revealed there was a significant differences in the overall average upstream movement in October with that in both August (p=0.000) and September (p=0.000), but not between August and September.

Above the dam in the northern tributary in 2010, and both the northern and southern tributaries in 2011, only adult Western Pygmy Perch were recorded, providing no evidence of breeding in those habitats, although only electrofishing was used not fyke netting and the latter may have been more effective in passively capturing juveniles such as occurred in the stream below the dam.
in October (Figures 10 and 11). Examination of the changes in density of the Western Pygmy Perch in both the northern and southern tributaries of Rushy Creek showed a substantial increase between September and October (i.e. from 0.06 to 2.98/m² in the northern tributary and from 0.06 to 2.97 in the southern tributary (Table 5). No such increase in the density of the species was recorded in the northern tributary in the 2010 sampling (Table 4). However, the upstream passage over the fishway system (mostly or exclusively over the spillway fishway) by the Western Pygmy Perch in October 2010 is supported by the considerable reduction in its density in the stream below the dam that occurred between September and October (Figure 10).

The results therefore suggest a much stronger upstream usage of the Western Pygmy Perch over both the bypass and spillway in 2011, and increase in downstream movement over both structures and an overall increase in abundance of the species in the upstream tributaries of Rushy Creek in 2011 relative to 2010. It should also be noted that considerable retro-fitting of the larger steps was undertaken by the Department of Water in May 2011 (Figure 1d); both below the fishway system and particularly in the bypass which may at least partially account for the differences in the strength of passage over the fishways of the Western Pygmy Perch and other species between the years. Although other factors may also have led to an increase in passage rate of Western Pygmy Perch between the years (particularly increased recruitment rates and survival in 2011 due to increased discharge compared to 2010), differences in the amount of upstream movement may also have directly contributed to, or be indicative of, the increase in overall abundance (see also the section below on hydrology and movements). It is also likely that the congregation of large Western Pygmy Perch below the dam in August 2010 and 2011 (and also September 2010) was associated with spawning movement and, as none were recorded passing through either fishway in those months, the fishways appeared not to have allowed passage of the species during much of its spawning period.
Figure 10: Length-frequency distributions of the Western Pygmy Perch in Rushy Creek at the sites and months sampled in 2010.
Figure 11: Length-frequency distributions of the Western Pygmy Perch in Rushy Creek at the sites and months sampled in 2011.
The **Nightfish** was recorded in very low numbers moving upstream over the spillway in September 2010, and the bypass in October 2010 (Figure 4 and 5) and this was probably attributed to resident fish in the small section of habitat below the nets, rather than evidence of passage through the fishways. Negligible movement of the species was again recorded in those months in 2011 and thus it is apparent that the species does not utilise either fishway. However, the additional monitoring of upstream movements in Rushy Creek below the dam also failed to detect the species and therefore it is apparent that it was not undertaking detectable upstream migrations during the sampling in 2011. Large annual downstream movement of juvenile Nightfish have been demonstrated in Layman’s Brook (Blackwood River) in November (Beatty et al. 2008b) and therefore a similar juvenile movement may have occurred in Rushy Creek outside of the 2010 and 2011 sampling programs. As found in 2010, the species was again recorded in the density estimates below the dam 2011, in all three sampling months within the northern tributary above the dam, and also the southern tributary above the dam in October 2011 (Table 5). Due to the very low abundances of Nightfish recorded during the 2011 sampling, examination of the length frequencies does not reveal a great deal of information aside from highlighting the fact that the species is recruiting to some degree within Rushy Creek as indicated by the few juveniles recorded in October on the bypass and spillway fishways (Figure 12).

The **Freshwater Cobbler**, as mentioned, was recorded for the first time in Rushy Creek or the McLeod Creek system during the sampling in 2011 (Figure 5, Table 5). The inclusion of the downstream fyke netting site proved successful in recording this additional species. It was recorded moving upstream below the fishways in October and also recorded in the density estimates in Rushy Creek below the fishways in September and October 2011, and the lower resting pool in September 2011 (Table 5). Its length-frequency distribution revealed a wide size range probably corresponding to multiple age cohorts, and therefore it appeared to be a self-maintaining population (Figure 13). The use of fyke netting to record and monitor Freshwater Cobbler movements is known to be highly effective and the species has been demonstrated to undertake considerable localised migrations during spring and summer associated with feeding and probably spawning activity (Beatty et al. 2010). As mentioned, it does not appear capable of negotiating either the bypass or spillway and its distribution appears limited to downstream section of Rushy Creek, although it is possible it also utilises the reservoir itself. If the species is present in the reservoir, its presence in the resting pool (single individual recorded once in September) may have been due to downstream colonisation from the dam rather than upstream passage through the lower riffle zones below the fishway system. Additional sampling in the reservoir and fyke netting to detect upstream passage over the lower riffle zones would determine which was more likely.
Figure 13: Length-frequency distributions of the Nightfish in Rushy Creek at the sites and months sampled in 2011.
Figure 14: Length-frequency distributions of the Freshwater Cobbler in Rushy Creek at the sites and months sampled in 2011.
Swan River Goby captures were dominated by downstream movements over the spillway in August and September in 2010 with only limited upstream movement (i.e. <5 individuals per month) being recorded (Figure 6). However, similar to the Western Pygmy Perch, the 2011 sampling demonstrated the species had a much greater upstream passage over the spillway with it contributing to 15.2% of upstream moving fish captures and also 24.2% of downstream captures (Figure 6). Upstream movement was consistently high in September and October 2011 with those months also having the greatest numbers of downstream movement over the spillway (Figure 6). The species was also recorded in relatively low numbers moving upstream in Rushy Creek below the dam in September and October 2011 (Figure 6). There was an overall significant difference (p=0.000) in the upstream movement of the species between the sites (i.e. bypass, spillway, and the site downstream in Rushy Creek) and an overall significant difference between the months (p=0.002), but the interaction of sites with months was also not significant (p=0.054). Pairwise tests revealed there was a significant differences in the upstream movement of the Swan River Goby between the spillway and both the bypass (0.000) and downstream site (p=0.000), but not between the bypass and the downstream site (p=0.144). There were also significant differences between the overall upstream movement of the species in August with both September (p=0.005) and October (p=0.004), but no significant difference existed between September and October (p=0.994).

A relatively wide size range of the Swan River Goby was recorded moving upstream and downstream over the spillway in all months sampled in 2010 and 2011, although in October 2010 and 2011 captures were dominated by upstream moving individuals (Figures 14 and 15). The Swan River Goby was recorded in Rushy Creek below the dam in all sampling events in both 2010 and 2011 and in the resting pools in both years (Tables 4 and 5). Interestingly, the species was never recorded in the northern tributary above the dam but was recorded in the southern tributary in all months in 2011 (Tables 4 and 5). A wide size range was recorded in 2011 in the resting pools, and to a lesser extent the southern tributary above the dam (Figures 15 and 16). Therefore, it is clear that the Swan River Goby utilises the spillway fishway to move both upstream and downstream, and is a self-maintaining population within Rushy Creek, however it appears not to utilise the northern tributary above the dam or the bypass channel.
Figure 14: Length-frequency distributions of the Swan River Goby in Rushy Creek at the sites and months sampled in 2010.

Rushy Creek Fishways 2010-2011
Figure 15: Length-frequency distributions of the Swan River Goby in Rushy Creek at the sites and months sampled in 2011.
The **Western Hardyhead** was recorded in the current study for the first time in Rushy Creek having not previously been recorded in the Creek by Beatty et al. (2008a) or in 2010 (Tables 4 and 5). As with the Swan River Goby and the South-western Goby, this is a typically estuarine species that has penetrated upstream through almost the entire Blackwood River catchment; an expansion that has been facilitated by the secondary salinisation of the main channel and major tributaries of the upper catchment (Morgan et al. 2003; Beatty et al. 2008b, 2011). It was not found to utilise either the bypass or the spillway and appears restricted to downstream reaches of Rushy Creek and McLeod Creek.

The **South-western Goby** was only recorded on one occasion in Rushy Creek below the dam in 2011 in September (Table 5). It was also recorded at that site in August and September 2010 and, as in the case of the Western Hardyhead, appears restricted in distribution to the lower reaches of Rushy Creek and McLeod Creek.

The **Eastern Gambusia** was found to move upstream on the spillway in very low numbers in October 2010 and 2011 (Figure 6). Although electrofishing the crest below the nets occurred in 2011 which may have reduced the upstream moving captures of the species in that year compared to 2010, it is still assumed that those very individuals captured moving upstream on the spillway were actually inhabiting the reservoir and not negotiating the entire length of the fishway. The species generally prefers shallow, warm, slow moving water or lentic habitats in south-western Australia (Morgan and Beatty 2005), and as discussed below, has an inferior swimming ability to native fishes of the region (Keleher 2011), so whilst they may be able to negotiate less steep rock ramp systems it is unlikely they are able to negotiate the rock ramp sections of the Rushy Creek fishways. It is likely that those individuals found their way around the blocked net as 100% blockage was still not possible given the small size of this species and its observed high abundances in the reservoir. The Eastern Gambusia was recorded in both 2010 and 2011 on a number of occasions at a number of other sites in Rushy Creek including: below the dam, within the resting pools, and in low abundance in both the northern tributary (September and October 2010) and southern tributary (August 2011) (Tables 4 and 5).

The other introduced species recorded was the **Goldfish**. This represents the first record of this species from the McLeod Creek or Rushy Creek system. It is known from the Blackwood River further upstream (Beatty et al. 2008b). It was recorded below the dam in the density sampling in August 2011 (Table 5). The species is known to potentially introduce disease, and influence nutrient cycles by re-suspending nutrients from the sediment through its feeding habits. The nearby Vasse River population was shown to have the fastest growth rate of any wild population in the world reaching 180 mm TL in their first year of life (Morgan and Beatty 2007b). Its existence in the Rushy Creek system is therefore of concern and control options should be assessed to limit its impact on native species.

*Freshwater crayfishes*

The native Gilgie (*Cherax quinquecarinatus*) and introduced Yabby (*Cherax destructor*) were both again recorded at a number of sites in the Rushy Creek system. The Gilgie and Yabby were
recorded in both the northern and southern tributaries in 2011 (Table 5). Both species were also recorded in either 2010 or 2011 below the dam. Although Smooth Marron was recorded below the dam in very low numbers in 2010, it was only detected in the northern tributary in 2011 sampling (Table 5).

A major find of the study was the discovery of *Engaewa* burrows and the sighting of a single individual from the upstream, native vegetated section of the southern tributary of Rushy Creek (Figure 16). Although not positively identified, the species is likely to be the Augusta Burrowing Crayfish *E. similis* (Quinton Burnham pers. comm.; and see Morgan et al. 2011). The *Engaewa* crayfish are endemic to south-western Australia and are obligate burrowing species, effectively spending their entire life-time underground surfacing only rarely. Their distinctive burrows are therefore usually the only way of determining their presence and they favour swamp habitats. Little is known about their biology or ecology.

![Figure 16: Engaewa burrows (E. similis) in the southern tributary of Rushy Creek, September 2011. Note the chimney shaped entrance to the burrows and small balls created during burrow excavation.](image)
**Relationship of fish movement to hydrology and swimming performance**

Much greater average flow velocities were recorded on both the bypass and spillway in 2011 compared with 2010, and average water velocities on the spillway at the time of sampling in October 2011 (when the largest upstream movement of Western Pygmy Perch occurred) approximated average velocities on the bypass in that month in 2010 (when effectively no upstream passage of that species occurred) (Tables 2-4, Figure 2). Therefore, flow rate alone does not explain the lack of upstream passage of the Western Pygmy Perch in October 2010 on the bypass. Indeed, greater and earlier onset of flows in Rushy Creek probably facilitated an overall increase in population abundances of most species in 2011 which then resulted in an overall increase in passage rate of Western Minnow, Swan River Goby and Western Pygmy Perch. However, during the high-flow months of August and September in both years, no upstream passage of the Western Pygmy Perch occurred at a time when a relatively high density of mature individuals congregated below the dam. Therefore, as discussed below, it appears that hydrology on the fishways may prevent upstream passage of the species during a major part of its spawning period. Furthermore, although the bypass operates before the spillway, the relative overall greater usage of the spillway fishway by all species suggests that the bypass may be, to a degree, superfluous. However, monitoring fish passage earlier in the year when the bypass begins to operate, but flow rates are less than those recorded in the current study, is required to determine how beneficial the bypass is to earlier passage of these species.

Swimming performance of the Western Pygmy Perch, Western Minnow and Eastern Gambusia (along with the introduced Pearl Cichlid) were recently examined by Keleher (2011) and he demonstrated that the performance of all species increased with individual size, and that the swimming performance of the native species was not highly variable across temperatures. However, the study did show a slight improvement in the swimming performance of the Western Pygmy Perch with increasing temperature (over the range of 10-25°C). Mature Western Pygmy Perch could maintain their $U_{sprint}$ swimming speed (65cm.sec$^{-1}$) for an average period of 26.4 seconds. The study also revealed the $U_{sprint}$ of the Eastern Gambusia was significantly lower than either of the native species.

Keleher (2011) recommended average velocities should not exceed 65 cm.sec$^{-1}$ over maximum distances of ~11 m, to cater for Western Pygmy Perch. By comparing to the 2010 flow data on the Rushy Creek bypass and spillway fishways, the study found that the greatest hypothetical distance that the Western Pygmy Perch could travel over those structures peaked in October at 1106 and 1384cm on the bypass and spillway, respectively. The previous study concluded that based on average velocities, the species would not have been predicted to negotiated either structure at that time. However, although a potentially very useful metric in predicting passage on uniform structures such as road culvers, obviously on fishways, uniform flow does not occur and therefore using average velocity and $U_{sprint}$ values to predict fish passage is theoretical at best. Indeed, during October 2010, an average of seven (±1.22) Western Pygmy Perch were recorded moving upstream at the exit of the spillway at that time, suggesting that either, 1) They were utilising burst swimming and/or could find a minimum flow passage produced by the complex flow profile.
(as highlighted in Figure 2), or 2) Those individuals did not actually pass over the spillway and were already present on the crest prior to the nets being set.

In re-analysing this distance with the average velocities on both structures in October 2011 (see Table 2), the predicted ground distance the species could travel at its $U_{\text{sprin}}$ would be further reduced to 896 and 1101 cm of passage on the bypass and spillway fishways (much less than their actual lengths), respectively, yet a substantial increase in passage of Western Pygmy Perch (average of 224 per 24 hour period) was recorded in October 2011. As mentioned, the 2011 sampling involved removing any resident fish on the crest and therefore those individuals were likely to have achieved full passage over the fishways.

Therefore, it appears likely that the passage ability of the Western Pygmy Perch cannot be solely predicted through rock-ramp fishways based on comparing its $U_{\text{sprin}}$ with the average velocities on those structures. It is more likely that as stated above, the complex flow profiles coupled with variability in swimming performance of the species (that would use a combination of aerobic and anaerobic respiration) facilitates its upstream passage despite average flow velocities and fishway length theoretically preventing its passage. However, it appears that its ability to negotiate those fishways was exceeded during the much greater flow rates experienced on both the bypass and spillway in August and September in both years; the period that appeared to better coincide with spawning according to its population structure (i.e. detection of juveniles in October).

An additional factor that may have contributed to greater capture rates in 2011 of the Western Pygmy Perch and other species was the instream works conducted (May 2011) on a small instream drop that was situated below the fishway system in the 2010 sampling period, and also a major drop that existed on the bypass during sampling in 2010 (K. Seewraj, Department of Water pers. comm.). Placing rocks to reduce the slope of those steps may have contributed to the greater passage rate of Western Pygmy Perch over the fishways; particularly the bypass if that step was not negotiable by the species in 2010. Therefore, taking into account the lack of usage of the bypass in 2010 that may have been caused by that step, the maximum average flow conditions (see Table 2) that allow upstream passage for the Western Pygmy Perch would therefore likely be somewhere within the range of ~31 (i.e. maximum average flow rate when upstream passage was recorded, i.e. in October 2011 on the bypass) to ~61 cm.sec$^{-1}$ (minimum flow rate when upstream passage was not recorded on the spillway, i.e. September 2010).

Although the results of Keleher (2011) are an important first step in understanding swimming performances of south-west species and can be used to help set design criteria for future fishways and particularly road culverts (where more uniform flow often exists) more intensive studies on the hydrology of fishways (particularly the highly variable rock ramp fishways), and burst swimming speeds for all south-west species is required.

**Summary and recommendations**

The current study recorded nine species of freshwater fish during the 2011 monitoring of Rushy Creek that included the first records of the native Freshwater Cobbler and Western Hardyhead.
from the system. It revealed that considerably greater numbers of fish utilised the Rushy Creek fishway system in 2011 (4183 individuals) compared to 2010 (1760 individuals) and there was an overall more even number of fish recorded utilising the bypass and spillway in 2011. However, significant differences existed in the average upstream movement between the bypass, spillway and site downstream of the dam for the three most abundant fish captured, the Western Minnow, Western Pygmy Perch and Swan River Goby. Discharge and flow rates undoubtedly explain many of these differences. It is likely that greater and earlier onset of flows in Rushy Creek in 2011 probably resulted in an overall increase in abundance and recruitment to populations relative to 2010 which probably contributed to the increase in upstream passage of key species on the fishways in 2011. Although the Western Pygmy Perch can obviously travel greater distances on these fishways than would be predicted by using \( U_{\text{sp}} \) value and average flow velocities (resulting in its successful passage in October 2010 and 2011), excessive flow rates in August and September at the time of sampling in both years (that approximated or exceeded its \( U_{\text{sp}} \) value of 65 cm.sec\(^{-1}\)) probably prevented its upstream passage during much of its spawning period. Furthermore, lower overall abundances of the species in 2010 and/or the presence of major steps on the bypass and below the spillway, that were retrofitted between the sampling years, probably contributed to its lack of passage on the bypass in 2010.

Replicating the sampling program in 2011 also revealed that a wide size range of the Western Pygmy Perch could negotiate upstream over the bypass and spillway fishways in October 2011 (and spillway in October 2010) including both juveniles and adults. Monitoring upstream movements and densities in Rushy Creek at the site below the dam also provided valuable information in assessing the functioning of the fishways. For example, it demonstrated that both adult and juvenile Western Pygmy Perch undertook strong upstream movements below the fishway system in October which corresponded to the species also moving over both the spillway and the bypass fishway at that time; however, as mentioned it was probably unable to negotiate either fishway in August and September when congregations of adults were detected. Furthermore, the Freshwater Cobbler appeared unable to utilise either the bypass or spillway fishway as it was recorded moving upstream at the lower site in August 2011, but not on both fishways and it is likely a substantial reduction in their slopes would be required to cater for the passage of this species that is known to migrate in large numbers through riffle zones. Although the Nightfish, Western Hardyhead and South-west Goby were effectively not found to move upstream over either fishway, they were also not recorded moving upstream at the site below the dam (aside from the Western Hardyhead recorded once in September) and therefore may simply not require upstream passage as part of their lifecycle.

Undertaking the additional sampling in the upstream southern tributary of Rushy Creek demonstrated that it provided habitat for the Western Minnow, Western Pygmy Perch, Nightfish, Swan River Goby, the Gilgie and also a species of *Engaewa*.

The study demonstrated that the Rushy Creek bypass and spillway structures were successful in allowing native fish passage and thereby at least partially mitigate the impact of the dam on recruitment and abundance of native fishes in the system. Although the bypass would allow
earlier upstream passage of resident species, greater overall utilisation of the spillway fishway was recorded for key species. Monitoring fish passage earlier in the year when the bypass begins to operate, but flow rates are less than those recorded in the current study, is required to determine whether the bypass is, to some degree, superfluous. However, it is unclear as to whether species that enter the dam rather that the bypass channel continue their passage upstream into the upper branches of Rushy Creek. For the larger species (i.e. Western Minnow), the relative degree of upstream passage into Rushy Creek could be investigated by a mark-recapture program utilising passive internal transponders (PIT tags) and electronic monitoring stations. It is recommended that low flow bypass and spillway fishway systems similar to that of Rushy Creek be constructed on other water supply dams where native migratory freshwater fishes are shown to be present and demonstrated to be impacted.

References


Beatty, S., Morgan, D.L. and Fazeldean, T. (2008a) McLeod Creek (Blackwood River) fish survey: December 2007, Centre for Fish and Fisheries Research, Murdoch University, Western Australia.


Morgan, D.L. and Beatty, S. (2004a) Margaret River Fishway, Centre for Fish and Fisheries Research, Murdoch University, Western Australia.

Morgan, D.L. and Beatty, S. (2004b) Monitoring the Lion’s Weir Fishway - Hotham River, Centre for Fish and Fisheries Research, Murdoch University, Western Australia.

Morgan, D.L. and Beatty, S. (2005) The Lion’s Weir Fishway – Hotham River, Western Australia, Centre for Fish and Fisheries Research, Murdoch University, Western Australia.


Seewraj K., Beatty, S., Allen, M., Keleher, *in press* Fish passage for on-stream farm dams in the south west of Western Australia: a large-scale case study. 5th Technical Workshop on Fishways. Proceedings.