The role of early life history traits on the survival of a coral reef fish

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This thesis includes some collaborative work with my supervisors Assoc. Prof. Mark McCormick and Dr Mark Meekan (Australian Institute of Marine Sciences). While undertaking these collaborations, I was responsible for the project concept and design, data collection, analysis and interpretation and final synthesis of results into a format suitable for publication. My co-authors provided intellectual guidance, financial support, technical instruction and editorial assistance.

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General Abstract

Selective mortality within a population, based on the phenotype of individuals, is the foundation of the theory of natural selection. Even small phenotypic differences among individuals early in ontogeny can strongly affect survival and performance later in life. Consequently, variation in early life history traits can have important repercussions on population structure and dynamics. Yet, the role of phenotypic variation throughout the ontogeny of tropical marine fishes remains largely unexplored. This study examined the extent to which environmental and parental effects generate variation in the early life history of a tropical marine fish (*Pomacentrus amboinensis*) and the consequences of such variation for survival in the wild.

Variation in early life history traits and survivorship during embryonic and larval development of the coral reef damselfish, *P. amboinensis* was examined in relation to water temperature. High rearing temperature (31ºC) strongly defined the relative number of embryos that successfully hatched and their post-hatching longevity. Embryonic mortality was significantly higher in hotter rearing environments (31ºC) than in cooler ones (25 and 29ºC) and accounted for over 54% of mortality prior to hatching across all three rearing temperatures. Under high temperature conditions, the probability of embryonic survival was largely determined by the initial size of the yolk-sac with larger energy stores reflecting enhanced rates of survival. Following hatching however, the survival advantages afforded by yolk-sac size switched to egg size, a commonly cited indicator of fitness. Yet, the benefits associated with egg size were heavily dependent on temperature. Overall, early environmental conditions and intrinsic developmental schedules had a significant influence on the outcome of selective mortality by producing substantial shifts in selective pressure through the early ontogeny of this species.

The extent to which maternal condition at the time of gametogenesis affected the relationships among early life history traits and survivorship during early development of

P. amboinensis was examined in a field study. Maternal condition was manipulated by altering food availability, a key factor influencing maternal energy allocation to offspring. Surprisingly, maternal condition had no effect on the *number* of offspring that successfully completed the embryonic phase, nor did it influence the relative number of individuals that survived to a given time after hatching. Nonetheless, maternal nutritional state did significantly affect offspring *quality* by causing substantial changes in individual egg composition (i.e. yolk-sac and oil globule size) and thus, the energetic value of embryos and hatchlings. By acquiring additional nutritional resources, supplemented mothers gained a fitness advantage over fish feeding on natural levels of plankton. Most importantly, however, they passed this advantage on to their offspring by provisioning their eggs with greater energy reserves (yolk-sac and oil globule size) than non-supplemented fish. Among offspring originating from supplemented mothers, those with larger yolk-sacs were more likely to hatch successfully and survive for longer periods on these reserves after hatching. Among offspring from non-supplemented mothers, yolk-sac size was either inconsequential to offspring survival or, peculiarly, individuals with smaller yolk-sac sizes were favoured. Mothers appear to influence the physiological capacity of their progeny and in turn, the efficiency of individual offspring to utilise endogenous reserves. Interestingly and contrary to theoretical predictions, there were no significant differences in egg size in relation to maternal nutritional state, suggesting that provision of energy reserves, rather than egg size, more closely reflected the maternal condition. Overall, the maternal environment greatly influenced the relationship between offspring life history characteristics and survival through energy-driven selective mechanisms.

To determine the relevance of these findings to patterns of future survival on the reef, the early life history traits of *P. amboinensis* surviving on the reef were compared with those of individuals from that same cohort at earlier times. Growth information stored in the otoliths of individual fish revealed that both maternally-determined condition at hatching and environmental conditions encountered early in the larval life had strong carry-over effects. Consistent with the findings presented above, wild individuals with larger energy stores were found to survive through to settlement and beyond in the new reef environment. Interestingly, results revealed that not all selective advantages established during embryonic and larval phases were maintained later in life. The direction of selective pressures acting on growth rates changed significantly and repeatedly during the first few weeks of post-settlement life. These changes in phenotypic selection may mediate growth-mortality trade-offs between the risk of predation and that of starvation during early juvenile life.

To explore the mechanisms underlying early juvenile survival, growth histories exhibited by individuals that survived the first 4 weeks on the reef were compared with conspecifics outgrown experimentally to produce fast- and slow-growing fish. Nutritional conditions experienced by new recruits during the first few weeks contributed noticeably to observed patterns of juvenile survival. Results revealed considerable flexibility in the growth rates of young fish. Specifically, the occurrence of periods of rapid (presumably compensatory) growth may enhance post-settlement survival by attenuating the high risk of size-selective mortality.

By exploring the causes and consequences of phenotypic variation in the life of a tropical reef fish, this study unveiled the significant contribution past and present events make in sculpting patterns of survival in the wild. In addition, it suggests that changes in selective pressures that shape an individual's life are a critically important mechanism maintaining phenotypic (and hence genetic) variation within a population and, ultimately regulating the dynamics of natural populations.

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