The ecological impacts of secondary salinisation on halo-tolerant fishes in south-western Australia

Mahmoud Rashnavadi

D.V.M

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DECLARATION

I declare that this thesis is my own account of my research and contains as its main content work that has not previously been submitted for a degree at any tertiary institution.

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Mahmoud Rashnavadi

Abstract

Secondary salinisation is a anthropogenic process that is increasingly disrupting the health of freshwater ecosystems in Australia. In a continent where supplying future water resources for a growing population is challenging, secondary salinisation not only makes freshwater ecosystems unsuitable for human use, but may also have substantial negative impacts on aquatic biota. A large body of research in Australia and overseas has found that increasing salinisation is associated with a loss of biodiversity in freshwater ecosystems. However, most of these studies are based on salinity tolerance tests conducted in the laboratory, which determine physiological effects of salinity without considering the synergistic impacts of other existing stressors in the system.

The south of Western Australia is a biodiversity hot spot, but has been severely impacted on by secondary salinisation. Only 44% of flow in the 30 largest rivers in the Southwest Coast Drainage Division is fresh and more than half of the rivers in the region can be classified as brackish or saline. Among these rivers, the Blackwood River is the second largest in the region, has the highest discharge and contains all eight native riverine fish species which are endemic to the south-west. More than 85% of the river catchment has been cleared and salinity has an annual upward trend throughout the upper catchment and in the main channel of the lower catchment, while lower catchment tributaries remain fresh. In this study, I have used a combination of field and laboratory studies to investigate the impacts of increasing salinity on the biological performance of native and exotic freshwater fishes in different parts of the Blackwood River.

Eleven species of fish were captured in the Blackwood River during the study; *Galaxias occidentalis, Gambusia holbrooki, Leptatherina wallacei, Pseudogobius olorum, Edelia vittata, Tandanus bostocki, Nannatherina balstoni*, *Bostockia porosa, Afurcagobius suppositus, Galaxiella munda* and *Oncorhynchus mykiss*. The greatest diversity of fish species (*G. occidentalis, G. holbrooki, L. wallacei, P. olorum, E. vittata, T. bostocki, N. balstoni*, *B. porosa* and *A. suppositus*) was found in the main channel of the lower catchment, where salinity typically varies between 2 and 5 ppt. Eight species (*B. porosa*, *E. vittata, G. occidentalis, N. balstoni*, *T. bostocki, A. suppositus, G. munda* and *O. mykiss*) were found in freshwater tributaries of the lower catchment, where salinity is always less than 0.5 ppt. In the upper catchment, where salinity varied from 7 ppt to over 31 ppt, only four species of fish were captured; the native riverine species *G. occidentalis*, the introduced *G. holbrooki* and the euryhaline species *L. wallacei* and *P. olorum*.

For the four species of fish that were distributed throughout the Blackwood River (*G. occidentalis*, *G. holbrooki*, *L. wallacei* and *P. olorum*), I investigated the size, morphology, life-cycle, diet and rate of parasitism between populations in the upper and lower catchment. All four fish species have relatively short life spans and this was more evident in the case of *G. holbrooki* and *P. olorum* in which 100% (n = 558) and 98% (n = 163), respectively, were classified as 0+. Forty-five percent of *L. wallacei* (n=788) and 41% of *G. occidentalis* (n=942) were classified as 0+. Significant numbers of *G. occidentalis* (46%) and *L. wallacei* (43%) were found in their second year of life, while this number was only 2% for *P. olorum*. No *L. wallacei* (n = 776) older than three years were captured in this study, while 1% (n = 937) of *G. occidentalis* were recorded as four years old.

Spawning of *L. wallacei* in the upper catchment peaked by mid spring, while fish in the lower catchment delayed spawning until early summer. There were no significant differences between spawning time of *G. occidentalis* and *P. olorum* populations in the upper and lower catchments of the Blackwood River, although biannual spawning of *P. olorum* was only recorded in upper catchment sites. The breeding season of *G. holbrooki* in both the upper and lower catchments of the Blackwood River lasted for a period of at least six months (from October to beyond March).

Dietary analyses of all four fish species from the upper and lower catchments of the Blackwood River revealed their opportunistic feeding behaviour. Overall, the highest diversity of invertebrate fauna was recorded in the diet of *L. wallacei*, while the lowest diversity was recorded in *P. olorum*. Crustaceans including Amphipoda, Copepoda, Cladocera and Ostracoda, made up a greater proportion of the diet of all four fish species in the salt affected upper catchment than in the lower catchment. There were significant differences between the dietary compositions of all fish species in both upper and lower catchments. The eggs or larvae of native fishes were not commonly found in the diet of *G. holbrooki*, although dietary analysis showed that this species is clearly in competition with native fish fauna.

Over all, five species of macroparasites, including nematodes, trematodes and cestodes, were found in association with the four fish species studied. The highest prevalence of parasite infections were recorded in the native species *G. occidentalis* (5.9%), *P. olorum* (5.7%) and *L. wallacei* (2.8%) with the lowest prevalence in the introduced *G. holbrooki* (0.2%), despite *G. holbrooki* making up approximately 77% of the fish population in the river. This reduced parasite diversity in introduced species, compared with native hosts, has also been reported in a wide range of other taxa, and may contribute to the competitive advantage of introduced pest species. There was a correlation between the distribution of one species of parasite, *Diplostomum* sp., and position of its fish intermediate host in the catchment. This trematode, which has a complex life-cycle involving a number of different hosts, was mainly restricted to the freshwater tributaries, occurred rarely in the main channel of the lower catchment where the salinity was relatively low and was never found in the salinised upper catchment.

Despite the circumstantial evidence from field studies that the current pattern of fish distributions in the Blackwood River has been influenced by secondary salinisation, salinity tolerances of native freshwater fishes have not previously been measured under controlled laboratory conditions. The acute salinity tolerance of populations of *G. occidentalis* from the upper and lower catchments of the Blackwood River was studied experimentally, and compared with the tolerance of two other native fish species; *E. vittata* which is found in the main channel of the lower catchment, but not in the upper catchment; and *N. balstoni* which is restricted to a single small, freshwater tributary of the lower catchment. *Nannatherina balstoni* was found to have the lowest salinity tolerance with EC_{50} = 8.2 ppt and EC_{95} = 9.3 ppt. This confirms that the upper catchment of the Blackwood River, where the salinity was significantly higher than this range throughout most of the year, is unsuitable for this species and this may explain its absence from most of the catchment. The salinity tolerance of both *E. vittata* (EC_{50} = 14.5 and EC_{95}=15.6) and *G. occidentalis* (EC_{50} = 14.6 ppt and EC_{95} = 15.8 ppt) was considerably higher than that of *N. balstoni* (LC_{50} = 8.2 ppt and LC_{95} = 9.2 ppt). It is possible that the eggs, larvae or juvenile stages of *E. vittata* are more sensitive to salinity than adults and this prevents this species from establishing its life-cycle in the upper catchment of the Blackwood River. Additionally, the greater dispersal capabilities of *G. occidentalis* may enable it to maintain its life-cycle in the upper catchment by moving into refuge areas as salinity increases.

This study has provided valuable insight into the impact of secondary salinisation on the biological performance of freshwater fishes in south-western Australia. These impacts are likely to be further exacerbated by continued increases in salinisation and reduced rainfall due to climate change.

Acknowledgements

I used to be a vet clinician and this study gave me the opportunity to look at the world from a different angle. This shift in my career had its own hardships but at the same time it offered much to learn. This time I was facing the Blackwood River and as with the veterinary environment, when something goes wrong there are environmental symptoms which communicate the problem. This study was all about finding these symptoms and interpreting them. In this endeavour, I had the privilege to be supervised by Professor Alan Lymbery. I would like to extend my sincere thanks to you and my co supervisors Dr David Morgan and Dr Stephen Beatty, who were also beside me throughout this journey.

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