Translocations of freshwater crayfish: contributions from life histories, trophic relations and diseases of three species in Western Australia

Stephen John Beatty

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MURDOCH
UNIVERSITY
PERTH, WESTERN AUSTRALIA

DECLARATION

I declare that the information contained in this thesis is the result of my own research unless otherwise cited

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Stephen John Beatty

Frontispiece: Elizabeth Gratwick

Abstract

By examining Western Australian freshwater crayfishes, this thesis aims to further our understanding of how life-history strategies, trophic relationships and disease introductions contribute to the threats posed by introduced species. Reproductive and population biology of two species of freshwater crayfish endemic to Western Australia (the marron *Cherax cainii* and gilgie *Cherax quinquecarinatus*) and the introduced yabbie *Cherax destructor* were described. Multiple stable isotope analysis was employed to determine the trophic positions of sympatric populations of *C. cainii* and the invading. A serious microsporidian disease of freshwater crayfishes was also discovered in a wild population of *C. destructor*. These data were used to determine the potential threat that *C. destructor* poses to the endemic crayfishes of Western Australia.

Cherax cainii supports an iconic recreational fishery that has been in steady decline for three decades. It is likely that considerable plasticity in the biology of *C. cainii* exists amongst the *ca* 100 populations and that this may result in the current fishery management regulations being not effective in protecting all stocks. To test these hypotheses, the biology of *C. cainii* were described from populations occurring in an impoundment dam (Lake Navarino) at the approximate centre of its current range and in the Hutt River at the northernmost point of its range and compared with those from a previous study near the southernmost point of its distribution. The study confirmed these hypotheses. For example, the onset of spawning was later in the more southerly Lake Navarino population (August) than in the northerly Hutt River population (July). Furthermore, the respective orbital carapace lengths (OCL) at which *C. cainii* reached maturity in the two populations studied here differed markedly. The lengths at which 50% of female and male *C. cainii* matured in Lake Navarino were 32.1 mm and 28.6 mm OCL for females and males, respectively, compared with 70 mm and 40 mm OCL for females and males in the Hutt River, respectively. Therefore, these data clearly demonstrate that the current minimum legal size limit of 76 mm

CL (~55 mm OCL) is ineffective in allowing females to undertake a spawning event prior to legal capture. It is therefore recommended that the minimum legal size limit be increased to 98 mm CL in the Hutt River to allow 50% of females to reach maturity prior to exploitation. Furthermore, as the spawning rate of mature female *C. cainii* in the Hutt River was low (10%) compared with those mature females in the more southerly Lake Navarino (96%), this increase in minimum legal size of capture is of particular importance should fisheries managers wish this translocated population to be exploited sustainably.

It is proposed that the much larger lengths at first maturity and low spawning rate in the Hutt River were due to faster growth rates likely caused by relatively high water temperatures and in response to competition with the sympatric, introduced crayfish, *C. destructor*, respectively. This highlights the plasticity of the biology of *C. cainii* and has considerable implications for effective management of the size-regulated recreational fishery.

Cherax quinquecarinatus, a south-western Western Australian endemic: occupies a broad range of aquatic systems, is likely to be an important component to those aquatic food webs, and is also subject to recreational fishing pressure. *Cherax quinquecarinatus* was found to mature at a relatively small size (*cf C. cainii*) with the L_{50}s for females and males being 18.8 and 24.5 mm OCL, respectively, with the majority of *C. quinquecarinatus* first spawning at the end of their second year of life. The potential (ovarian) and pleopodal fecundities of *C. quinquecarinatus* were relatively low compared to other freshwater crayfishes, being 81.7 (±5.93 s.e.) and 77.1 (±13.76 s.e.), respectively. *Cherax quinquecarinatus* underwent an extended spawning period, from late winter to late summer (i.e. August to February). Three spawning events were facilitated by short brood and rapid gonadal recovery periods, traits consistent with other crayfish species able to exist in temporary environments.

The seasonal von Bertalanffy growth curve, fitted for the first 14 months of life for female and male *C. quinquecarinatus*, had respective K and OCL_{∞}s of 0.29 and 59.6 mm

OCL for females, and 0.25 and 73.8 mm OCL for males, respectively. At 12 months of age, the OCLs of females and males were 14.7 and 14.1 mm, respectively. Estimates of total mortality (*Z*) were relatively high at 2.34 and 1.95 $year^{-1}$ based on an age-converted catch curves for females and males, respectively, with a considerable proportion of this attributed to fishing mortality (exploitation rates of 0.76 and 0.75 for females and males, respectively). *Cherax quinquecarinatus* exhibited traits of both an *r*- and a K-strategist, which has likely to have aided the success of this species across a wide range of permanent and temporary systems.

During this study, *C. destructor* was found in many wild aquatic systems in the southern Pilbara and Southwest Coast Drainage Divisions of Western Australia. This is of great concern as all native freshwater crayfishes in Western Australia are restricted to the southwest while the aquatic systems of the Pilbara Division do not naturally house freshwater crayfish.

Despite the reported impacts that invasive freshwater crayfish species may have on native crayfish species and food webs, the biology and ecology of *C. destructor* in wild systems in Western Australia was unknown and therefore an assessment of their potential impact has not previously been possible. *Cherax destructor* was collected monthly from the Hutt River (Pilbara Drainage Division) for determination of life-history and reproductive biology in a wild aquatic system in Western Australia. Proliferation in that system was attributed to specific traits including: a small size at first maturity with 50% (L_{50}) of females and males maturing at 21.6 and 26.5 mm OCL, respectively, a size attained at the end of their first year of life; a protracted spawning period (July to January); high mean ovarian fecundity of 210.2 (±9.24 s.e.); and a rapid growth rate that was comparable to the larger sympatric *C. cainii* in this system. Life-history characteristics of *C. destructor* in the Hutt River were typical of many other invasive crayfish species and were likely to have aided in its establishment.

This study is the first to examine the diet and trophic position of sympatric populations of two species of freshwater crayfish in Australia. By determining temporal changes in the assimilated diet and trophic positions of sympatric populations of *C. destructor* and *C. cainii*, this study tested the hypothesis that *C. destructor* has the potential to compete with *C. cainii* for food resources. This was tested using multiple stable isotope analyses with samples of *C. cainii*, *C. destructor* and a wide variety of their potential food sources analysed in the Hutt River in summer and winter, 2003. Summer samples indicated that these species occupied similar predatory trophic positions when their assimilated diet consisted of a large proportion of *Gambusia holbrooki* (either when the fish were alive or deceased due to a presumably large natural mortality rate). Although *C. cainii* continued to assimilate animal matter based on winter signatures, those of *C. destructor* appeared to shift towards more of herbivorous trophic position. It appeared that *C. destructor* and *C. cainii* were keystone species in the Hutt River and were likely to be important in the cycling of nutrients and in structuring the aquatic food web that may have been considerably altered by their introduction into this system.

As *C. destructor* has the ability to switch trophic positions, when an otherwise abundant, high protein food sources (i.e. fish) becomes limited (as was the case in winter in the Hutt River), it was able to co-exist with *C. cainii*. Furthermore, the ability of *C. destructor* to switch from a diet of fish in summer to a predominantly herbivorous/detrital diet in winter suggests that it may compete for food resources with the other smaller native freshwater crayfishes (such as *C. quinquecarinatus*) in the small, unproductive lotic and lentic systems common to south-western Australia, which often lack fish during summer.

The recently described *Thelohania parastaci* was identified in *C. destructor* in the Hutt River and *Vavraia parastacida*, previously recorded from *C. cainii* and *C. quinquecarinatus* populations elsewhere in the region, appeared to be infecting *C. cainii*. Although not confirmed to have infected *C. cainii*, the presence of *T. parastaci* in the sympatric *C. destructor* is of serious concern as there is the potential that the disease may be

able to be transmitted to the native congeners of the region, particularly as *C. destructor* establishes itself in other natural waterbodies.

This thesis has addressed major gaps in the understanding of the biology, ecology and threats to the unique freshwater crayfish fauna of Western Australia. The results of this research highlight the plasticity of the biology and ecology of freshwater crayfishes and enabled an initial assessment to be made of the potential ecological impacts of an invading species. Considerable implications for fisheries and other natural resource management agencies ensuing from this research are detailed. The conclusions drawn from this study are also discussed in the broader context of invasive species in general and important future investigations stemming from these results are identified.

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Table of contents

Publications

The following publications form the basis of many of the chapters in this thesis.

Beatty, S. J., Morgan, D. L., and Gill, H. S. (2003). Reproductive biology of the large freshwater crayfish *Cherax cainii* in south-western Australia. *Marine and Freshwater Research* **54**, 597-608.

Beatty, S. J., Morgan, D. L., and Gill, H. S. (2004). Biology of a translocated population of the large freshwater crayfish, *Cherax cainii* Austin and Ryan, 2002 in a Western Australian river. *Crustaceana* **77** (11), 1329-1351.

Beatty, S. J., Morgan, D. L., and Gill, H. S. (2005). Life-history and reproductive biology of the gilgie *Cherax quinquecarinatus*, a freshwater crayfish endemic to south-western Australia. *Journal of Crustacean Biology* **25** (2).

Beatty, S. J., Morgan, D. L., and Gill, H. S. (*in press*). Role of life-history strategy in the colonisation of Western Australian aquatic systems by the introduced crayfish *Cherax destructor*. *Hydrobiologia*.

Additional publication produced from this research:

Beatty, S. J., Molony, B. W., Rhodes, M., and Morgan, D. L. (2003). A methodology to mitigate the negative impacts of dam refurbishment on fish and crayfish values in a south-western Australian reservoir. *Ecological Management and Restoration* **4** (2), 147–49.