Mitigating the impact of Serpentine Pipehead Dam works on Carter’s Freshwater Mussel

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Summary & recommendations

- This management program aimed to mitigate the risk to the Carter’s Freshwater Mussel (*Westralunio carteri*) population within the Serpentine Pipehead Dam associated with the draining of the reservoir for engineering works.

- Three sites within the upper half of the Serpentine Pipehead Dam were surveyed for freshwater mussel populations and a portion of the population was relocated to maintain the population which would otherwise be at risk of dehydration and predation.

- Immediately prior to the draining event, 1163 live freshwater mussels were hand-collected and relocated to a permanent pool at the upstream end of the reservoir, known as ‘The Clams’ in order to ensure their survival.

- It was revealed that a sizeable population of *W. carteri* existed throughout the length of the dam in densities ranging from 1 to at least 8 mussels/m², with sizes ranging from 16 to 100 mm in length. Although the age of this population of mussels is unknown, the mussels surveyed were dominated by larger individuals and are probably an aging population.

- Mussels exposed to drying experienced 21.7% mortality, but those that remained in moist substrate along steeper banks in more heavily shaded areas were mostly alive (93% survival).

- A subsequent survey of the population following refill is recommended to determine the viability of the remaining population. Furthermore, maintaining the live *W. carteri* within ‘The Clams’ site is recommended.

- As demonstrated for other freshwater mussel species, Carter’s Freshwater Mussel would undoubtedly significantly contribute to filtration of water within this and other water supply reservoirs of the south-west and therefore should be viewed as a valuable biological asset within these reservoirs.

- Undertaking draining of reservoirs during cooler periods is recommended to increase the likelihood of survival of Carter’s Freshwater Mussel and other aquatic fauna.

- Although draining of reservoirs have the potential to have major impacts on resident aquatic fauna, faunal management programs such as that conducted here can offset that impact and ensure ongoing population viability post refill.
Introduction

Freshwater mussels in south-western Australia

In order to mitigate the potential negative impacts on aquatic fauna caused by the draining of impoundment reservoirs, surveys and management programs within numerous reservoirs in south-western Australia have been successfully undertaken over the past decade (e.g. Beatty et al. 2003; Molony et al. 2003; Molony et al. 2005; Morgan & Beatty 2004; Beatty et al. 2006; Klunzinger et al. 2011a). Freshwater mussels are important in maintaining functional freshwater ecosystems (Vaughn & Hakenkamp 2001) with a great capacity to filter plankton, algae and other particulate material from the water column, thus maintaining water clarity and quality. Their empty shells also provide refuge for other freshwater fauna, including juvenile Marron (Cherax cainii and Cherax tenuimanus), gobies (Pseudogobius olorum and Afurcagobius suppositus) and other freshwater crayfishes. They oxygenate the sediments through their burrowing habit, as evidenced by tracks that can be seen in the sediments. They are also a favoured food item by water birds (e.g. Porphyrio porphyrio, Threskiornis molucca, Threskiornis spinicollis), water rats (Hydromys chrysogaster), aquatic reptiles and Marron (see Vestjens 1972; Woollard et al. 1978; Shannon & Mendyk 2009; Klunzinger et al., unpublished data). Their sensitivity to environmental changes makes freshwater mussels important bio-indicators of freshwater ecosystem health (Ponder & Walker 2003).

Most freshwater mussels have a life cycle intricately associated with freshwater fishes. The larvae of most species have an obligate parasitic phase which generally requires a fish as a host for development and dispersal. A recent study by Klunzinger et al. (2012a) has revealed that glochidia (parasitic larvae) of Carter’s Freshwater Mussel (Westralunio carteri), the only freshwater mussel species found in south-western Australia, undergo metamorphosis to the juvenile stage on most native freshwater fishes and Eastern Gambusia (Gambusia holbrooki), but not Goldfish (Carassius auratus) or Pearl Cichlid (Geophagus brasiliensis). Failure of these feral species to support the life cycle of W. carteri has serious implications for the species in areas dominated by these feral fishes.

Glochidia were generally restricted to the fins of host fishes and virtually non-existent on the gills or body. The fishes which were exposed to glochidia in captivity showed no ill effect. Rather than being a threat to fish stocks, freshwater mussels improve and maintain water quality in freshwater rivers, lakes and other water bodies, which benefit freshwater fishes (Treasurer et al. 2006). Glochidia attachment to host fishes is a natural phenomenon and a necessary part of the mussel’s life history, which also functions as a dispersal method. In the host fishes which were experimentally exposed to glochidia of W. carteri, juvenile mussels (i.e. metamorphosed glochidia) detached from the fishes 21-27 days post-exposure (Klunzinger et al. 2012a).
*Westralunio carteri* is a seasonal spawner, spawning in late winter (July); embryos are brooded until mid-spring/early-summer developing into mature glochidia, which are released on mucus strands in response to warming water temperatures and external stimuli during late August, peaking in October to November. Females are virtually spent by December (Klunzinger 2011; Klunzinger *et al.* 2011b, 2012a and unpublished data). Little is known about the juvenile stage of freshwater mussels due to their difficulty to locate in wild populations, but mortality is generally thought to be high from predation by other macroinvertebrates and they are quite sensitive to interstitial ammonia (Walker *et al.* 2001).

Results of a PhD study have shown that *W. carteri* has undergone major population loss from salinity, climate change and human activity (Klunzinger *et al.*, unpublished data), suggesting the species is probably more threatened than previously believed to be and its current IUCN listing as ‘Least Concern’ is probably inappropriate. Significant mortalities of the species resulting from water removal and dehydration within the Helena Pipehead Dam, necessitated the translocation of remaining live mussels (n = 1205) into a refuge pool downstream from the dam in April 2011 (Klunzinger *et al.* 2011a). The current study is the second to focus on freshwater mussels within reservoirs of the south-west.

**Scope of works**

The Western Australian Department of Fisheries sub-contracted the Murdoch University Freshwater Fish Group and Fish Health Unit to manage a population of Carter’s Freshwater Mussel within Serpentine Pipehead Dam, as part of a planned reduction in water levels during engineering works, in April 2012. The aims of the management program were to:

- Determine the rate of mortality of exposed mussels within the dam.
- Determine the population structure, density and viability of *W. carteri* within the sections of the dam which were most likely to become exposed during dewatering.
- Relocate a portion of the live *W. carteri* to a holding pool in the Serpentine Dam to mitigate the risk of population loss via ensuring brood stock survival.
Materials and methods

**Sampling sites**

The study area included a total of 1250 m² at three localities within the Serpentine Pipehead Dam (Figure 1). To estimate mortality of mussels within areas of the dam that had already become dry, a series of transects (n = 6), each 50 m in length were arranged along the shore line with two transects in each sampling site. Live mussels from the transects and from within the submerged areas of each site were collected and relocated to a permanent pool containing a gauging station weir near the base of the Serpentine Dam wall, known as ‘The Clams’ (Figure 1).

**Freshwater mussel sampling techniques**

Within each sampling locality, two transects, each 50 m in length were oriented parallel to the water’s edge and ~2 m from the water in areas of the dam which had been exposed to drying. For each transect, on either side of the transect line, 10 x 1 m² quadrats were placed randomly and the number of mussels within each quadrat were counted, measured according to McMichael & Hiscock (1958) and their status (living or dead) was recorded. Any mussels from the quadrats found to be living were relocated to The Clams site. Additionally, live mussels were collected from the submerged area within each locality and relocated to The Clams in order to maintain brood stock within the dam. A sub-sample (n = 200) of *W. carteri* from each submerged collection group was measured for maximum shell length prior to being released into the holding pool at The Clams. Substrate type from each quadrat was also noted.

**Water sampling methods**

Water quality (temperature (°C), pH, dissolved oxygen (DO as % and ppm), salinity (ppm), total dissolved solids (TDS as ppm) and conductivity (µS/cm)) was measured using a YSI™ Professional Plus multimeter (YSI Inc., Yellow Springs, Ohio 45387, USA), which was pre-calibrated according to the manufacturer’s instructions. At each sampling locality, measurements were taken at three sampling points and a mean and standard error for each test variable was determined.

**Statistical Analysis**

Mapping of mussel distributions was undertaken under license using ArgGIS™ Desktop 10. Graphical and statistical analysis of mussel densities was undertaken using SigmaPlot™ 12.0. Differences were tested for significance at the P<0.05 level by analysis of variance and correlations of substrate and density were tested using Spearman’s analysis. Comparisons of proportional data were tested using Chi-square analysis.
FIGURE 1. Distribution of Carter’s Freshwater Mussel within the Peel Catchment. Study area (Serpentine Pipehead Dam) shown in red. (Klunzinger et al., unpublished data). Sampling sites for this study are shown (top right). 'The Clams' gauging station is located adjacent to and upstream from Site 1.
Sampling quadrat

Mussel Length measured with callipers (mm)

Water quality testing
### Results and discussion

**Freshwater mussel ecology**

*Westralunio carteri* was found throughout the Serpentine Pipehead Dam, including upstream areas of Site 1 all the way downstream through Sites 2 and 3 and to the dam wall. Where mussels were found, densities ranged from 1 to 8 mussels/m\(^2\) within quadrats, with means ranging from 0.10 to 2.55 mussels/m\(^2\). The greatest density of live mussels occurred within Transect 6 (\(H = 29.9, \text{ df } = 5, \ P < 0.001\)), however there were no other significant differences between transects (Table 1). Transect 6 was unique in that it was well shaded and had a greater mean estimated bank slope than any other transect, which probably contributed to the greater overall density and density of live mussels than other transects. Mussel density was positively correlated with bank slope (\(P = 0.02\)), which is in agreement with other studies of freshwater mussels elsewhere (e.g. Hastie *et al.* 2004).

<table>
<thead>
<tr>
<th>Site</th>
<th>Transect</th>
<th>Area (m(^2))</th>
<th>No. live mussels</th>
<th>Density of live mussels (number/m(^2))</th>
<th>No. dead mussels</th>
<th>Density of dead mussels (number/m(^2))</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>20</td>
<td>5</td>
<td>0.25 (±0.30)</td>
<td>2</td>
<td>0.10 (±0.14)</td>
</tr>
<tr>
<td>1</td>
<td>2</td>
<td>20</td>
<td>2</td>
<td>0.10 (±0.14)</td>
<td>10</td>
<td>0.50 (±0.32)</td>
</tr>
<tr>
<td>1</td>
<td>Submerged</td>
<td>260</td>
<td>263</td>
<td>1.01</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>2</td>
<td>3</td>
<td>20</td>
<td>14</td>
<td>0.70 (±0.34)</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>2</td>
<td>4</td>
<td>20</td>
<td>9</td>
<td>0.45 (±0.36)</td>
<td>2</td>
<td>0.10 (±0.14)</td>
</tr>
<tr>
<td>3</td>
<td>5</td>
<td>20</td>
<td>13</td>
<td>0.65 (±0.41)</td>
<td>10</td>
<td>0.50 (±0.42)</td>
</tr>
<tr>
<td>3</td>
<td>6</td>
<td>20</td>
<td>51</td>
<td>2.55 (±1.22)</td>
<td>2</td>
<td>0.10 (±0.14)</td>
</tr>
</tbody>
</table>

**Mortality**

Overall, mortality within transects was 21.67%. The greatest level of mortality was observed in Transect 2 and the least in Transects 3 and 6 (\(\chi^2 = 47.48, \text{ df } = 5, \ P < 0.0001\)). Transect 6 was the most well shaded of all of the transects, which could have allowed exposed sediments and the mussels themselves to retain more moisture than those exposed to direct sunlight. Although we did not test exposed sediment moisture, Transects 3 and 4 appeared to have retained more moisture than other transects (apart from Transect 6), which may have been accredited to an overlying layer of algal cover, which was not present in other transects. Transect mortalities are presented in Figure 2. The number of dead mussels submerged within Site 1 was effectively nil. We were unable to measure the mortality of mussels within submerged areas of Sites 2 and 3 because of water source protection restrictions.
Figure 2  Mortality observed in each transect surveyed for freshwater mussels (*Westralunio carteri*) within the Serpentine Pipehead Dam. 95% confidence intervals are given in brackets.

Examples of dead (left) and live burrowed (right) *W. carteri* within the Serpentine Pipehead Dam.
**Freshwater mussel population composition**

Mussels ranged in size from 16 to 100 mm shell length. Shell morphology conformed to *W. carteri* as described by McMichael & Hiscock (1958) and Walker (2004). Length-frequency histograms of *W. carteri* each sub-population of *W. carteri* from transects and submerged areas within the Serpentine Pipehead Dam are presented in Figure 3. There were no significant differences in mean length between submerged mussels in Site 1 and those within Site 1 transects (68.36 vs. 74.47 mm, respectively) or between Sites 2 and 3 (79.66 vs. 80.84 mm, respectively). Mean shell lengths of mussels in sites 2 and 3 were, however, significantly larger than mussels from Site 1 (*F* = 12.53; d.f. = 3, 317; *P* < 0.001). To explain these differences would require a more thorough sampling regime to locate smaller mussels and to sample submerged mussels in Sites 2 and 3, but the location of smaller, presumably juvenile mussels in Site 1 may be of significance. Compared to *W. carteri* populations within the lower Serpentine River (see Klunzinger et al. 2012a), the mussels within the dam are large, which may or may not represent differences in age. Other authors caution the assumption that large freshwater mussels equate to old animals and recommend that growth rates and internal shell ring analysis of each individual population should be performed to obtain accurate growth-to-size and age estimates because growth conditions and mussel diets strongly influence these biotic parameters (Walker et al. 2001; Haag et al. 2008; Haag 2009).

**Habitat assessments**

The habitat requirements for juvenile *W. carteri* are not known with certainty, but from our observations in previous studies, they appear to inhabit a range of habitats, particularly favouring shallow habitats with coarse sand. If this is the case, Site 1 may be an important recruitment area for *W. carteri* within the dam. During the study, this area was also noted for its relatively large number of juvenile Marron. Although we do not know the composition of potential host fish populations within the dam, Western Minnows and Eastern Gambusia were seen during this study, both of which are presumed hosts for *W. carteri* (Kunzinger et al. 2012b).

Freshwater mussel habitats within the study area were defined primarily by sediment composition. Woody debris was relatively rare within the areas sampled as is typical of impoundment reservoirs in the region (Morgan et al. 2002; Beatty et al. 2003), but did occur occasionally. Woody debris and leaf litter are important components of freshwater ecosystem complexity, which support fauna at various trophic levels (Pen 1999). In general, the characteristics of sediment types for each transect are described by the following:

**Site 1, Transect 1:** composed primarily of rocky sand with some cobbles and patches of wet to moist mud and silt; very similar in submerged areas except the headwaters which had mostly smooth round rocks and cobbles.
Site 1, Transect 2: mostly wet silt with occasional patches of sand or gravel

Site 2, Transects 3 and 4: mostly damp silt, but seldom with sand or gravel; most of the area was covered by dried filamentous algae, macrophytes that had formed a crust overlying the substrate; Transect 4 also had small and occasionally large woody debris intermingled with the substrate.

Site 3, Transect 5: comprised of large patches of silt or loamy sand which was relatively dry with occasional woody debris.

Site 3, Transect 6: characterised by red coloured substrate, which probably contained a significant amount of laterite; this transect was much better shaded by riparian vegetation than the other sampling localities; substrates were a mixture of sandy loam and silt with some gravel and cobble. This site had the greatest densities of mussels of all of the areas that were sampled for *W. carteri*, which was probably associated with shading and bank slope and the substrates may have been ideal for live adult mussels. A combination of shading and substrate moisture retention probably improved mussel survivability, but the steep slopes may have also been unsuitable for potential predators, such as feral pigs, which are known to predate mussels within the dam (P. Adams pers. comm., 2012).

**Water quality**

The sites we sampled during this study all had well-oxygenated fresh waters with semi-basic pH, low TDS and mild temperatures, which are presented in Table 2.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Site 1</th>
<th>Site 2</th>
<th>Site 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Date</td>
<td>24 April, 2012</td>
<td>24 April, 2012</td>
<td>24 April, 2012</td>
</tr>
<tr>
<td>Time</td>
<td>10:00 AM</td>
<td>10:20 AM</td>
<td>3:00 PM</td>
</tr>
<tr>
<td>Temperature (°C)</td>
<td>17.6 (±0)</td>
<td>17.7 (±0.27)</td>
<td>19.4 (±0.03)</td>
</tr>
<tr>
<td>Conductivity (µS/cm)</td>
<td>244.2 (±0.97)</td>
<td>265.9 (±0.67)</td>
<td>246.5 (±0.35)</td>
</tr>
<tr>
<td>Salinity (ppm)</td>
<td>140 (±0)</td>
<td>150 (±0)</td>
<td>130 (±0)</td>
</tr>
<tr>
<td>TDS (ppm)</td>
<td>184.6 (±0.38)</td>
<td>200.6 (±0.78)</td>
<td>191.1 (±0)</td>
</tr>
<tr>
<td>pH</td>
<td>7.3 (±0.01)</td>
<td>7.2 (±0.04)</td>
<td>7.3 (±0.01)</td>
</tr>
<tr>
<td>DO (%)</td>
<td>90.8 (±0.80)</td>
<td>90.8 (±1.35)</td>
<td>80.4 (±3.56)</td>
</tr>
<tr>
<td>DO (ppm)</td>
<td>8.7 (±0.06)</td>
<td>8.6 (±0.12)</td>
<td>7.4 (±0.34)</td>
</tr>
</tbody>
</table>
Figure 3  Length-frequency histograms of freshwater mussels (*Westralunio carteri*) sampled from the Serpentine Pipehead Dam.
Conservation implications and recommendations

- Serpentine Pipehead Dam contained high densities of Carter’s Freshwater Mussel, which almost certainly be acting as an important biological water filter in this and other Water Corporation reservoirs.

- This study shows that Carter’s Freshwater Mussel is recruiting within the dam, but a majority of mussels collected are large and probably old, although growth studies are recommended to determine age and future population viability.

- Follow-up monitoring of *W. carteri* within the areas that were exposed and those which remained submerged after the reservoir has been drained and after water levels return should be undertaken in order to determine long-term population viability.

- Maintaining adequate water levels for the relocated population of *W. carteri* within ‘The Clams’ site will be vital in future restocking efforts.

- Undertaking draining of reservoirs during cooler periods is recommended to increase the likelihood of survival of Carter’s Freshwater Mussel and other aquatic fauna.

- Although draining of reservoirs has the potential to have major impacts on resident aquatic fauna, faunal management programs such as that conducted here can offset that impact and ensure ongoing population viability post refill.

**Acknowledgements:**

We thank Mike Snow and Rodney Duffy for coordinating the project. Thanks also to Jeff Doust for coordinating access and site induction within the study area and catchment ranger Kevin Lillee for site orientation. We also thank Alan Lymbery for helpful comments during the drafting of this report.
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Morgan D & Beatty S (2004). *The aquatic macrofauna of Pinwernying Dam (Katanning)*. Centre for Fish & Fisheries Research, Murdoch University Report to the Water Corporation of Western Australia.


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*After relocation to ‘The Clams’, live freshwater mussels were actively burrowing through the sediments, as shown above.*