March 2020

Aquatic fauna and flora surveys at the Lennox Weir, Busselton

Prepared for:
Water Corporation

Prepared by:
Centre for Sustainable Aquatic Ecosystems
Harry Butler Institute
Murdoch University

Prepared for:

Water Corporation
Contact: Klara Allsopp
Senior Advisor - Environmental Approvals
Operations Services Group

Prepared by:

S. Beatty, R. Paice[1], K. Hastings[1], V. Summers, L. Ma, D. Morgan
Centre for Sustainable Aquatic Ecosystems, [1]Ottelia Ecology
Harry Butler Institute
Murdoch University, South St
Murdoch, Western Australia 6150

Distribution List:

Organisation	Contact Name	Date
Water Corporation	**Klara Allsop**	**19/02/2020**

Document Control:

Document Status	Prepared By	Date
Draft report Version 1	**Stephen Beatty, Robyn Paice, Kirrily Hastings, Vita Summers, Le Ma**	**19/02/2020**
Draft report Version 2	**Stephen Beatty, Robyn Paice, Kirrily Hastings, Vita Summers, Le Ma**	**11/03/2020**

The authors acknowledge the Noongar people who are the Traditional Custodians of the land on which this research took place.

Frontispiece: Lennox Weir in January 2020.

Executive Summary

Water Corporation proposes to undertake infrastructure works on the Lennox Weir, near Busselton, Western Australia. Due to the potential impact on aquatic fauna and flora associated with the proposed works, the Water Corporation engaged the Harry Butler Institute (Murdoch University) to carry out a desktop review and field survey for flora and fauna upstream and downstream of the structure. The study aimed to provide an assessment of the likely impacts of the proposed works on prevailing native species, and develop recommendations to mitigate any potential identified impacts.

A desktop assessment of the fauna and flora communities around Lennox Weir was initially conducted. Subsequently, standardised surveys were conducted for flora and fauna at Lennox Weir in August 2019, again in October 2019 for flora, and finally in January (into early February) 2020 for flora and fauna.

The proposed replacement or removal of the Lennox Weir was found to have a moderate to high risk of localised impacts on freshwater fishes upstream; based on the four storm surge scenarios modelled by GHD (2018a). Contrary to recent impact assessment by GHD (2018b), high abundances of native fishes were found to be present upstream of the weir in summer, which could be impacted by sudden increases in salinity predicted by the storm surge modelling. The upstream spatial extent of this impact would depend on the storm surge scenario. However, under all scenarios freshwater fishes are likely to be impacted (including potential high levels of mortality) in zone 2 (from the weir to 500m upstream) and a proportion of zone 3 (between 500-1100m upstream). However, while the known acute salinity tolerances of resident native fishes would be exceeded in those sections, the behavioural responses of the fishes may help to partially or totally) mitigate the impacts. This could include moving upstream away from the incoming saline water, or more likely, utilising a freshwater lens that may be present. However, the hydrological modelling by GHD (2018a) did not consider or model the potential for a freshwater surface layer to form. Additional modelling would be required to better predict whether these factors could occur to mitigate the impacts on freshwater fishes.

The assessment also revealed that the Threatened (EPBC Act 1999) Carter's Freshwater Mussel *Westralunio carteri* was present in the Lennox River from just upstream of the weir to at least the Vasse-Yallingup Siding Rd. However, its relative abundance increased significantly with distance upstream of the weir and the lowest abundances were found in zones 2 and 3; the sites predicted to be most affected by increased salinity under the modelled storm surge scenarios. As concluded by the previous impact assessment (GHD 2018b), the risk to the species of the increase in salinity would be high to moderate in zones 2 and 3 with residual salinity after 24 hours under all four storm surge scenarios projected to exceed its known tolerances in zone 2 and a proportion of zone 3. However, there remains uncertainty of this impact owing to the fact that modelling of residual salinity was only undertaken for a 24 hour period. Previous acute salinity trials of the species revealed the initial deaths occurred after 10 days at 8 mg/l, highest salinity level tested. The impact on the species in terms of mortality would therefore likely depend on the longer-term residual salinity levels following storm surges.

The impact on the South-west Snake Neck Turtle *Chelodina colliei* upstream of the Lennox Weir was assessed as low in the current study. While there may be a short-term decline in abundances of salt-intolerant freshwater fishes and invertebrates associated with the modelled storm surges, there were high abundances of alternative prey items present particularly the Blue-spot Goby *Pseodogobius olorum* and South-west Glass Shrimp *Palaemon australis*. While the Smooth Marron *Cherax cainii* was not detected during the current sampling in the impacted reach (only visually observed upstream at the Vasse-Yallingup Siding Rd), additional anecdotal information from the landholder suggested they may be present in low abundances within zone 3. If present, those individuals would have a high risk of impact under all scenarios and would likely walk out of the river to avoid the salinity.

The Lennox Weir survey area occurs within a Conservation Category Wetland area. Upstream and downstream vegetation differed in terms of community structure and condition. The upstream vegetation is an example of very old remnant riparian vegetation and included poorly represented community types. The vegetation provides habitat for the Critically Endangered Western Ringtail Possum, with extensive scat noted throughout the survey area. The P4 species *Eucalyptus rudis* subsp. *cratyantha* occurs in riparian vegetation upstream and downstream and on adjacent land north-east of the weir. Changes to the salinity regime associated with altering the function of the weir are likely to impact this vegetation.

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Introduction and Scope

Water Corporation plans to undertake infrastructure works on the Lennox Weir (CD00162), which is located on the Lennox River between Dunsborough and Busselton. The works are proposed to involve either replacing or removing the weir structure.

The proposed works have the potential to impact resident fauna and flora that would have adapted to the existing habitat conditions at the site, including the hydrology and salinity. The structure is within the tidal reaches of the Lennox River and has restricted the upstream movement of salinity pulses; thus likely to have also enabled the establishment of instream or riparian salt-intolerant flora and fauna. The removal or replacement of the structure may increase the likelihood or frequency of upstream salt passage, and thus salt-sensitive species could be negative impacted. Furthermore, the physical disturbance of the bed and banks (and water quality) associated with on-ground engineering and construction works could also potentially negatively effect instream or riparian flora and fauna.

An assessment of the ecological values around the Lennox Weir was required in order to assess the possible impacts of the proposed works on sensitive (including threatened) flora and fauna and develop recommendations for mitigating identified impacts.

Water Corporation engaged the services of specialist freshwater ecologists from the Harry Butler Institute (Murdoch University) to undertake a desktop review and field surveys for aquatic fauna and flora, around the drainage structures. Specific aims of the study were to:

- Carry out an aquatic field survey at the Lennox Weir.
- Produce an inventory of taxa likely to occur and taxa currently present within the project footprint.
- Identify, map and discuss the significance of any aquatic TECs and any other areas of ecological importance based on results of the field survey.
- Identify and discuss potentially occurring significant aquatic species at the surveyed area.
- Identify and discuss any potential impacts on aquatic ecology at the surveyed area as a result of the proposed works.
- Provide recommendations to manage and minimise impacts on aquatic ecology in the surveyed area.
- Advise on any requirements and support environmental approvals for the proposed project under the *Environment Protection and Biodiversity Conservation Act 1999*, and the Western Australian Biodiversity Conservation Act (2016) and Biodiversity Conservation Regulations (2018).

A Memorandum (Beatty and Paice, 2019) was produced for the Water Corporation in December 2019 summarised the initial findings of the desktop and winter field surveys (at Lennox Weir along with three other proposed drainage infrastructure works sites) and identified knowledge gaps that should be filled and to confirm the scope of the subsequent field surveys.

The results of the desktop and winter fauna survey of Lennox Weir outlined in the Memorandum found that it housed three freshwater fishes both above and below the structure (along with the jawless Pouched Lamprey), with five estuarine species restricted below. Only shells of the *EPBC Act*

(1999) listed (Vulnerable) Carter's Freshwater Mussel *Westralunio carteri* were found upstream of the weir. While the winter survey found no evidence that the structure was directly maintaining freshwater species upstream by preventing salt intrusion during high flows, it recommended conducting an additional survey during summer within the modelled extent of saline intrusion (GHD, 2018a) to confirm that those species were not relying on the weir to survive within that section of the river at the time when the weir would have the greatest impact in terms of preventing upstream saline intrusion and potentially maintain freshwater species.

The results of the desktop and winter flora survey at Lennox Weir concluded that clearing as part of the weir replacement may have an impact due to the presence of significant flora, particularly *Eucalyptus rudis* subsp. *crassyantha*. It also found that contrary to the risk assessment by GHD (2018b), upstream and downstream vegetation differed in terms of community structure and condition. It suggested that changes to the salinity regime associated with altering the function of the Lennox Weir are likely to impact vegetation upstream of the weir. An additional spring survey at the Lennox Weir site was recommended to provide more accurate mapping of vegetation communities and complete targeted search for significant flora.

The current technical report combines the findings of the desktop and winter surveys that occurred at Lennox Weir (Beatty and Paice, 2019), with the findings of the additional surveys that were recommended at the site. Using these results, it assesses the potential impact of the proposed works on the prevailing aquatic flora and fauna.

Methods

Desktop survey

Existing data on the aquatic ecological values around the Lennox Weir were sourced using the following sources:

- Murdoch University's database of fish, freshwater crayfish and *W. carteri*.
- DPIRD and DWER online databases on aquatic flora and fauna.
- Database search requests from DBCA for locations of significant listed flora and threatened and priority ecological communities (TECs and PECs) including use of the NatureMap online resource.
- Relevant reports (e.g. river action plans, catchment vegetation strategies).
- Existing mapping of regional vegetation complexes (Heddle et al. 1980; Mattiske and Havel 1998).
- More detailed likely vegetation complexes associated with soil types and their post-clearing extent from Connell et al. (2000).
- Use of aerial photography to check extent and condition of vegetation as far as practical.
- Species records searches in Atlas of Living Australia online resource; and
- Cross-referencing species searches with a list of priority flora species in the City of Busselton boundary obtained from FloraBase online resource of the Western Australian Herbarium.

Field survey

Fauna

A field survey was conducted at Lennox Weir in August 2019 and in January 2020. The site was split into two sections, one upstream and one downstream of the weir. Each of these sections was 100 m long. Sampling for fish movements and relative abundance involved the use of dual fyke-netting set overnight at upstream and downstream points at the site, and fish traps between the fyke nets. In order to estimate fish and crayfish densities on each sampling occasion, a combination of replicate seine netting and/or back-pack electrofishing (depending on depth and habitat complexity) also occurred. All fish and crayfish captured were identified, enumerated, and a sub-sample measured to provide an indication of population structure and viability. All native fish and crayfish were released unharmed at the site of capture and all introduced species euthanased in an ice-slurry and disposed of at Murdoch University's secure facility in accordance with permits, or preserved for future research into the impacts of introduced species.

Targeted surveys for Carter's Freshwater Mussel (*W. carteri*) involved manual searching of 1 m^2 quadrats along the bank, in each stream section in August 2019 (Klunzinger et al. 2011, 2012a,b, 2013, 2014, 2015; Beatty et al., 2017). The January 2019 sampling at Lennox Weir also involved upstream surveys for *W. carteri* to better assess the potential impact of changes in salinity regimes associated with the replacement or removal of the structure given its location relative to the ocean.

Water quality *in situ* readings were taken including measurements of water temperature, dissolved oxygen (% saturation and mg/L), conductivity (mS/cm), total dissolved solids (g/L), salinity (ppt), pH, and ORP (mV). Photographs were taken at fixed locations at each site on each sampling occasion and to provide a visual baseline for future seasonal changes in riparian vegetation cover and surface water availability.

Flora

In August 2019, a detailed survey was completed of riparian vegetation at Lennox Weir. Vegetation community composition and condition was assessed upstream and downstream of the structure using transects. Transects were positioned at right angles to the river from the seasonally-inundated zone to the edge of the riparian zone, defined by the presence of dryland vegetation communities or pasture. Four transects were established on each side of the Lennox River, upstream and downstream (16 transects in total). For each transect, cover for each flora species present was recorded at five 1m^2 randomly placed quadrats within each vegetation community. Where a community covered less than 5m of the transect line, additional quadrats were done on perpendicular to the transect line. In October 2019, traversing was undertaken throughout the Lennox Weir site to search thoroughly for priority flora, with a focus on potentially occurring species identified in the desktop study.

Flora were identified on site and through identification of voucher specimens, with confirmation sought from the Western Australian Herbarium where required.

Assessment of aquatic plants was undertaken at the Lennox Weir site in August 2019, and again in October 2019 and February 2020. The river reaches were assessed as sections corresponding to transect locations, and visual assessment of plants done within wadable distance from each bank. All aquatic (submerged and semi-emergent) plant species present were identified and scored using the Braun-Blanquett cover scale: (r = solitary plant, small cover; x = few plants, small cover; 2 = cover 5-25%; 3 = cover 25-50%; 4 = cover 50-75%; 5 = cover > 75%).

Results

Desktop survey

Fauna

The desktop review of aquatic fauna revealed that no threatened species of freshwater fish or crayfish were known from near the Lennox Weir nor within conceivable upstream incursions of tidal movement should it be removed or replaced. However, it revealed that there was a lack of past survey effort around the structure.

The historical *W. carteri* presence sites in the Lennox River were from upstream of the Lennox Weir (Figure 1). Sampling effort in the region was greatest in the Vasse system owing to recent studies by Beatty et al. (2017, 2019a, b).

Modelling of saline intrusion upstream of the Lennox Weir (assuming weir removal) was undertaken by GHD (2018a). It revealed that for a 15 year ARI storm surge, (i.e., marine water levels reaching ~70 cm above the weir crest), a saline (30 PSU) intrusion would extend ~750 m upstream of the weir. They also concluded that this incursion would be short-term (~24 hrs), however, similar residual salinity levels would be reached upstream of the weir for at least 24 hrs in the 1, 2, 5, 15 year storm surge scenarios that were modelled. Lymbery et al. (2008) reported the species ~2 rkm upstream of the Lennox Weir. GHD (2018b) reported a species list around the Lennox Weir (combined with AECOM (2017)). They noted a shell of *W. carteri* in the vicinity of Lennox Weir. Sampling by Klunzinger et al. (2015) also recorded the species ~6 rkm upstream of the Capel Weir. GHD (2018b) stated the risk to the species as high, medium and low within Zones 2 (i.e. ~450 m upstream of the weir), 3, and 4 (further upstream), respectively, depending on the increase of salinity modelled by GHD (2018b). However, as mentioned, they did not record live mussels from within that zone.

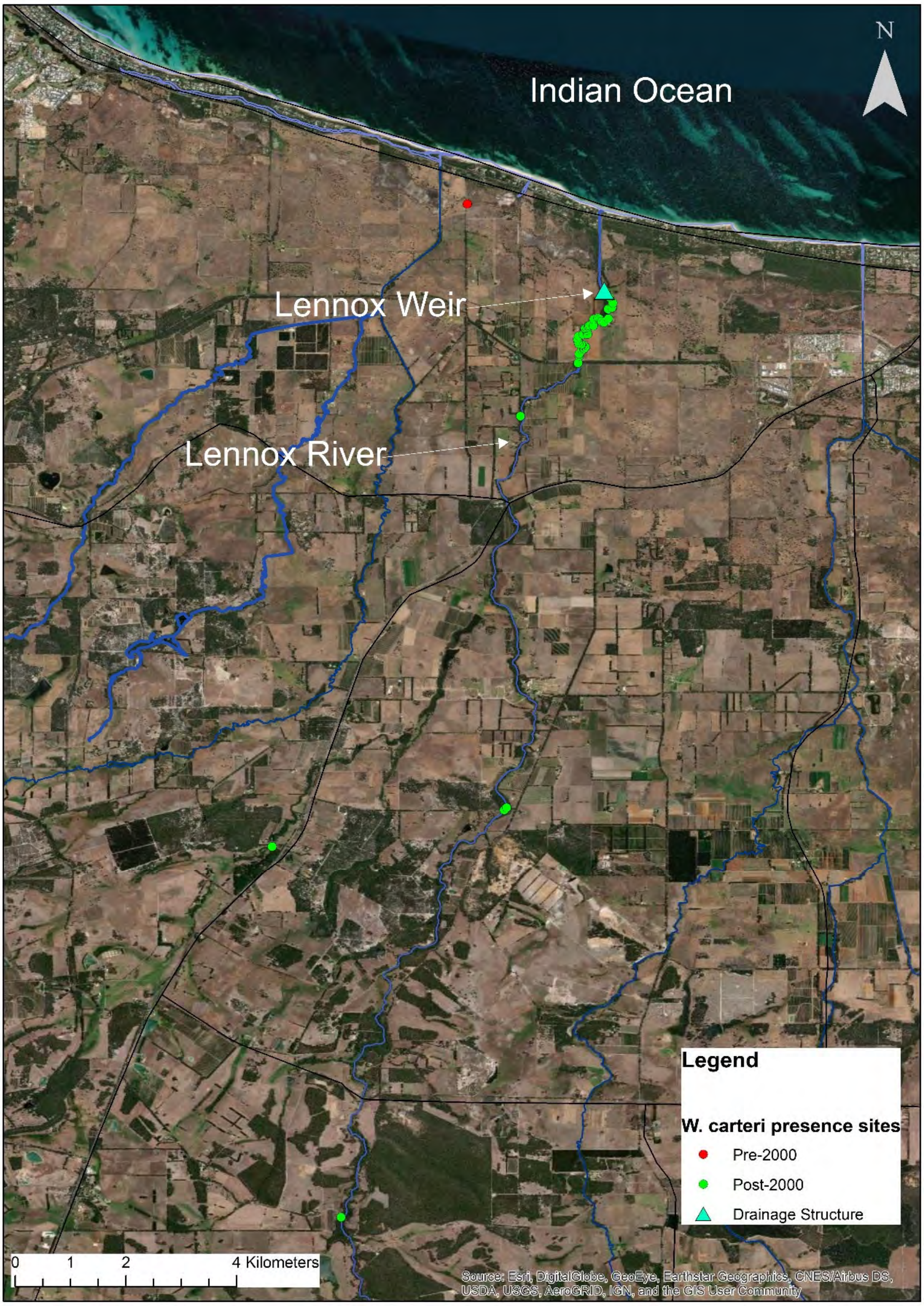

Figure 1: Location of the sites that had been sampled for *W. carteri* prior to the current study in the Lennox River. N.B. presence sites for the species are categorised as pre (red) and post (green) 2000 and are sourced from the DBCA threatened and priority ecological communities database combined with the currrent field survey.

Flora

The desktop flora study results for the Lennox Weir area is outlined below with species list from the desktop review provided in Appendix 1.

Lennox Drain and Weir are within Reserve 40676A, managed for drainage by the Water Corporation. Lennox Drain forms the lower section of what is widely referred to as the Carbunup River, but also referred to locally as the Lennox River. Upstream of the weir, the river is within its natural drainage line. This originally flowed to the east just upstream of the weir, where there are now seasonal wetlands. Downstream of the weir is a constructed drainage channel, connecting to Geographe Bay. Aerial photographs show remnant vegetation throughout the drainage reserve, with adjacent lands largely cleared for farming.

A previous flora and vegetation survey for this site was completed in October 2017, targeting areas that may require clearing for infrastructure upgrade (AECOM 2019). It excluded large areas of riparian vegetation and in-stream vegetation. Important findings in the report were:

- The location of the site within an Environmentally Sensitive Area (ESA) owing to the listing of the Carbunup River as a conservation category wetland and the downstream occurrence of the EPBC Act-listed Subtropical and Temperate Coastal Saltmarsh TEC.
- Vegetation at the site did not represent the above or any other TEC or PEC.
- The likely common occurrence of the Priority 4 *Eucalyptus rudis* subsp. *cratyantha* at the site. (Although the report did not confirm this subspecies, recent survey for this project concurs its presence and samples have been taken for confirmation by the WA herbarium.)
- No other listed threatened or priority flora were encountered.
- Description of three vegetation units, including one woodland and two riparian units.

The survey site is within a Conservation Category Wetland area (Landgate 2019). The site also forms part of a South West Region Ecological Linkage Axis Line, which extends along the length of the Carbunup River (Molloy et al. 2009)

The *Carbunup River Action Plan* (CEM 2000) provides results of foreshore condition assessment and species lists along the Carbunup River / Lennox Drain. The assessment, done 20 years ago, graded the river foreshore at the site as ranging from A3 (slightly disturbed) to B1/2 (weed infested) upstream of the weir; and B2 (heavily weed infested) to C1 (erosion prone) downstream.

An aquatic plant survey including upstream sites on the Lennox River and tributaries in November 2013 (Paice et. al. 2017) found native Water Ribbons *Cycnogeton huegelii* common in this catchment. The emergent aquatic *Liparophyllum lasiospermum* was also found and records n FloraBase suggest other species of *Liparophyllum* may occur.

The survey area is within the Yoongarillup vegetation complex (Heddle et al. 1980, Mattiske and Havel 1998), which currently has 35% remaining uncleared. More detailed RFA mapping Vegetation complexes in the vicinity of the river/drain and weir are described in Table 1. All are poorly represented (<30% pre-clearing extent remaining). Vegetation along the river at the site also forms part of the Riverine Jindong plant communities associated with the loamy soils of the Carbunup River, which is extensively cleared and noted as requiring further protection in reservation (Webb et al. 2009).

A list of 98 native plant species potentially occurring at this site from public database records is provided in Appendix 1. This included four priority taxa:

- *Eucalyptus rudis* subsp*. cratyantha* (P4)
- *Leucopogon* sp*. Busselton* (P2)
- *Acacia lateriticola* var*. glabrous variant* (P3)
- *Grevillea brachystylis* subsp*. brachystylis* (P3)

Database searches requested from DBCA did not return any records of listed priority flora taxa occurrences in the vicinity of the Lennox Weir survey area.

Based on vegetation complexes occurring in the area and published listing descriptions (DBCA 2019), TECs and PECs with potential to occur in the survey are listed in Table 2. Database searches requested from DBCA identified the occurrence of four Priority Ecological communities in the vicinity of Lennox Weir survey area (Figure 2):

- Subtropical and Temperate Coastal Saltmarsh
- Quindalup *Eucalyptus gomphocephala* and/or *Agonis flexuosa* woodlands (floristic community type 30b).
- Vasse Blackbutt (near Busselton) *Eucalyptus patens, Corymbia calophylla, Agonis flexuosa* Closed Low Forest
- Banksia Woodlands SCP Banksia Dominated Woodlands of the Swan Coastal Plain IBRA Region.

Table 1. Lennox Weir survey area vegetation complexes and post-clearing remnant status (Connell et al. 2000).

Vegetation complex	Description	Area remaining	
		% pre-clearing extent	% in conservation reserves
Ludlow Lw	Ludlow wet flats Open woodland of *Melaleuca rhaphiophylla* and sedgelands of *Cyperaceae-Restionaceae* spp. on broad depressions in the subhumid zone.	28	31
Quindalup Qw	Quindalup wet flats Tall shrubland of *Acacia saligna-Agonis flexuosa* and open heath on depressions amongst recent dunes in the subhumid zone.	28	0
Quindalup Qwy	Quindalup very wet saline flats Mixture of closed scrub of Melaleuca spp. and fringing woodland of *Eucalyptus rudis*.	NA	NA
Abba AF	Abba very fertile flats Woodland of *Corymbia calophylla – Agonis flexuosa* and tall shrubland of *Myrtaceae-Proteaceae* spp. on terraces and valley floors in the humid zone	18	0.05

Table 2. Threatened and Priority Ecological Communities that may occur and those recorded in the vicinity of the Lennox Weir survey area.

Community Description	WA Listing	C'wealth Listing	Records in vicinity
Southern Wet Shrublands, Swan Coastal Plain (SCP02)	TEC, EN		
Shrublands on calcareous silts of the Swan Coastal Plain (SCP18)	TEC, VU		
Forests and woodlands of deep seasonal wetlands of the Swan Coastal Plain (SCP15)	TEC, VU		
Subtropical and Temperate Coastal Saltmarsh	P3	TEC, VU	YES
***Corymbia calophylla, Melaleuca rhaphiophylla, Banksia littoralis, Eucalyptus rudis, Agonis flexuosa* low open forest with seasonal subsoil moisture of the Dunsborough area.**	P1		
***Eucalyptus rudis, Corymbia calophylla, Agonis flexuosa* Closed Low Forest (near Busselton)**	P1		
***Eucalyptus patens, Corymbia calophylla, Agonis flexuosa* Closed Low Forest (near Busselton)**	P1		
Quindalup *Eucalyptus gomphocephala* and/or *Agonis flexuosa* woodlands (floristic community type 30b)	P3		YES
Vasse Blackbutt (near Busselton) *Eucalyptus patens*, *Corymbia calophylla*, *Agonis flexuosa* Closed Low Forest	P1		YES
Banksia Woodlands SCP Banksia Dominated Woodlands of the Swan Coastal Plain IBRA Region	P3	TEC, EN	YES

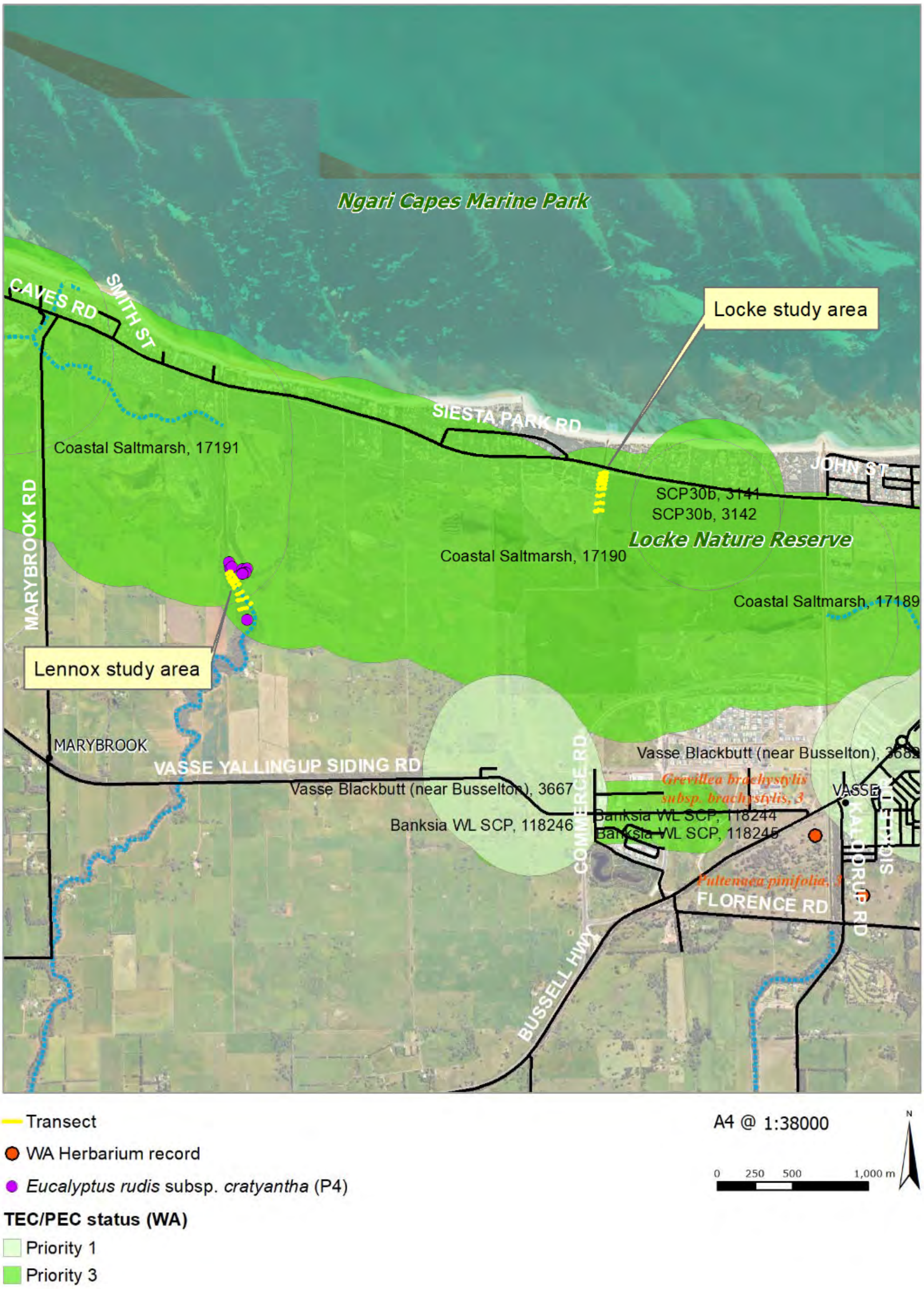

Figure 2. Records of Threatened and Priority Ecological Communities and listed significant flora in the vicinity of Lennox survey areas (also shown are reviewed areas around the Locke Weir, reviewed in a separate report to the Water Corporation (Beatty et al. 2020)) from DBCA database search requests, 2019.

Field surveys

Water quality measurements undertaken in August 2019 and January 2020 at the Lennox Weir study area are presented in Appendix 2. Notably, the water both upstream and downstream of the Lennox Weir was fresh (<0.26 ppt) in August 2019, with salinity during January remaining fresh upstream (0.40-0.39 ppt), but became saline downstream (~44 ppt) reflecting tidal influence.

Fauna

In August, three species of freshwater fishes were located above and below the Lennox Weir, five species of estuarine fishes were restricted to below the weir, the native Gilgie crayfishes was also recorded upstream of the weir. The native freshwater fishes present in winter are all endemic to south-western Australia but not currently listed as threatened, and included the Western Minnow *Galaxias occidentalis*, Western Pygmy Perch *Nannoperca vittata*, and the Nightfish *Bostockia porosa* (Table 3). Multiple size classes of those three south-western Australian endemic fishes were present suggesting that all species were self-maintaining in the Lennox River (Appendix 3).

The estuarine species in winter included Black Bream *Acanthopagrus butcheri*, Yelloweye Mullet *Aldrichetta forsteri*, Sea Mullet *Mugil cephalus*, Western Hardyhead *Lepthatherina wallacei*, and Blue-spot Goby *Pseudogobius olorum*. The Lennox Weir site in winter also housed the anadromous Pouched Lamprey *Geotria australis* (adult and a metamorphosed downstream migrant captured) confirming the anecdotal reports of the species from the site by the long-term landholder (Keith Rose, pers. comm.). The introduced Eastern Gambusia *Gambusia holbrooki* was also present upstream of the weir. In winter, only dead shells of *W. carteri* were present upstream of the Lennox Weir although the survey extend was limited. The lack of Smooth Marron at the Lennox Weir site is also consistent with the anecdotal past decline of the species around the site (Keith Rose, pers. comm.).

In January 2020, the survey of *W. carteri* that occurred between Vasse-Yallingup siding Rd and the Lennox Weir recorded the species throughout the river (n = 232) (Figure 3). However, there was a significant correlation between the density of *W. carteri* and the distance upstream of the Lennox Weir ($R = 0.46$, $p = 0.003$) with the greatest abundances recorded in the middle and upper sections of the reach (with a maximum density of 57 individuals/m^2 (Figures 3-6). Most absent quadrats were recorded in the pool habitat downstream of the Rose homestead, however, the species was present within 200 m of the weir in low abundances (Figure 3).

A large increase in abundances of Western Pygmy Perch and Blue-spot Goby occurred in summer upstream of the Lennox Weir compared with the winter survey (Table 3). Multiple size classes of freshwater fishes were again present upstream of the weir in January (Appendix 4). Downstream of the weir, juvenile Black Bream were present highlighting that the lower Lennox River housed a self-maintaining population of this recreationally important species.

Table 3. Abundances of aquatic fauna downstream (DS) and upstream (US) of Lennox Weir in August 2019 and January 2020. N.B green and red shading represents conceptually positive and negative species presence from a conservation perspective.

Species		AUGUST DS	AUGUST US	JANUARY DS	JANUARY US	Total
Native Freshwater Fish						
N. vittata		45	457	0	845	1347
B. porosa		2	16	0	31	49
G. occidentalis		8	15	0	17	40
G. australis		1	1	0	0	2
Native Estuarine Fish						
A. butcheri		2	0	44	0	46
A. forsteri		1	0	0	0	1
L. wallacei		2	0	22	0	24
M. cephalus		290	0	16	0	306
A. bifrenatus		0	0	13	0	13
P. olorum		1	10	19	663	693
Native Crayfish						
C. cainii		0	0	0	0	0
C. quinquecarinatus		0	2	0	4	6
Other Natives						
C. colliei		0	0	0	0	0
Littoria		0	0	0	11	11
P. australis		66	52	118	428	664
W. carteri	Alive	0	0	0	232	232
	Dead	0	5	-	-	5
Exotic Fish						
G. holbrooki		0	3	0	186	189
Exotic Crayfish						
C. destructor		0	0	0	0	0
Total		418	561	232	1524	3628

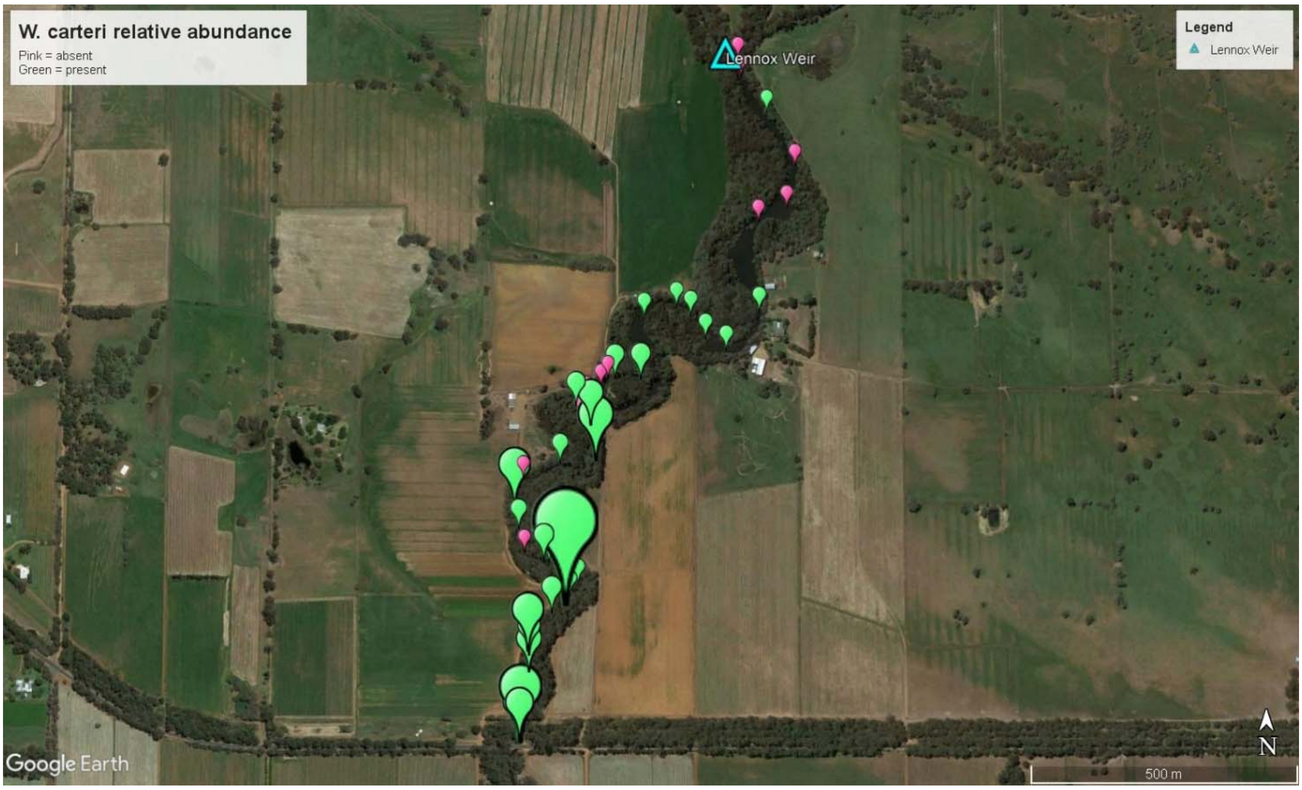

Figure 3. Relative abundance of *W. carteri* upstream of the Lennox Weir to the Vasse Yallingup Siding Rd in January 2020. N.B. symbol sizes are proportional to the density (greatest density was 57/m^2) and quadrat placement targeted those habitats that are known to be preferred by the species. Pink symbols correspond to the species being absent.

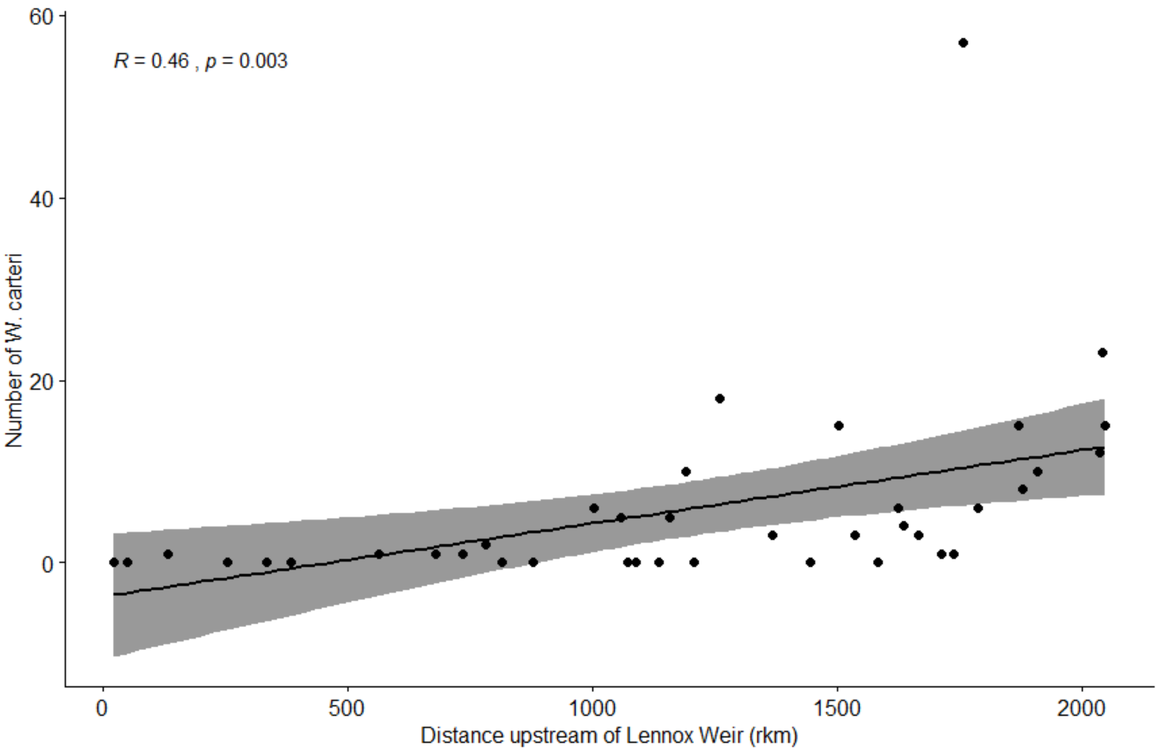

Figure 4: Relationship between the density of *W. carteri* and distance upstream from Lennox Weir.

Figure 5: Habitat conditions the Lennox River in January 2020. (clockwise from top left) moving upstream from below the weir finishing at the Vasse-Yallingup Siding Rd. N.B. the change in habitat from wide pools (upstream of the weir) to more natural habitat morphology (bottom left photo). Also shown is the ~1m high earthen weir crossing located ~1100 rm upstream of Lennox Weir that created additional pool habitat upstream and would represent a barrier to fish movement for extended periods of the year.

Figure 6. Carter's Freshwater Mussels in the Lennox River upstream of the Lennox Weir in January 2020. N.B. right photo mussels were moved to the bank for measure and release.

Flora

Transects were located 25m apart from 18-93m downstream and 50m apart from 10-160m upstream of Lennox Weir. Three main riparian vegetation communities were described (Table 4). Remnant riparian vegetation at the site aligned with the original drainage line of the river prior to weir installation and diversion and differed from vegetation downstream of the weir. A total of 55 flora species were encountered in the survey site, including 33 native and 22 introduced species (Appendix 5).

Vegetation communities

The upstream riparian zone was dominated by Community 2, which extended to the east along the original drainage line; and vegetation downstream was dominated by Community 1 (Figure 7). Community 3 was present in an upstream area on the western bank associated with a floodway and was in very good condition (aside from an isolated area of disturbance owing to fallen tree removal from the river). A narrow strip of rushes and semi-aquatic herbs occurred along the bank edge, overlapping with the three riparian communities, sampled as the 'bank community'. Average width of this community was 1.25m downstream and 2.9m upstream.

The channel downstream was more degraded in terms of bank erosion and the two banks differed in vegetation condition. The downstream east bank had good condition vegetation with only minimal weed invasion, although some areas were narrow. Vegetation was completely degraded on the western foreshore with dense weed infestation.

Comparison of the bank community up- and downstream of the weir shows notable differences in cover for all native species (Figure 8). This reflects the dominance of Community 1 downstream and Community 2 upstream. There was greater cover of native rushes along downstream banks (*Gahnia triffida, Juncus krausii, Baumea juncea*), however these were situated higher on the banks due to erosion of the lower banks. Freshwater semi-aquatic herbs were more common upstream (*Alternanthera nodiflora, Pesicaria decipiens*).

Significant flora and vegetation

Community 3 description aligns with Ludlow wet flats vegetation complex, which is poorly represented (<30% remaining, Connell et al. 2000), and is also representative of the Riverine Jindong vegetation (Webb et al, 2009), noted as requiring further protection in reserves. Much of this community in very good condition and in-tact examples of riparian vegetation are uncommon on lower reaches of the main rivers in this region, which have been greatly modified for drainage. Dominant species in this community are *Melaleuca rhaphiophylla* (Swamp paperbark) and *Baumea vaginalis* (Sheath twigrush), which are freshwater species unlikely to tolerate prolonged salt water intrusion. Their presence in low-lowing floodway areas would make them particularly susceptible. It is also important to note that very large, old trees in Communities 2 and 3 may hold conservation significance. Trunk circumferences of 4-5m were measured for both *E. rudis* and *M. raphiophylla*.

The vegetation communities did not represent threatened or priority ecological communities. However, the Priority 4 species *Eucalyptus rudis* subsp. *cratyantha* was present in Community 2, and on the levee and adjacent land downstream on the east side of Lennox Drain. Voucher specimens were taken from *E. rudis* trees with small and large fruiting bodies (an important feature distinguishing subspecies). All were confirmed as the P4 subspecies by the WA Herbarium, suggesting most, if not all, *E. rudis* at the site are *E. rudis* subsp. *cratyantha*. Extensive traversing at the site in spring did not encounter any other priority flora. These occurrences were not included in the DBCA database searches.

Table 4. Vegetation communities in the Lennox Weir survey area, winter 2019.

		Downstream		Upstream	
Community description		East bank	West bank	East bank	West bank
***1. Agonis flexuosa* open forest with occasional *Eucalyptus rudis* over *Lepidosperma effusum* sedgeland**	% transects	75	100	25	0
	mean width (m)	10	12	10	-
	condition	G-VG	CD	G	-
2. Open forest of *Melaleuca raphiophylla* and *Eucalyptus rudis* with occasional *Agonis flexuosa* and mixed understorey of shrubs and *Lepidosperma effusum*	% transects	25	0	75	100
	mean width m)	12	-	11	4
	condition	G	-	D-CD	G-VG
3. *Melaleuca raphiopylla* and *Eucalyptus rudis* forest closed forest over Baumea *vaginalis* in the floodway	% transects	0	0	25	0
	mean width m)	-	-	31	-
	condition	-	-	VG-D	-

condition rating: VG=very good, G=good, D=degraded, CD=completely degraded

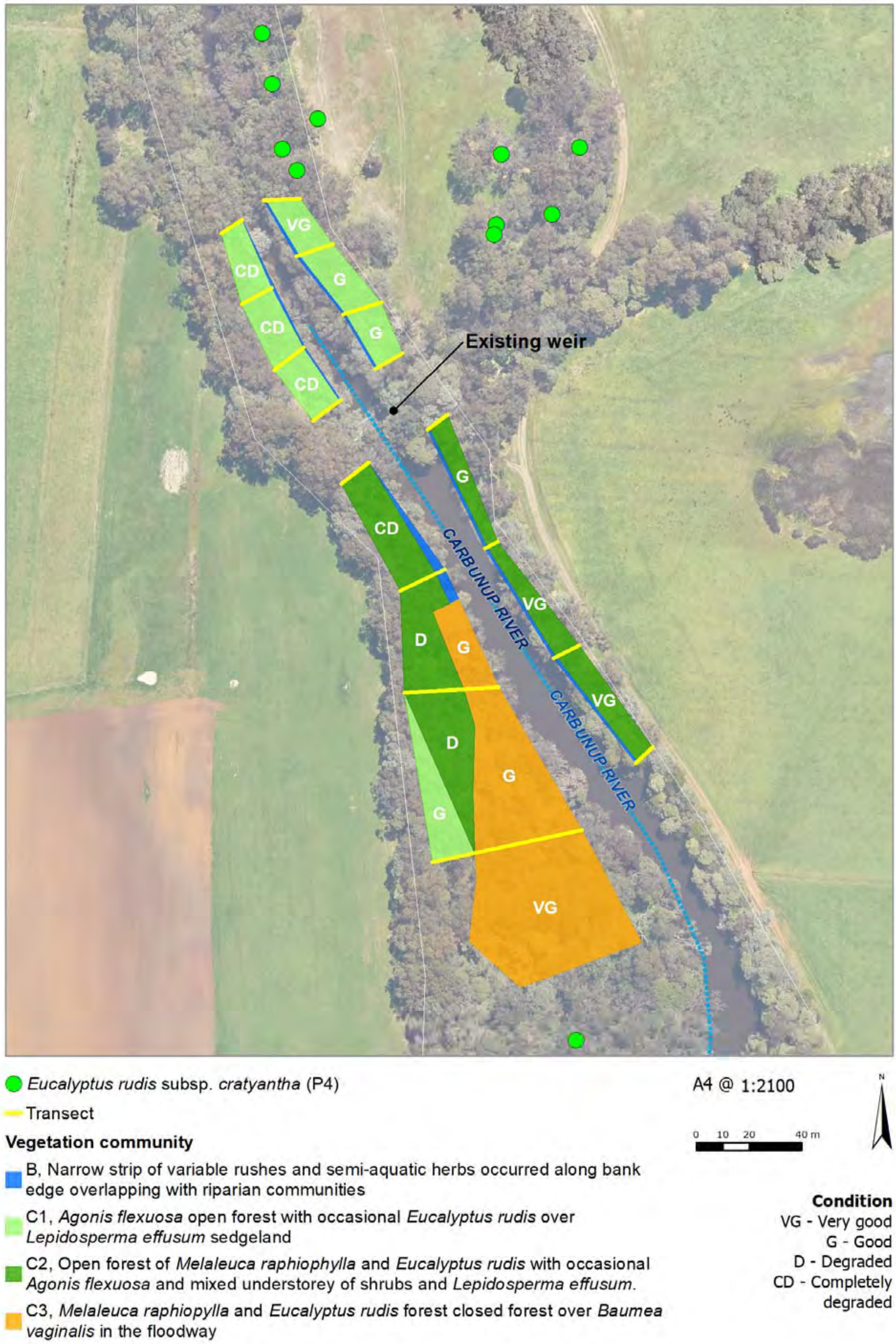

Figure 7. Lennox Weir survey area transect locations and vegetation communities.

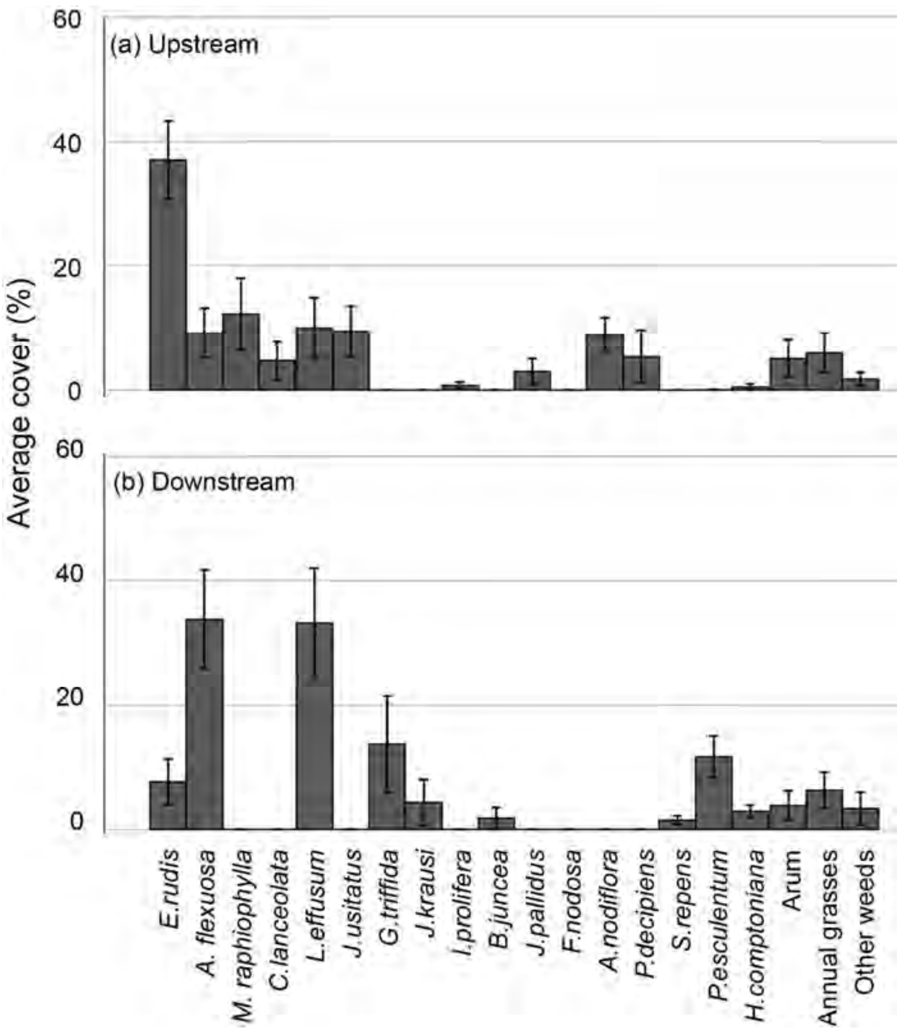

Figure 8. Bank vegetation community composition upstream (a) and downstream (b) of Lennox Weir, winter 2019.

Aquatic plants

Aquatic plants within the river channel occurred only upstream and included both native and introduced species (Table 5). They were most extensive in the wide shallow habitat shallows upstream of the weir and in shallow near-shore habitats. During winter, these included the semi-emergent species *Persicaria decipiens* and *Alternanther denticulate*; the common introduced aquatic starwort *Callitriche stagnalis*; and a small stand of an unidentifiable aquatic plant, tentatively identified as *Gratiola* sp. In spring and summer, the semi-emergent species were no longer inundated, *C. stagnalis* was growing in damp areas and *Gratiloa* sp. was no longer present. Charophytes were common, particularly further upstream of the wier, and young plants of *Ottelia ovalifolia* occurred aliong the eastern bank. There was evidence of a rapid water level decline, with many *O. ovalifolia* plants drying out on the bank above the water.

Table 5. Aquatic plant cover upstream of the Lennox Weir, winter 2019 (none found downstream).

Species	Braun-Blanquet cover-abundance score#				
	area assessed	whole channel	<5m banks	<5m banks	<5m banks
	distance upstream	0-20m	50-70m	100-120m	150-170m
Winter:					
Persicaria decipiens		3			
Alternanthera denticulata				1	
Callitriche stagnalis*		4		1	1
***Gratiola* sp.#**				1	
Spring:					
Ottelia ovalifolia				1	3
Charophyte sp.			1	2	3

#1= <5%, 2=5-25%, 3=25-50%, 4=50-75%, 5=75-100%

*Introduced

#Unconfirmed identification (sterile specimen)

Discussion and Conclusions

Fauna

GHD (2018a) modelled short term saline ingression upstream of the Lennox weir that would arise from the proposed decommissioning of the Lennox Weir. For all four storm survey scenarios modelled, the spatial extent of this risk increases with the distance of ingression, with salinity of 30 mg/l moving between 400m (scenario 1, ~annually) to 750 m scenario 4 (1 in 15 year event) upstream of the Lennox Weir. The residual salinity after 24 hours at the weir was similar across all scenarios, ranging from ~27 mg/L TDS) for scenarios 3 and 4 to 30 mg/L for scenarios 1 and 2. All scenarios also predicted salinities >15 mg/l to remain after 24 hours just downstream of the farmhouse (i.e. 500m upstream of the weir) and salinities of 9, 6, and 3 mg/l for scenarios 4, 3/2 and 1 at the farmhouse (i.e. 600 m upstream of the weir), respectively.

The subsequent impact report (GHD 2018b, also citing AECOM (2017)) assessed the site splitting it into four zones of potential impact (Figure 9). Their findings were largely based on desktop reviews of previous surveys further upstream in the Carbunup River, field observations (e.g. a shell of the Carter's Freshwater Mussel) and anecdotal reports of aquatic fauna. The GHD (2018b) concluded the impact on aquatic fauna would be "generally insignificant" aside from minor to moderate impacts on the Oblong Turtle and Carter's Freshwater Mussel, due to a further restriction in their distribution.

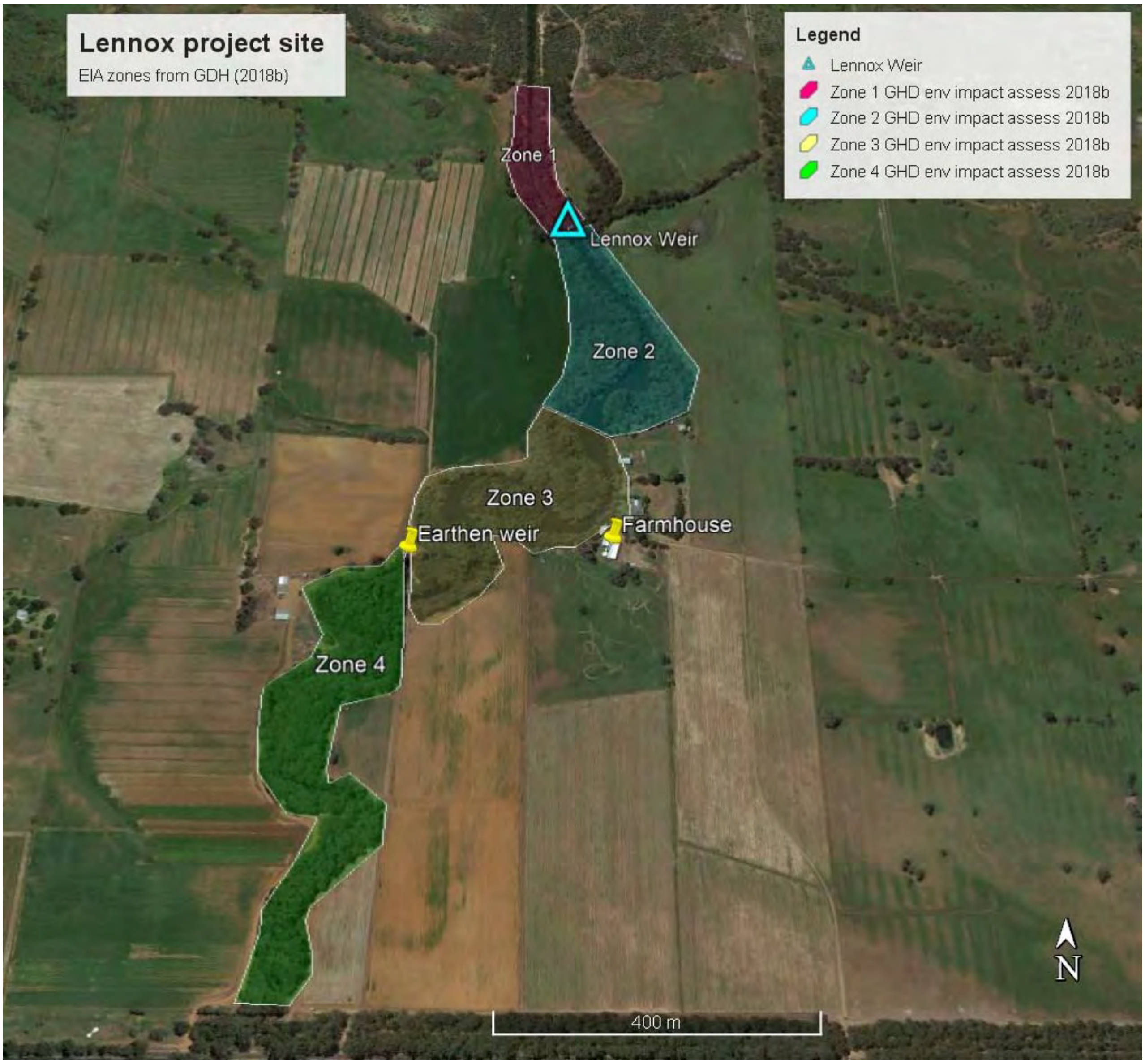

Figure 9: Lennox study reach including the approximate environmental impact assessment zones outlined in GHD (2018b). N.B. the location of the earthen weir and the farmhouse are also shown.

Based on anecdotal information, it was assumed the distribution of the Smooth Marron and freshwater fishes were limited to the upstream extent of the survey area within the Carbunup River owing to the periodic incursion of saline water upstream of the Lennox Weir (GHD 2018b). Therefore, risk rating at zones 2-4 for invertebrates (including crustaceans) and fish were assessed as low. However, the results of the current assessment suggest that fishes are in high abundances in zone 2 (and therefore highly likely in zones 3 and 4). Moreover, while not detected in our sampling, anecdotal evidence suggests that the Smooth Marron was still present in at least zone 3 (but in low abundances, P. Rose pers. comm.). As discussed below, these findings are therefore likely to affect those risk ratings.

The acute salinity tolerances (50% mortality) for the Western Pygmy Perch and Western Minnow is ~14.6 mg/L (Beatty et al. 2011). Therefore, to reach salinity levels less than those that would cause <50% acute mortality of these species, they would need to rapidly move upstream to at least ~650m, 780m, 850m, and 930m upstream of the weir under the modelled scenarios 1-4 (GHD

2018a), respectively. However, there may be mitigating factors that could reduce the risk of mortalities during those storm surge events, these include:

- The potential behavioural response of the resident freshwater fishes upstream of the weir to sudden increases in salinity. It is possible that some fishes may be able to move upstream in response to the saline ingression, however, whether they would respond in this manner is unknown.
- The likely presence and possible use by fish of an upper freshwater lens as the more dense saline water penetrates upstream under the storm surge scenarios. The authors have recorded freshwater fishes utilising such a lens previously in tidal reaches of rivers (Beatty and Morgan, 2008) and it is therefore possible that they could make use of the fresher section of the halocline during and after the projected surges. However, a better understanding as to the extent of the haloclines would be required though additional hydrological modelling to that carried out by GHD (2018a) who did not consider changes in vertical profile in the modelling.

Depending on the engineering options available, a 'stationary weir' structure with a fish ladder may benefit resident fishes by enabling the upstream movement of freshwater fishes as flow declines during spring; noting that three species were detected below the weir during the August winter sampling that were no longer present during the January sampling (and were likely to have died due to increased tidal intrusion). A fishway would also enhance the upstream movement of the estuarine species such as *M. cephalus*. However, a potential fishway would need to be carefully designed and be based on additional temporal hydrological and ecological data to ensure, for example, that estuarine species that used the fishway to move upstream were also able to move downstream as required. Such design considerations have been assessed as part of the Kent Street Weir fishway on the Canning River (Ryan et al., 2016).

It is also unclear as to whether the weir at the crossing located ~1100m upstream of the Lennox Weir (Figures 5, 9) was present or detected during the previous studies, however, it was not mentioned during the modelling of saline ingression undertaken by GHD (2018a) or the impact assessment by GHD (2018b). Under scenario 4 (i.e. 15 year ARI storm surge) this structure was located within the 3-6 mg/l TDS zone of ingression. This structure would also represent a barrier to fish movement for extended periods of the year and had a ~1m head loss at the time of sampling during January 2020.

While the abundance of the Threatened *W. carteri* within zones 2 and 3 were found to be relatively low in the current study, the salinity ingressions under all four scenarios after 24 hours projected to still exceed the upper limit of 5 mg/l for the species for zone 2 and a considerable proportion of the downstream section of zone 3. There was also no modelling of the longer term (i.e. >24 hours) salinity in the zones following the salinity ingressions; although dilution of the salinity was predicted to occur slowly (GHD 2018a). The medium-term response of *W. carteri* to sudden increases in salinity has yet to be fully assessed. Ma (2018) subjected mussels to acute salinity increases from 0 to 5, 6, 7 and 8 g/L. The first deaths occurred at the highest salinities after 10 days. Anecdotal evidence indicated that mussels closed their valves immediately, but there are no quantitative data on valve opening in response to changes in salinity. Eight g/L is the highest salinity that has been tested, however, it is not recommended that those results be extrapolated to rapid responses at salinities above that level without further testing.

The potential loss of host fishes for the larval stage of *W. carteri* could also have an impact on recruitment; although the Blue-spot goby is also a known host, which could mitigate this effect. Notwithstanding these knowledge gaps, the assessment of a high and moderate risk rating for the species for zones 2 and 3, respectively, by GHD (208b) is probably a reasonable assessment in light of the current understanding on the species. A key mitigation strategy for the species would be to undertake a relocation from the impact zone to upstream habitats. This would require obtaining permits from DBCA including a Regulation 25 (Biodiversity Conservation Regulations 2018).

The impact on the South-western Snake-necked turtle was assessed as high and moderate in zones 2 or 3, respectively (GHD 2018b). While a large mortality of native freshwater fish prey may occur as a result of saline ingressions as discussed above (which could potentially enable a sudden, short term increase in food availability), the species has a broad diet and the current study revealed the presence of other salt-tolerant potential prey items for the species (i.e. Blue-spot Goby and South-west Glass Shrimp). Therefore, the risk to the species would likely to be low under any of the scenarios.

Flora

The Lennox Weir survey area occurs within a Conservation Category Wetland area and therefore within an Environmentally Sensitive Area. The upstream vegetation is an example of very old remnant riparian vegetation, as evidenced by large trees. This upstream area is within the poorly represented Ludlow wet flats vegetation complex, and includes good condition Riverine Jindong Community, which has been identified as requiring further protection (Webb et al. 2009). The P4 *Eucalyptus rudis* subsp. *cratyantha* occurs in riparian vegetation up-stream and downstream and on adjacent land north-east of the weir.

This survey found that upstream and downstream vegetation differ in terms of community structure and condition, in contrast to the findings of GHD (2018). Downstream riparian vegetation is dominated by Peppermint woodland, which is completely degraded the western foreshore. This vegetation follows the artificial drainage line of the Lennox Drain, unlike the upstream reach which occurs within the natural river course.

Changes to the salinity regime associated with altering the function of the weir are likely to impact vegetation upstream of the weir. Freshwater species such as Swamp Paperbark *Melaleuca rhaphiophylla* and *Baumea vaginalis* are particularly vulnerable and are dominant components of the Riverine Jindong Community. While outside the scope of this assessment, the vegetation provides habitat for the Critically Endangered Western Ringtail Possum (WRP), with extensive scat noted throughout the survey area. Peppermint trees upstream of the weir occur mainly on the upper banks, and their presence downstream suggests they may not be substantially impacted by changes to salinity in the river. However, it was evident that *M. rhaphiophylla* also provides WRP habitat in the survey area. This species occurs extensively, and these trees are likely to be impacted by increased salinity, reducing habitat extent.

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Online Resources

DBCA Naturemap: https://naturemap.dbca.wa.gov.au/

Atlas of Living Australia: https://www.ala.org.au/

Appendix 1. Desktop study flora lists for potentially occurring taxa.

N.B. List includes a combined taxa from the current Lennox Weir and also from the Locke Weir survey, see Figure 2 (Beatty et al. 2020).

Family	Species	Common name	Conservation Status
Amaranthaceae	*Ptilotus drummondii var. drummondii*	Pussytail	
Apiaceae	*Apium annuum*		
Apiaceae	*Daucus glochidiatus*	Australian Carrot	
Apiaceae	*Eryngium pinnatifidum*	Blue Devils	
Araliaceae	*Hydrocotyle callicarpa*	Small Pennywort	
Araliaceae	*Hydrocotyle diantha*		
Araliaceae	*Hydrocotyle hispidula*		
Araliaceae	*Hydrocotyle scutellifera*		
Araliaceae	*Hydrocotyle tetragonocarpa*		
Araliaceae	*Trachymene pilosa*	Native Parsnip	
Asparagaceae	*Acanthocarpus preissii*	Prickle Lily	
Asparagaceae	*Dichopogon preissii*		
Asparagaceae	*Lomandra nigricans*		
Asteraceae	*Hypochaeris glabra*	Smooth Catsear	
Asteraceae	*Lagenophora huegelii*		
Asteraceae	*Pogonolepis stricta*	Stiff Angianthus	
Asteraceae	*Rhodanthe citrina*		
Asteraceae	*Waitzia suaveolens*	Fragrant Waitzia	
Celastraceae	*Stackhousia monogyna*		
Chenopodiaceae	*Atriplex cinerea*	Grey Saltbush	
Chenopodiaceae	*Dysphania glomulifera*		
Chenopodiaceae	*Rhagodia baccata*		
Chenopodiaceae	*Sarcocornia quinqueflora*	Beaded Samphire	
Chenopodiaceae	*Tecticornia halocnemoides*	Shrubby Samphire	
Convolvulaceae	*Dichondra repens*	Kidney Weed	
Crassulaceae	*Crassula closiana*		
Cyperaceae	*Baumea articulata*	Jointed Rush	
Cyperaceae	*Baumea juncea*	Bare Twigrush	
Cyperaceae	*Bolboschoenus caldwellii*	Marsh Club-rush	
Cyperaceae	*Carex thecata*		
Cyperaceae	*Eragrostis elongata*	Clustered Lovegrass	
Cyperaceae	*Gahnia trifida*	Coast Saw-sedge	
Cyperaceae	*Isolepis cernua*		
Cyperaceae	*Lepidosperma angustatum*		
Cyperaceae	*Lepidosperma gladiatum*	Coast Sword-sedge	
Cyperaceae	*Lepidosperma squamatum*		
Cyperaceae	*Schoenus sculptus*	Gimlet Bog-rush	
Cyperaceae	*Schoenus unispiculatus*		
Dilleniaceae	*Hibbertia cuneiformis*		
Ericaceae	*Leucopogon australis*	Spiked Beard-heath	
Ericaceae	*Leucopogon parviflorus*		
Ericaceae	*Leucopogon sp. Busselton (D. Cooper 243)*		P2
Fabaceae	*Acacia lateriticola*		
Fabaceae	*Acacia lateriticola var. Glabrous variant (B.R.Maslin 6765)*		P3
Fabaceae	*Acacia littorea*		
Fabaceae	*Acacia pulchella*	Prickly Moses	
Fabaceae	*Hardenbergia comptoniana*	Native Wisteria	
Fabaceae	*Vicia sativa*	Common Vetch	
Fabaceae	*Viminaria juncea*	Swishbush	
Haemodoraceae	*Conostylis aculeata*	Prickly Conostylis	
Haemodoraceae	*Conostylis setigera subsp. setigera*		
Hemerocallidaceae	*Dianella brevicaulis*		

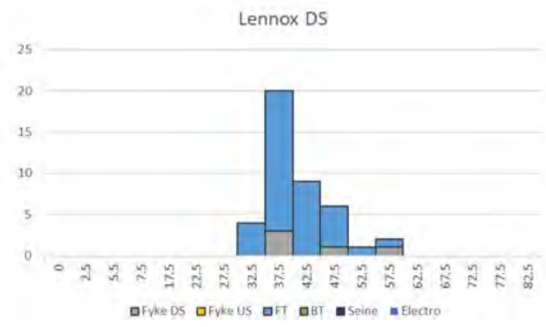
Iridaceae	*Patersonia occidentalis var. occidentalis*		
Juncaceae	*Juncus kraussii*		
Juncaginaceae	*Triglochin mucronata*		
Juncaginaceae	*Triglochin striata*		
Lauraceae	*Cassytha racemosa*	Dodder Laurel	
Loganiaceae	*Phyllangium paradoxum*		
Myrtaceae	*Agonis flexuosa*	Peppermint	
Myrtaceae	*Babingtonia camphorosmae*	Camphor Myrtle	
Myrtaceae	*Eucalyptus rudis*	Flooded Gum	
Myrtaceae	*Eucalyptus rudis subsp. cratyantha*	Flooded Gum	
Myrtaceae	*Hypocalymma cordifolium*		
Myrtaceae	*Melaleuca cuticularis*	Saltwater Paperbark	
Myrtaceae	*Melaleuca osullivanii*		
Myrtaceae	*Melaleuca rhaphiophylla*	Swamp Paperbark	
Myrtaceae	*Melaleuca viminea*		
Onagraceae	*Epilobium billardiereanum*	Glabrous Willow Herb	
Orchidaceae	*Caladenia chapmanii*		
Orchidaceae	*Caladenia latifolia*	Pink Fairy Orchid	
Orchidaceae	*Corybas despectans*	Sandhill Helmet Orchid	
Orchidaceae	*Corybas recurvus*	Helmet Orchid	
Orchidaceae	*Cryptostylis ovata*	Slipper Orchid	
Orchidaceae	*Cyanicula gemmata*		
Orchidaceae	*Cyrtostylis huegelii*		
Orchidaceae	*Eriochilus dilatatus*	White Bunny Orchid	
Orchidaceae	*Microtis media*	Tall Mignonette Orchid	
Orchidaceae	*Pterostylis brevisepala*		
Orchidaceae	*Pterostylis pyramidalis*	Snail Orchid	
Phyllanthaceae	*Phyllanthus calycinus*	False Boronia	
Poaceae	*Austrostipa flavescens*		
Poaceae	*Poa poiformis*	Coastal Poa	
Poaceae	*Poa porphyroclados*		
Poaceae	*Sporobolus virginicus*	Marine Couch	
Podocarpaceae	*Podocarpus drouynianus*	Wild Plum	
Portulacaceae	*Calandrinia calyptrata*	Pink Purslane	
Primulaceae	*Samolus repens*	Creeping Brookweed	
Proteaceae	*Banksia ilicifolia*	Holly-leaved Banksia	
Proteaceae	*Grevillea brachystylis subsp. brachystylis*		P3
Ranunculaceae	*Clematis linearifolia*	Slender Clematis	
Restionaceae	*Leptocarpus coangustatus*		
Rhamnaceae	*Spyridium globulosum*	Basket Bush	
Rutaceae	*Philotheca spicata*	Pepper and Salt	
Santalaceae	*Exocarpos odoratus*	Scented Ballart	
Santalaceae	*Exocarpos sparteus*	Broom Ballart	
Solanaceae	*Anthocercis littorea*	Yellow Tailflower	
Stylidiaceae	*Stylidium adnatum*	Common Beaked Triggerplant	
Thymelaeaceae	*Pimelea argentea*		
Thymelaeaceae	*Pimelea lanata*		
Urticaceae	*Parietaria debilis*	Pellitory	

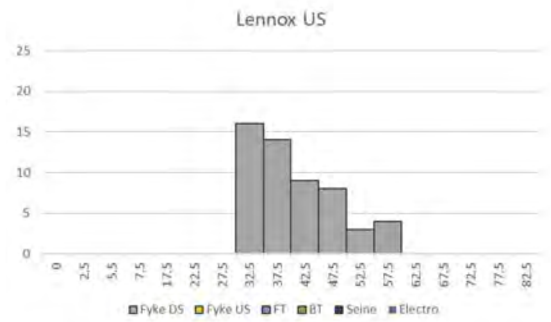
Appendix 2 Water quality upstream and downstream of the Lennox Weir.

Site	Time	Depth	Temperature (°C)	DO (%)	DO (mg/L)	Conductivity (µS/cm)	Salinity (PPT)	TDS (mg/l)	pH
Upstream of weir	Aug-19	Top	12.9	100	10.6	388	0.25	328	8.6
		Bottom	12.8	96.5	10.1	3.88	0.25	3.28	6.88
	Jan-20	Top	26.57	54.47	4.33	806.33	0.40	522.00	8.31
		Bottom	24.00	24.30	1.73	655.67	0.39	515.00	7.60
Downstream of weir	Aug-19	Top	12.7	100	10.6	411	0.26	348	7.86
	Jan-20	Top	21.73	45.30	3.03	64744.33	43.92	42098.33	7.44
		Bottom	20.87	40.07	2.72	64401.67	43.55	41865.33	7.22

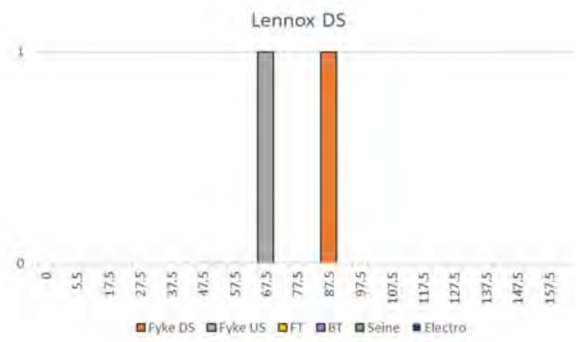
Appendix 3 Length-frequency histograms (fish (TL), crayfish (OCL), turtle (SL) all in mm) of aquatic fauna from the August 2019 sampling events upstream and downstream of Lennox Weir.

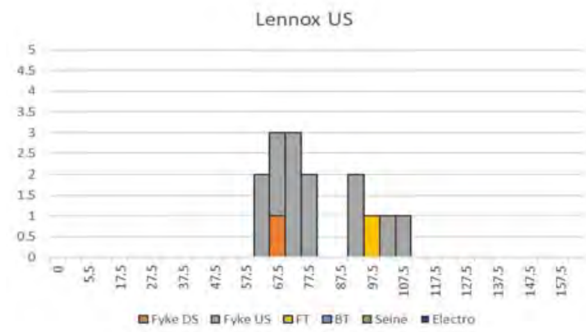
Western Pygmy Perch



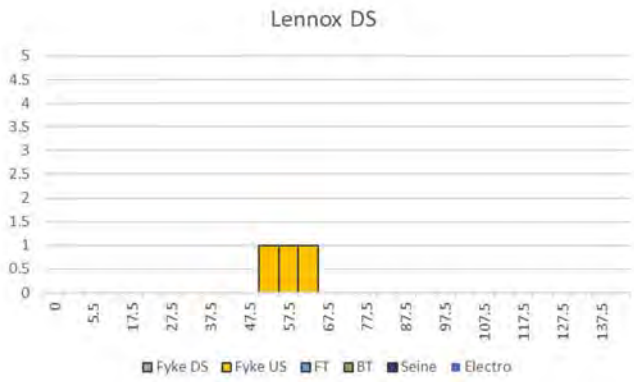


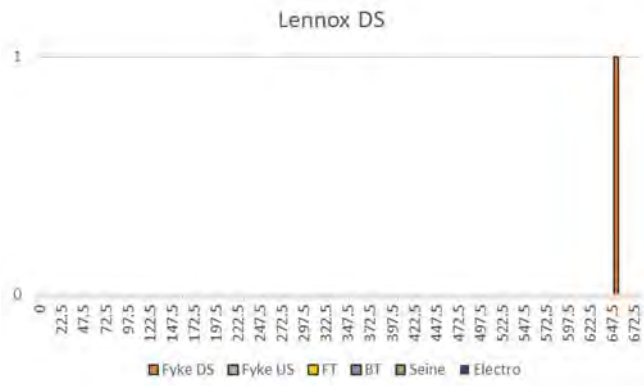
Nightfish

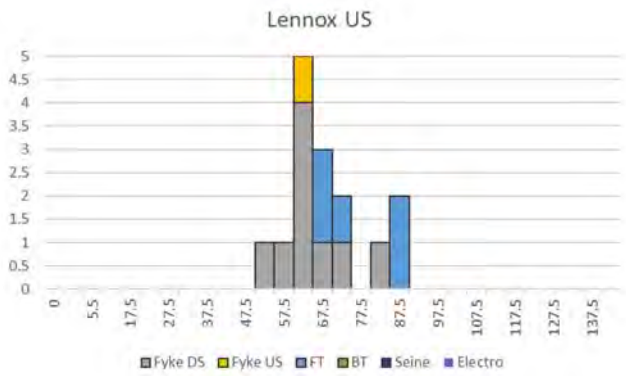


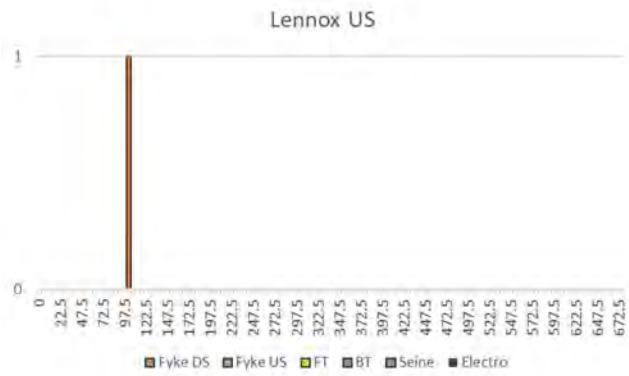


Western Minnow **Pouched Lamprey**

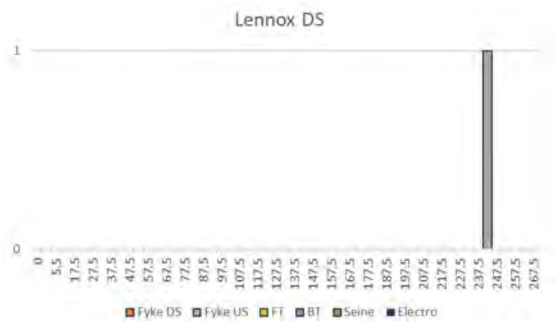


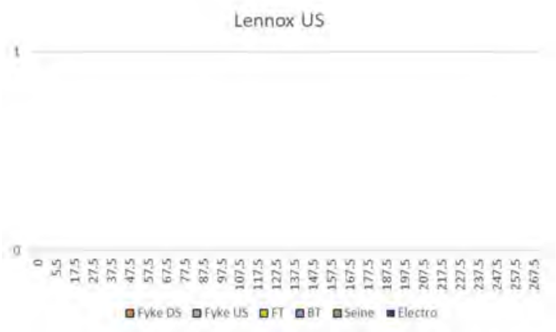




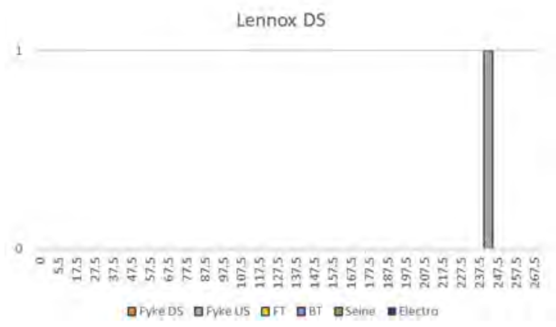


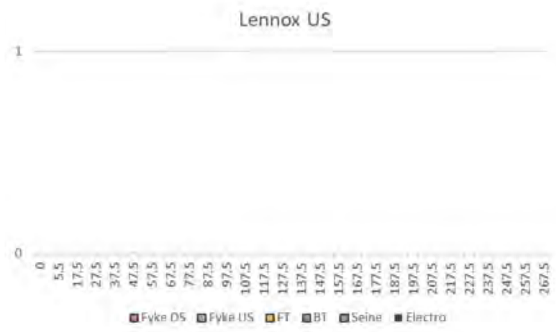
Black Bream



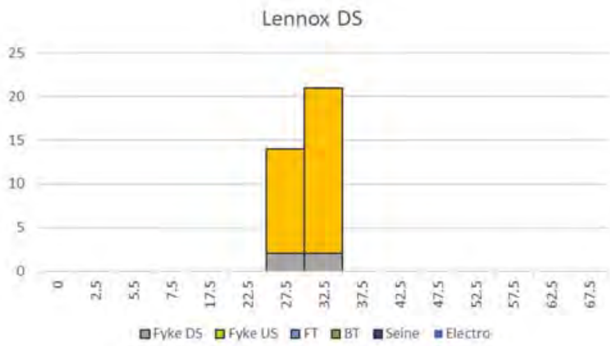


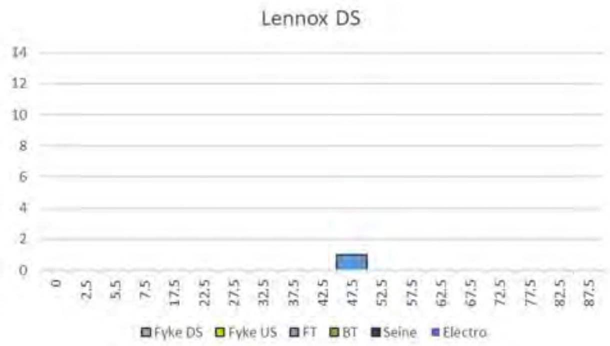
Yellow-eye Mullet

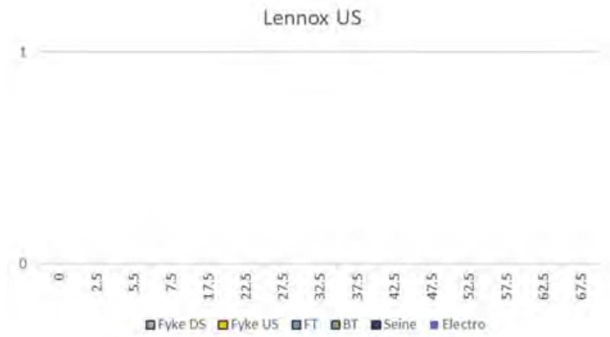


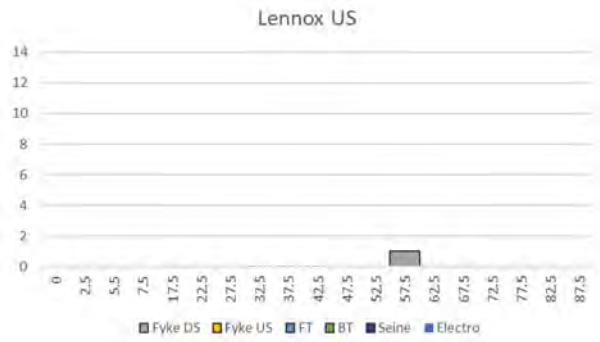


Sea Mullet **Blue-spot Goby**



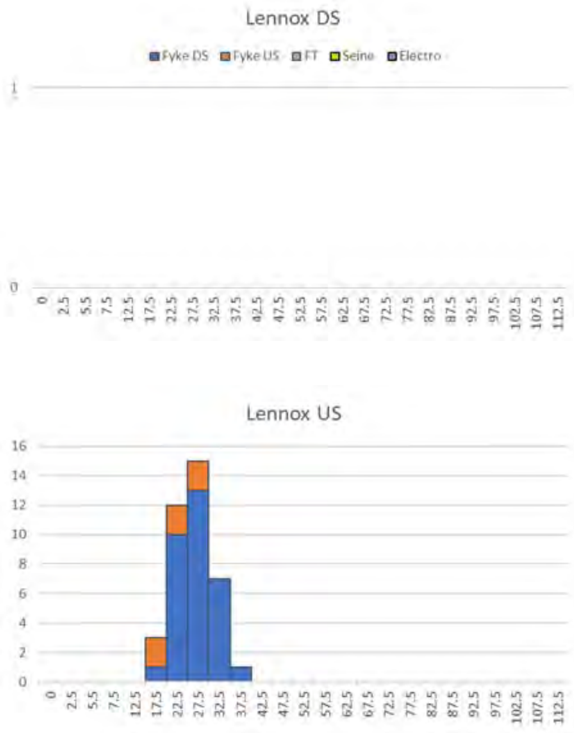




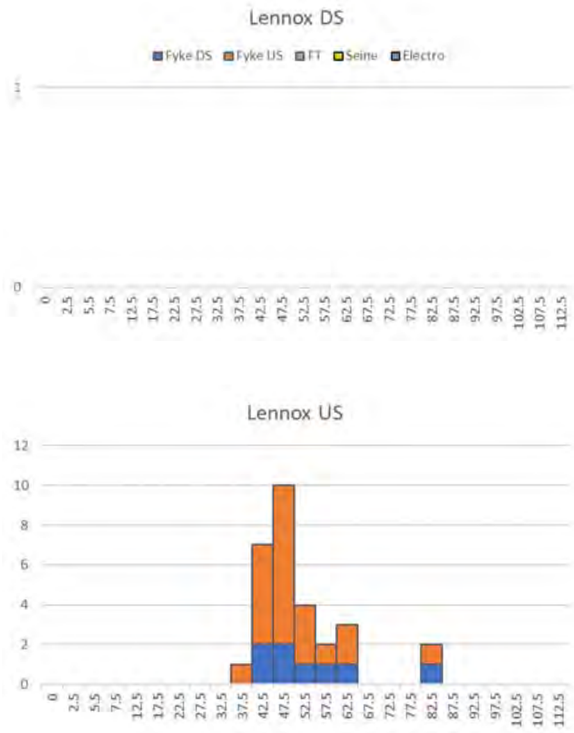


Appendix 4 Length-frequency histograms (fish (TL), crayfish (OCL), turtle (SL) all in mm) of aquatic fauna from January 2020 sampling events upstream and downstream of Lennox Weir.

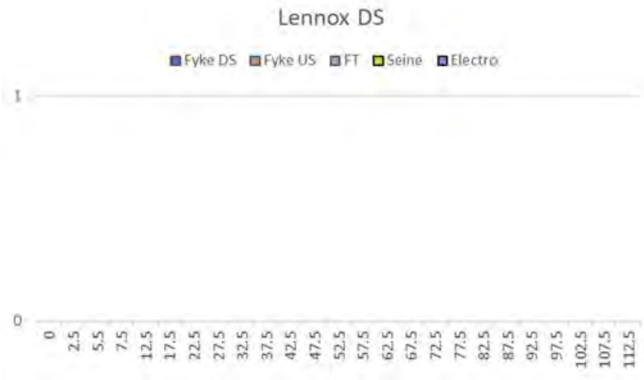
Western Pygmy Perch

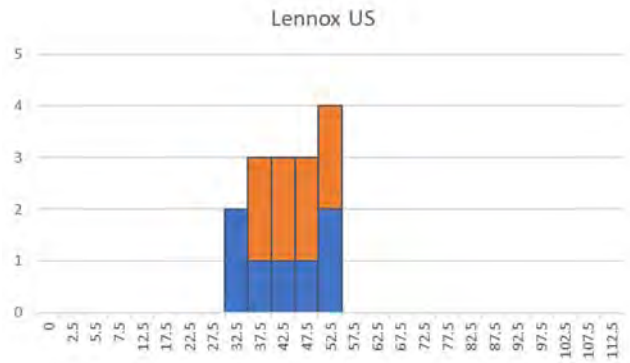


Nightfish

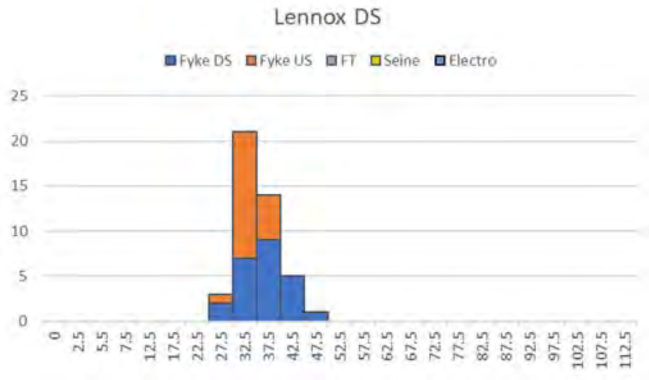


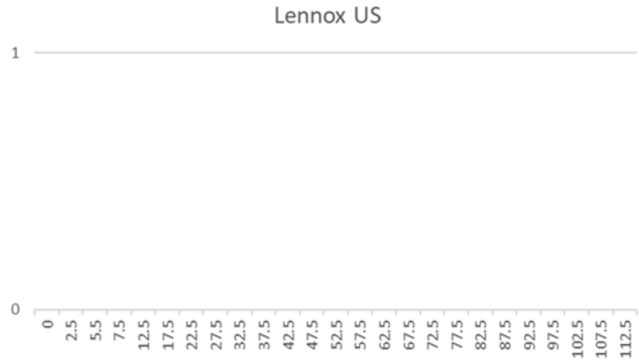
Western Minnow





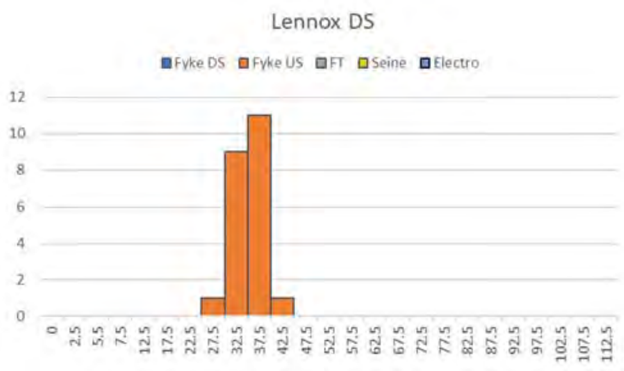
Black Bream

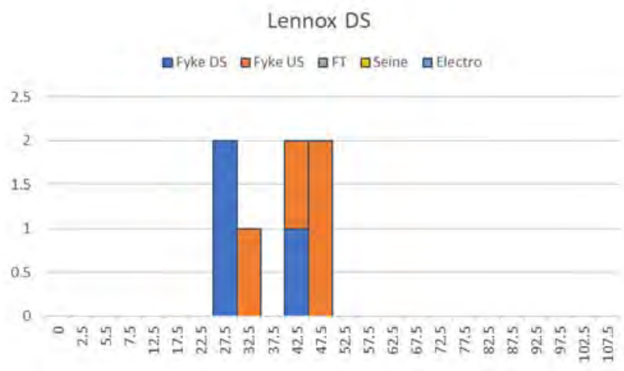


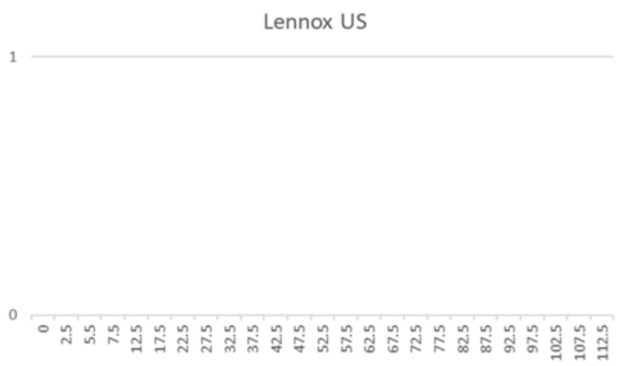


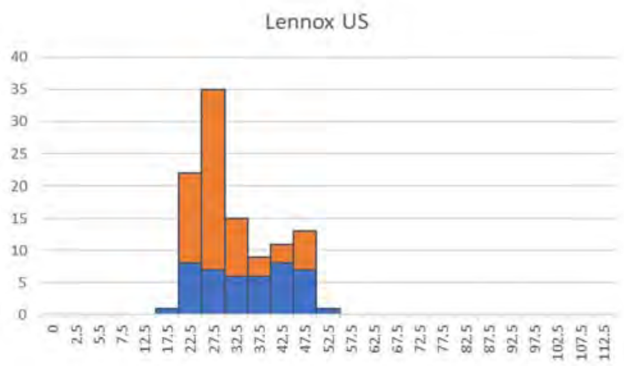
Western Hardyhead

Blue-spot Goby

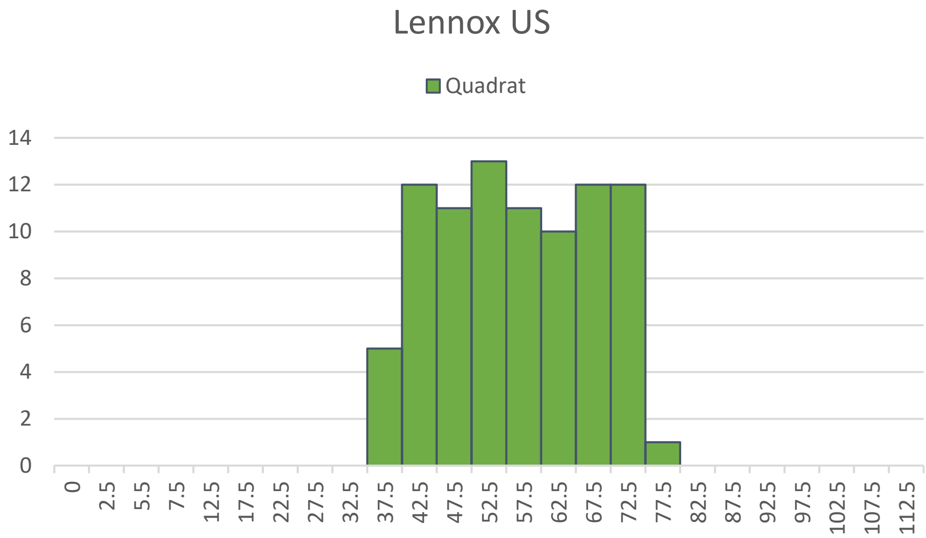


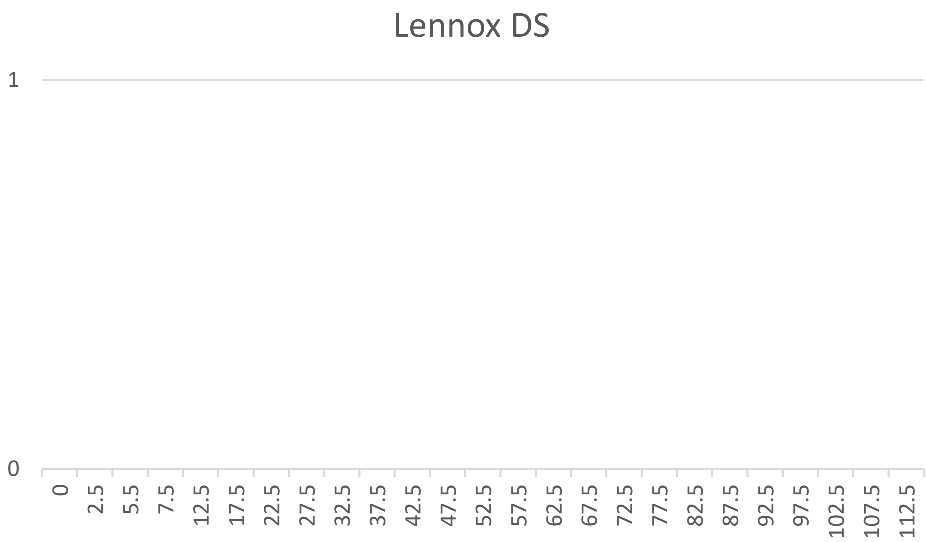






Carter's Freshwater Mussel





Appendix 5 Field survey flora species lists for Lennox Weir survey area.

Family	Species	Common Name	Conservation Status
Amaranthaceae	*Alternanthera nodiflora*	Common joyweed	
Australian Bracken	*Pteridium esculentum*	Bracken	
Campanulaceae	*Lobelia anceps*	Angled lobelia	
Cyperaceae	*Baumea juncea*	Bare twigrush	
Cyperaceae	*Baumea vaginalis*	Sheath twigrush	
Cyperaceae	*Ficinia nodosa*	Knotted club-rush	
Cyperaceae	*Gahnia triffida*	Coast Saw Sedge	
Cyperaceae	*Ledpidosperma effusum*	Spreading sword sedge	
Cyperaceae	*Ledpidosperma longitudinale*	Pithy sword sedge	
Fabaceae	*Callistachys lanceolata*	Native willow	
Fabaceae	*Hardenbergia componiana*	Native wisteria	
Fabaceae	*Kennedia coccinea*	Coral Vine	
Fabaceae	*Paraserianthes lophantha*	Albizia, Cape Leeuwin Wattle	
Haloragaceae	*Myriophyllum crispatum*		
Hydrocharitaceae	*Ottelia ovalifolia*	Swamp Lily	
Iridaceae	*Pattersonia occidentalis*	Purple flags	
Juncaceae	*Juncus kraussii*	Sea rush	
Juncaceae	*Juncus pallidus*	Pale rush	
Juncaginaceae	*Cycnogeton huegelii*	Water ribbons	
Menyanthaceae	*Liparophyllum latifolium*		
Menyanthaceae	*Ornduffia albiflora*		
Myrtaceae	*Agonis flexuosa*	WA peppermint	
Myrtaceae	*Astartea* sp.		
Myrtaceae	*Eucalyptus rudis*	Flooded gum	
Myrtaceae	*Eucalyptus rudis* subsp. *cratyantha*	Large-flowered Flooded Gum	P4
Myrtaceae	*Melaleuca raphiophylla*	Swamp paperbark	
Plantaginaceae	*Gratiola* sp.	Brooklime	
Polygonaceae	*Persicaria decipiens*	Slender knotweed	
Polygonaceae	*Persicaria hydropiper*	Water pepper	
Primulaceae	*Samolus repens*	Creeping brookweed	
Restionaceae	*Leptocarpus thysananthus*		
Rhamnaceae	*Spiridium globulosum*	Basket bush	
Rhamnaceae	*Trymalium odoratissimum*	Karri hazel	
Weeds			
Amarylidacea	*Leucojum aestivum*	Snowflake	
Araceae	*Zantedeschia aethiopica*	Arum Lily	
Asparagaceae	*Asparagus asparagoides*	Bridle creeper	

Asteraceae	*Carduus* sp.	Thistle	
Asteraceae	*Cotula coronipifolia*	Waterbuttons	
Asteraceae	*Hypochaeris* sp.	Flatweed	
Asteraceae	*Sonchus*	Sowthistle	
Brassicaceae	*Cardamine hirsuta*	Hairy Bittercress	
Cyperaceae	*Isoepis prolifera*	Budding Club-rush	
Juncaceae	*Juncus usitatus*	Common rush	
Moraceae	*Ficus carica*	Edible Fig	
Oxalidaceae	*Oxalis pes-caprae*	Sour sob	
Papveraceae	*Fumaria capreolata*	White Fumitory	
Plantaginaceae	*Callitriche brutia*	Starwort	
Plantaginaceae	*Plantago lanceolata*	Robwort plantain	
Poaceae		Annual grasses	
Poaceae	*Paspalum*	Couch	
Poaceae	*Pennisetum clandestinum*	Kikuyu	
Polygonaceae	*Persicaria maculosa*	Redshank	
Polygonaceae	*Rumex* sp.	Dock	
Primulaceae	*Anagallis arvensis*	Pimpernel	
Scophulariaceae	*Verbascum virgatum*	Mullein	