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Utilization of mangrove crab-burrow micro-habitats by the goby *Redigobius dewaali*: Evidence for dominance hierarchy

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ABSTRACT

When a range of life-history groups within a population exploit similar niches, hierarchies are often established whereby optimal resources are capitalized by dominant individuals. The present study investigates the feeding and movement of a size structured population of gobies residing in crab burrow micro-habitats, within this context. All life-history stages of the goby *Redigobius dewaali* were found to utilize burrow-pools formed by the crab *Scylla serrata* in the mangrove intertidal zone of an estuary at low tide. Gut content analysis was therefore conducted to test for feeding overlap and potential intraspecific competition among various sizes of fish residing in these habitats. In addition, an exclosure experiment was conducted to determine whether these fish leave the burrow-pools at high tide to forage over the intertidal flats. While ontogenetic dietary shifts across size-classes occurred, copepods and amphipods comprised the most important components of the diet for most size-classes, resulting in a large degree of dietary overlap. Of the adult *R. dewaali* sampled from pools, a single large mature male was sampled from each burrow, suggesting territoriality, a trait well observed in males of many goby species. The experimental component of the study highlighted the movement of smaller individuals, but not larger individuals, from the burrow-pools at high tide. As all life-history stages occur in the same micro-habitats, and forage on much of the same prey, we suggest that the existence of a competitive hierarchy resulted in the need for the smaller individuals to find alternate feeding areas, consistent with dominance hierarchy theory.

1. Introduction

The facultative and obligatory utilization of estuaries as nursery and refuge areas by various fish species is well recognized, with much research having been conducted on coarse-scale estuarine utilization by ichthyofauna (Rountree and Able, 2007; Wasserman et al., 2010; Weinstein and Brooks, 1983). There is however, limited information pertaining to the small scale movement, utilization of micro-habitats, and feeding ecology of many of the fish species exploiting these environments, particularly within the context of ontogeny (Morrison et al., 2002; Wasserman, 2012; Wasserman and Mostert, 2014). In this regard, the present study expands on work conducted by Wasserman and Mostert (2014), in which burrows of the Estuarine Mud Crab (*Scylla serrata*, Forksal), in a mangrove estuary, were found to form micro-habitats extensively used by a specific gobiid. In their study, Wasserman and Mostert (2014) sampled numerous intertidal *S. serrata* burrows at low tide, when the burrows were isolated from the main estuary channel, creating pool-like habitats in the intertidal mangrove flats. They found large numbers of a single goby species, the Checked Goby (*Redigobius dewaali*, Weber, 1987), dwelling in all sampled burrows. The burrow dwelling *R. dewaali* populations comprised a range of life-history stages, from adult to post-flexion larvae, with the vast majority belonging to the early life-history stages (Wasserman and Mostert, 2014).

Competition theory asserts that when population densities expand to the point where resources become limited, antagonistic interactions reduce the success of individuals (Bolnick, 2004). One way in which this is observed is through the establishment of dominance hierarchies within a population. Individuals within a population are often an assemblage of heterogeneous units that are not ecologically equal, differing in life-history stage, body size and competitive abilities (Polis, 1988; Wilbur, 1980; Wissinger, 1992). Dominance hierarchy theory predicts that when a range of life-history groups of a given population exploit similar niches, dominance will ensue (Werner and Gilliam, 1984). In this way, subordinate groups can be forced to occupy broader home ranges than dominant individuals, who capitalize on smaller easily-defendable territories that offer superior foraging opportunities (Buchheim and Hixon, 1992; Chase et al., 1994). Within this context, we investigate the diet and movement of various size-classes of *R. dewaali* that reside within *S. serrata* burrow microhabitats. We

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postulated that niche overlap across size-classes would facilitate social dominance, with younger individuals being inferior due to their smaller size. To assess this, diet and movement of *R. dewaali* across a range of size-classes, representing various life-history stages, were investigated. The study comprised two distinct components. For the first component, we determined the diet of *R. dewaali* sampled from burrow-pool microhabitats and assessed the degree of dietary overlap between size-classes. Secondly, the movement of fish from the burrows was experimentally tested during a high-tide period, when movement from the burrows was possible. We hypothesized that:

1) high levels of dietary overlap would be evident among size-classes of *R. dewaali*, and
2) smaller, subordinate *R. dewaali* would be more likely to leave the burrows, consistent with dominance hierarchy theory.

2. Materials and methods

2.1. Study site and experimental procedure

The medium-sized Mgazana Estuary, with a catchment area of 275 km^2 (Emmerson, 2005), enters the Indian Ocean along the subtropical south-east coast of South Africa (31°42′S, 29°25′E). The intertidal zone supports a mangrove system, covering an area of approximately 145 ha (Colloty et al., 2002; Rajkaran et al., 2004). The present study was conducted in the middle reaches of the estuary on a single stretch of intertidal flat (Fig. 1). This region was selected as it accommodated numerous *S. serrata* burrows, creating the pool like microhabitats utilized by the gobiids (Fig. 2A). As *S. serrata* burrows house a variable number of ellipsoid-shaped tunnels leading from the pool, deeper into the sediment, burrow-pool selection for the experiment was based on the presence of a single tunnel, to ensure no escape of sampled gobiids when collected (see below). To remove the confounding factor of shading, all burrow-pools employed in the study were in an un-shaded salt marsh habitat along the intertidal flat, adjacent to a mangrove stand.

Experimental burrow-pools were photographed from directly above. Photographs included a ruler to allow calculation of the surface area of each pool (Wasserman and Mostert, 2014). To assess the movement of gobiids from the selected burrows, *R. dewaali* leaving burrows during periods of intertidal inundation (high tide) were prevented from returning to the burrows as the water level dropped with the receding tide. This was achieved using simple exclosures erected around individual burrow-pools and comprizing four 150 cm long steel rods, driven 50 cm into the sediment, resulting in a square frame outlining the outer edges of the selected burrows (Fig. 2B). Frames were erected at low tide (10:00 AM), when the burrow-pools became isolated patches of water (Fig. 2A). At high tide, 1 mm stretch-mesh netting was carefully placed around each frame, isolating the burrows from the surrounding waters completely. Treatments 1 and 2 had sides of 2 and 1 m respectively, while treatment 3 was a procedural control, including steel rods, but no netting. Each treatment was replicated three times, i.e. three *S. serrata* burrows per treatment. Exclosures were left until the following low tide (22:00 PM) excluding any *R. dewaali* that had left the burrow during flooding tide.

At the subsequent low tide, all *R. dewaali* were removed from each burrow. This was done, following Wasserman and Mostert (2014), by approaching burrows from the same angle as the downward facing crab tunnel (Fig. 2A) and placing a 1000 μm mesh sheet across the entrance of the tunnel. This prevented the escape of the gobiids down the tunnel. Once the mouth of the tunnel was blocked, a 1000 μm mesh net was used to collect all fish in the pool.

Fish collected during the exclosure experiment were retained for the feeding component of the study. Further burrows were sampled for larger size *R. dewaali*, to attain adequate numbers for gut content analysis. Fish collected for the feeding component of the study were anesthetized using Tricaine mesylate (MS-222) and preserved in 10% buffered formaldehyde for fixation.

2.2. Laboratory analysis

Once in the laboratory, sampled fish were transferred to 70% ethanol. Fish were sorted into five size-classes (Size-class 1 = "<11 mm"; 2 = "11–20 mm"; 3 = "21–30 mm"; 4 = "31–40 mm"; 5 = ">40 mm" body length (BL)) and enumerated. Fish larger than 30 mm BL were considered sexually mature (Whitfield, 1998) and were sexed based on sexually dimorphic maxilla characteristics (Smith and Heemstra, 2003). Small fish were very abundant and the smaller size-classes were randomly subsampled, while all larger individuals were processed for gut content analysis. Fish stomachs were dissected and the contents emptied into a 50 mm (long) × 50 mm (wide), 1 mm (deep) tray, the bottom of which was marked with a 1 mm × 1 mm grid. The stomach contents were sorted, identified to the lowest possible taxon and counted. Where soft body parts were digested and unidentifiable, counts were based on the number of heads present. Body lengths of all whole prey items were measured

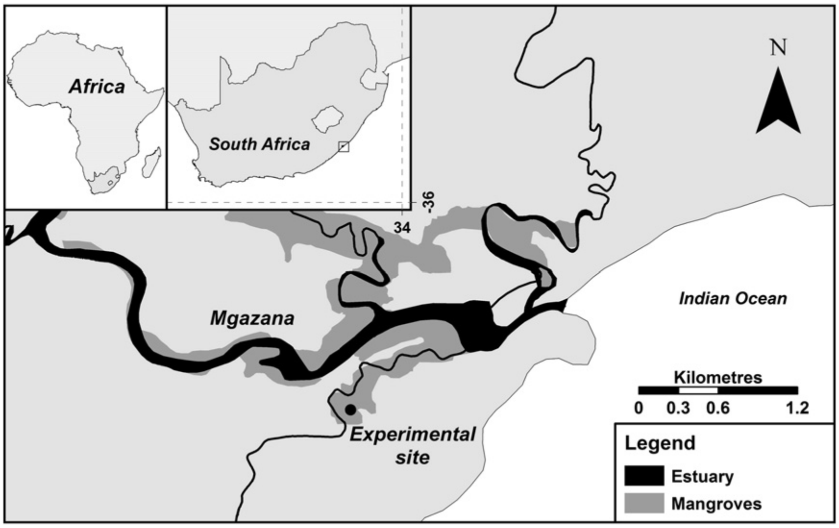

Fig. 1. The geographic position of the Mgazana Estuary in the subtropical biogeographic region of southern Africa, showing locations of intertidal mangrove stands and experimental site.