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Baseline assessment of Carter's Freshwater Mussel, *Westralunio carteri*, at proposed bridge construction sites on the Lower Vasse River

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SUMMARY AND RECOMMENDATIONS

Freshwater mussels are important components of freshwater ecosystems as they can act as ecosystem engineers and improve water quality through filtration. Carter's Freshwater Mussel, *Westralunio carteri*, is the only freshwater mussel species in the south-west of Western Australia and is classified as *Vulnerable* on the IUCN Red List of threatened species, and as *Threatened* under the Western Australian Wildlife Conservation Act 1950. The species has lost approximately 50% of its former habitat through salinisation and habitat degradation.

City of Busselton proposes to undertake an extension of the existing Causeway Road Bridge and additionally, construct a new bridge (the 'Eastern Link') east of the existing footbridge, on the Lower Vasse River (hereafter referred to as the 'impact sites'). As *W. carteri* is known to inhabit the Lower Vasse River, construction at the proposed bridge development sites had the potential to affect mussels, should they be present at or near the impact sites; particularly given the proponents existing data that suggests bridges can attract the species. Therefore a baseline assessment of the distribution and population density and structure of the species at the impact and reference sites was undertaken with the aim of assessing the likelihood of impact on the species and provide recommendations to mitigate any impacts identified associated with the proposed bridge development activities.

The study revealed that Carter's Freshwater Mussel were present at both of the impact sites and also at each reference site upstream and downstream of the bridge development sites. Mussel density was greater at the impact sites compared with the reference sites, possibly reflecting its preference for occupying habitats under and adjacent to bridges. Given the disturbance of the river bed and potential increased turbidity and reductions in dissolved oxygen that may occur due to resuspension of anoxic sediments (including Monosulfidic Black Ooze) associated with the construction phase of the bridge developments, it is recommended that active management of the species occurs to mitigate the effects of the bridge construction at the impact sites.

Specific recommendations:

1) Prior to any disturbance of the river banks or bed associated with the bridge developments, undertake an intensive translocation program of Carter's Freshwater Mussel to mitigate the likelihood of mortality of the species.

2) The translocation site should be upstream where known suitable habitat exists and should be at a distance that would avoid any adverse conditions that may arise from the construction works (such as elevated turbidity.

3) Following completion of the construction phase of the developments, similar numbers of mussels should be relocated to the sites they were collected to avoid density dependent impacts on the population and to ensure the ecosystem services (particularly water filtration) provided by the species are maintained at the impact sites.

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INTRODUCTION

Freshwater mussels (Bivalvia: Unionoida) are an important component of freshwater ecosystems. The filter feeding function of the group is able to remove sediment and pollutants from the water columns (Idrisi et al., 2001; Caraco et al., 2006), thereby improve water quality (Caraco et al., 2006; Mackie & Claudi, 2009). Estimates of filtration rates vary among species but can be up to 1.81 L/hr/g of dry weight of mussels; meaning entire lakes can be filtered by mussel populations in a matter of a few days (e.g. Ogilvie and Mitchell 1995; James et al., 1998). In addition, the activities of freshwater mussels bring numerous other benefits to benthic and pelagic systems (Greenwood et al., 2001; Strayer, 2014). Unfortunately, however, freshwater mussels constitute one of the most endangered groups of organisms throughout the world (Bogan, 2008; Walker et al., 2014; IUCN, 2016).

Carter's Freshwater Mussel, *Westralunio carteri*, is the only native freshwater mussel in south-western Australia. Until recently, however, until recently almost nothing was known about the biology or conservation status of this species. The distribution of *W. carteri* has recently been mapped and it was found that the range of the species has contracted by 49% in less than 50 years, principally because of secondary salinisation and reduced water flow from a drying climate (Klunzinger et al., 2015). As a direct result of this research, the species has recently been classified as *Vulnerable* on the IUCN Red List of threatened species (Klunzinger & Walker, 2014), and as *Threatened* under the Western Australian Wildlife Conservation Act 1950.

Mussels are routinely (albeit often accidentally) removed during river engineering works (e.g. McIvor, 2004). Previous work by the proponents revealed *W. carteri* to be present in the Lower Vasse River, Busselton. The City of Busselton proposes to undertake an extension of the existing Causeway Road Bridge and additionally, construct a new bridge (the 'Eastern Link') east of the existing footbridge, on the Lower Vasse River (hereafter referred to as the 'impact sites'), Busselton. During planning for the proposed bridge development, Strategen Environmental and the City of Busselton identified the possible presence of *W. carteri* at the proposed construction area. Given the proposed bridge development would involve physical disturbance of the river bed and potential elevated turbidity, it may therefore impact *W. carteri* populations in the impact sites should it be present. While Lymbery et al. (2008) found the species to be present in the section of the river, a baseline assessment of the species in the impact sites was required in order to provide an assessment of the potential impact to the species associated with the bridge construction works and develop a strategy to mitigate any impact this may have.

The current project aimed to provide a robust assessment of the status of Carter's Freshwater Mussel at the proposed bridge development sites in the lower Vasse River. It also aimed to provide an assessment of the risk and potential impact to the population of the species in the lower Vasse River that may arise from the proposed bridge development. It then aimed to provide specific recommendations to mitigate the risks to the species at the bridge development sites.

METHODS

The survey approach followed the methods previously used to quantify the distribution and population structure of the species at impact and reference sites in the lower Vasse River (Klunzinger et al., 2012a; Klunzinger et al., 2012b). A total of four sites were surveyed in early September 2017 and included the two impact sites and two reference sites upstream and downstream of the impact sites (Figure 1). In each of the impact sites, both banks were surveyed for mussels to a wadeable depth; known to be the primary habitat for the species (Klunzinger et al., 2012a). A single bank was surveyed in each reference site.

At each site, the benthos within five randomly placed 1 m^2 quadrats was intensively surveyed by hand (total of 30 quadrats) and the shell length of each individual measured to the nearest 1 mm, before being returned to the site of capture. Mussel density was determined within each quadrat and the significance of differences in density between impact and reference sites determined using a bootstrap t-test. Length-frequency distributions of mussels at each site were plotted and the mussel age distribution estimated using the method of Klunzinger et al. (2014).

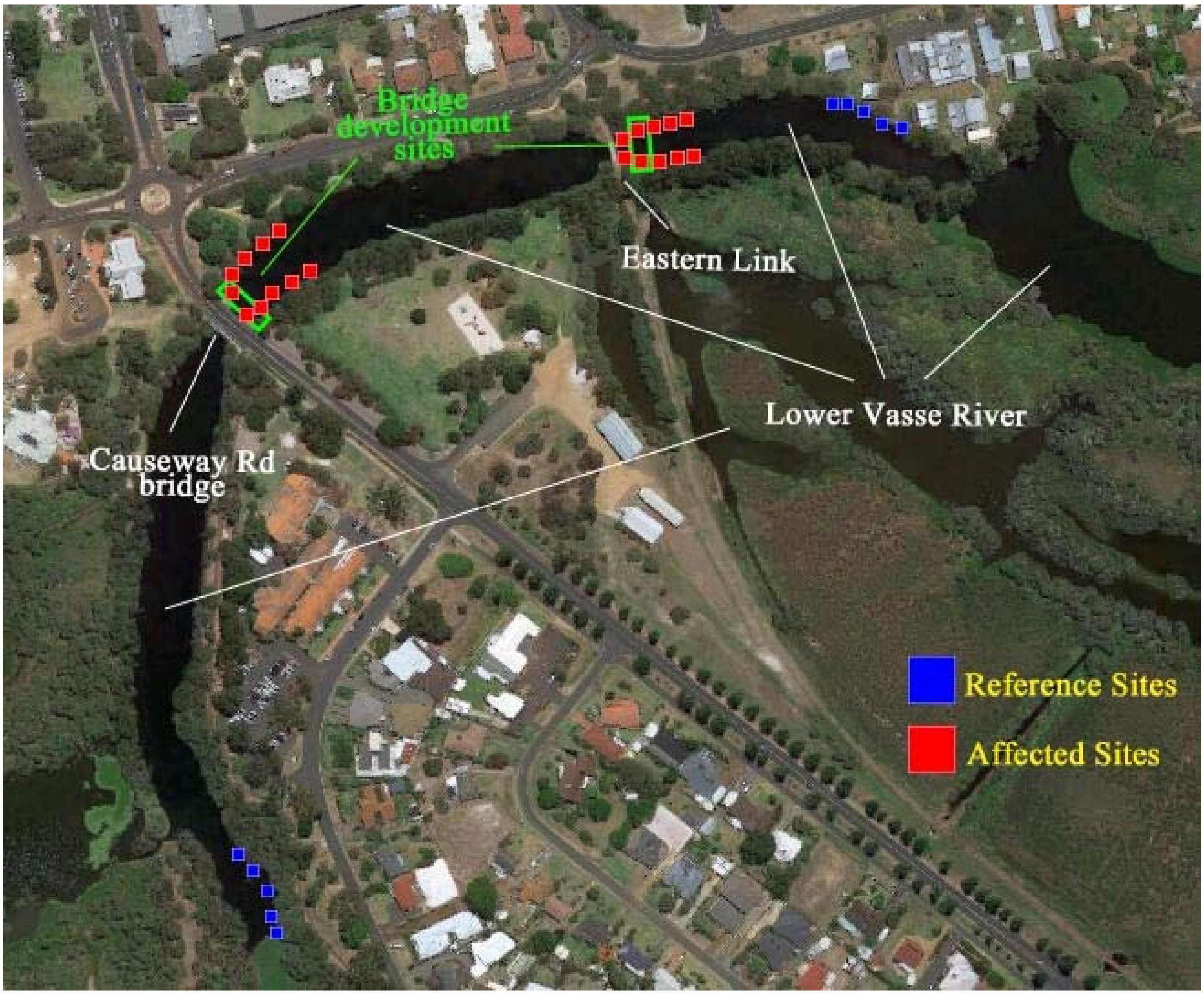

Figure 1: The quadrats and proposed bridge development sites on the Lower Vasse River, Busselton.

RESULTS AND DISCUSSION

Westralunio carteri was recorded at all four sites in the Lower Vasse River. Mussels were not evenly distributed among the sites, with the highest densities occurring at the Causeway Rd bridge site and second highest at the Eastern Link bridge site (Table 1). However, due to the relatively small sample sizes, the differences in mussel densities between impact and reference sites were not significant ($p = 0.119$). The mussel densities at the impact sites was higher than three sites surveyed previously in the lower Vasse River (mean density: 0.9 ± 0.2 mussels/m^2) and similar to densities at other localities in the Geographe Bay catchment (Vasse River Diversion Drain, Carbanup River, Abba River and Ludlow River: 3.1 ± 1.4 mussels/m^2) (Lymbery et al. 2008). The only other quantitative surveys of densities for *W. carteri* have been in the Serpentine River (0.8 ±0.3 mussels/m^2; Klunzinger et al. 2012b) and the Helena River (2.0 ±0.7 mussels/m^2; Klunzinger et al. 2011). Despite great densities of mussels being recorded in this survey compared with that of Lymbery et al. (2008) in the Lower Vasse River, this is the first survey for the species at the actual impact site so we cannot conclude that mussel density has increased in the Lower Vasse given densities may vary within river reaches.

Table 1 Mean density (± standard error) of *Westralunio carteri* at the four localities sampled in the Lower Vasse River.

Site	Locality	Density (Individuals/m^2)
RB	Causeway Road Bridge	2.5 ± 1.2
FB	Eastern Link (Foot Bridge)	1.8 ± 0.8
ReU	Upstream Reference	0.6 ± 0.2
ReD	Downstream Reference	1 ± 0.4
Subtotal Bridge Development Sites		2.15 ± 0.7
Subtotal Reference Sites		0.8 ± 0.2
All Sites		1.7 ± 0.5

These findings support anecdotal evidence from our previous presence/absence surveys in the south-west of Western Australia (Klunzinger *et al.* 2015) that has suggested habitat around bridges is preferred by *W. carteri*. This apparent preference for bridge sites may be due to the species favouring the shade created by the bridge that may provide benefits in terms of a cooler, more stable environment (Hastie et al., 2000). Moreover, bridge piers may act as shelter from high flow events. While there are no published studies on the micro-habitat preferences of *W. carteri*, this topic currently being investigated as part of a PhD study by one of the authors (L. Ma). Preliminary analyses have found a significant positive effect of large woody debris on mussel density ($P = 0.02$), suggesting that protection from water flow may be important in determining habitat quality.

The population structure of *W. carteri* in the impact sites and the reference sites was interpreted through the analysis of length-frequency histograms (Figure 2). Evidence of consistent recruitment to the population was only noted at the impact sites due to the presence there of multiple size cohorts including a single juvenile mussel (shell length < 45 mm, less than 5-year-old at a lower estimate) (Figure 2). However, it should be noted that the hand-searching method, while very efficient at rapidly assessing densities and size structure of larger cohort of mussels is biased to larger mussels. Nonetheless, it is reasonable to conclude that the mussel population in the lower Vasse River is self-maintaining and the impact sites contribute significantly to the viability of the population by providing preferred habitat. One quadrat that contained water lilies had no mussels present, that may suggest the species avoids habitat invaded by this macrophytes that has greatly increased its distribution and abundance in the Lower Vasse River over the past ~5 years (S. Beatty pers. obs.).

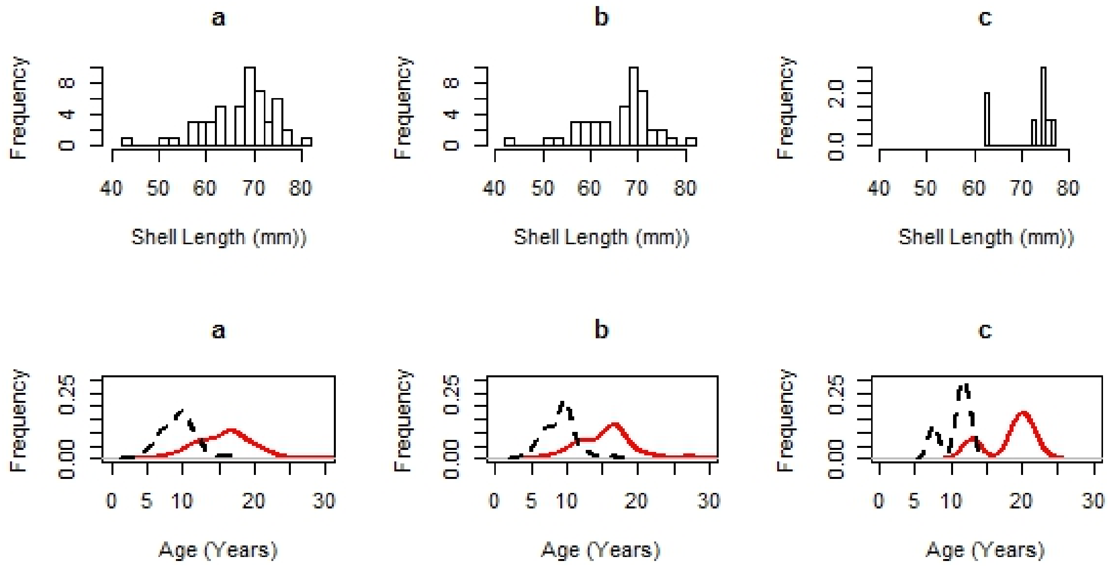

Figure 2: The length-frequency distribution and estimated age structure of *Westralunio carteri* in a) all sites, b) proposed bridge development sites and c) reference sites, in the Lower Vasse River.

Westralunio carteri is unique in being the only species of freshwater mussel found in south-western Australia and the only member of the genus *Westralunio* in Australia. Klunzinger et al. (2015) found that the range of *W. carteri* has contracted by 49% in less than 50 years, principally as a result of secondary salinisation. The species is now confined to non-salinised rivers and streams, principally in forested catchments along the west and south coasts. In the Geographe Bay catchment, *W. carteri* has apparently been lost from the Sabina River and the Buayanup River (Lymbery et al. 2008; Klunzinger et al. 2015). Maintaining existing populations is crucial for the survival of the species and, considering the importance of freshwater mussels in improving water quality, for the maintenance of freshwater ecosystem function.

The construction activities will impact on the current mussel bed by direct physical disturbance of the sediment arising from construction of earth abutments to reduce the span of the bridge. Along with berrying and smothering mussels, the construction may result in suspension of Monosulfidic Black Ooze (MBO, organic material high in iron monosulfides) into the water. The negative impacts of sedimentation on the Carter’s Freshwater Mussels have been discussed in previous studies (Klunzinger et al., 2015). Additionally, sulfides from MBO may react with metal cations, produce toxic metal sulfides and decrease the dissolved oxygen level (Sheldon & Walker, 1989; Bush et al. 2004). While specific toxicity tests for metal sulfides have not been undertaken for Carter's Freshwater Mussel, freshwater mussels elsewhere are known to be sensitive to such contaminants (Wang et al., 2013) and prolonged periods of low dissolved oxygen is also known to negatively impact other mussel species (Chen et al., 2001). To mitigate these risks to the resident mussels, it is therefore highly recommended that the mussel beds be relocated prior to the construction phase of the project commencing and that every effort be made to minimise resuspension of sediments.

CONCLUSIONS

The study has provided a baseline assessment of the mussel population in the lower Vasse River and revealed that it is likely to be self-maintaining. *Westralunio carteri* was present at both of the impact sites and also at each reference site upstream and downstream of the bridge development sites. The proposed bridge development sites had higher densities and a greater range of age cohorts than the reference sites and would contribute to the viability of the population by providing preferred habitat. Given the known impacts of river bed disturbance on freshwater mussels and the potential impact of the bridge developments on the species, it is recommended that active management of the species occurs to mitigate the effects of the bridge construction at the impact sites. Mussels can be successfully translocated from impact sites and returned following disturbance, as shown by previous studies during maintenance work on the Helena River pipehead dam (Klunzinger et al. 2011) and the Serpentine River pipehead dam (Klunzinger 2012b).

RECOMMENDATIONS

1) Prior to any disturbance of the river banks or bed associated with the bridge developments, undertake an intensive translocation program of Carter's Freshwater Mussel to mitigate the likelihood of mortality of the species. This should involve thorough searching of the impact site, including sieving of sediments to locate juvenile mussels.

2) The translocation site should be upstream where known suitable habitat exists and should be at a distance that would avoid any adverse conditions that may arise from the construction works (such as elevated turbidity. The upper Vasse River, in the vicinity of the junction with the Vasse Diversion Drain, would provide a suitable site for translocation

because it supports a large, viable population of mussels (Lymbery et al. 2008) and is protected from public access.

3) Mussels can be maintained in cages within the translocation site, with weekly monitoring to ensure that an adequate flow of water is maintained in the cages. Following completion of the construction phase of the developments, relocated to the sites they were collected to avoid density dependent impacts on the population and to ensure the ecosystem services (particularly water filtration) provided by the species are maintained at the impact sites.

4) Prior to relocation, the water quality (particularly DO_2 and turbidity) of the impact site should be monitored to ensure that conditions are suitable before the mussels are released.

5) It is recommended that the translocation process be undertaken or overseen by qualified freshwater biologists to ensure that all mussels, including juveniles, are collected and to minimise the risk of mortality during mussel relocation.

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