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## SHORT COMMUNICATION

**TIME—ACTIVITY BUDGETS OF STOPLIGHT PARROTFISH (SCARIDAE: SPARISOMA VIRIDE) IN BELIZE: CLEANING INVITATION AND DIURNAL PATTERNS**

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**KEY WORDS:** parasite, South Water Caye Marine Reserve, coral reefs, symbiosis, behavior

**INTRODUCTION**

Stoplight parrotfish (Scaridae; *Sparisoma viride*) are relatively large Caribbean reef fish, characterized by distinctive coloration and behavior. They are large herbivores (Mumby et al. 2012), and play a major role in coral—reef ecosystems due to their grazing and bioerosion of living reefs (Bruggemann et al. 1996). Like all parrotfish, *S. viride* are protogynous hermaphrodites with 3 distinct life phases: juvenile phase (JP), initial phase adults (IP), and terminal phase males (TP) (van Rooij et al. 1995). While other parrotfish employ a variety of feeding modes including scraping, *S. viride* utilize an excavating foraging strategy (Bruggemann et al. 1994). This behavior leads to bioerosion of the coral reef, and has a significant impact on algal biomass of the ecosystem.

The contribution of parrotfish to coral reef ecosystems is well established (reviewed by Welsh and Bellwood 2012). In the Caribbean, a 1983 disease—induced mass mortality of the sea urchin *Diadema antillarum* resulted in a renewed interest in parrotfish. This die off resulted in more algal—dominated reefs, and left parrotfish as the major grazers of the reef ecosystem (Gardner et al. 2003, Mumby et al. 2006). According to one model, 42% of the reef is grazed every 6 months, which is the level required for an equilibrium state of high coral cover instead of high algae cover. This grazing level was possible with both *Diadema* and parrotfish grazing the reef, but parrotfish alone fall short of the grazing intensity necessary for equilibrium in many reefs (Mumby et al. 2007). Further, *S. viride* populations have declined in recent years (Mumby et al. 2012), yet remain vital members of Caribbean reefs and must be protected as such. They are the largest common parrotfish in Belize. Mumby et al. (2006) analyzed the effect of reserves (preservation areas) on parrotfish—grazing capacity and documented the important role played by *S. viride*. Behavioral studies are valuable for understanding the ecological role of coral reef species such as parrotfish, and aid in conservation and management decisions.

Activity budgets of *S. viride* provide insight into the behavior of the fish, their habitat use, temporal patterns, and time—related energy resources. Reef fish are known to show

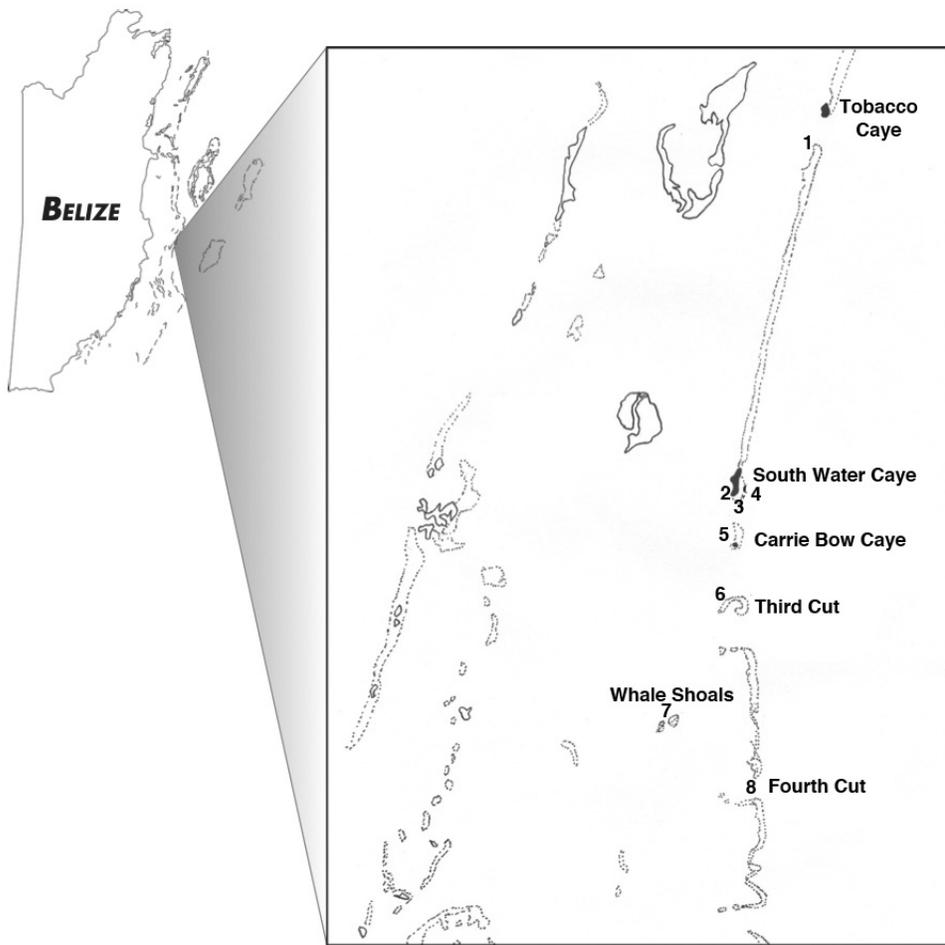
variation in diel (daytime) activities, especially feeding and cleaning (Zemke—White et al. 2002, Sikkel et al. 2004). Activity budgets have been used to characterize behavior of many species, and are especially helpful in distinguishing daily behavioral differences among age groups (Altmann 1974). A previous activity budget study of *S. viride* in Jamaica (Hanley 1984) demonstrated differences among activities by fish life phase and habitat types. Hanley determined that activities of all 3 phases of *S. viride* were dominated by swimming, hovering, and feeding. Our preliminary studies in Belize corroborated some of the findings by Hanley, but also indicated that *S. viride* spent significant time at cleaning stations, an activity seldom observed in Jamaica. Those preliminary observations led to initiation of this study.

The primary objective of this study was to analyze diurnal behavior of *S. viride* in South Water Caye Marine Reserve (SWCMR), Belize. Time—activity budgets were used to characterize behavior (using swimming, feeding, hovering, sheltering, defecating, and cleaning categories) during the diel cycle, and to illustrate differences among the life phases of this species.

**MATERIALS AND METHODS**

All 640 observations for this study were collected during May—June 2011 at 8 different shallow reef environments in the South Water Caye Marine Reserve (SWCMR), Belize (16°38' to 16°55'N, 88°02' to 88°13'W). The study area centered around South Water Caye, a 6.1 ha (15—acre) island located about 32 km SE of Dangriga and 1.6 km north of the Smithsonian's Caribbean Coral Reef Ecosystems research facility on Carrie Bow Caye. The SWCMR is located along the Belize Barrier Reef; it supports only a small human population, and marine ecosystems surrounding the island remain relatively undisturbed. The SWCMR was established in 1996, and covers 29,800 ha (United Nations Environment Programme 2011).

The 8 sites of this study (Figure 1) consisted of shallow—reef environments 2.5—4.0 m depth. Most observations



**Figure 1:** Study area in the South Water Caye Marine Reserve, Belize (from Gaston et al. 2009).

were made over patch reefs surrounded by sandy bottom off the south end of South Water Caye; only one site included much seagrass (site 2). Although the sites varied in coral makeup and topography, all were characteristic of shallow Caribbean patch reefs. Numerically dominant species of fish included a variety of wrasses, parrotfish, surgeonfish, grunts, snapper, and damselfish. Dominant large coral species were elkhorn coral (*Acropora palmata*), staghorn coral (*A. cervicornis*), lettuce coral (*Agaricia tenuifolia*), star corals (especially *Montastrea annularis* and *Stephanocoenia meehani*), brain corals (especially *Diploria strigosa*), and a variety of gorgonians (especially *Gorgonia ventalina* and *Briareum asbestinum*).

The behavior of *S. viride* was assessed by classifying their activities into one of 6 categories (Table 1). Activities were recorded by divers who snorkeled at the ocean surface. Data were recorded by pencil on an AquaSketch Minno Wrist Slate. For each observation we recorded: date, start time, location, maximum depth, any pertinent hydrological data, fish developmental stage, and time spent in each behavior. Observation at each site began with the first individual seen, and each individual was observed for 20 sec. Observations

were conducted between the hours of 0600–1800 local time. During preliminary analyses that we conducted during 2010 we ascertained that a 20 sec time interval was ideal. Increments of 20 sec was usually the maximum time possible to make observations without disturbance of the fish or the fish moving beyond view, and allowed the opportunity to witness more than one type of behavior. We used instantaneous observations. The fish closest to the observer was selected whenever more than one individual was present. Fish that were deemed disturbed by diver presence were excluded from the data, as were fish that moved beyond view within 20 sec. A Timex waterproof sport watch was used to record time.

The number of seconds per activity in each observation was divided by the total observation time (20 sec) to determine the percentage of time spent on each activity; percentage data were then used for statistical analyses on each behavior (feeding, swimming, sheltering, hovering, defecating, and cleaning) as a separate response variable. For each response variable, we conducted separate multi-factor

ANOVAs (using SAS version 9.2) in which the predictor variables were time category, study site, life phase, and water depth. When life phase was a significant predictor, means for pairs of life phase categories were compared by Student's

**TABLE 1.** List of behaviors used for stoplight parrotfish time-activity budget in this study.

Behavior	Description
Swimming (Sw)	Directional locomotion
Feeding (Fe)	Biting, chewing, and scraping food
Hovering (Ho)	No movement or activity other than stabilizing fin movements
Sheltering (Sh)	Time spent inside reef crevices, including while the fish was swimming and stationary
Defecating (De)	Voiding of material
Cleaning (Cl)	Fish oriented itself at an upward angle to invite cleaning from cleaners

T-tests followed by Tukey's Honestly Significant Difference test to determine adjusted *p*-values. Response variables could not be transformed to achieve normality, so we obtained *p*-values using randomization tests conducted using a macro wrapper in SAS (modified from Cassel 2002). To determine linear trends in behaviors over the diel cycle, the results from each dive were averaged, and a simple linear regression was conducted for each behavior separately versus time of day (R Statistical Package, version 2.15.1). The data points for each regression are assumed to be independent since different groups of fish likely were observed on each dive. All statistical tests used alpha of 0.05 for significance.

## RESULTS

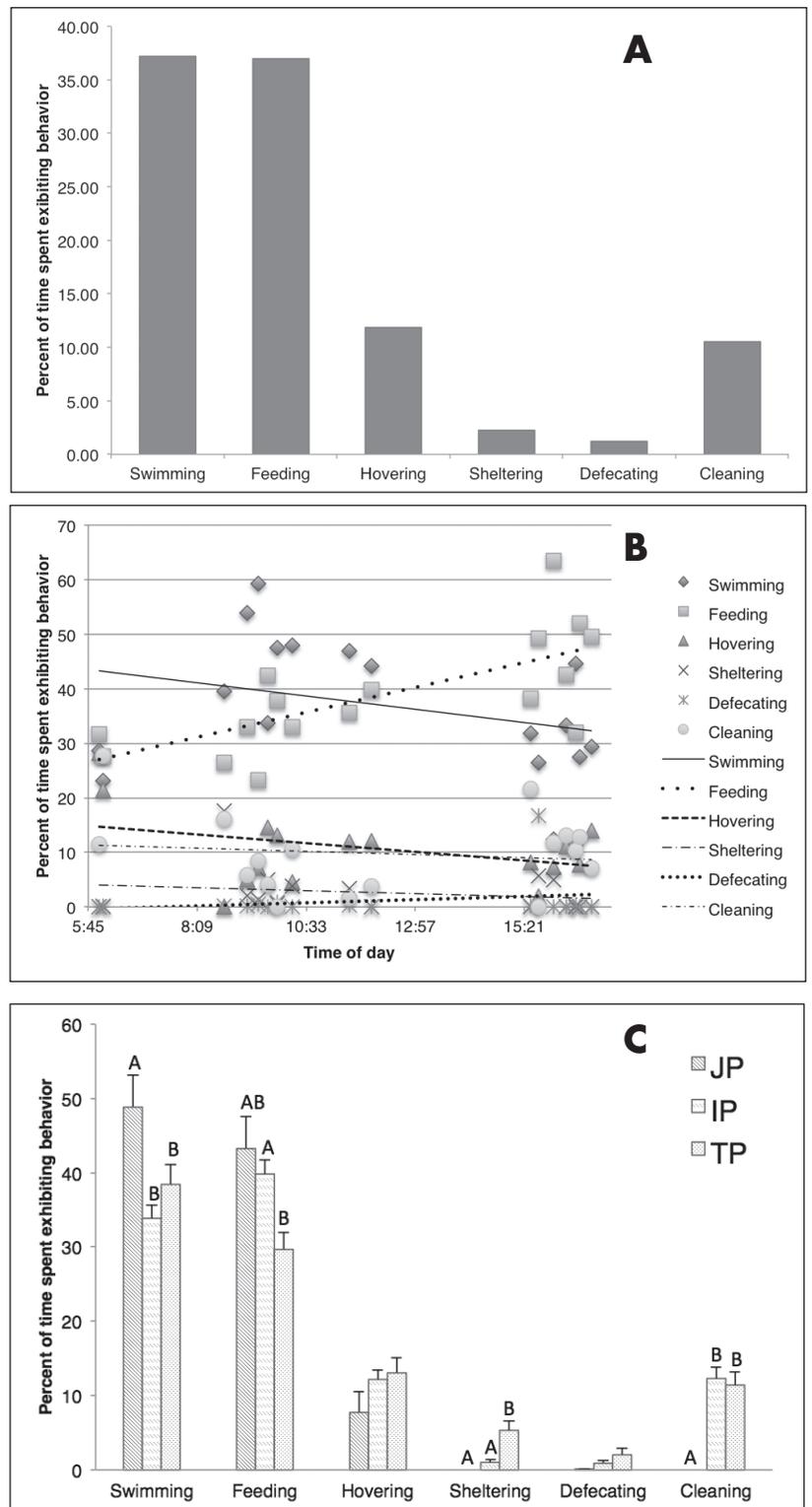
The overall activity budget of *S. viride* was dominated by swimming (37.26%) and feeding (36.91%) (Figure 2A). Hovering, cleaning, sheltering, and defecating were lesser activities (11.90%, 10.51%, 2.23%, 1.19%, respectively).

Feeding increased linearly during the day (Figure 2B) ( $p < 0.001$ ,  $r^2 = 0.49$ ), and was the only activity significantly related to time of day. There was greater cleaning activity during morning (prior to 0800 CST) when morning was used as a category ( $p < 0.01$ ), but the pattern was not linear through the diel period ( $p > 0.05$ ).

The proportion of time spent among the 6 behavior categories differed among the 3 life phases in all behaviors except hovering (Figure 2C). Juvenile phase individuals spent more time swimming than IP ( $p < 0.001$ ) or TP individuals ( $p < 0.05$ ). Initial phase individuals spent more time feeding than TP individuals ( $p < 0.01$ ). Juvenile phase and IP individuals spent less time sheltering than TP individuals ( $p < 0.001$  and  $p < 0.0001$  respectively). Initial phase and TP individuals spent more time at cleaning stations than JP ( $p < 0.01$ ).

## DISCUSSION

The most comprehensive investigation of *S. viride* activities was conducted in Jamaica by Hanley (1984). Most salient in his results, and contrary to ours, was his mention that almost no incidence of cleaning invitation (visits to cleaning stations) was observed. Similarly, *S. viride* in Barbados had very low rates of cleaning invitation (Arnal et al. 2000, 2001), and no other study, even those with early-morning observations, documented cleaning invitation as a common activity of *S. viride*.



**Figure 2.** Time-activity budgets of *Sparisoma viride* in Belize. **A.** Percentage of time spent in behaviors at all observation sites ( $n = 640$ ). **B.** Percentage of time spent in behaviors by time of day. Values for each time are means of observations made during that dive period. Linear regression lines are shown for each activity category. Only the regression line for feeding was significant (percent time =  $45.617(\text{time of day}) + 15.621$ ,  $r^2 = 0.49$ ,  $p < 0.01$ ). **C.** Percentage of time (mean  $\pm$  se) spent in behaviors by life phase. JP - Juvenile Phase; IP - Initial Phase; TP - Terminal Phase. For each response variable, means sharing the same letter were not significantly different from each other. Bars with no letters were not significantly different. Number of observations:  $n = 76$  (JP);  $n = 357$  (IP);  $n = 207$  (TP).

We found that cleaning invitation was a significant activity of *S. viride* in Belize (10.5% of activities overall). Cleaning invitation was highest during morning, but did not decrease linearly thereafter. Rather, cleaning activity decreased during midday, but trended higher later. Thus, *S. viride* spent significantly more time at cleaning invitation during mornings (before 0800; 20.4%) and less often thereafter (8.1%). These patterns were similar to activities reported for yellow-tail damselfish in Barbados, the first study to estimate total diel cleaning time budgets in a marine reef fish (Sikkel et al. 2005). Sikkel et al. (2005) also reported about 20% of early-morning time spent with cleaners.

We considered 3 hypotheses to explain the differences observed related to cleaning behavior of *S. viride* between our study and those of Hanley (1984) and Arnal et al. (2000, 2001). First, we considered that methods between the 2 studies may have accounted for the differing results, but it seems unlikely that methods could yield such different results in fish behavior. We also considered whether variations in mucous load caused *S. viride* to visit cleaning stations more often, but there is no evidence that mucous loads of a species would vary across the Caribbean, nor would non-cleaning activities vary due to mucous loads. Finally, we investigated if habitat could account for higher levels of cleaning invitation. Even though many aspects of physical habitat were similar between Belize and Jamaica (both were shallow reefs), parasite loads are known to change both spatially and temporally by habitat (Grutter 1994, Sikkel et al. 2009). Previous studies reported that *S. viride* carry at least moderate ectoparasite loads (Soares et al. 2007) and visit cleaning stations for parasite removal (Grutter 2001). Thus, we submit that differing parasite burdens among the habitats led to higher cleaning activity, despite having no direct data on parasite loads for the regions.

*Sparisoma viride* activity budgets are not known for many regions of the Caribbean, but our observations and those in Bonaire (Bruggemann et al. 1994) established that feeding begins about an hour after sunrise. The feeding activity of herbivorous fish is typically highest in the late morning and afternoon and lower in the early morning (Zemke-White et al. 2002). Our data indicated that *S. viride* follow this trend as well. Our earliest records were at 0600 (~ 45 min after sunrise) and feeding was seen to increase linearly throughout the day (Figure 2B).

Hovering may be related to territorial behavior, especially in TP parrotfish (Bruggemann et al. 1994). *Sparisoma viride*

hovering close to the bottom may have been exhibiting a horizontal cleaning invitation to cleaner shrimp (Huebner and Chadwick 2012). However, none of the fish that we observed were being cleaned by shrimp, and cleaning shrimp were not observed on those reefs during invertebrate surveys (G. Gaston, personal observation). Terminal phase fish in our study spent more time hovering than did other life phases.

Our study corroborated Hanley's (1984) report that swimming, feeding, and hovering were the dominant activities throughout the day, even though the percentages of each activity varied between the studies. Hanley (1984) distinguished between individuals by size. Small individuals spent most time hovering (40–50%), swimming (20–30%), and feeding (17–23%); large individuals by swimming (40–52%), hovering (21–30%), and feeding (9–14%). *Sparisoma viride* in our study spent more time feeding and less time hovering than Hanley (1984) observed. We found that juvenile individuals spent more time in active behaviors (swimming and feeding), and less time in other behaviors (hovering, sheltering, and cleaning) (Figure 2C). This makes sense physiologically, because smaller individuals generally have higher metabolic demands than larger fish, but Bruggemann et al. (1994) reported that juvenile *S. viride* in Bonaire spent less time swimming between food patches and more time hovering, presumably looking for animal prey. Bruggemann et al. (1994) conducted comprehensive analyses of food intake and assimilation efficiencies of *S. viride*, which accounted for the discrepancy. They found that daily number of bites decreased with fish size, and number of bites also depended on life phase and foraging depth. Juvenile *S. viride* must grow quickly in habitats with high predation pressure (van Rooij et al. 1995), and they attain that rapid growth by higher assimilation efficiencies than adults (Bruggemann et al. 1994). Their success at growth apparently is unrelated to cleaning symbiosis. We seldom observed juvenile *S. viride* being cleaned, and previous research concluded that juvenile fish are rarely cleaned (Côté et al. 1998).

In summary, we used time activity budgets to discern significant patterns in activities of *S. viride* in Belize related to time of day, life phase, and behavior. We propose that early morning visits to cleaning stations likely were related to ectoparasite burden and/or mucous load. More conclusive evidence awaits future investigations of *S. viride*'s cleaning symbiosis, parasite loads, and diurnal activities.

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