
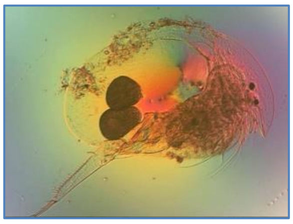

Assessing Obligate Habitat of Threatened Pygmy Perches in Lake Alexandrina

Report to the Murray–Darling Basin Authority and the South Australian Department of Environment, Water and Natural Resources

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Acknowledgements

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The rotifer *Keratella americana* is a new record for Australia, and was probably introduced from the Americas via the pet trade or aquaculture.

Summary

This intervention monitoring project relates to the Lower Lakes, Coorong and Murray Mouth (LLCMM) Environmental Water Management Plan (MDBA 2014), and the refined LLCMM Condition Monitoring Plan (CMP) target/objective F2 to ensure recruitment success of threatened small-bodied fish species in the Lower Lakes to maintain or establish self-sustaining populations. The objective of this intervention monitoring is to determine the suitability of habitats relating to water levels, aquatic plants, zooplankton and cohabiting fishes in six sites on Hindmarsh Island to better understand the factors limiting recovery of the threatened pygmy perch populations.

Southern pygmy perch (*Nannoperca australis*) was recorded at four of the six sites, with a high abundance at a location in Hunters Creek. Common galaxias (*Galaxias maculatus*) was the most common native fish, captured at all sites and generally in high abundances. Alien fish dominated the catch, predominantly due to high abundances of eastern gambusia (*Gambusia holbrooki*) at all sites (77% of total catch). High cover of emergent, floating and submergent plants were recorded at each site, and vegetation was variable between sites. Sites where southern pygmy perch were captured included abundant submergent feathery leaved plants *Ceratophyllum demersum* and *Myriophyllum salsugineum* which was fringed by emergent *Typha domingensis*. The greatest contrast for total density of zooplankton between the open water and vegetation samples was at the site where southern pygmy perch was most abundant, and relates to higher numbers of protists, rotifers and copepods collected amongst aquatic plants. Analyses, however, failed to indicate any clear patterns related to zooplankton assemblages and the presence of southern pygmy perch.

Despite the low sample size (six sites), the data showed some patterns that warrant further investigation. The data suggested that southern pygmy perch have a preference for small linear sites with the feathery leaved submergent species *Ceratophyllum demersum* and *Myriophyllum salsugineum* and the emergent *Typha domingensis*. It is unclear why southern pygmy perch were not captured at a site in Boggy Creek where the vegetation appeared suitable. The other site where southern pygmy perch was absent is noticeably different from other sites, being in a large lagoon dominated by the strappy leaved submergent *Vallisneria australis* and lacking emergent plant species.

Ideally, to overcome the main limitation of small sample size, this study design would be expanded to include all 17 sites sampled in Lake Alexandrina in the threatened fish condition monitoring program so that the habitat, resource requirements and threats of pygmy perches are specifically determined, particularly in relation to water level management. Further, an expansion of sites would allow the inclusion of Murray hardyhead into the study. The information would contribute towards achieving the condition monitoring target to maintaining or establish self-sustaining populations of threatened fishes. For example, the best locations for reintroductions of Yarra pygmy perch (*Nannoperca obscura*) would be identified. Currently the target is not being met due to the apparent extinction of Yarra pygmy perch and the slow recovery (limited recruitment) of southern pygmy perch in the LLCMM icon site.

Introduction

A range of habitats fringe Lake Alexandrina in South Australia including stream, river, swamp, wetland, lake and brackish water areas (estuarine conditions). Two threatened pygmy perches occupy the wetland sites, and their populations have been assessed since 2007–08 through the condition monitoring program under The Living Murray (TLM) initiative of the Murray–Darling Basin Authority (MDBA). Monitoring showed the only known population of Yarra pygmy perch (*Nannoperca obscura*) in the Murray–Darling Basin (MDB) was extirpated from Lake Alexandrina during the 1997–2010 Millennium Drought (Wedderburn *et al.* 2014; Wedderburn *et al.* 2012). Yarra pygmy perch is 'Vulnerable' under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) and 'Critically Endangered' in South Australia (Hammer *et al.* 2009), due to population decline and regional extinctions (Saddlier *et al.* 2013; Wager and Jackson 1993). Southern pygmy perch (*Nannoperca australis*) is 'Endangered' in South Australia (Hammer *et al.* 2009), and was also extirpated from the Lake Alexandrina during the Millennium Drought (Wedderburn *et al.* 2014).

An attempt to reintroduce Yarra pygmy perch to the MDB in 2012–13 appears unsuccessful (Bice *et al.* 2014; Wedderburn 2014). A second attempt to reintroduce Yarra pygmy perch in November 2015 also had limited success, but on this occasion factors potentially associated with recovery (e.g. water levels, food availability, predation, competition) were examined through an intervention monitoring project (Wedderburn *et al.* 2016). On the other hand, populations of southern pygmy perch persisted in tributaries of the lake (Hammer *et al.* 2012; Whiterod *et al.* 2015), thereby providing the possibility of natural recovery. Southern pygmy perch reintroduced to the Hindmarsh Island region in 2011 and 2012 persist with limited wild recruitment (Bice *et al.* 2014; Wedderburn and Barnes 2014; Wedderburn and Barnes 2017).

This intervention monitoring project relates to the Lower Lakes, Coorong and Murray Mouth (LLCMM) Environmental Water Management Plan (MDBA 2014), and the refined LLCMM Condition Monitoring Plan (CMP) target/objective F2 to ensure recruitment success of threatened small-bodied fish species in the Lower Lakes to maintain or establish self-sustaining populations. The objective of this intervention monitoring is to determine the suitability of habitat as they relate to water levels, aquatic plants, zooplankton and cohabiting fishes in six sites on Hindmarsh Island to better understand the factors limiting recovery of the threatened pygmy perch populations.

Materials and methods

Fish and water quality

Six sites were included in the current intervention monitoring project (Table 1; Figure 1). The same sites were sampled during the March 2017 condition monitoring, using a repeated sample method to account for imperfect detection, and the fish (fyke catches only) and water quality data are used in the current report (see detailed methods in Wedderburn and Barnes 2017). The selection of six study sites in this intervention monitoring represented an array of habitat types where southern pygmy perch was either present (sites 3, 5, 68 and 71) or absent (sites 31 and 34).

Table 1. Sites sampled in March 2017 intervention monitoring (UTM zone 54H, WGS84).

Site	Site description	Easting	Northing	Habitat type
3	Hunters Creek (upstream Denver Rd)	309489	6066309	Natural channel
5	Channel off Steamer Drain	310426	6066005	Modified channel
31	Boggy Creek	312194	6067197	Modified channel
34	Shadows Lagoon	311165	6067555	Wetland
68	Shadows Lagoon–Hunters Creek	310784	6067009	Wetland
71	Shadows Lagoon channel (S)	311250	6067348	Artificial channel

Figure 1. Intervention monitoring sites on Hindmarsh Island.

Zooplankton assemblages

Quantitative zooplankton sampling occurred on a single occasion at the six study sites on the 22nd of March 2017. Zooplankton was collected at each site with 3×4 L Haney trap samples, and the total 12 L was filtered through a 60 µm mesh net. The concentrate was captured in a 200 ml PET bottle at the end of the tow net, and immediately preserved in 100% ethanol. The zooplankton sampling equipment was cleaned in a bucket with dilute detergent and rinsed with tap water prior to sampling at each site to prevent cross contamination. At each site, samples were collected from (1) open water and (2) aquatic vegetation.

The zooplankton samples were decanted into a 200 ml measuring cylinder and the volume recorded. The cylinder was then capped with Parafilm, inverted three times to distribute the contents, and a 1 ml Gilson pipette sample taken from approximately the centre of the agitated sample. The 1 ml was run into a Pyrex® gridded Sedgewick-Rafter cell, the contents counted in their entirety and zooplankters identified on an Olympus BH-2 compound microscope (Nomarski optics). The density of zooplankton in the 1 ml aliquot was multiplied by the sample volume to provide an estimate of the density in the volume, and the number of zooplankter/L was calculated. Taxonomic guides were Shiel (1995) and the series *Guides to Identification of the Microinvertebrates of the Continental Waters of the World* (Backhuys, Leiden).

To examine the links between zooplankton assemblages and habitat data were analysed by Non-metric Multi-dimensional Scaling (NMS) ordination using the Relative Sørensen distance metric in PC-ORD (ver. 6: McCune and Mefford 2011). The ordination separated open water and vegetation samples at each of six sites based on the composition and abundance of zooplankton assemblages.

Aquatic plants assessment

Habitat surveys were undertaken at each of the sites; the percentage cover of each species at or below the water level was visually estimated by two observers. In several instances the total cover of plants was greater than 100%, which was due to species occupying different levels (e.g. floating *Azolla* over submergent vegetation).

Comparison of the vegetation between sites was analysed using Principal Coordinates Analysis (PCO) ordination with the Bray-Curtis distance metric (Bray and Curtis 1957). Vectors of species abundances with a Spearman correlation coefficient >0.3 were overlayed on the ordination plot. Analyses were undertaken using PRIMER version 6.0.12 (Clarke and Gorley 2015).

Results

Water quality and depths

The study sites had salinities ranging from 577 EC in the channel off Steamers Drain (site 5) to over 1700 EC in Shadows Lagoon (site 34 and 68), whereas pH was comparable between sites (Table 2). Secchi depth was the most widely variable habitat measure with a low transparency at Shadows Lagoon–Hunters Creek (site 68) and high water clarity in the channel coming off Shadows Lagoon (site 71). Water depth was generally shallow throughout and ranged from 39 cm to 66 cm at sites, which related to the managed water levels of Lake Alexandrina and the Goolwa Channel during the study period (Figure 2).

Table 2. Water quality values at intervention monitoring sites in March 2017.

Site	Salinity (TDS)	EC (µS/cm)	pH	Secchi (cm)	Water Temp. (ºC)	Mean depth (cm)
3	403	616	7.58	>53	18.8	39
5	377	577	7.22	55	20.4	66
31	496	767	7.6	46	20.4	65
34	1131	1741	7.86	53	20.3	41
68	1168	1797	7.2	28	19.8	62
71	685	1058	7.62	>73	19.1	39

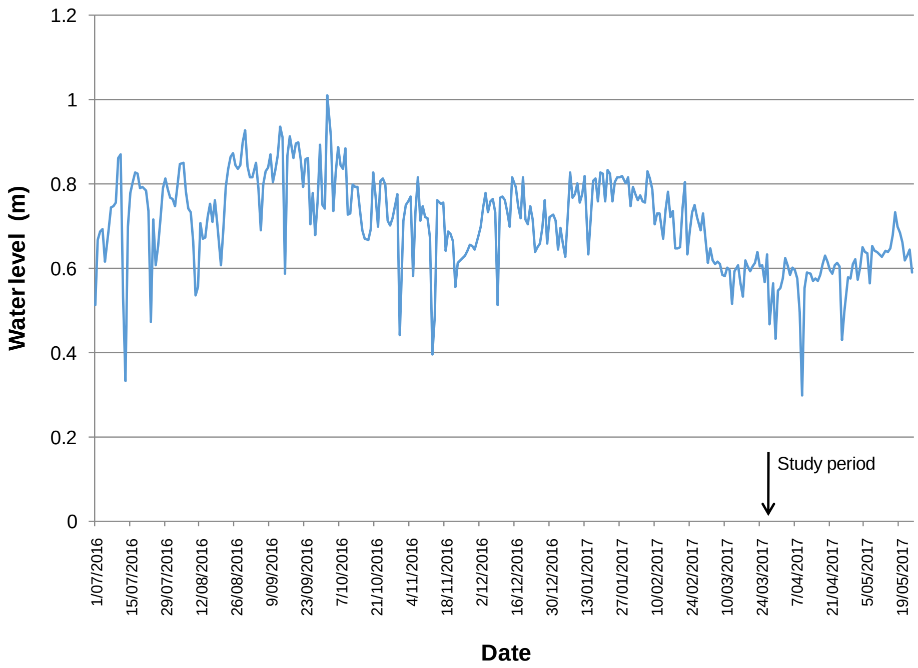

Figure 2. Water levels at Hindmarsh Bridge (Beacon 23) in 2016–17 with study period indicated (South Australian Government, unpublished data).

Fish assemblages

Condition monitoring in March 2017 at the six intervention monitoring sites recorded a total of 8022 fish represented by 11 native and four alien species (Table 3). Southern pygmy perch was recorded at four of the six sites, with a high abundance at site 3 in Hunters Creek. The probability of detection for southern pygmy perch was 0.75 (SE ±0.101) for the 17 sites sampled three times during condition monitoring in March 2017 (Wedderburn and Barnes 2017). Therefore, there is a high level of confidence that the species was detected at the six intervention monitoring sites if it was present (i.e. low chance of false absence being recorded). Common galaxias (*Galaxias maculatus*) was the most numerous native fish, captured at all sites and generally in high abundances.

Sites 31 and 34 had the highest species richness which included 5–6 native species and the four alien fishes (Figure 3). Alien fish dominated the catch at the six intervention monitoring sites in March 2017, predominantly due to high abundances of eastern gambusia at all sites (77% of total catch). The alien redfin perch, however, was mostly recorded at sites 31 and 34. Common carp was also most abundant at sites 31 and 34 where it comprised approximately 25% of the catch. Southern pygmy perch was absent at sites 31 and 34, and was only a notable proportion of the catch (7%) at site 3 in Hunters Creek. Southern pygmy perch was also detected at sites 5, 68 and 71 but only represented a low proportion (<0.4%) of the catches.

Habitat consisting of abundant *Ceratophyllum demersum* covered by filamentous green algae and fringed by *Typha* in Hunters Creek (site 3), which was the site of greatest abundance of southern pygmy perch in March 2017.

Table 3. Total numbers of each fish species captured at the six intervention monitoring sites during condition monitoring in March 2017 (Wedderburn and Barnes 2017).

Common name	**Scientific name**	**Site 3**	**Site 5**	**Site 31**	**Site 34**	**Site 68**	**Site 71**
Southern pygmy perch	*Nannoperca australis*	80	6	0	0	5	2
Murray hardyhead	*Craterocephalus fluviatilis*	0	0	8	0	0	1
Unspecked hardyhead	*Craterocephalus fulvus*	0	0	2	0	0	0
Bony herring	*Nematalosa erebi*	0	0	37	44	0	0
Flathead gudgeon	*Philypnodon grandiceps*	1	1	36	27	17	0
Dwarf flathead gudgeon	*Philypnodon macrostomus*	2	0	1	0	11	2
Carp gudgeon	*Hypseleotris* spp.	3	15	4	6	1	37
Congolli	*Pseudaphritis urvillii*	1	1	4	0	0	0
Common galaxias	*Galaxias maculatus*	114	410	26	37	11	1
Blue-spot goby	*Pseudogobius olorum*	0	0	0	1	3	0
Lagoon goby	*Tasmanogobius lasti*	0	0	0	0	1	0
Alien fishes							
Common carp	*Cyprinus carpio*	15	66	151	245	84	11
Goldfish	*Carassius auratus*	11	44	26	10	105	43
Redfin perch	*Perca fluviatilis*	0	0	20	38	7	0
Eastern gambusia	*Gambusia holbrooki*	920	2729	230	562	1125	621

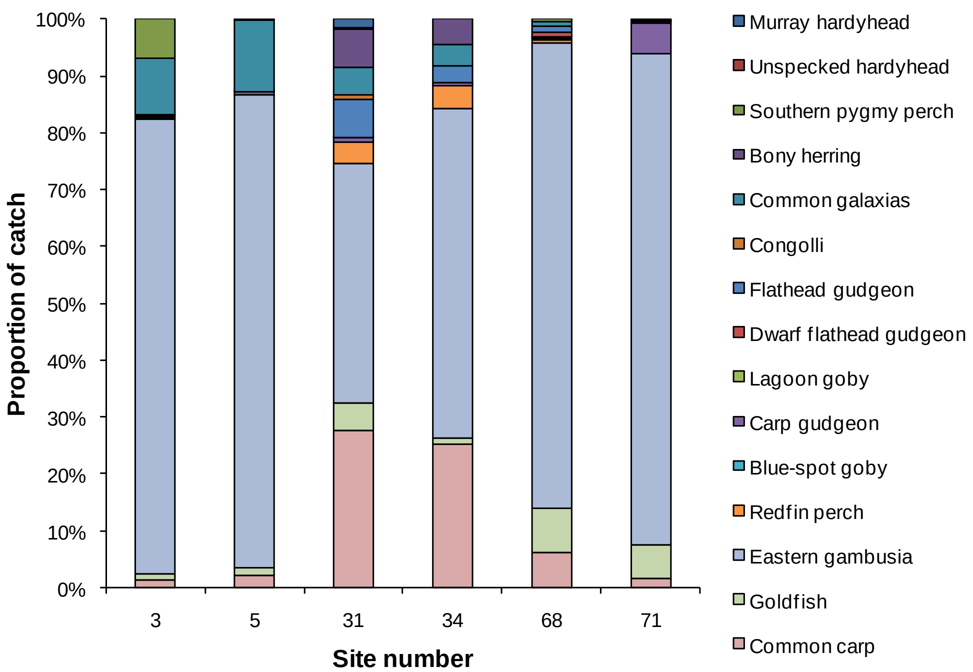

Figure 3. Proportion of each fish species in total catches at each intervention monitoring site in March 2017.

Aquatic plants

High cover of emergent, floating and submergent plants were recorded at each site (Table 4). Principal coordinates ordination showed the vegetation between sites was variable, with sites 31 and 68 being the most similar (Figure 4). Sites where southern pygmy perch were captured were typically dominated by *Ceratophyllum demersum* and *Typha domingensis*, except site 5 which had high cover of *Typha domingensis* and 25% cover of *Myriophyllum salsugineum*. Southern pygmy perch was not captured at site 31 despite the location having a similar plant community as site 68. The plant community at site 34, also where no southern pygmy perch were captured, was dominated by *Vallisneria australis* and *Azolla filiculoides*.

Table 4. Abundance of each plant species at the six intervention monitoring sites in March 2017.

Species name	Abundance (%)					
	Site 3	Site 5	Site 31	Site 34	Site 68	Site 71
Azolla filiculoides	10	10	25	40	30	60
Ceratophyllum demersum	75	1	40	1	30	80
Crassula helmsii	0	0	0	1	0	0
Eleocharis acuta	0	0	0	0	0.5	0
Filamentous green	60	25	0	0	0	0
Ludwigia peploides	0	0	2	0	5	0
Myriophyllum caput-medusae	0	0	1	0	0	0
Myriophyllum salsugineum	0.5	25	1	0	0.5	0
Paspalum distichum	0.5	10	1	1	0	0.5
Phragmites australis	0	0	0	0	0.5	0
Potamogeton pectinatus	3	0	0	0	0	0
Schoenoplectus validus	0	0	0	0	0	0.5
Triglochin procerum	0	0	0	0	0	0.5
Typha domingensis	20	50	40	0	40	10
Vallisneria americana	0	0	0	40	1	10

Habitat preferred by southern pygmy perch includes submergent feathery leaved plants *Ceratophyllum demersum* and *Myriophyllum salsugineum* fringed by *Typha domingensis*.

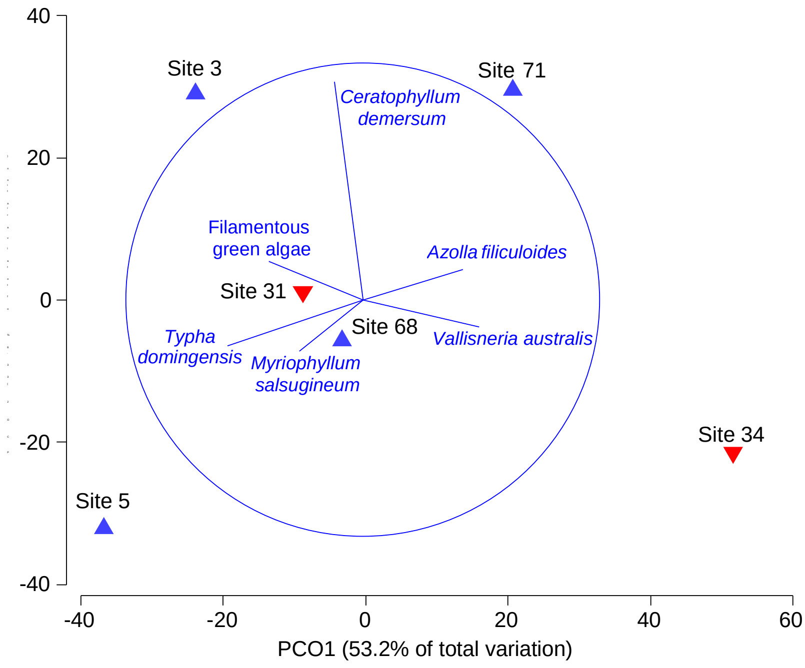

Figure 4. Principal coordinates ordination comparing the vegetation between sites where southern pygmy perch were captured (blue) and were not captured (red).

Zooplankton

The greatest contrast for total density of zooplankton between the open water and vegetation samples was at site 3, which largely relates to higher numbers of protists, rotifers and copepods collected amongst aquatic plants (Figure 5). Most sites had an equal density of rotifers, which were noticeably more abundant in vegetation compared to open water at sites 68 and 71. Similarly at sites 68 and 71, the density of protists was high, and corresponds to the high water transparency and shallow mean depth (see Table 2).

The ordination shows several rotifer species are correlated with open water samples (red dots) at sites 31 and 34, where southern pygmy perch was absent in March, and include *Keratella procurva*, *Keratella americana*, *Keratella tropica*, *Lecane* (M.), *Proalides tentaculatus, Trichocerca pusilla*, *Filinia* cf. *longiseta*, *Filinia* cf. *terminalis*.

There is a correlation between the protist *Halteria* sp., and the rotifers *Cephalodella forficula* and *Lecane lunaris* in the open water collected at site 5, where southern pygmy perch was most abundant. In vegetation samples at site 5 there is a correlation with the protists *Arcella bathystoma* and *Centropyxis aculeata*, and rotifers *Squatinella* sp. and *Lepadella* sp.a.

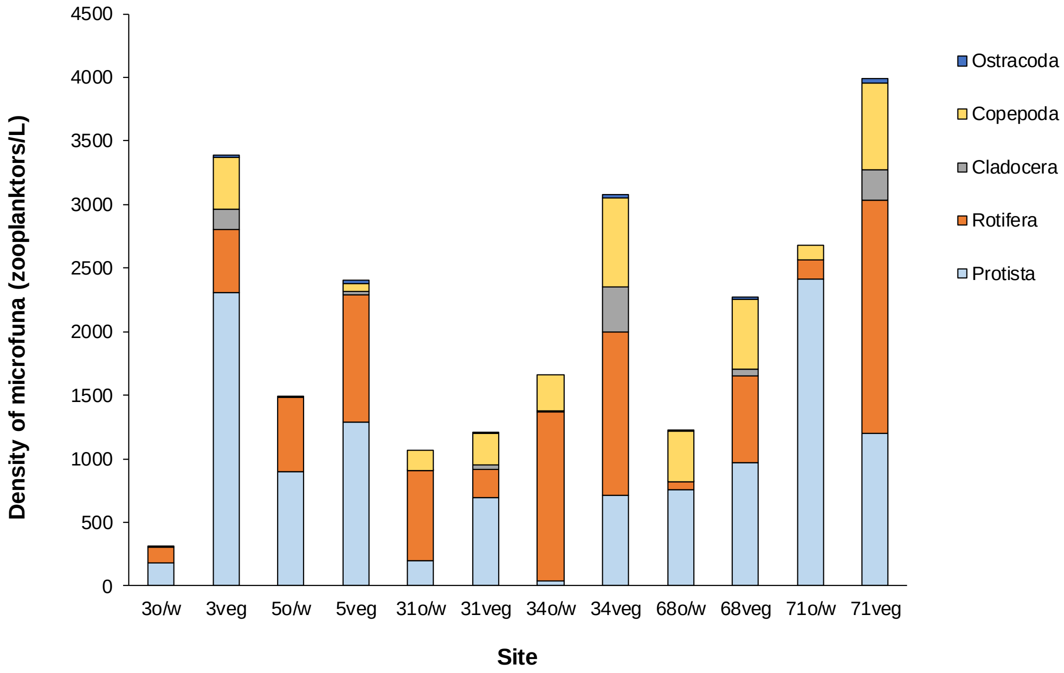

Figure 5. Density of each major zooplankton group collected at the six intervention monitoring sites in the open water (o/w) and vegetation (veg) samples in March 2017.

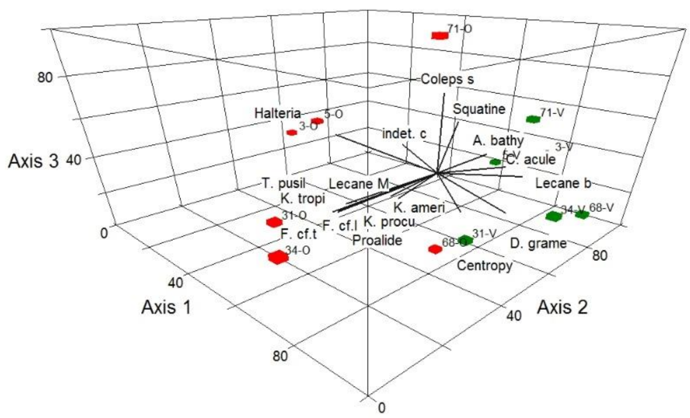

Figure 6. Three dimensional NMS ordination (stress 6.2) with open water (red) and vegetation (green) sites plotted and zooplankton species overlayed with vector proportional to and directed towards their correlations (if $r > 0.4$) with sites for species.

Discussion

Evidence points towards the specific plant types as a key factor influencing the distribution and abundance of southern pygmy perch regardless of the presence of specific prey items. The current intervention monitoring indicates that southern pygmy perch utilises feathery leaved aquatic plants while also feeding on the associated microfauna (cf. Wedderburn *et al.* 2016). It is likely pygmy perch utilise the habitat for cover to avoid predation by birds or fish (e.g. redfin perch: Hutchison 1991) or harassment from the prolific eastern gambusia (Pyke 2008). This fails to explain, however, the absence of southern pygmy perch at site 31 where most, if not all, habitat features and zooplankton were comparable to sites where the species was present (e.g. sites 3 and 68). The most notable measured difference was the higher number of species in the fish assemblage at site 31, which consisted of a high proportion of alien common carp and redfin perch. Indeed, the predatory redfin perch was absent at site 3 where southern pygmy perch was most abundant.

High densities of surface-associated testates (Protista) at site 3 suggests an association with the vegetation, predominantly *Ceratophyllum demersum* and filamentous algae. Similarly, the vegetation may account for the diverse epiphytic/benthic chydorid cladocerans. The absence of a similar zooplankton assemblage at site 31 is likely related to differences in vegetation (e.g. less filamentous algae) or possible sampling variation. The high density of protists at site 3 is likely unrelated to the high abundance of southern pygmy perch due to the low nutritional value of testates, most of which have a siliceous test (shell). The pygmy perch were more likely feeding on cladocerans – this diet was shown for Yarra pygmy perch in an earlier intervention monitoring project (Wedderburn *et al*. 2016).

Curiously, in the samples there was an absence of larger daphniids (e.g. *D. carinata*, *D. galeata*, *D. lumholtzi*) which generally are relatively abundant in Lake Alexandrina (Shiel and Tan 2013; Wedderburn *et al*. 2016). Similarly, centropagid calanoids (e.g. *Boeckella*, *Calamoecia*) are usually common in open water in the lake but were unrecorded in the current intervention monitoring. These groups of zooplankton are favoured prey items of small-bodied fishes, and their absence is possibly a reflection of high levels of predation (e.g. by prolific eastern gambusia: see Wedderburn *et al*. 2016). The few larger cladocerans which were recorded in the current monitoring were in the vegetation samples, with some degree of 'shelter'. The few copepods recorded were cyclopoids which also have a preference for vegetated littoral habitats. Of the diverse rotifer assemblage recorded across all sites, relatively few taxa are planktonic in habit (e.g. *Polyarthra*, *Filinia*), and these were only notable in sites 31 and 34. The majority of rotifers recorded during the intervention monitoring are epiphytic, epibenthic or otherwise surface-associated, apparently dislodged from substrates by submergence of the sampling trap in some shallow sites.

Whilst it was difficult to ascertain firm relationships between the presence of southern pygmy perch and the aquatic plant community, due to low sample size, the data did show some patterns that warrants further investigation. The data suggested that southern pygmy perch have a preference for small linear sites with the feathery leaved submergent plants species *Ceratophyllum demersum* and *Myriophyllum salsugineum* and the emergent *Typha domingensis*. It should be noted that *Typha domingensis* when growing in shallow water often has adventitious roots growing out of rhizomes that are of feathery appearance, which resemble the structure of *Myriophyllum salsugineum* and *Ceratophyllum demersum* leaves. It is unclear why southern pygmy perch were not captured at site 31 because it has a similar plant community and morphology to sites where the threatened fish was captured. The other site where southern pygmy perch was absent (site 34) was in a large lagoon dominated by a strappy leaved submergent species (*Vallisneria australis*) with no emergent plant species present.

Data from the vegetation condition monitoring program showed there have been increasing trends in the abundance of native submergent species since spring 2010 in Lake Alexandrina, Goolwa Channel and permanent wetlands. Furthermore, similar trends for *Typha domingensis* were observed for Goolwa Channel and Lake Alexandrina (Nicol *et al.* 2017). These trends suggest hydrological and physicochemical conditions since 2010 are favourable for the recruitment and growth of the species that may be important habitat for southern pygmy perch. Nevertheless, monitoring is important because complementary actions may need to be undertaken to ensure southern pygmy perch is maintained. For example, evidence from this study showed *Typha domingensis* provides habitat for southern pygmy perch when growing with *Myriophyllum salsugineum* or *Ceratophyllum demersum.* However, *Typha domingensis* growing as a monospecific stand, which is common for this species (e.g. Finlayson *et al.* 1983), may not provide suitable habitat so management actions such as its physical removal may be required to maintain pygmy perch habitat. This situation appears to be the case on Mundoo Island where southern pygmy perch has disappeared from the drainage system which has been overrun by *Typha domingensis* in recent years (Wedderburn and Barnes 2017).

The current intervention monitoring project was conducted with limited resources, so only general conclusions can be drawn from the patterns observed at a small number of sites. Ideally, this study design would be expanded to include all 17 sites sampled in the threatened fish condition monitoring program so that the habitat, resource requirements and threats of pygmy perches are specifically determined. Further, an expansion of sites would allow the inclusion of Murray hardyhead (*Craterocephalus fluviatilis*) into the study – the third fish species under the CMP target. The information gained from expanded intervention monitoring would assist management of the threatened fishes in the icon site (e.g. identify best locations for reintroductions of Yarra pygmy perch), particularly as it relates to decision making regarding water levels of Lake Alexandrina. Such information would contribute towards achieving the condition monitoring target to maintaining or establish self-sustaining populations of threatened fishes. Currently the target is not being met due to the apparent extinction of Yarra pygmy perch and the slow recovery (limited recruitment) of southern pygmy perch in the icon site (Wedderburn and Barnes 2017).

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