Small cryptic fishes on coral reefs:

A new perspective on reef fish ecology and life histories

Thesis submitted by
Martial Depczynski *BSc (Hons)*, James Cook University
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School of Marine Biology and Aquaculture
James Cook University, Townsville, Queensland, Australia

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Statement on the Contribution of Others

This James Cook University thesis contains some collaborative work with Dr Christopher Fulton (James Cook University) and Dr Michael Marnane (World Conservation Society). While undertaking these collaborations, I was responsible for the project concept and design, most data collection, all analysis and interpretation, and the synthesis of results into a form suitable for publication. My collaborators provided three additional data sets towards the final data chapter of the thesis and editorial assistance with the publication process.

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Abstract

Small cryptic fishes represent over 50% of fishes on coral reefs. Yet our knowledge of them lags far behind that of larger species and their significance to coral reef ecosystems remains unclear. Vastly different in their ecology due to their small size, this thesis examines their community structure and identifies key life history features that highlight their unique ecological status. These results are combined to model the relative contribution of small cryptic fishes to reef fish assemblages and define their significance to coral reef ecosystems.

Small-scale clove oil samples ($0.4m^2$) were used to quantify the spatial distribution of small (< 10cm) cryptic fishes across reef zones and microhabitats at both exposed and sheltered reefs. Marked variation in abundance, species numbers, size-class distribution and community composition were found among reef zones at exposed sites; in contrast, comparatively little among-zone variation was found at sheltered sites. At exposed sites, there was a strong trend of declining abundance, species numbers and larger body sizes with increasing wave energy; whereas at sheltered sites, microhabitat type played a more important role. There was little taxonomic overlap between sheltered and exposed reefs even of highly abundant species. Overall, wave energy was found to play a pivotal role in the spatial distribution of this community with microhabitat type playing a significant, yet secondary role.

Contrasting the life history (LH) characteristics of the most abundant genus (*Eviota*: 3 species of Gobiidae) at the two study sites with those of existing coral reef fishes in a meta-analysis revealed vastly different LH features. Otolith

analysis revealed rapid linear growth trajectories and extremely short maximum life spans of < 100 days (*E. queenslandica* 99 days; *E. melasma* 97 days and *E. sigillata* at 59 days - the shortest recorded lifespan for any vertebrate). Although settlement marks on otoliths disclosed unremarkable pelagic larval durations (PLDs) of 24 - 26 days, this represented 24 - 42% of their total lifespan. The complete lack of response in shortening PLDs to compensate for such short life spans suggests that developmental constraints may be the primary determinant of PLDs in coral reef fishes. Histological examinations indicated that *Eviota* mature at an earlier than expected size and showed a strong female bias in their sex ratios (1 ♂:1.4 - 1.7 ♀) indicating the possibility of protogyny or harem keeping by males. A field tagging study indicated remarkably high daily mortality rates of 7-8% which closely matched otolith-based estimates of 4-7% d^{-1}.

An experimental breeding study using *E. sigillata* revealed a frequent semi-lunar spawning pattern and batch sizes of 108-163 eggs. Although small in comparison to those of larger species, the frequency of spawning events coupled with generational turnover rates of 47 days indicated potential annual offspring production to be orders of magnitude higher than that of much larger reef fish species. Collectively, these LH attributes revealed how the smallest of reef fish size-classes respond to their vastly different ecological environments and highlight the extensive range and versatility of coral reef fish evolutionary strategies.

The relative contribution of the small cryptic group to reef fish assemblages was examined using visual censuses of 14 coral reef fish families. In total, data on 58,944 fish were utilized over five reef zones providing 86g m^{-2} of

biomass. The clear trend among size-class distributions was one of rapidly decreasing densities with increasing size. Small cryptic fishes represented 45-90% of the numbers of individuals across reef zones with a reef average contribution of 67%. Among families, the numerical dominance of the Gobiidae was evident ($11m^{-2}$ ± 1.4SE) with significant contributions made by the Pomacentridae, Apogonidae, Blenniidae, Labridae and Tripterygiidae. For biomass, the Acanthuridae made the largest contribution ($35g\ m^{-2}$ ± 11.6SE) followed by the Pomacentridae, Scaridae and Serranidae. Small cryptic families made up < 3%.

To examine the implications of taxa-specific growth rates in the energy dynamics of coral reef systems, a community growth model was produced. Size-specific growth estimates for all genera censused were calculated over a 7-day period. Overall, small cryptic fishes contributed 79.5% to reef fish assemblage patterns of growth in length and 14% to the period's total weight accumulation in grams. This cryptic contribution stands in marked contrast to the static biomass estimate presented above and highlights the significance of LH's in defining community and ecosystem energetics.

Overall, small cryptic fishes make a substantial contribution to coral reef communities but differ considerably from their larger counterparts in the way they achieve this. Demographic evidence of drastically shortened life spans, rapid linear growth and high turnover rates, coupled with high average abundances and rates of mortality suggests they play a significant role in the energetics of coral reefs. This addition of demographic information on small cryptic reef fishes emphasized this role, uncovered new extremes in vertebrate biology and showcases the rich potential for coral reef fishes to test general life history theory.

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