Population biology and fishery ecology of the painted crayfish, *Panulirus versicolor*, on the Great Barrier Reef

PhD thesis submitted by

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I concieved, designed, performed, analysed and reported all sections of this thesis and associated publications. Mr Jean-Paul Hobbs, a fellow post-graduate student, assisted with the collection of data, provision of funds, and editing of text (Chapters 2 and 3 only). Dr Mark McCormick, my supervisor, provided general guidance with respect to statistical analysis and thesis writing (Chapters 1−8).

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DECLARATION ON ETHICS

The research presented and reported in this thesis was conducted within the guidelines for research ethics outlined in the *National Statement on Ethics Conduct in Research Involving Human (*1999*),* the *Joint NHMRC/AVCC Statement and Guidelines on Research Practice* (1997)*,* the *James Cook University Policy on Experimentation Ethics*. *Standard Practices and Guidelines* (2001), and the *James Cook University Statement and Guidelines on Research Practice* (2001). The proposed research methodology received clearance from the James Cook University Experimentation Ethics Review Committee (approval number A927), the Great Barrier Reef Marine Park Authority (permit number G04/12708.1), and the Department of Primary Industries (permit number PRM05020B).

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ABSTRACT

Panulirus versicolor, otherwise known as the painted crayfish, is a palinurid (spiny lobster) that inhabits coral reefs of the Indo-Pacific region, including Australia's Great Barrier Reef (GBR) where it forms an esteemed component of the local recreational spearfishery. At present, management strategies for *P. versicolor* are based solely on precautionary principles, since prior to this study virtually nothing was known about this species. The broad goal of this thesis was therefore to describe the population biology and fishery ecology of *P. versicolor* on the GBR, thereby providing a framework for the development of a comprehensive management scheme for this important fishery resource.

To quantify the fishery for *P. versicolor*, teams of spearfishers conducted 135 hr of recreational fishing activities during 12 trips spread across 15 months and seven reefs. It was found that *P. versicolor* was the second most abundant component of the catch, after common coral trout (*Plectropomus leopardus*). Catch per unit effort (CPUE) was estimated to be 0.155 ± 0.025 crayfish hr^{-1}, which is equivalent to one crayfish for each 6.4 hr of spearfishing. Assuming this CPUE was representative of the recreational spearfishery as a whole, and given 37,110 hr as the total annual spearfishing effort on the GBR (Henry and Lyle 2003), the total annual catch of *P. versicolor* was estimated to be 5,773 ± 928 individuals (8,660 ± 1,530 kg). By world standards, this amount is relatively small. However, because this species is highly sought-after and is not abundant anywhere within its distributional range, fishing pressure on *P. versicolor* in readily accessible areas of the

GBR may still be relatively high. Thus, a comprehensive management scheme should be implemented to ensure this species is not over-exploited.

Development of a fishery management scheme requires knowledge of a range of population parameters (*e.g*. abundance, growth, mortality) which can be estimated by mark-recapture techniques. However, it was first necessary to develop a method of tracking individual crayfish in the wild, since most conventional tagging methods are ineffective due to moulting of the exoskeleton. As such, three unconventional tracking methods (ablation, elastomer implants, photographic identification) were evaluated in the field over periods of 6–36 months. Ablation proved to be ineffective due to a high incidence of infection and exoskeletal repair. In contrast, elastomer implants and photographic identification were shown to be highly effective (96.5% and 100% effectiveness, respectively), even after numerous episodes of moulting. Consequently, only the latter two methods were used for the remainder of the study.

To investigate the population biology of *P. versicolor*, a multiple mark-recapture program was conducted at Northwest Island, an offshore coral cay in the GBR complex. Censuses were performed daily for ten consecutive days on six occasions between December 2003 and December 2006, thereby enabling estimation of population parameters over both short- (1−10 d) and long-term (6−36 months) periods. Fifty-six percent of crayfish (50/89) were recaptured (resighted) after 1−10 d, whereas 59% of crayfish (50/85) were recaptured after 6−36 months. Some animals were recaptured (or resighted) on multiple occasions; hence, there were 122 short-term observations and 86 long-term observations.

Ovigerous female crayfish were captured in both summer and winter, suggesting that this species has a protracted spawning period. Although some females reproduced *in situ*, the majority of mature females appeared to emigrate temporarily during summer, resulting in a male-biased local population at that time. Using a sample of crayfish from both inshore and offshore reefs, the size at first maturity (SFM) was estimated to be 88 and 78 mm carapace length (CL) for males and females, respectively. This is substantially larger than estimates of SFM for *P. versicolor* from Western Australia, which may reflect regional differences in either environmental conditions or fishing pressure.

Growth of *P. versicolor* was shown to be asymptotic and well described by a von Bertalanffy growth model (L_∞ = 144.7 mm CL; K = 0.27 yr^{-1}; t_0 = -0.18 yr). Moult interval for larger (>125 mm CL) and smaller (90−125 mm CL) individuals was estimated to be 326 ± 31 and 159 ± 18 d, respectively. Growth increment was estimated to be 2−3 mm CL and appeared to be constant across the range of sizes examined (98−153 mm CL). In general, growth of *P. versicolor* was similar to that of other tropical palinurids, but markedly faster than that of temperate palinurids, which supports the notion of increasing growth rate with decreasing latitude.

The population of *P. versicolor* at Northwest Island was estimated to be small in size (1,400 ± 185 individuals) and sparsely distributed (1.3 ± 0.2 individuals ha^{-1}). The estimated total mortality rate (0.28 ± 0.04 yr^{-1}) was low and probably represented only natural mortality, because the study was conducted at a relatively inaccessible part of the reef that was rarely or never fished. With respect to replenishment of the population, preliminary observations suggested that individuals recruit to inshore reefs and then

migrate offshore as they approach maturity – an ontogenetic pattern that is characteristic of palinurids in general.

Adult crayfish were found to aggregate in dens during the day. At night, individuals moved to and from nearby dens, such that group composition changed frequently. Despite this, two male crayfish never occupied the same den simultaneously, indicating that groups were not merely random mixtures of individuals. Surprisingly, the relationship between body size (CL) and male social status (number of co-habiting females) was weak or non-existent, and experimental translocation of single male and female crayfish to occupied dens did not result in eviction, regardless of CL. Thus, body size appears to be less important in shaping the social system of *P. versicolor* than it is in other species.

Despite the capacity to move considerable distances during short periods of time (*i.e*. up to 459 m d^{-1}), at least 59% of tagged individuals (50/85) remained within a 60 ha reef area for at least 6−36 months. Also, these individuals were shown to repeatedly inhabit the same, readily identifiable dens. That *P. versicolor* lives in predictable places and maintains a high level of site-fidelity predisposes this species to over-exploitation, which underscores the need to implement effective management strategies.

Based on the results of this study and assuming the presence of a large unfished breeding population, three important management desiderata were identified. Firstly, the current prohibition on possession of spermatophoric and ovigerous females should be revoked. This will reduce wastage of breeding females that are currently inadvertently killed by the fishery. The basis of this recommendation is that there appears to be little chance of

localised recruitment overfishing and hence there is little need to protect breeding females at a local level. Secondly, introduction of a 100 mm CL minimum size limit would optimise yield and population biomass without greatly impacting current fishing practices. Thirdly, establishment of small marine reserves (1−2 km in dimension) is an effective strategy to counteract localised depletion of adult *P. versicolor*, since individuals appear not to roam widely. Implementation of these knowledge-based management strategies will help to ensure this highly desirable fishery resource is exploited on a sustainable and rational basis.

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