

RNA Performance Topic 2

Chapter 3: Regional connectivity of fishes within the Tortugas region of Florida

Investigators

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Project Description

With the establishment of the Dry Tortugas National Park (DRTO) no-take Research Natural Area (RNA), a series of performance measures were defined to assess the efficacy of the RNA in protecting marine habitat, conserving biodiversity, enhancing productivity and sustainability of exploited fish populations, and determining the effects of fishing on surrounding exploited areas. Consequently, field studies were undertaken to monitor the immigration and emigration of targeted fish species in the RNA (Performance Topic 2) and assess connectivity of fishes in the greater Tortugas region. An understanding of migration patterns and habitat requirements of fish species is critical to establishing an effective marine protected area (MPA) design (Sale et al. 2010), especially no-take marine reserves (NTMR). NTMRs can be effective in sustaining fish populations when spawning occurs within their boundaries or when strong connectivity exists between populations within NTMR boundaries and fish spawning aggregations (FSAs) located elsewhere.

The Tortugas region refers to 1,243 km² of ocean located approximately 112 km west of Key West and 225 km from mainland Florida, comprised of three carbonate banks and seven small islands. The carbonate banks are individually known as the Dry Tortugas, Tortugas Bank, and Riley's Hump (RH) and collectively are considered highly productive coral reef habitat critical to the south Florida marine ecosystem (Ault et al. 2006). RH rises to 30 m depths at the intersection of the Gulf of Mexico and the Straits of Florida approximately 20 km southwest of Garden Key, the location of historic Fort Jefferson. The established NTMRs and associated open-use areas of the Tortugas provide an excellent system in which to document habitat use, broad-scale movements of fishes, and connectivity across reserve boundaries. Acoustic telemetry methods were used to determine the temporal dynamics of fishes and to study spawning aggregations and demographic

connectivity with emphasis on testing the hypothesis that adult reef fish emigrate from DRTO to spawn at an offshore FSA.

An array of 64 underwater VEMCO (VR2) acoustic receivers provided partial coverage across approximately 755 km² and was deployed by July 2008 in water 6–50 m deep (Fig. 1). These receivers recorded the presence of fish tagged with coded transmitters as they swam within a detection range of up to 800 meters when conditions were ideal. A more typical effective range was 300 meters. From May 2008 through March 2011, selected reef fish species were captured and acoustically tagged in DRTO and at RH, which is located within the Tortugas South Ecological Reserve (TSER). Fish were surgically implanted with VEMCO V16 coded transmitters on board a research platform or in situ to avoid barotrauma-induced mortality associated with capturing fish from relatively deep water (30–40 m).

Within the context of how RNA habitat contributes to regional connectivity, results are presented on the annual spawning migratory movements of adult mutton snapper (*Lutjanus analis*) between the RNA and RH, which, according to Lindeman et al. (2000), protects the most valuable known snapper spawning habitat in south Florida. Preliminary observations suggested that the mutton snapper spawning aggregation had begun to reform on RH after years of intensive fishing pressure (Burton et al. 2005) (Table 1). Additionally, the movements of acoustically tagged nurse sharks (*Ginglymostoma cirratum*), lemon sharks (*Negaprion brevirostris*), and bull sharks (*Carcharhinus leucas*) are presented. Nurse sharks, a common resident of Florida waters and DRTO, have been recorded in the waters that are now within the Nurse Shark Special Protection Zone (SPZ) for reproductive activities for nearly 100 years (Gudger 1912) (see map on inside front cover).

Results

Reef Fish

Fifty-five mutton snapper (45.7–89.7 cm) were acoustically tagged offshore at the RH FSA (n=28) and inshore within the RNA and recreational-fishing-only Natural Cultural Zone (NCZ) (n=27). Four of the 55 tagged mutton snapper were never detected on the receiver array and were removed from further analysis. Approximately 1.4 million mutton snapper tag detections were recorded by the array between May 2008 and August 2011. Of those detections, approximately 1.3 million were in DRTO, 265 were in open fishing areas outside of DRTO, 45 were in the Tortugas North Ecological Reserve

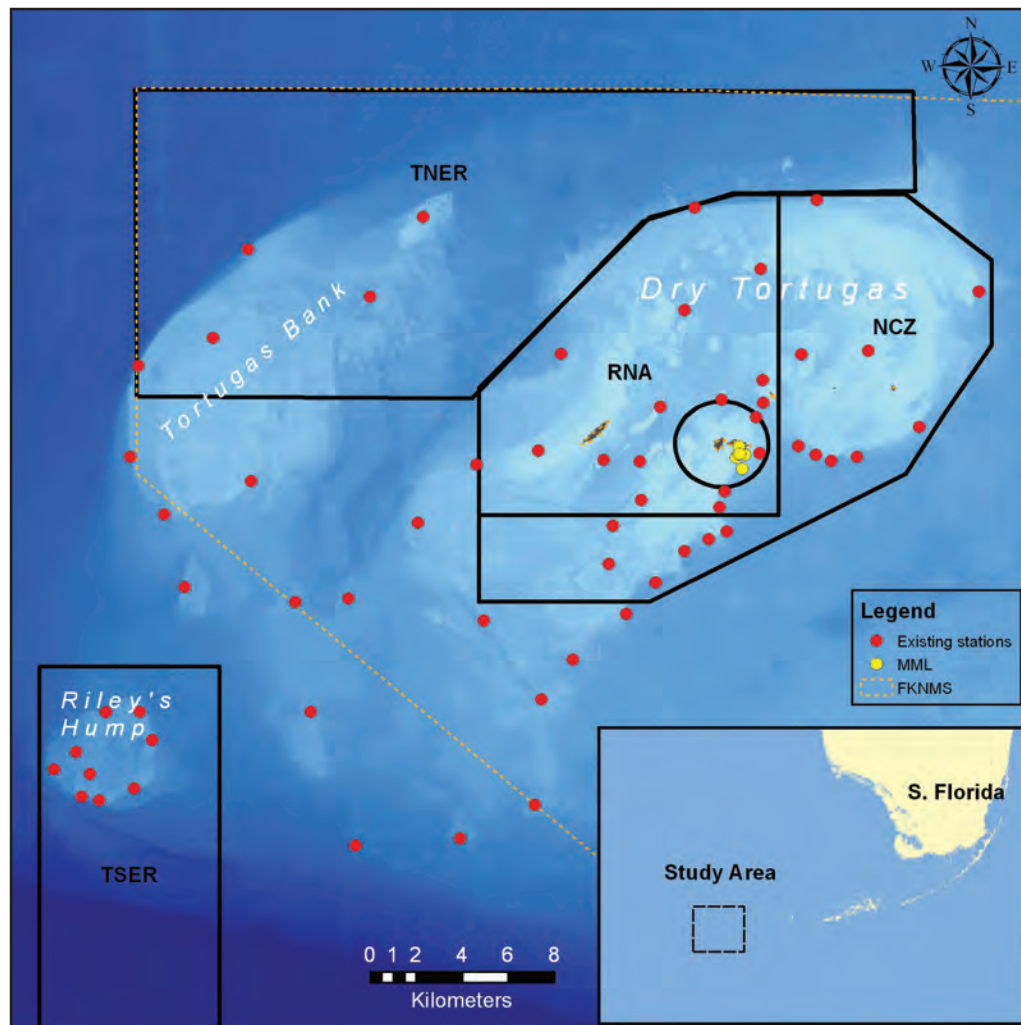


Figure 1. Location of VR2 receiver stations relative to bathymetry and management zones including the recreational fishing only Natural Cultural Zone (NCZ), no-take Research Natural Area (RNA), no-take Tortugas South Ecological Reserve (TSER), no-take Tortugas North Ecological Reserve (TNER), and open-use areas of the Florida Keys National Marine Sanctuary (FKNMS) and surrounding waters in the Tortugas study area, Florida. Mote Marine Laboratory (MML) receivers (yellow) are located in the Nurse Shark Special Protection Zone (SPZ).

Table 1. Observations of mutton snapper at Riley's Hump.

Date	Number observed	Moon phase
May 28–June 1, 1999	1 fish in 3 of the 11 dives	Full moon May 30 ¹
July 31–August 3, 2000	1 fish in 5 of the 6 dives	New moon July 30 ¹
July 17, 2001	10	3 days before new moon ¹
May 27, 2002	75–100	1 day after full moon ¹
June 15, 2003	75–100	1 day after full moon ¹
June 15, 2003	200+	1 day after full moon ¹
July 4, 2004	300	2 days after full moon ¹
July 3, 2007	100+	3 days after full moon ²
June 12, 2009 (1415–1715 hrs)	~4,000	5 days after full moon ³

¹Burton et al. 2005.

²Michael Burton, NOAA, pers. comm.

³This study.

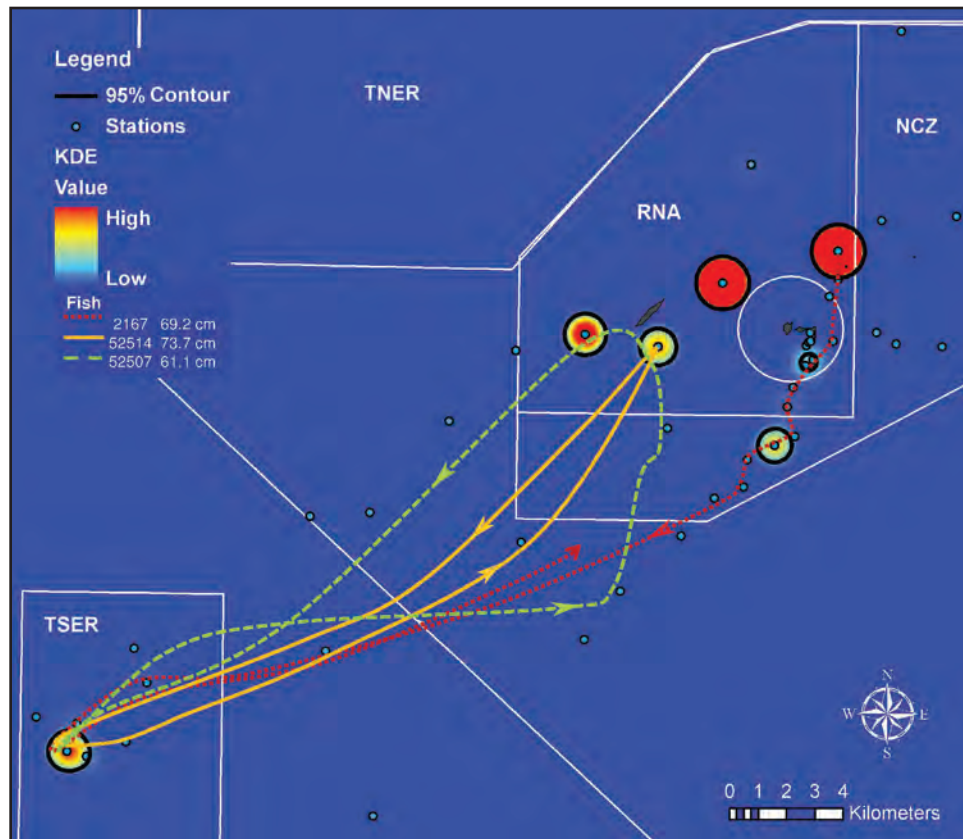


Figure 2. Fixed kernel density estimate (KDE) and home range estimate (95% contour) for pooled DRTO adult mutton snapper ($n=12$) indicating connectivity between the Research Natural Area (RNA) and Riley's Hump. All VR2 stations detecting tagged mutton snapper, the relative probability of finding a fish in a location (higher color intensity [blue to red] indicates higher probability), and migrations of three individual fish are shown.

(TNER), and the remaining detections were recorded at RH (33,460). Individual mutton snapper ($n=51$) were tracked an average (\pm standard deviation) of 315 (± 338) days (d) with a range of 3–1,056 d.

Of the 51 tracked mutton snapper, we conclusively documented that 15 made seasonal migratory movements to spawning grounds on RH. These mutton snapper made migratory round trips of as many as four trips per fish per spawning season. Twelve of these mutton snapper were residential fish of the RNA or migrated through the RNA. The home ranges of these mutton snappers and the movement patterns of three selected individual fish are presented in Figure 2 to elucidate the migratory routes. We used the kernel density estimation (KDE) technique to determine “hotspots” of mutton snapper activity in the region.

KDE is a method used to identify one or more areas of disproportionately heavy use (the colored regions on the map) within a home-range boundary. The colored regions within the black contour lines represent 95% of the detections of mutton snapper and within each contour, the probability of finding a fish increases as the coloration moves toward red. The light blue areas outside the contours represent other areas where detections occurred. These mutton snapper resided

within the RNA most of the time, as indicated by the yellow to red areas of heavy use; and had hotspots of detections along the migratory route in the southern NCZ and at RH. The migratory routes are hand-drawn but when they pass near one of the stations, it means that a fish was detected at that station. For example, fish 2167 (69.2 cm total length, gender

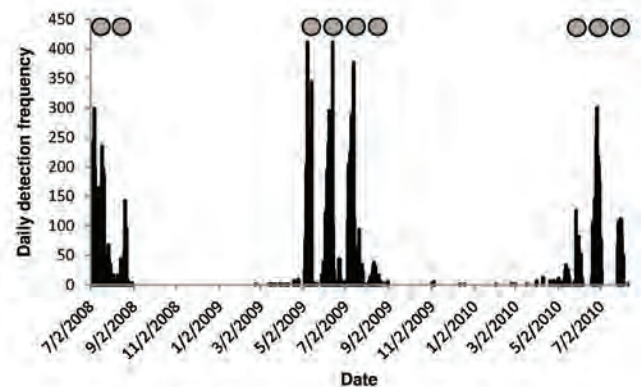


Figure 3. The daily frequency of mutton snapper transmitter detections from the south slope receiver in the Tortugas South Ecological Reserve on Riley's Hump relative to the full moon phase. Circles indicate the time of the full moon.

unknown; see red dashed line, Fig. 2) was initially tagged on May 30, 2008, within the RNA; it first moved offshore near the full moon on June 18, 2008, and returned to the RNA 11 days later. It next arrived at RH on May 6, 2009, and stayed until May 14 (8 days). It arrived back at the RNA on May 15, 1 day later. This fish then remained undetected until June 5 when it again began moving toward RH, arriving 2 days later. It stayed at RH for 6 days and returned to the RNA area 1 day later. This entire pattern was repeated one more time during the July full moon. The tag battery expired shortly thereafter and no more detections of this fish were possible. The other two mutton snapper made similar multiple spawning migrations.

Daily transmitter detection frequency peaked at RH on the full moon during the spawning season (May through August) (Fig. 3). Mean residence time on the spawning grounds was 7 (± 3) d. The mean day of arrival relative to the full moon ($+1 \pm 3$ d) varied significantly ($p=0.002$); however, the mean day of departure ($+7 \pm 1$ d; $p=0.06$) did not vary significantly over seven distinct spawning periods.

Twenty-eight of the 55 tagged mutton snappers were initially tagged at RH. Some of these fish were among the residents in the RNA. However, mutton snapper tagged at RH also exhibited a much wider range of movement patterns. One RH-tagged mutton snapper traveled through the TNER and was ultimately detected in the northeastern area of the

NCZ near Pulaski Shoal, a movement of 40 km in two days. Another mutton snapper (71.1 cm), initially tagged at RH during the June 2009 full moon, left RH shortly thereafter and was detected on the array in the open fishing area to the south of DRTO and east of RH. It returned to RH during the July 2009 full moon and was again detected in the same area later that month. It was then no longer detected on the array but traveled eastward and was ultimately caught on December 5, 2009, by an angler fishing near Rebecca Shoals approximately 50 km east of RH. Finally, some of the RH-tagged fish left RH but were not detected within our array of acoustic receivers.

A large mutton snapper aggregation ($\sim 4,000$) and repeated spawning events were documented by divers on June 12, 2009, between 1415 and 1715 hrs, 5 d after the full moon, along the south slope of RH (35–50 m) (Table 1; Fig. 4). Additionally, groups of cubera snapper (*Lutjanus cyanopterus*), dog snapper (*Lutjanus jocu*), and permit (*Trachinotus falcatus*) were observed on the south slope of RH. Spawning coloration displays by blue runners (*Caranx crysos*), horse eye jacks (*Caranx hippos*), crevelle jacks (*Caranx latus*), and actively nesting ocean triggerfish (*Canthidermis sufflamen*) also were noted.

Some mutton snapper demonstrated that they used certain geographic features to travel to and from the spawning aggregation site at RH. For example, six mutton snapper uti-



Figure 4. A subgroup of mutton snapper spirals upward just before a spawning event at Riley's Hump during the fish spawning aggregation of July 2009. Photo by ©Christopher Parsons, Photography by Chris Parsons.

lized the reef edge margin south of Long Key, with the longest continuous reef edge movement recorded as 16.2 km. This movement involved passing through multiple management zones, including the Florida Keys National Marine Sanctuary (FKNMS) waters south of the RNA, through the RNA, and eastward of Long Key on the eastern bank of the NCZ.

Sharks

The receiver array also recorded 190,828 acoustic tag detections from 31 nurse sharks tagged within DRTO. Additionally, 700 detections were recorded within our VR2 array for 3 lemon sharks and 6 bull sharks tagged and released off Jupiter, Florida (Dr. Steven Kessel, pers. comm.). Adult male and female nurse sharks arrive in the Bush Key bight to mate during mid-June. Females typically reside for 3–4 weeks using the shallows within the Nurse Shark SPZ to take refuge from courting males (Pratt and Carrier 2001). Male nurse sharks visit frequently, patrolling Long and Bush Keys. Forty to 60 pregnant females return to the same warm shallows to rest and gestate in September and October prior to giving birth. Three lemon sharks tagged off Jupiter, Florida, reached the Tortugas in late January to early February and all departed the area by the end of April. Six bull sharks tagged off Jupiter, Florida, also made migrations (500 km) to the Tortugas with detections recorded from late November to late May; two

of these sharks were later detected by acoustic receivers 320 km miles north in the Gulf of Mexico (Angela Collins, pers. comm.). Most bull sharks were only briefly detected (1 d), with most detections offshore, including four sharks at RH.

Performance Measure Evaluation

Our acoustic telemetry research on mutton snapper has definitively revealed the regional connectivity between the shallow waters of the RNA and the spawning aggregation site at RH. However, the RNA is not the only location from which mutton snapper migratory movements originate. Although some mutton snapper initially tagged at RH moved to the RNA, others moved to a different location within our array, and some have moved off RH and have gone undetected. However, we were able to document DRTO, especially RNA-resident, mutton snapper migrating multiple times over the spawning season to the aggregation site at RH. These results suggest that the RNA may be important to support the mutton snapper spawning aggregation at RH.

Repeated directional use of the high- and low-profile contiguous reef edge near and south of Long Key coinciding with the full moon, suggests that these features play an important role in spawning movements between the RNA and RH. The maximum documented distance along the Long Key route



A courting male nurse shark (left) attempts to grasp the pectoral fin of a female on the Dry Tortugas shark mating grounds. The fin grasp is a necessary prelude to mating. Photo by Harold L. Pratt, Jr., Mote Marine Laboratory.

was 16.2 km, after which the reef edge is less well defined south of the Dry Tortugas. The Long Key pathway includes movement across NTMR boundaries, including movements across RNA boundaries into the recreational fishing areas of the NCZ and the open-use areas of the FKNMS. Farmer and Ault (2011) report similar migration-related movement of a mutton snapper along the contiguous reef edge northwest of Loggerhead Key.

The RNA provides year-round protection to a proportion of the population excluding the estimated time (1–2 d) it takes to migrate across the open-use area between NTMRs. Although this is a relatively short exposure, mutton snapper migration pathways have previously been targeted by commercial fishing leading to permanent collapse of the FSA (Craig 1966), emphasizing the importance of protecting both migration corridors and spawning sites (Graham et al. 2008). As knowledge of migratory pathways of the RNA residents to the spawning areas becomes better defined, consideration of appropriate management action along these corridors could be considered to further enhance the mutton snapper fishery.

The migration of several shark species from as far as Jupiter, Florida, through the Tortugas NTMR network expands the connectivity of this area to both the east and west coasts of Florida (up to 500 km). Pratt and Carrier (2001) determined that DRTO is an important annual mating site for nurse sharks. Preliminary results show juveniles to be year-round residents of the RNA while adults make seasonal movements relative to their gender and reproductive condition. Male sharks wander thru the RNA and the TNER and a few have been detected in the middle and upper Florida Keys. Females may remain in the area until giving birth and then range for hundreds of kilometers, to return every two or three years to the Nurse Shark SPZ mating grounds. Future tag detections will help fill in gaps in our knowledge of their movements. The purpose of the long-range movements of bull sharks and lemon sharks to the Tortugas remains unknown (Dr. Steven Kessel, pers. comm.).

A large mutton snapper spawning aggregation at RH supports the hypothesis that this FSA has rebounded nearly 10 years after the establishment of the TSER and provides direct evidence of the spawning of this species for the first time in Florida. The RNA, complemented by the Tortugas Ecological Reserves, provides critical protection of essential reef fish habitat and multispecies FSA habitat, and temporary refuge for transient fish species. The regional connectivity of fishes and protection of residential habitat within the RNA, combined with the relative increase in the number of mutton snapper at the RH FSA, can be linked to a suite of successful management actions including the establishment of the RNA. This research primarily focused on mutton snapper utilizing one known spawning site; however, other potential ecologically and economically important species also may use RH as an aggregation site (for example, black grouper (*Mycteroperca bonaci*)) and potentially other important regional spawning sites yet to be discovered.

Acknowledgements

Dr. Steven Kessel, BBFS, Bimini, Bahamas; Dr. James Locascio, USF, St. Petersburg, Florida; Angela Collins, FWC/FWRI, St. Petersburg, Florida; Michael Burton, NOAA/NMFS, Beaufort, North Carolina; Lee Richter, NPS/SFCN, Palmetto Bay, Florida; and Paul Barbera and Ben Binder, FWC/FWRI, Marathon, Florida.

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