Marine Sanctuaries Conservation Series MSD-05-4

Movement of yellowtail snapper (*Ocyurus chrysurus* Block 1790) and black grouper (*Mycteroperca bonaci* Poey 1860) in the northern Florida Keys National Marine Sanctuary as determined by acoustic telemetry

U.S. Department of Commerce
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Movement of yellowtail snapper (*Ocyurus chrysurus* Block 1790) and black grouper (*Mycteroperca bonaci* Poey 1860) in the northern Florida Keys National Marine Sanctuary as determined by acoustic telemetry

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COVER

Top: Yellowtail snapper, *Ocyurus chrysurus* Bloch 1790. Photo Credit: Virginia O. Skinner
Bottom: Black grouper, *Mycteroperca bonaci* Poey 1860. Photo Credit: University of Massachusetts.

SUGGESTED CITATION

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ABSTRACT

We tagged a total of 14 yellowtail snapper (*Ocyurus chrysurus* Bloch 1790) and black grouper (*Mycteroperca bonaci* Poey 1860) inside the Conch Reef Research Only Area (a no-take marine reserve) in the northern Florida Keys National Marine Sanctuary in November 2001. Both species are heavily exploited in the region. Our objective was to characterize site fidelity and movement behavior along the reef tract to the north and south of the release point. Fishes were collected by baited hook and line from the surface, surgically-tagged with coded-acoustic transmitters, and returned to the reef by snorkelers. Tracking of fish movement behavior was conducted by five acoustic receivers deployed on the seafloor from Davis Reef in the south to Pickles Reef in the north. Fishes were tracked for up to eight months. Results indicated that the majority of signal detections for individual fish from both species were recorded at the two Conch Reef receivers. Limited movement from Conch Reef to Davis Reef was recorded, but no signal detections were recorded at the two sites to the north of Conch Reef. These results suggest that both species show site fidelity to Conch Reef. Future studies will seek to characterize this site fidelity with increased temporal and spatial resolution at Conch Reef.

KEY WORDS

Yellowtail snapper, *Ocyurus chrysurus*, black grouper, *Mycteroperca bonaci*, acoustic telemetry, marine reserves, site fidelity, movement patterns, Florida Keys National Marine Sanctuary

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INTRODUCTION

Members of the grouper-snapper complex are mostly long-lived and like many other species in the Florida Keys have been the focus of high-intensity commercial and recreational fishing pressure for more than 40 years (Thompson and Munro, 1978; Bohnsack et al., 1994: Sadovy, 1994; McClellan and Cummings, 1998; Ault et al., 1998, 2005; Coleman et al., 2000). As a result of this fishing effort, the biomass and abundance of black grouper (Serranidae: *Mycteroperca bonaci* Poey 1860) in the Florida Keys have declined substantially (Chiappone et al., 2000; Ault et al., 2002). Yellowtail snapper (Lutjanidae: *Ocyurus chrysurus* Bloch 1790), though still exploited, are no longer considered over-fished in the Keys (Muller et al. 2003).

The ecological requirements and geographic distributions of each species are well known. *O. chrysurus* prey on a diverse array of taxa in coastal waters from Massachusetts to Brazil (Thompson and Munro, 1983; Acosta and Beaver, 1998; McClellan and Cummings, 1998) taking prey opportunistically both in the water column and on the benthos. In the Florida Keys *O. chrysurus* occurs year round (McClelland and Cummings, 1998). *M. bonaci* inhabit coral reef habitat and rock ledges from North Carolina to southern Brazil (Smith, 1971; Bullock and Smith, 1991; Sullivan and Sluka, 1996) and prey principally on fishes and crustaceans (Thompson and Munro, 1978).

Though coral reef fish are generally considered to be highly sedentary (Sale, 1991; Chapman and Kramer, 2000), little is known about the fine-scale movement patterns of individual fish, such as *O. chrysurus* and *M. bonaci*, within the geographical range in which they occur. However, it is precisely this information that will be vital for the conservation and management of both of these exploited species, particularly where spatial management measures are under consideration. For example, in 1997 a total of 23 no-take reserves were zoned and designated in the Florida Keys National Marine Sanctuary (FKNMS; U.S. Department of Commerce, 1996). The Tortugas Ecological Reserve was added in 2001 (U.S. Department of Commerce, 2000). The zones, designated primarily to protect the biological diversity and ecological integrity of heavily used reefs, as well as to reduce user conflicts, exclude all extractive activities from inside their boundaries (U.S. Department of Commerce, 1996). Understanding how particular fishes move relative to the boundaries of these reserves will be critical to successful management.

Data from traditional tag and recapture studies suggest that post-settlement movement of many tropical reef fishes is limited (Bardach 1958; Randall 1961). These data provide insight into the large-scale (one to 1000s of kilometers) movement of fishes, but generally cannot resolve fine scale movements (one to 1000s of meters) of fish within a particular reef complex. Until recently, the difficulties in following individual fish for extended periods of time made precise quantification of fish movement rates one of the most difficult demographic parameters to assess (Jones 1991). As such, important questions remain regarding the movements of individual fish at these smaller spatial scales.

The site fidelity of coral reef fishes has been demonstrated using acoustic telemetry for a number of species worldwide (Zeller 1997, Zeller and Russ 1998; Bolden 2002; Meyer et al. 2003). Where fish were once tracked primarily by receivers from the surface, advances in acoustic technology have made possible field deployments of acoustic receivers that record data continuously for months to years (Klimley et al., 1998; Heupel and Hueter, 2001; Starr et al. 2001; Lindholm et al. 2005).

In the present study we surgically tagged a small number of *O. chrysurus* and *M. bonaci* inside the Conch Reef Research Only Area in the northern FKNMS. Movements of individual fish from both species were tracked using five acoustic receivers deployed along the reef tract. Our objectives in this initial effort were to characterize site fidelity of tagged fish from each species to the location where they were caught and released and to record any movement to the north or south of Conch Reef along the reef tract.

METHODS

Fish were collected and tagged from 8 - 14 November 2001 inside the southeast corner of the Conch Reef Research Only Area, one of two no-take marine reserves designated at Conch Reef by the FKNMS (Figure 1). All fish collection and tagging operations were conducted aboard a chartered fishing vessel. Each fish was caught by hook and line from the surface using small, baited “J” hooks. Following capture and stabilization in the live-well (15 – 30 min), each fish was briefly submerged in an anesthetic bath containing buffered MS-222 (100 mg l^{-1}; Summerfelt and Smith, 1990)**.** Stage IV anesthesia was achieved in 1-3 minutes depending on species and fish size. Once anesthetized, each fish was removed from the anesthetic bath and placed upside-down in a padded V-shaped container for tag insertion (Winter 1996). A damp towel was placed over the fish, with only the intended tag insertion point exposed. A 20 mm incision was made just above the ventral midline on the left side of the fish, forward of the vent. All fish were tagged with V8SC-6L coded-acoustic transmitters (VEMCO Ltd., Shad Bay, Nova Scotia) measuring 20 mm dia x 9 mm. Each transmitter was pre-programmed to emit a unique ID code randomly between 30 – 90 seconds. Each transmitter was coated with triple-antibiotic ointment and inserted into the peritoneal cavity with transmitter head facing forward. The incision was closed using 2 -3 black monofilament sutures (5-0 Ethilon) and coated with triple-antibiotic ointment.

Following tagging, each fish was handed to a snorkeler in the water. The snorkeler revived the fish by swimming it slowly around the boat just below the surface. As the fish recovered from the anesthetic (3-15 minutes), the snorkeler swam the fish down toward the bottom for release. Each fish was observed for 15-20 minutes, or until the fish swam out of visual range.

Movement of tagged fishes were recorded by single-channel VR2 acoustic receivers (VEMCO Ltd., Shad Bay, Nova Scotia) deployed at five locations (Figure 1) extending from Davis Reef (one receiver), to Conch Reef (two receivers), to Pickles Reef (two receivers, including a location midway between Conch and Pickles Reefs). Each receiver continuously recorded the simple presence/absence of tagged fish within approximately 300 m, or an area of intersection with the seafloor equal to approximately 0.2826 km^2. Data were downloaded from each receiver at 2-3 month intervals throughout the study period.

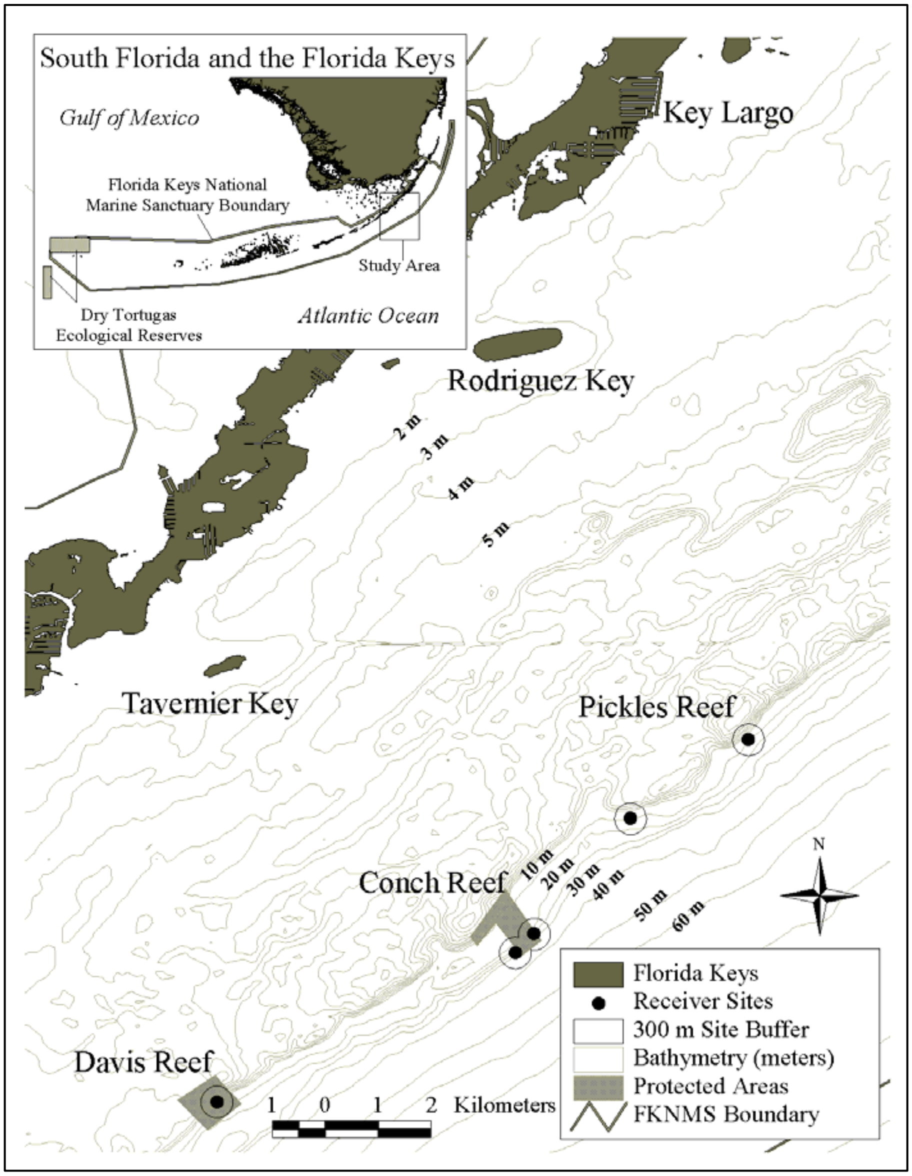

Figure 1 Map of study area in northern Florida Keys National Marine Sanctuary, including the locations of each receiver, a 300 m site buffer around each site depicting the estimated range of detection for each receiver, as well as the boundaries of the FKNMS, Conch Reef Research Only Area, and the Davis and Conch Reef SPAs.

The time at-liberty (a record of the time period from the first record to the last record) was quantified at the scale of individual 24 hr periods for each tagged fish. Further analyses were conducted to compare usage of receiver sites by tagged fish in minute-scale intervals throughout the study. Recorded signals were grouped into 15-minute and 30-minute time bins standardized for all receivers, to allow direct comparison between signals logged by different receivers and ultimately describe a set of average behaviors during a period of 24 hours. There were a total of 96 15-minute time bins and 48 30-minute time bins. For example, each bin was assigned a number, with bin number 1 corresponding to 00:00:00 – 00:15:00 for the 15-minute analysis and 00:00:00 – 00:30:00 for the 30-minute analysis. Each signal detection was assigned a rank depending on the time bin to which it belonged, based upon time of reception (as per Starr et al.

2001). A sum for the number of signals per time bin, per receiver was calculated for each fish to identify the predominant receiver sites occupied in cases where sums for one time bin included more than one receiver. The resulting data were plotted as the average number of detections per fish per bin at each receiver from which records were collected. The number of signal detections per diel period—sunrise, daylight, sunset, night—was also quantified for each tagged fish.

RESULTS

We collected records for a total of nine *O. chrysurus* measuring 215 to 265 mm FL (mean = 231.6 mm, SD = 15.39 mm) and five *M. bonaci* measuring 380 to 740 mm SL (mean = 630 mm, SD = 137.1 mm) over the course of eight months (Table 1). Tagged fish from each species were recorded at the two Conch Reef sites (NE Waystation and Pinnacle Site) and at Davis Reef located approximately 4 km to the south. No records were collected at either the Pickles Reef site or at the site located midway between Pickles and Conch reefs.

The recorded fish movement behavior varied widely among species and between individual fish from each species. The time at-liberty for tagged *O. chrysurus* (Figure 2) ranged from two days (Fish 8) to 237 days (Fish 6), with six fish recorded by at least one of the Conch Reef receivers for more than five months. Signal detections for eight of the nine tagged fish were recorded at both the NE Waystation and the Pinnacle site for nearly all of the detections (Table 1). Five of the nine tagged *O. chrysurus* made visits to Davis Reef immediately following release. In each case the visit was brief based on the number of signal detections and the fish returned to Conch Reef within the same 24-hour period. Only *O. chrysurus* Fish 6 made return visits to Davis Reef over the course of the study. Each of the three return visits occurred seven months into the study and each visit consisted of single signal detections.

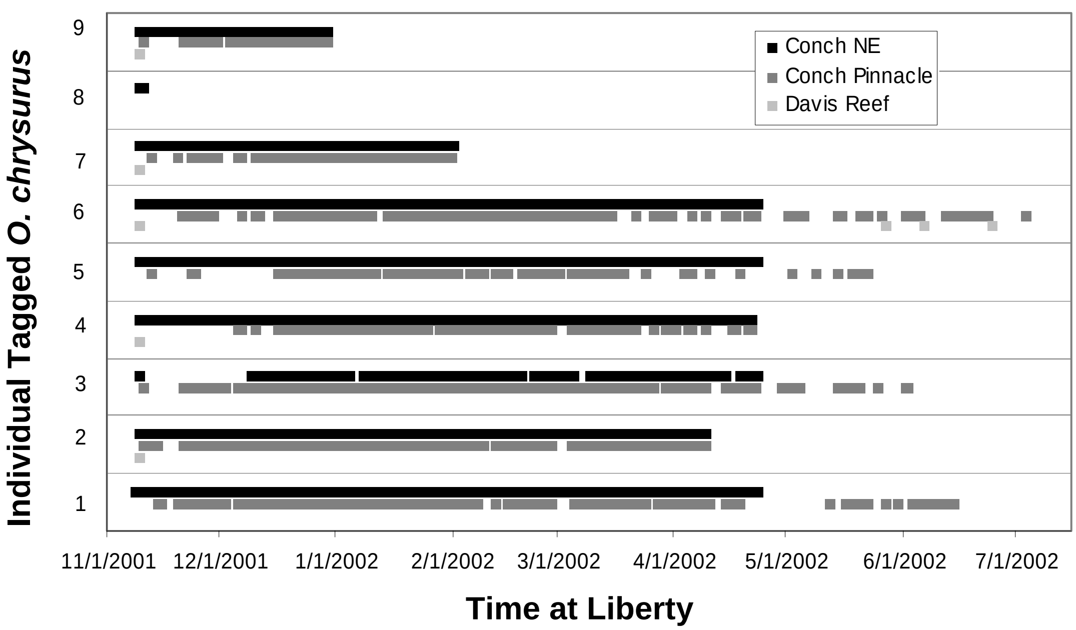

Figure 2 Recorded time at-liberty for tagged *O. chrysurus* at Conch Reef (NE Waystation and Pinnacle site) and Davis Reef from November 2001 to July 2002.

The time at-liberty for tagged *M. bonaci* (Figure 3) ranged from approximately one month following release (Fish 4 and 5) to more than five months (Fish 1). The vast majority of signal detections for each fish (> 90%) were recorded at the NE Waystation where the fish were caught and released (Table 1). The signal detections per fish numbered in the hundreds (Fish 2) to thousands (Fish 1, 3 and 5), with the exception of Fish 4 (11 pings). Movement to the southern portion of Conch Reef (Pinnacle site) was recorded for four of the five *M. bonaci*. Further, all fish movements to the Pinnacle site were brief, with each fish returning to the northern portion of the reef within the same 24-hour period. Only *M. bonaci* Fish 1 made brief visits to Davis Reef 4 km to the south of Conch Reef immediately following release (Figure 3). The fish returned to the NE Waystation at Conch Reef within the same day.

Figure 3 Recorded time at-liberty for tagged *M. bonaci* at Conch Reef (NE Waystation and Pinnacle site) and Davis Reef from November 2001 to April 2002.

Table 1 Number of signal detections for each tagged *O. chrysurus* and *M. bonaci* at each receiver site. The number of detections per receiver is shown in parentheses as a percentage of the total detections for each fish.

Species	Fish #	Pickles Reef	Between Conch and Pickles	Conch Reef NE Waystation	Conch Reef Pinnacle	Davis Reef	Total Detections
O. chrysurus	1	-------	------	7948 (67.1)	3891 (32.9)	-------	11839
	2	-------	-------	15221 (58.5)	10798 (41.5)	4 (0.02)	26023
	3	-------	-------	9229 (49.1)	9583 (50.9)	-------	18812
	4	-------	-------	27361 (94.4)	1621 (5.6)	9 (0.03)	28991
	5	-------	-------	45892 (96.5)	1669 (3.5)	-------	47561
	6	-------	-------	11277 (74.1)	3940 (25.9)	4 (0.03)	15221
	7	-------	-------	6402 (68.6)	2928 (31.4)	4 (0.04)	9334
	8	-------	-------	26 (100)	-------	-------	26
	9	-------	-------	6451 (66.7)	3222 (33.3)	2 (0.02)	9675
						Total:	167482
M. bonaci	1	-------	-------	7656 (94.1)	9 (0.11)	469 (5.8)	8134
	2	-------	-------	592 (99.3)	4 (0.67)	-------	596
	3	-------	-------	2150 (95.9)	93 (4.1)	-------	2243
	4	-------	-------	10 (91)	1 (9.0)	-------	11
	5	-------	-------	1250 (100)	-------	-------	1250
						Total:	12234

The mean number of signal detections for tagged *O. chrysurus* and *M. bonaci* for each diel period is shown in Table 2. A total of 58% of signal detections for *O. chrysurus* were recorded during daylight hours, with 25% recorded during the night. The number of detections during the two crepuscular periods was similar, with 9% during sunrise and 8% during sunset. No differences were recorded among the tagged *O. chrysurus* ($F_{8,27}$ = 1.36, p-value = 0.257) with respect to the total number of signal detections per diel period. The distribution of signal detections for *M. bonaci* was more uniform between day and night hours, with 44% and 42%, respectively. The distribution of signal detections for the two crepuscular periods was also uniform for *M. bonaci* (6% sunrise and 8% sunset). However, differences were recorded among individual tagged *M. bonaci* with respect to detections per period ($F_{4,15}$ = 3.19, p-value = 0.04). Fish 1 (with 66.5% of the total signal detections for all tagged *M. bonaci*) was recorded more than 1.5 times more often at night (4247 signal detections) than during the day (2896 signal detections).

Analysis of tagged *O. chrysurus* at the scale of 15- and 30-minute time intervals (Figures 4 and 5) indicated that tagged fishes traveled between the NE Waystation (Receiver 1) and the Pinnacle site (Receiver 2) during the day, with nocturnal behavior recorded primarily at the NE Waystation. Only one visit was made to Davis Reef (Receiver 3), by Fish 8 during the night. The 30-minute time bins lacked much of the detail provided by 15-minute groupings. For example, in the case of Fish 1, only one visit to the Pinnacle site is depicted in the 30-minute bin, whereas the 15-minute bins show four such visits.

Table 2 Number of signal detections for tagged *O. chrysurus* and *M. bonaci* across the diel cycle. Sunrise and Sunset are defined as the event ± 1 hr. The mean and standard deviation are reported for each species.

Species	Sunrise Mean / SD	Day Mean / SD	Sunset Mean / SD	Night Mean / SD
O. chrysurus	1765 / 1162	10808 / 6162	1405 / 1140	4631 / 8133
M. bonaci	164 / 110	1115 / 1129	200 / 250	1052 / 1801

Signal detections for four of the five tagged *M. bonaci* (Fish 1, 2, 3, and 5; Figure 6) indicated continual residence at NE Waystation during the time at-liberty, with brief peaks in the number of detections occurring at dawn and dusk. Fish 4, the smallest in the study (SL = 380 mm) showed little site fidelity to the NE Waystation.

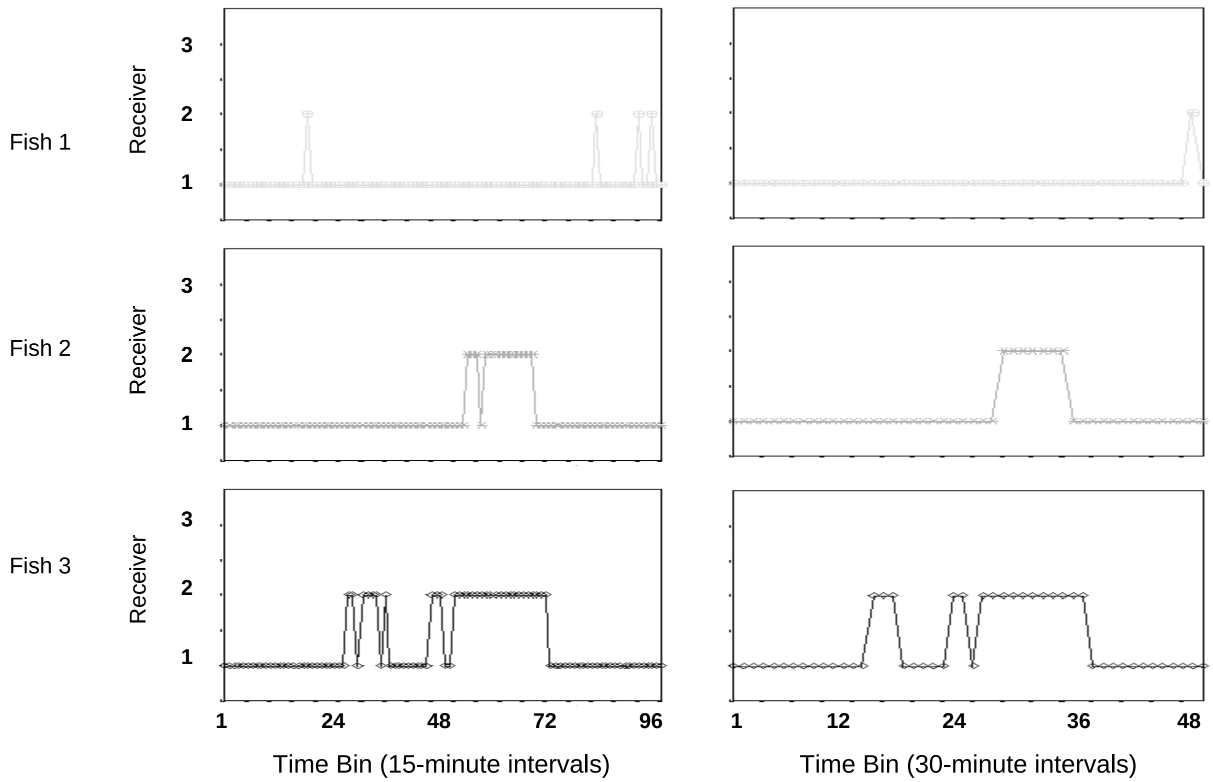

Figure 4 Recorded movement of tagged *O. chrysurus* Fish 1-3 among receiver sites in 15- and 30-minute time bins. The average number of signal detections per bin is shown for each individual fish for which movement among receivers was recorded. Receiver 1 = NE Waystation, Receiver 2 = Pinnacle, Receiver 3 = Davis Reef.

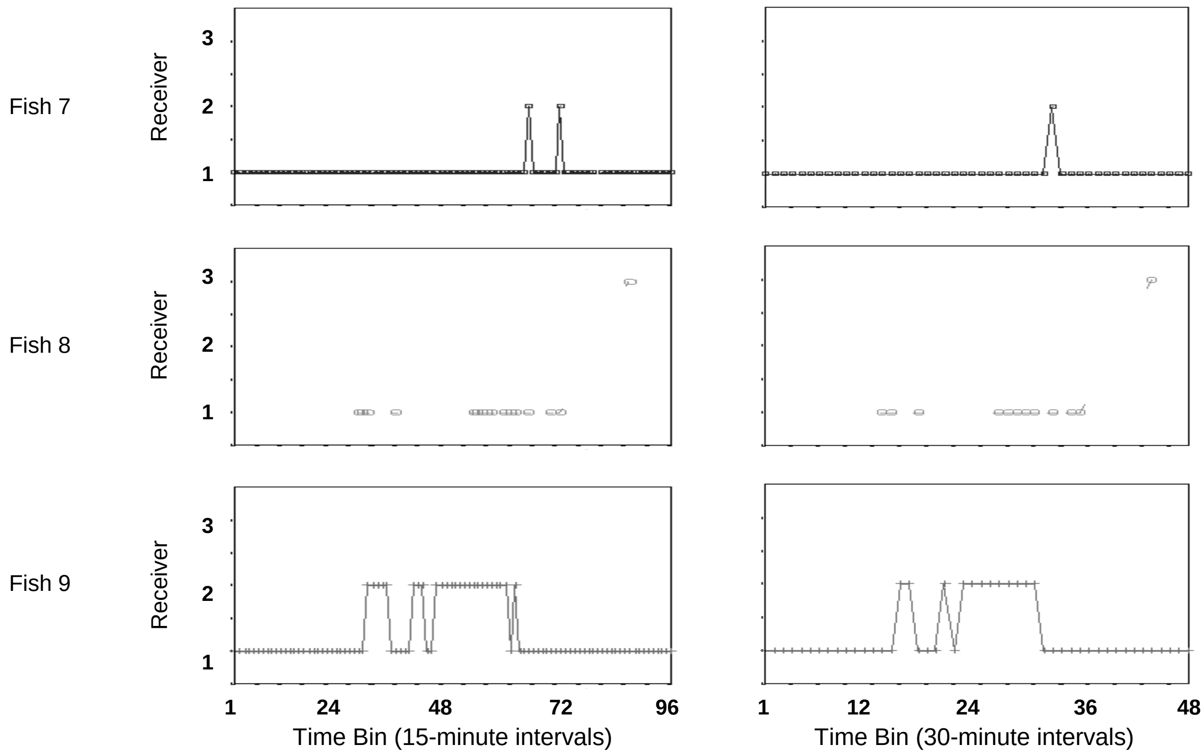

Figure 5 Recorded movement of tagged *O. chrysurus* Fish 7-9 among receiver sites in 15- and 30-minute time bins. The average number of signal detections per bin is shown for each individual fish for which movement among receivers was recorded. Receiver 1 = NE Waystation, Receiver 2 = Pinnacle, Receiver 3 = Davis Reef.

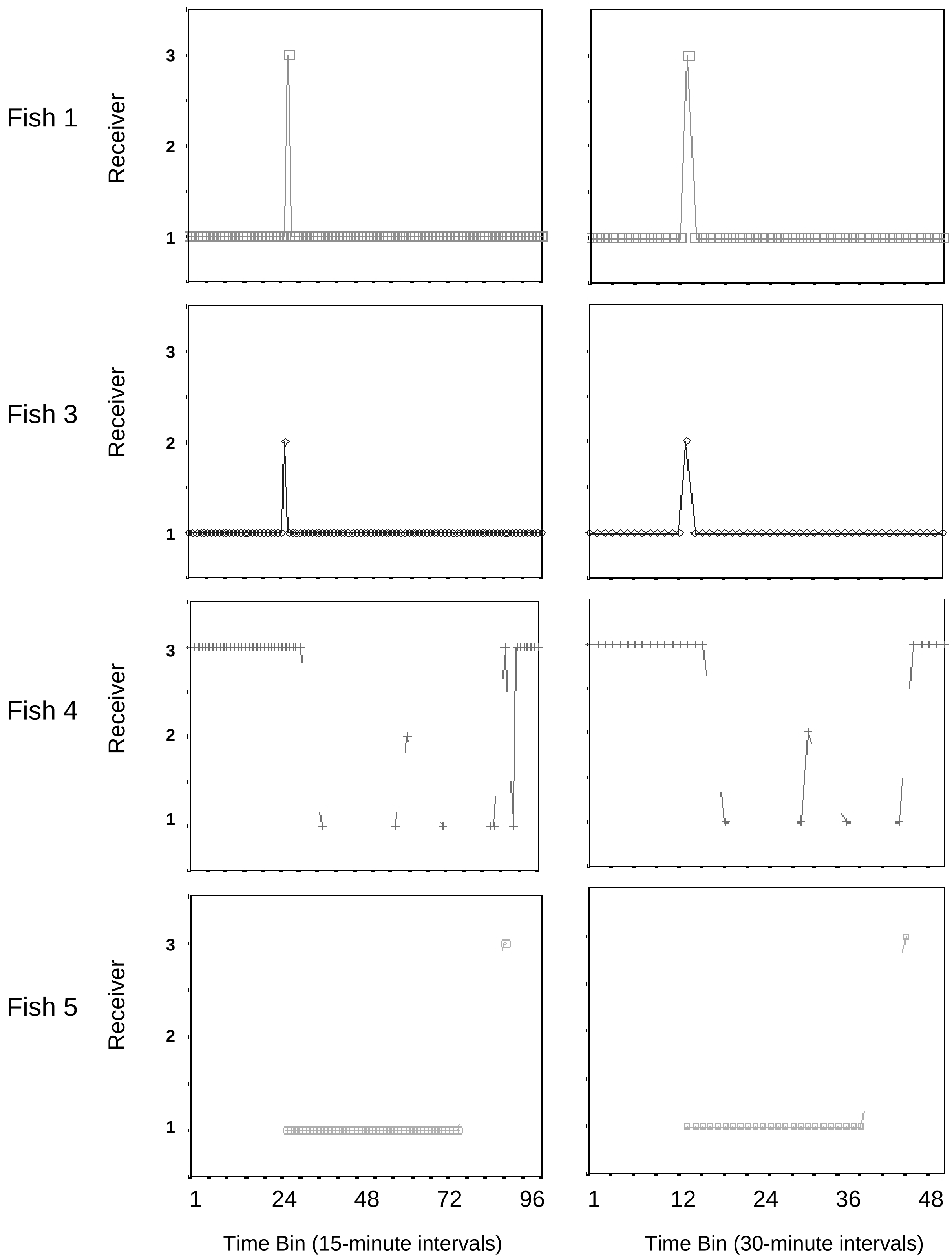

Figure 6 Recorded movement of tagged *M. bonaci* Fish 1, 3, 4 and 5 among receiver sites in 15- and 30-minute time bins. The average number of signal detections per bin is shown for each individual fish for which movement among receivers was recorded. Receiver 1 = NE Waystation, Receiver 2 = Pinnacle, Receiver 3 = Davis Reef.

DISCUSSION

Despite the small amount of data obtained in this preliminary effort, the recorded patterns of movement for both *O. chrysurus* and *M. bonaci* provide insight into the behavior of both species and can lead to further study. Our first objective was to identify site fidelity to the location where the fish were caught and released at Conch Reef. Among the nine tagged *O. chrysurus*, Fish 1-6 were each recorded during their time at-liberty at either one or both of the Conch Reef receivers in excess of five months, through the winter and into the spring (Figure 2). Fish 6 was recorded at the Pinnacle site well into the middle of summer.

These results did not conform to our a priori expectations. We expected less site fidelity for *O. chrysurus*, which we have observed forming transient aggregations in the water column at Conch Reef, often moving out of visual range. Site fidelity in this species is also suggested by data from elsewhere in the Keys. In the four years following designation of the small no-take marine reserves throughout the Keys by the FKNMS, densities of *O. chrysurus* within the reserves increased fifteen-fold (Bohnsack and Ault, 2002). This increase suggests high site fidelity to the areas encompassed by the reserves.

Fewer *M. bonaci* were tagged, but the results were similar. Three of five individual fish (Fish 1-3) were recorded at Conch Reef longer than three months, with Fish 1 recorded over a period of approximately 5.5 months (Figure 3). These results are also supported by data elsewhere in the Keys, where the density of groupers within no-take reserves increased by an order of magnitude over the four years following closure (Bohnsack and Ault, 2002). This apparent site fidelity to Conch Reef is notable given the knowledge of grouper spawning behavior. *M. bonaci* (mean TL = 640 mm) have been observed to form reproductive aggregations to the north of our study sites beginning annually in January (Ecklund et al., 2000). In this context, the presence of Fish 1 (740 mm TL) and Fish 3 (630 mm TL) at Conch Reef throughout this period is particularly interesting. Additional tagging will be necessary to more completely investigate *M. bonaci* movement during spawning periods.

Our second objective was to capture any movement of tagged fishes up and down the reef tract. Though movement of individuals of both *O. chrysurus* and *M. bonaci* was recorded at Davis Reef, 4 km to the south of their point of release, no movement was recorded to the north of Conch Reef and the majority of records in the study were collected at the two Conch Reef receivers (Table 1). The movement of individuals of both species between Conch Reef and Davis Reef to the south is notable given the distance covered and the habitats occurring between the two sites. For instance, the distribution of serranids within their larger assemblage boundaries has been shown to vary with seafloor habitats (Sluka and Sullivan, 1996, 1998; Sluka et al., 2001). The journey from Conch Reef to Davis Reef would have involved swimming more than 4 km over relatively featureless sand habitats, depending upon the water depth at which the trip was made. Also interesting is the relative brevity of the visits each fish made to Davis Reef (with visits not exceeding four days for either species) and the fact that only one *O. chrysurus* (Fish 6) made more than a single visit to Davis Reef over the course of the study (Figures 2 and 3).

The high relative abundance of signal detections for *O. chrysurus* in daylight hours when compared to night is not surprising, and is likely attributable to actual fish behavior. During the daylight hours, *O. chrysurus* were often observed in the water column at Conch Reef, which would place them in direct line of sight with the receivers on the seafloor. At night, the limited number of direct observations of *O. chrysurus* was as solitary individuals foraging close to the reef, where reception by the receiver would probably be limited by topographic complexity of the reef. Tagged *M. bonaci* were observed diurnally (no nocturnal observations were made) swimming within the spur and groove formations that characterize Conch Reef, which would also limit their detectability by the receivers. The uniform distribution of signal detections between day (44%) and night (42%) suggests that the behavior of *M. bonaci* is similar nocturnally, though a more explicit study would be necessary to characterize this behavior.

While the fate of tagged fish outside the receiver array was not addressed in this study, the loss of tagged fish from the study area is likely attributable to two primary factors: receiver coverage and exploitation. Each acoustic receiver recorded the presence of tagged fish within approximately 300 m, or an area of intersection with the seafloor equal to approximately 0.2826 km^2. The small areas of the reef tract included in this study occur within a much larger coral reef sea landscape that extends 10's of kilometers to the north and south of the study area. It is possible that those fish that did not remain within the study area throughout the study were in fact still utilizing coral reef habitats in adjacent areas beyond the range of the receiver array, either to the north and south or onshore and offshore.

It is likely that the topographic complexity at Conch Reef limited the number of signal detections we recorded there, particularly for tagged *M. bonaci*. As mentioned above, any movement by tagged fishes close to the reef, even if adjacent to a receiver, may have placed them in an acoustic shadow where signal detections were not recorded. The relative differences in signal detections per fish for *O. chrysurus* and *M. bonaci* were likely the result of this interaction between fish behavior and the limits of the acoustic telemetry. *O. chrysurus* were observed at Conch Reef on multiple occasions both foraging along the reef as solitary individuals, as well as in transient aggregations in the water column (Lindholm et al., unpublished). *M. bonaci*, on the other hand, were observed primarily as solitary individuals close to the reef. Subsequent studies will attempt to minimize the presence of acoustic shadows to more accurately characterize fish movement close to the reef.

It is also possible that tagged fish were caught by fishing in adjacent areas. Both species are heavily exploited in the Florida Keys (Thompson and Munro, 1978; Bohnsack et al., 1994; Sadovy, 1994; Ault et al., 2002, 2005; McClellan and Cummings, 1998). Each day during our tagging operations we observed multiple fishing boats moored to the buoys immediately adjacent to the no-take reserve at Conch Reef. Because all tagged fish for which records were collected made daily movements out of the range of the receiver array, all were subject to capture by these and other boats further up and down the reef tract. Indeed, we recaptured two of our tagged fishes during the course of the study, and later a third was terminally recaptured (and eaten) by the very fisherman we hired to help us with this study.

Clearly, there are limits to what can be extrapolated from this study alone, particularly with respect to the implications for the design of marine reserves. A more comprehensive investigation, involving greater numbers of fish and other fish species, other sites along the reef tract, and greater temporal coverage, will be required to more fully understand the movement behavior of fishes in the Florida Keys generally, and specifically within the no-take marine reserves. While we recorded high site fidelity to Conch Reef, the distribution of receivers was insufficient to characterize the fine-scale movement of those fish. Given the relatively small-scale of the reserves at Conch, this fine-scale movement will be important. We do not yet know to which specific features of Conch Reef the fish tagged in this study responded. Future efforts will expand both the spatial and temporal scale of the acoustic receiver array at Conch Reef and will include fishes from a variety of functional groups, including algal grazers, benthic invertebrate feeders, and additional benthic piscivores.

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LITERATURE CITED

Acosta, A. and R. Beaver. 1998. Fisheries, growth, and mortality of yellowtail snapper, *Ocyurus chrysurus*, in the Florida Keys, U.S.A. Proc. Gulf Caribb. Fish. Inst. 50: 851-870.

Ault, J.S., J.A. Bohnsack and G.A. Meester. 1998. A retrospective (1979-1996) multispecies assessment of coral reef fish stocks in the Florida Keys. Fish. Bull. U.S. 96: 395-414.

Ault, J.S., S.G. Smith, G.A. Meester, J. Lou, J.A. Bohnsack and S.L. Miller. 2002. Baseline multispecies coral reef fish stock assessment for the Dry Tortugas. NOAA Technical Memorandum NMFS-SEFSC-487. 117 pp.

Ault, J.S., J.A. Bohnsack, S.G. Smith, and J. Lew. 2005. Towards sustainable multispecies fisheries in the Florida, USA, coral reef ecosystem. Bull. Mar. Sci. 76: 595-622.

Bardach, J.E. 1958. On the movements of certain Bermuda reef fishes. Ecology 39: 139-146.

Bohnsack, J.A. and J. Ault. 2002. Reef fish community dynamics and linkages with Florida Bay. 2002 Annual Progress Report for South Florida Ecosystem Restoration Program. NOAA/NMFS/SEFSC/Protected Resources Division PRD/01/02-06.

Bohnsack, J.A., D.E. Harper and D.B. McClellan. 1994. Fisheries trends from Monroe County, Florida. Bull. Mar. Sci. 54: 982-1018.

Bolden, S.K. 2002. Using ultrasonic telemetry to determine home range of a coral-reef fish. Pages 167-188 *in* J. Silbert and J.L. Nielsen , eds. Proceedings of the symposium on tagging and tracking marine fish with electronic devices. Kluwer Academic Publishers, Netherlands.

Bullock, L.H. and G.B. Smith. 1991. Seabasses (Pisces: Serranidae). Mem. Hourglass Cruises, Volume 8, no. 2, Florida Mar Res Inst., Dep. Nat. Resour., St Petersburg, FL.

Chapman, M.R. & D.L. Kramer. 2000. Movements of fishes within and among fringing coral reefs in Barbados. Environ. Biol. Fish. 57: 11-24.

Chiappone, M., R. Sluka and K.S. Sealey. 2000. Groupers (Pisces: Serranidae) in fished and protected areas of the Florida Keys, Bahamas and northern Caribbean. Mar. Ecol. Prog. Ser. 198: 261-272.

Coleman, F.C., C.C. Koenig, G.R. Huntsman, J.A. Musick, A-M. Eklund, J.C. McGovern, R.W. Chapman, G.R. Sedberry, and C.B. Grimes. 2000. Long-lived reef fishes: the grouper-snapper complex. Fisheries 25: 14-21.

Eklund, A-M, D.B. McClellan, and D.E. Harper. 2000. Black grouper aggregations in relation to protected areas within the Florida Keys National Marine Sanctuary. Bull. Mar. Sci. 66: 721-728.

Heupel, M.R. and R.E. Hueter. 2001. Use of an automated acoustic telemetry system to passively track juvenile blacktip shark movements. Pages 217-236 *in* Sibert, J.R. and J.L. Nielsen,eds. Electronic Tagging and Tracking in Marine Fisheries. Kluwer Academic Publishers, Netherlands.

Holland, K.N., J. D. Peterson, C.G. Lowe and B.M. Wetherbee. 1993. Movements, distribution and growth rates of the white goatfish *Mulloides flavolineatus* in a fisheries conservation zone. Bull Mare Sci 52: 982-992.

Jones, G.P. 1991. Postrecruitment processes in the ecology of coral reef fish populations: a multifactorial perspective. Pages 294-328 *in* Sale P.F. (ed) The Ecology of Fishes on Coral Reefs. Academic Press, San Diego, California.

Klimley, A.P., F.Voegli, S.C.Beavers, and BJ. Le Boeuf. 1998. Automated listening stations for tagged marine fishes. Mar. Technol. Soc. J. 32: 94-101.

Lindholm, J., S. Fangman, L. Kaufman and S. Miller. 2005. *In situ* tagging and tracking of coral reef fishes from the *Aquarius* undersea laboratory. MTS Journal 39: 68-73.

McClellan, D.B. and N.J. Cummings. 1998. Fishery and biology of the yellowtail snapper, Ocyurus chrysurus, from the southeastern United States, 1962 through 1996. Proc. Gulf Caribb. Fish. Inst. 49: 25-45.

Meyer, C.G., K. N. Holland, B.M. Wetherbee, and C.G. Lowe. 2000. Movement patterns, habitat utilization, home range size and site fidelity of whitesaddle goatfish, *Parupeneus porphyreus*, in a marine reserve. Env. Bio. Fishes 59: 235-242.

Muller, R.G., M.D. Murphy, K deSilva, L.R. Barbieri. 2003. A stock assessment of yellowtail snapper, Ocyurus chrysurus, in the Southeast United States. Final report submitted to the National Marine Fisheries Service, the Gulf of Mexico Fishery Management Council, and the South Atlantic Fishery Management Council as part of Southeast Data, Assessment, and Review (SEDAR) III. FWC-FMRI Report: IHR 2003-10.

Randall, J.E. 1961. Tagging reef fishes in the Virgin Islands. Proc. Gulf Caribb. Fish. Inst. 14: 201-241.

Sadovy, Y. 1994. Grouper stocks of the western central Atlantic: the need for management and management needs. Proc. Gulf. Caribb. Fish. Inst. 43: 43-64.

Sluka, R. and K.M. Sullivan. 1996. The influence of habitat on the size distribution of groupers in the upper Florida Keys. Environ. Biol. Fish. 47: 177-189.

Sluka, R.D. and K.M. Sullivan. 1998. The influence of spear fishing on species composition and size of groupers on patch reefs in the upper Florida Keys. Fish. Bull. 96: 388-392.

Sluka, R.D., M. Chiappone, and K.M. Sullivan Sealy. 2001. Influence of habitat on grouper abundance in the Florida Keys, U.S.A. J. Fish Biol. 58: 682-700.

Smith, C.L. 1971. A revision of the American Groupers: Epinephalus and allied genera. Bull. Am. Mus. Nat. Hist. 146: 67-242.

Starr, R.M., Heine, J.N., Felton, J.M., and Cailliet, G.M. 2001. Movements of bocaccio (*Sebastes paucispinis*) and greenspotted (*S. chlorostictus*) rockfishes in a Monterey submarine canyon: implications for the design of marine reserves. Fish. Bull. 100: 324-337.

Sullivan, K.M. and R. Sluka. 1996. The ecology of shallow-water groupers (Pisces: Serranidae) in the upper Florida Keys, USA. ICLARM Conf. Proc. 48: 74-84.

Summerfelt, R.C. and L.S. Smith. 1990. Anesthesia, surgery, and related techniques. Pages 213-272 *in* C.B. Schreck and P.B. Moyle, eds. Methods for Fish Biology. American Fisheries Society, Bethesda.

Szedlmayer, S.T. 1997. Ultrasonic telemetry of red snapper, *Lutjanus campechanus*, at artificial reef sites in the northeast Gulf of Mexico. Copeia 4: 846-850.

Thompson, R. and J.L. Munro. 1978. Aspects of the biology and ecology of Caribbean reef fishes: Serranidae (hinds and groupers). J. Fish. Biol. 12: 115-146.

Thompson, R. and J.L. Munro. 1983. The biology, ecology, and bionomics of Caribbean reef fishes: Lutjanidae (snappers). Pages 94-109 *in* J.L. Munro, ed. Caribbean Coral Reef Fishery Resources. ICLARM Studies Rev. 7. Manila, Philippines.

Tulevech, S.M. and C.W. Recksiek. 1994. Acoustic tracking of adult white grunt, *Haemulon plumieri*, in Puerto Rico and Florida. Fish Res 19: 301-319.

U.S. Department of Commerce. 1996. Strategy for Stewardship: Florida Keys National Marine Sanctuary Final Management Plan/Environmental Impact Statement, Volume I-II. National Oceanic and Atmospheric Administration/National Ocean Service/Sanctuaries and Reserves Division, Silver Spring, MD, USA.

U.S. Department of Commerce. 2000. Strategy for Stewardship: Tortugas Ecological reserve Final Supplemental Environmental Impact Statement/Final Supplemental Management Plan. National Oceanic and Atmospheric Administration/National Ocean Service/Office of National Marine Sanctuaries, Silver Spring, MD, USA.

Winter, J. 1996. Advances in underwater biotelemetry. Pages 555-585 in Murphy, B.R. and D. W. Willis (eds) Fisheries Techniques. American Fisheries Society, Bethesda, Maryland.

Zeller, D.C. 1997. Home range and activity patterns of the coral trout *Plectropomus leapardus* (Serranidae). Mar. Ecol. Prog. Ser. 154: 65-77.

Zeller, D.C. and G.R. Russ. 1998. Marine reserves: patterns of adult movement of the coral trout (Plectropomus leopardus (Serranidae)). Can. J. Fish. Aquat. Sci. 55: 917-924.