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Site Fidelity and Movement of the Parrotfishes *Scarus coeruleus* and *Scarus taeniopterus* at Conch Reef (northern Florida Keys)

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ABSTRACT.—The largely sedentary behavior of many fishes on coral reefs is well established. However, information on the movement behavior of individual fish, over fine temporal and spatial scales, continues to be limited. While conducting a larger project in the northern Florida Keys in 2002, we surgically-tagged a small number of *Scarus coeruleus* Bloch 1786 and *S. taeniopterus* Desmarest in Bory de Saint-Vincent 1831 with acoustic transmitters inside the Conch Reef Research Only Area (a no-take marine reserve). Our objective was to characterize the movement of both species across Conch Reef, and to quantify any fish fidelity to the site where they were caught and released. All fish were captured, surgically-tagged, and released *in situ* during a saturation mission to the *Aquarius* Undersea Laboratory. Movement of tagged fishes was recorded in 5 receiving zones formed by the overlapping ranges of 3 acoustic receivers deployed on the seafloor. Results show limited movement of both species occurred across Conch Reef. Recorded site fidelity was higher among tagged *S. taeniopterus* than among *S. coeruleus* and varied considerably among individuals. While the number of fish departures from the receiving zones was varied, the majority of departures for each species were less than 30 min in duration for both species, suggesting that when departures occurred, the fish did not travel far. Future efforts will significantly expand the number of receivers at Conch Reef such that both movement and site fidelity can be quantified with increased temporal and spatial resolution.

KEYWORDS.—*Scarus coeruleus*, *Scarus taeniopterus*, acoustic telemetry, fish movement, site fidelity

The largely sedentary behavior of many fishes on coral reefs is well established (Bardach 1958; Randall 1961; Sale 1991). However, information on the movement behavior of individual fish, over fine temporal and spatial scales, continues to be limited (Chapman and Kramer 2000). Parrotfishes of the family Scaridae (including 79 species) are one of the two most speciose groups of herbivorous fishes (McAfee and Morgan 1996; Overholtzer and Motta 1999). They are large, conspicuous fish on Caribbean coral reefs (Bardach 1958), and consume all functional groups of algae (Overholtzer and Motta 1999). However, despite the importance of parrotfishes to the conservation of coral reefs (Ogden and Lobel 1978), the majority of biological information on Caribbean parrotfishes derives from studies of only two species, striped parrotfish (*Scarus iserti*) and stoplight parrotfish (*Sparisoma viride*; Mumby and Wabnitz 2002).

While conducting a larger study of fish movement in the northern Florida Keys in 2002 and 2003 using acoustic telemetry, we collected data on the movement of a small number of blue parrotfish (*Scarus coeruleus*

Bloch 1786) and princess parrotfish (*Scarus taeniopterus Desmarest in Bory de Saint-Vincent 1831*) at Conch Reef (off Key Largo, Florida, USA; Fig. 1). The distribution of *S. coeruleus* extends from Maryland (United States) to southeast Brazil, from depths of 3 to 25 m (Lieske and Meyers 1999). It is among the least studied of the common Caribbean Scarids (Overholtzer and Motta 1999). *Scarus taeniopterus* occur from south Florida (United States) and Bermuda to Brazil, also from depths of 3 to 25 m (Lieske and Meyers 1999). Our goals in this preliminary study were to characterize parrotfish movement patterns at Conch Reef and to quantify any site fidelity to the location within the reef where each fish was caught and released.

Parrotfishes were caught, surgically-tagged with coded-acoustic transmitters, and released at two locations within the Conch Reef Research Only Area (a no-take marine reserve) in August 2002 (Fig. 1). All project elements were conducted *in situ* during a 10-day saturation diving mission to the *Aquarius* Undersea Laboratory (see Lindholm et al. 2005). A total of 6 terminal phase (Tph) *S. coeruleus* and 9 *S. taeniopterus* (including 6 Tph and 3 initial phase, or Iph; Table 1) were tagged with V8SC-1H (69 kHz) coded-acoustic transmitters (VEMCO, Ltd., Shad Bay, Nova Scotia). The time at-liberty-recorded from the first signal detection to the last signal detection for each tagged fish varied widely (Table 1). The projected battery life for the V8SC-1H was 95 days; however we collected data for up to 224 days on selected fish. Data are re-

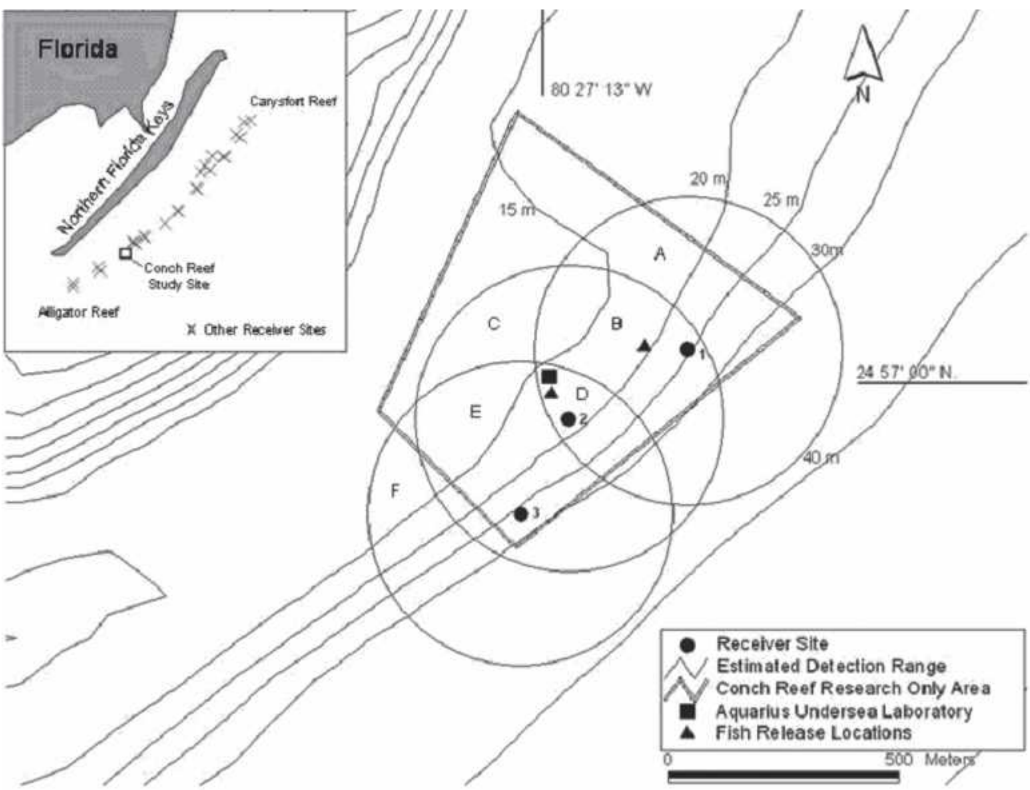

FIG. 1. Map of VR2 acoustic receiver array at Conch Reef, including the estimated 300 m range of detection for each receiver, the boundary of the Conch Reef Research Only Area, the location of the *Aquarius* undersea laboratory, and the locations where fish were collected and released. The letters A-F refer to the designation of receiving zones in Table 2. Five meter isobaths are provided. The complete receiver array (inset) is shown extending from Alligator Reef to Carysfort Reef.

TABLE 1. Summary data for acoustically-tagged *S. coeruleus* and *S. taeniopterus* at Conch Reef.

Fish #	TL (mm)	Life history phase	Recorded days at-liberty	Location of release	Number of zones visited	Max. potential distance traveled (m)
S. coeruleus						
1	250	Tph	159	Zone 2	3	1097
2	350	Tph	224	Zone 2	4	1097
3	300	Tph	209	Zone 2	2	816
4	300	Tph	124	Zone 2	1	600
5	300	Tph	86	Zone 2	1	600
6	300	Tph	31	Zone 2	3	897
S. taeniopterus						
1	170	Iph	49	Zone 1	3	897
2	250	Tph	50	Zone 1	1	600
3	250	Tph	50	Zone 1	1	600
4	250	Tph	27	Zone 2	3	816
5	250	Tph	173	Zone 2	2	816
6	150	Iph	59	Zone 2	3	816
7	250	Tph	174	Zone 2	3	816
8	250	Tph	204	Zone 2	1	600
9	150	Iph	118	Zone 2	2	897

ported for each tagged fish from 29 August 2002 through the last recorded signal detection for that fish.

Movement was recorded by three, omnidirectional, single-channel (69 kHz) VR2 acoustic receivers (VEMCO, Ltd., Shad Bay, Nova Scotia) deployed at Conch Reef (Fig. 1) at 25 m (Site 1), 20 m (Site 2), and 25 m (Site 3). Preliminary tests indicated that the range of detection for each VR2 receiver at Conch Reef had a radius of approximately 300 m. This range was considered an estimate and was likely to change somewhat over the course of study with fluctuating water conditions. The three receivers were located such that there was approximately 50% overlap with the range of detection for the adjacent receiver, creating a series of five receiving zones (Table 2; as per Starr et al. 2001). Simultaneous detections for a particular transmitter by more than one receiver allowed us to identify the likely position of that fish with greater precision. The larger project included an additional 24 VR2 receivers placed along the reef tract from Alligator Reef in the south to Carysfort Reef in the north, encompassing 40 km (Fig. 1 Inset). No data for *S. coeruleus* or *S. taeniopterus* tagged at Conch Reef were expected at these receivers, and none were collected over the course of the study.

Our first objective was to characterize parrotfish movement across Conch Reef. The number of signal detections per receiving zone varied widely for both *S. coeruleus* and *S. taeniopterus*. Both species were recorded in each of the 5 receiving zones over the course of the study (Fig. 2). The number of signal detections per fish did not vary significantly with fish TL for either *S. coeruleus* ($F_{1,5} = 3.15$; $p = 0.218$) or *S. taeniopterus* ($F_{1,8} = 3.18$; $p = 0.105$). Precise measurement of the distance traveled by tagged fishes was limited using the VR2 receivers. Only the maximum potential distance traveled by a fish was quantified (Table 1). For instance, for those fish that moved from the

TABLE 2. List of receiving zones at Conch Reef, including the corresponding acoustic receiver, region of coverage per zone (designations under the region of coverage refer to Figure 1), and the estimated area of coverage per zone based on a 300 m radius of detection for each receiver.

Receiving zone	Acoustic receivers	Region of coverage	Area of coverage (m^2)
1	1	A, B, D	282,743
1.5	1, 2	B, D	193,651
2	2	B, C, D, E	282,743
2.5	2, 3	D, E	153,540
3	3	D, E, F	282,743

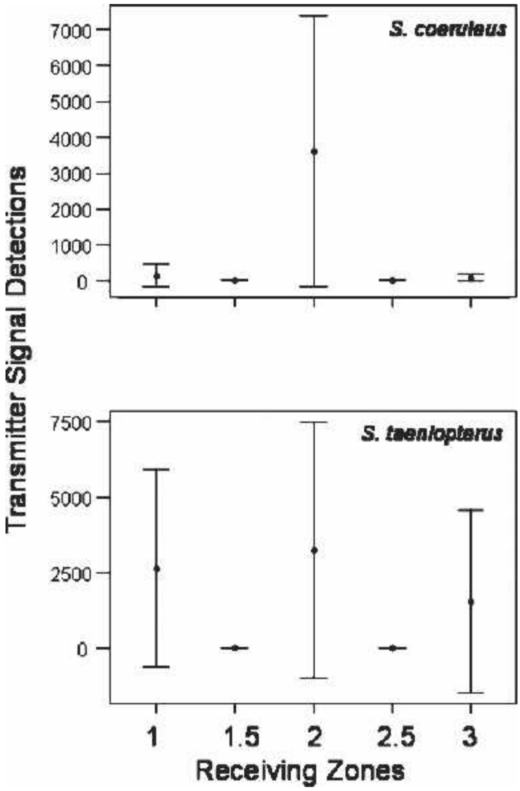

FIG. 2. Number of signal detections for *S. coeruleus* and *S. taeniopterus* in each of the five Receiving Zones. The mean and 95% confidence interval are reported.

northernmost boundary of Zone 1 to southernmost boundary of Zone 3 (Fig. 1), the maximum potential distance traveled was 1,097 m.

Observations by saturation divers indicated that each of the six *S. coeruleus* tagged in this study was visually observed to join a transient group of 10-15 conspecifics at some point during the course of the 10-day *Aquarius* mission. This behavior has been observed among mature *S. coeruleus* elsewhere within its range (Bohlke and Chaplin 1993). The aggregations regularly foraged in the sand areas adjacent to the reef. Participation in group foraging activities varied considerably within the visible range of saturation divers, lasting less than a minute to greater than 30 minutes. *S. taeniopterus* were relatively more abundant at Conch Reef during the saturation mission. Tagged and un-tagged individuals were observed swimming close (rarely more than 4 body lengths) to the reef. With the exception of two acts of conspecific aggression, no interaction was observed among *S. taeniopterus*.

Despite more than fifty percent overlap between the detection ranges of adjacent receivers, simultaneous detections in Zones 1.5 and 2.5 (Fig. 1 and Table 2) were minimal, and no simultaneous detections were recorded at all three receivers. This may have been a consequence of the topographical complexity of Conch Reef. Though each of the three receivers was placed at comparable depths, changes in seafloor topography between the receivers likely reduced significantly the estimated area of each receiving zone. For instance, while the area immediately surrounding the *Aquarius* was potentially encompassed by each of the three receivers, because the area is a sand flat surrounded by higher-relief spur and groove formations no signal detections were recorded simultaneously at the three receivers (Region D in Fig. 1) for fish that we observed swimming in that area.

Parrotfish are diurnally active (Dubin and Baker 1982), with several species observed to form mucous envelopes at night within reef crevices (Winn 1955), possibly as a predator avoidance strategy (Winn and Bardach 1959). Signal detections for both *S. coeruleus* and *S. taeniopterus* showed clear diurnal behavior (Fig. 3). The majority of detections for each species were recorded during daylight hours (daylight = 1 h after sunrise to 1 h before sunset), and no movement was recorded between zones during night hours (1 h after sunset to 1 h before sunrise) over the course of the study. Only princess parrotfish Tag 3, for which 64% of its signal detections occurred at night, departed from this pattern. This could have resulted from either nocturnal movement, or from the fish "over-nighting" within the range of receiver 1.

Our second objective was to quantify any fish site fidelity to the location on the reef where each fish was tagged and released. Signal detections for each individual fish were grouped into 15-min time bins standardized for all receivers during daylight hours over the course of its time at-liberty (Table 3). A minimum of one signal detec-

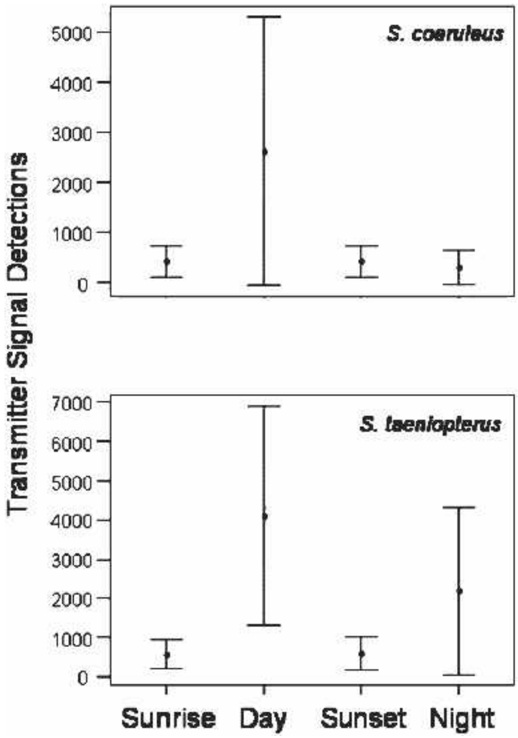

FIG. 3. Number of signal detections for *S. coeruleus* and *S. taeniopterus* across the diel cycle—sunrise, day, sunset, night. The periods of sunrise and sunset were characterized as the event ± 1 hr. The mean and 95% confidence interval are reported.

tion per 15-min bin was necessary for a fish to be considered present in a particular zone during that time period. None of the six *S. coeruleus* were recorded at a single receiving zone for greater than 38.4% of their time at-liberty, including Zone 2 where they were each tagged and released. Three (Tags 1, 5, 6) were absent from the receiver array for greater than 80% of the study. The majority of *S. coeruleus* departures from the receiver array (Table 4) were less than 30 minutes in duration, with the maximum lapse between signal detections ranging from 4.25 h (Tag 7) to 8.5 h (Tag 2).

S. taeniopterus Tags 1-3 were caught and released at Zone 1, while Tags 4-9 were caught and released at Zone 2 (Fig. 1 and Table 2). Each of the three fish released in Zone 1, and 2 of the fish released in Zone 2, were recorded in greater than 50% of the 15-min bins. Tags 1, 2, 4 and 8 were recorded in their zone of release for greater than 70% of their time at-liberty (Table 3). The majority of the departures of *S. taeniopterus* from the receiver array were less than 15 minutes in duration (Table 4). The maximum time away from the array ranged from 1 hour (Tag 1) to 7.5 hours (Tag 8).

Despite the small amount of data obtained in this preliminary effort, the re-

TABLE 3. Signal detections for tagged *S. coeruleus* and *S. taeniopterus* in each receiving zone expressed as a percentage of 15-minute time bins for daylight hours (Sunrise + 1 hr to Sunset-1 hr) from 29 August 2002 through 10 April 2003. None = the percentage of time bins in which no signal was recorded.

		Receiving Zone					
Species	Fish number	1	1.5	2	2.5	3	None
S. coeruleus	1	0.1	0	8.4	0	0.3	91.3
	2	0.3	0	30.4	0.2	1.2	68.5
	3	0	0	38.4	0	1.0	60.8
	4	0	0	21.2	0	0	78.8
	5	0	0	16.4	0	0	83.5
	6	3.9	0.2	5.1	0	0	91.3
S. taeniopterus	1	83.5	0.1	0.8	0	0	15.7
	2	90.4	0	0	0	0	9.6
	3	60.2	0	0	0	0	39.8
	4	0.6	0	75.4	0	0.3	23.9
	5	0	0	4.3	0	28.0	67.7
	6	0	0	27.9	0.5	18.1	55.0
	7	0	0	44.5	0.2	5.1	51.1
	8	0	0	73.1	0	0	26.9
	9	0.1	0	5.6	0	0	94.3

TABLE 4. Frequency of time lapse between signals after a time bin in which no receivers recorded signals from tagged *S. coeruleus* and *S. taeniopterus* during daylight hours (Sunrise + 1 hr to Sunset – 1 hr). The mean number of departures is reported for each category.

	Minutes				Hours		
Species	1-15	16-30	31-45	46-60	1-2	2-5	>5
S. coeruleus	144.5	63.3	30	23.5	34.5	18.3	2.5
S. taeniopterus	136.7	36.1	13.8	7.9	10.9	5.5	0.41

corded patterns of movement for both *S. coeruleus* and *S. taeniopterus* can lead to further study. Though the recorded site fidelity of the parrotfishes to the receiving zones was low (mean = 20% for *S. coeruleus* and 40% for *S. taeniopterus*) at the scale of 15-min bins, the fact that the majority of the departures from the receiver array for both species were 30 min or less suggests that if these fish did indeed leave the receiver area, they did not travel far. This raises two questions: where did they go? And why?

Assuming that the topographic complexity of Conch Reef was largely responsible for the lack of signal detections, a greater number of receivers, deployed up in the water column rather than down on the reef, should allow us to characterize the movements of these and other species more accurately. The resulting increase in the number of receiving zones will allow us to identify the likely location of a fish for which simultaneous signal detections are recorded with greater precision. And the elevation of the receivers into the water column should reduce the impact of seafloor topography on the simultaneous detections, increasing the total number of simultaneous detections. An increase in the resolution of movement data for both species should ultimately allow us to relate fish movement behavior to particular features of the seafloor.

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