RNA Performance Topic 1

Chapter 1: Status of reef fish resources of the Tortugas region based on fishery-independent visual and trap survey assessments

Investigators

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Project Description

The National Park Service established the Research Natural Area (RNA), a no-take marine reserve (NTMR), in the western half of Dry Tortugas National Park (DRTO) in 2007. The RNA was designed as a shallow-water complement to two relatively large marine reserves, the Tortugas North Ecological Reserve (TNER) and the Tortugas South Ecological Reserve (TSER), established in 2001 in the Florida Keys National Marine Sanctuary. The remainder of the park, the Natural Cultural Zone (NCZ), has been closed to commercial fishing, recreational spearfishing, and lobstering since the 1960s. This section of the park is, however, open to recreational hook-and-line fishing.

To better understand the effects of RNA implementation on the abundance and size structure of exploited species within the RNA relative to adjacent areas (Performance Topic 1), it is important to view DRTO and the Tortugas region relative to the larger Florida coral reef ecosystem and in relationship to the regional spatial management actions implemented during the past decade. The Florida coral reef ecosystem, stretching 400 km southwest from Miami to the Dry Tortugas, supports multibillion-dollar tourism and fishing industries (Ault et al. 2005a). Regional spawning in the Tortugas region provides the Florida Keys with recruits because of its relative isola-

Fishery-independent visual surveys were conducted during 1999–2011 throughout the Tortugas region to assess the resource status of the coral reef fish community, including hogfish and other exploited species. Photo by the South Florida/Caribbean Inventory and Monitoring Network, NPS.

tion and upstream location where the Loop Current merges into the Florida Current (Schmidt et al. 1999; Ault et al. 2006; Chapter 11, this volume). However, the sustainability of these fisheries resources is in question. The ecosystem's lucrative multispecies snapper-grouper complex has been intensively fished since at least the late 1970s (Ault et al. 1998; 2005b; 2009). The number of recreational vessels in Florida, an index of sportfishing fleet size, has risen in step with increases in the human population. From 1960 to 2010, Florida's human population increased from 4,951,560 to 18,801,310. During this same period registered recreational vessels increased by 697%, reaching 896,093 at present. The commercial fleet, in contrast, has remained stable during this period.

Fishery-independent visual surveys were conducted during 1999–2011 throughout the Tortugas region to assess the resource status of the coral reef fish community, and specifically to evaluate spatial and temporal trends in species-specific abundance metrics (occurrence, density, abundance, and size composition, for example) before and after implementation of the TNER and RNA (Performance Topic 1). Sampling effort was concentrated inside DRTO and the adjacent Tortugas Bank to the west of the park (Fig. 1). Highly trained and experienced divers collected biological data following a standard, non-destructive, in-situ monitoring protocol in which a stationary diver records reef-fish data (number and sizes of each species) while centered in a randomly selected circular plot 15 m in diameter. The field research team was comprised of scientific personnel from the National Oceanic and Atmospheric Administration, the University of Miami, the National Park Service, and the State of Florida. The statistical field design partitioned Tortugas Bank and DRTO into strata based on reef habitat characteristics (complexity and patchiness of reef structures, and depth) and spatial management zones (Fig. 1 and map shown on inside cover). This habitat-based survey design was developed in 1999 and 2000, and has been shown to provide accurate and precise abundance metrics for reef fishes in the Tortugas region in a cost-effective manner (Ault et al. 2006; Smith et al. 2011). Tortugas region-wide surveys were conducted during 1999, 2000, 2004, 2006, 2008, and 2010, with sample sizes ranging from 327 to 704 stations. In addition, DRTO-specific surveys were conducted in 2002, 2009, and 2011, with sample sizes ranging from 191 to 445 stations.

A complementary fishery-independent survey using baited chevron traps was conducted from May 2008 to June 2011 to evaluate potential changes in the relative abundance and size structure of exploited reef fishes within the RNA and NCZ. Sampling followed a seasonal (spring and fall) stratified-random survey design within the southern portion of DRTO (south of 24º 40' N). The survey design was based on the reef fish visual census, although reef habitats were aggregated into three reef strata: contiguous reef; spur-and-groove reef; and isolated reef. At each sampling station, four chevron traps were baited with Atlantic mackerel and deployed over sand bottom adjacent to targeted reef habitat. Traps were allowed to soak for a minimum of 90 minutes prior to retrieval. All trapping was conducted during daylight hours. Seasonal sampling effort ranged from 29 to 46 stations. In total, trapping

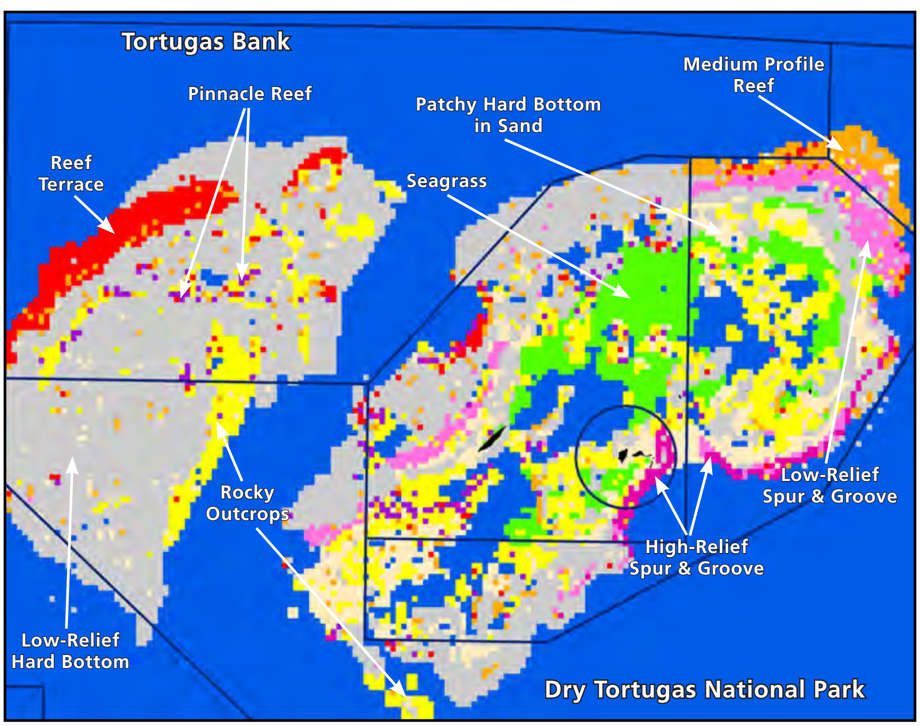

Figure 1. Map of benthic habitats and management zones in the Tortugas region (redrawn from Ault et al. 2006). See map on inside front cover for management zone identification.

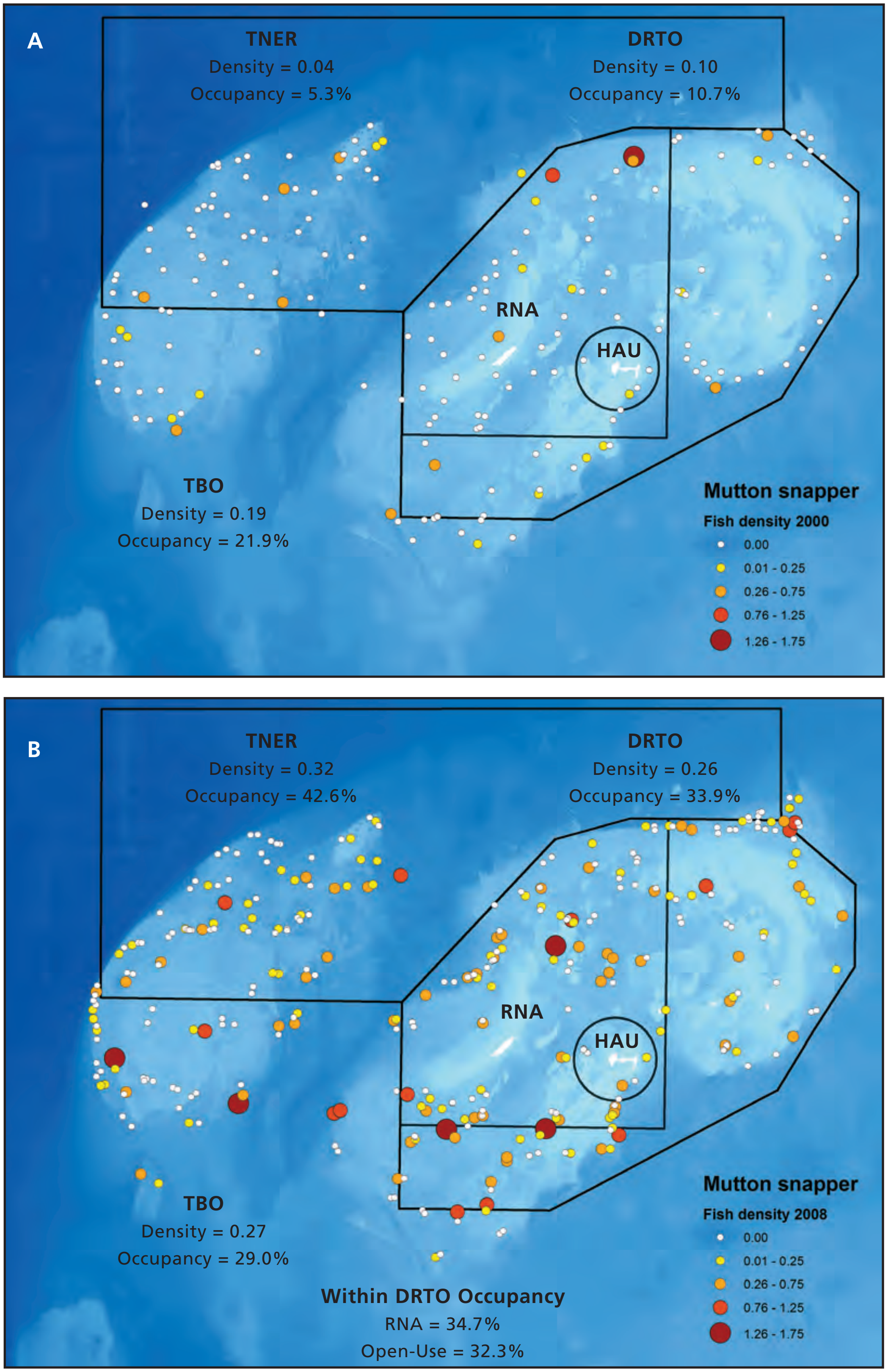

Figure 2. Spatial distribution of exploited mutton snapper density (mean number of fish per sample unit, 177 m^2) for Tortugas region visual surveys conducted in (A) 2000 and (B) 2008, and corresponding average densities and occupancy rates for three areas (TNER, DRTO, and TBO). Each sample point represents the average of four diver visual point counts. White circles represent sample points where no mutton snapper were observed. Colored circles represent sample points where mutton snapper were present. Occupancy rates within DRTO (RNA and open-use zones) are provided for 2008. Note that though the RNA was not established in 2000, boundary lines are shown for reference in Panel A.

surveys were conducted at 117 stations (468 chevron trap sets) within the RNA and 122 stations (488 chevron trap sets) within the NCZ. In the RNA, 3,968 fish representing 35 taxa were collected, whereas 4,130 fish representing 32 taxa were collected in the NCZ. In both areas, the three most abundant and frequently occurring taxa were yellowtail snapper, white grunt, and red grouper. Accordingly, we focused our trap data analyses on these three species.

Results

Reef-fish population metrics from fishery-independent surveys were assessed from three perspectives: (1) changes at the regional scale from 1999 to 2011, pre- and post-implementation of both the TNER and RNA; (2) changes within DRTO focusing on the 2006–2011 time period, pre- and post-implementation of the RNA; and, (3) analysis of the ecological role of DRTO in the ecosystem for providing habitat for both juveniles and adults.

Visual survey abundance metrics were evaluated for the region through time, beginning with the baseline pre-NTMR implementation surveys during 1999–2000, through implementation of the TNER (2001) and DRTO RNA (2007) management zones, and concluding in 2011. A principal abundance metric evaluated was animal density, the number of individuals per unit sample area (177 m^2, the area of a diver circular plot). Maps of spatial density are illustrated in Figure 2 for mutton snapper in the exploited life stage (fish at and above the minimum legal size of capture). A second abundance metric evaluated was frequency of occurrence (the percentage of diver visual samples in which at least one individual of a given species was observed). This statistic provides a measure of the occupancy rate (the percentage of the coral reef habitat area that is occupied by a species). As shown for mutton snapper in Figure 2 , both density and occupancy rates increased in the open-use area of Tortugas Bank (TBO), the TNER, and DRTO between the pre-implementation baseline survey of 2000 and the 2008 survey, post-implementation of both the TNER and DRTO RNA.

Evaluation of changes in density during 1999–2011 is illustrated for exploited-phase hogfish in Figure 3A. Because hogfish density in 1999, prior to implementation of management zones, varied across the region, density that year was set as a baseline of zero. Standard statistical procedures were used (described in Ault et al. 2006) to test for differences in density within each zone for each post-baseline survey year and the baseline level. For hogfish, statistically significant densities ($p<0.05$) above the baseline were detected in DRTO in three of seven years (2002, 2008, and 2011), whereas densities below baseline levels were detected in the TBO in two of the seven years (2006 and 2010) and were never above baseline. No differences from baseline levels were detected at the TNER. Table 1 summarizes the change in density from the 1999 baseline for a suite of exploited and non-target reef fish species, as well as two formerly exploited species that have been protected by a fishery moratorium since 1994. In DRTO, the densities of the exploited stage of the 5 exploited species were never below the baseline, and 4 were above the baseline in 16 of 35 sampling occasions. In contrast, densities of these species below the 1999 baseline were detected only in the TBO. As expected, the pattern of density change for non-target species fluctuated in a pattern unrelated to the management zones. The pattern of change was mixed for the two species under fishing moratoria. Densities above baseline were detected for goliath grouper in both the TNER and DRTO, whereas the density of Nassau grouper below the baseline was detected in DRTO during one survey.

Comparisons of length composition among management areas and time periods from the visual survey are illustrated for black grouper in Figure 4. A general increase between 2000 and 2008 in the proportion of fish at sizes at and above the legal minimum was observed in the TNER and particularly

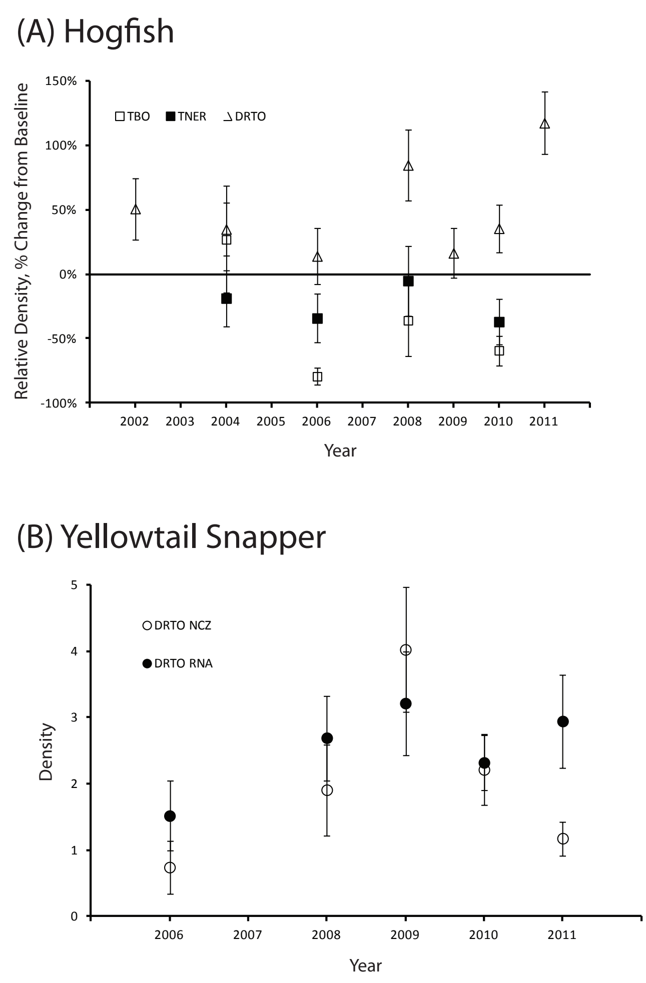

Figure 3. (A) Visual survey estimates of relative mean density (± Standard Error (SE)) for the exploited life stage of hogfish, 2002–2011, for three management areas. Density (number of fish per diver visual point count of area 177 m^2) is expressed as percent change from 1999–2000 baseline levels (solid line). (B) Visual survey mean densities (± SE) for the exploited life stage of yellowtail snapper in Dry Tortugas National Park, 2006–2011.

Table 1. Summary of 1999–2011 visual survey results for density for a suite of exploited and non-target reef fish species, and two other species under fishing moratoria. Baseline surveys were conducted during 1999–2000; four surveys were conducted post-baseline in the TBO and TNER zones, and seven surveys were conducted post-baseline in DRTO.

			TBO			TNER			DRTO	
Family	**Species**	**Increase**	**Decrease**	**No Change**	**Increase**	**Decrease**	**No Change**	**Increase**	**Decrease**	**No Change**
					Exploited					
Groupers	Red grouper	0	3	1	0	0	4	0	0	7
Groupers	Black grouper	0	0	4	1	0	3	2	0	5
Snappers	Mutton snapper	1	0	3	2	0	2	7	0	0
Snappers	Yellowtail Snapper	0	0	4	0	0	4	4	0	3
Wrasses	Hogfish	0	2	2	0	0	4	3	0	4
	Overall Exploited	**1**	**5**	**14**	**3**	**0**	**17**	**16**	**0**	**19**
					Non-Target					
Damselfishes	Bicolor damselfish	2	1	1	2	1	1	3	1	3
Damselfishes	Threespot damselfish	1	0	3	0	4	0	1	3	3
Parrotfishes	Princess parrotfish	2	0	2	0	2	2	2	1	4
Seabasses	Harlequin bass	1	1	2	2	0	2	0	2	5
Surgeonfishes	Ocean surgeon	0	0	4	1	0	3	0	1	6
Wrasses	Puddingwife	0	0	4	0	0	4	1	2	4
	Overall Non-target	**6**	**2**	**16**	**5**	**7**	**12**	**7**	**10**	**25**
					Moratorium					
Groupers	Goliath grouper	0	0	4	1	0	3	3	0	4
Groupers	Nassau grouper	0	0	4	0	0	4	0	1	6
	Overall Moratorium	**0**	**0**	**8**	**1**	**0**	**7**	**3**	**1**	**10**

in DRTO. These changes are characteristic of a relaxation of fishing pressure (fishing mortality rate) during the time frame, during which more fish survived and grew to larger mature sizes. In contrast, very few exploited phase fish were observed in the TBO in both time periods. Similar time-space patterns of change in length composition were observed for red grouper, mutton snapper, and hogfish. We also used our survey data to estimate abundance for the exploited phase of black grouper within each management zone pre- and post-implementation. Abundance markedly increased within DRTO, decreased in the TBO, and remained constant in the TNER. Six hurricanes impacted the Tortugas region between the surveys of 2004 and 2006, and many species, fishery and non-target alike, experienced declines in density and abundance during this period. Even though Figure 4 shows similar levels of exploited phase abundance for black grouper, in 2004 prior to the intense hurricane period, abundance of exploited phase black grouper in the TNER more than doubled over 1999–2000 baseline levels (Ault et al. 2006).

Direct comparisons of densities between the RNA and the NCZ are presented for yellowtail snapper in Figure 3B. Increases in density relative to the 2006 pre-RNA baseline

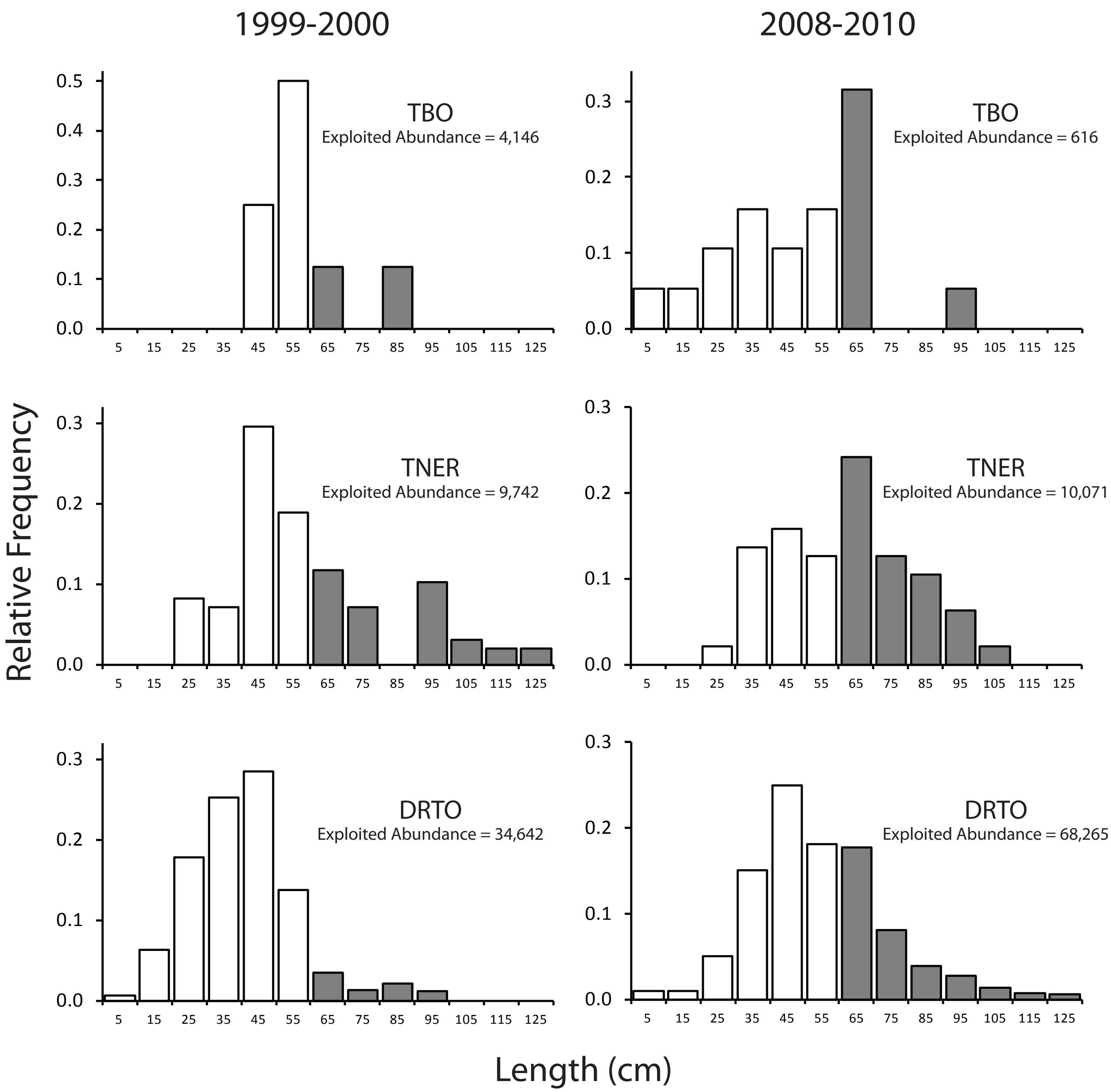

Figure 4. Visual survey length compositions for black grouper among three management zones for two time periods: the pre-implementation baseline, 1999–2000, and post-implementation of the TNER and RNA, 2008–2010. Open bars are the pre-exploited life stage, shaded bars are exploited (fished) life stage animals; exploited abundance is noted on each panel.

were detected for yellowtail snapper during the post-RNA period 2008–2011, but the pattern was inconsistent: significant increases occurred in both the NCZ and RNA zones in 2009, only in the open-use area in 2010, and only in the RNA in 2011. Similar inconsistent patterns of post-RNA density changes also were observed for hogfish, red grouper, and mutton snapper, with no changes detected in either zone for black grouper. Additionally, occupancy rates also were similar between the RNA and the NCZ for most species (for example mutton snapper, Fig. 2B). Similarly, no consistent differences in the relative abundance of red grouper, yellowtail snapper, or white grunt were evident between the NCZ and RNA zones in the trap survey. A comparison of size structure of red grouper, yellowtail snapper, and white grunt from the trap survey showed that the size of individuals was similar between the RNA and NCZ (Fig. 5). For both red grouper and yellowtail snapper, a substantial proportion of individuals collected were at and above the recreational legal-minimum size limit.

The Tortugas region-wide visual surveys also were analyzed to evaluate the ecological role of DRTO in providing habitat for juvenile and adult life stages of principal fishery species. While DRTO contains about 60% of the Tortugas survey area (live coral reef habitats, 0–33 m depth), the percentage of juvenile abundance in DRTO was similar to or greater than this percentage, ranging from 62 to 93% for the five species analyzed (Table 2A). The proportion of adult spawner abundance, which includes the exploited life stage, increased by 10% or more in DRTO during 1999–2000 and 2008–2010 for four of five fishery species (Table 2B). Over this period, the total number of adult spawners in the region decreased by about 10% for red grouper and hogfish, increased by 60% for black grouper, and more than tripled for mutton snapper and yellowtail snapper. By 2008–2010, DRTO contained 62–87% of adult spawners in the Tortugas region for four of the five species. The analysis of adult spawners was expanded to include the combined Dry Tortugas and Florida Keys survey areas (mapped live coral habitats, 0–33 m depth), which

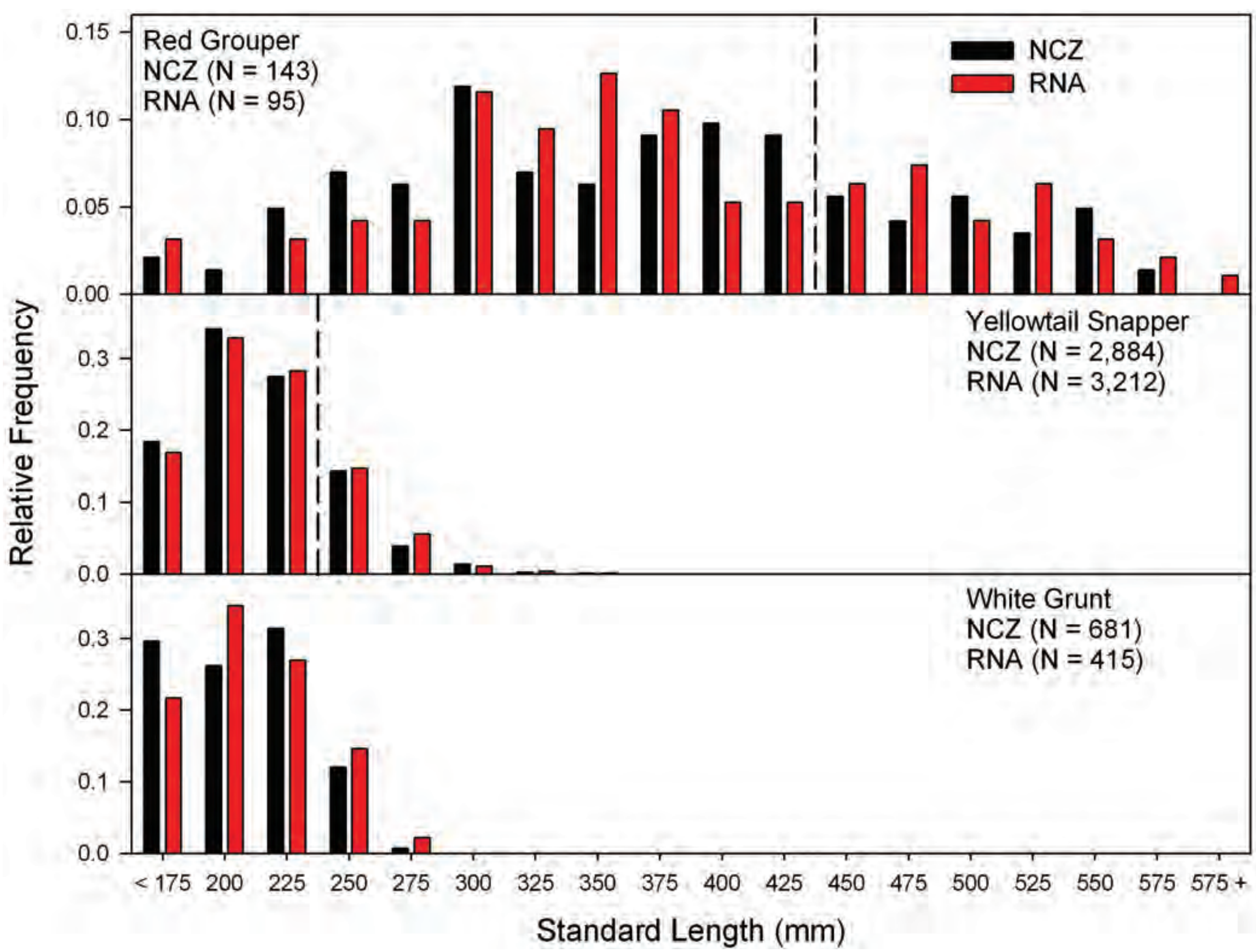

Figure 5. Length frequencies of red grouper, yellowtail snapper, and white grunt collected during the trap survey in the RNA and NCZ areas, 2008–2010. Dashed lines represent the recreational size limit for red grouper and yellowtail snapper; no size limit exists for white grunt.

Table 2. (A) Percentage of abundance (total numbers) of juveniles in three management zones in the Tortugas region for five principal reef fishery species; the percentage of reef habitat area is denoted for each zone. (B) Adult spawner abundance and percentages among management zones in the Tortugas region for two time periods, 1999–2000 and 2008–2010. (C) Adult abundance and percentages among management zones in the combined Florida Keys/Dry Tortugas reef ecosystem for two time periods.

(A) Tortugas region, Juveniles, 2008–2010

Species		Percentage of Juveniles		
		TBO	TNER	DRTO
	Area =	16.5%	23.7%	59.8%
Red Grouper		11.8	20.1	68.1
Black Grouper		2.3	4.7	93.0
Mutton Snapper		26.1	1.5	72.4
Yellowtail Snapper		10.3	28.1	61.6
Hogfish		3.8	12.7	83.6

(B) Tortugas region, Adults

Species	Time Period	Spawner Abundance (1000s)		Percentage of Adults		
				TBO	TNER	DRTO
			Area =	16.5%	23.7%	59.8%
Red Grouper	1999–2000	468.1		20.5	28.4	51.1
	2008–2010	423.6		6.6	31.5	61.9
Black Grouper	1999–2000	48.5		8.5	20.1	71.4
	2008–2010	79.0		0.8	12.8	86.5
Mutton Snapper	1999–2000	177.5		26.8	12.5	60.7
	2008–2010	616.9		21.4	22.7	55.9
Yellowtail Snapper	1999–2000	3,379.5		17.2	33.5	49.2
	2008–2010	10,021.1		4.9	25.9	69.2
Hogfish	1999–2000	1,067.7		21.9	21.6	56.5
	2008–2010	937.5		13.9	19.9	66.2

(C) Florida Keys and Dry Tortugas, Adults

Species	Time Period	Spawner Abundance (1000s)		Percentage of Adults				
				TBO	TNER	DRTO	Keys Open-Use	Keys NTMR
			Area =	6.2%	8.9%	22.4%	58.9%	3.6%
Red Grouper	1999–2000	522.8		18.3	25.4	45.7	9.9	0.6
	2008–2010	540.1		5.1	24.7	48.6	19.9	1.6
Black Grouper	1999–2000	68.5		6.1	14.2	50.6	16.0	13.2
	2008–2010	130.5		0.5	7.7	52.3	34.9	4.6
Mutton Snapper	1999–2000	409.7		11.6	5.4	26.3	53.1	3.6
	2008–2010	1,078.4		12.3	13.0	32.0	39.5	3.3
Yellowtail Snapper	1999–2000	7,707.5		7.6	14.7	21.6	38.9	17.3
	2008–2010	14,982.7		3.2	17.3	46.3	28.5	4.6
Hogfish	1999–2000	2,758.3		8.5	8.3	21.9	59.0	2.3
	2008–2010	4,314.1		3.0	4.3	14.4	74.8	3.4

were conducted concurrently over the 1999–2010 time period (Smith et al. 2011). Between 1999–2000 and 2008–2010, total spawner abundance increased for all five species, more than doubling in most cases (Table 2C). For the combined Florida Keys/Dry Tortugas regions, DRTO contained 22% of the total survey area yet harbored a disproportionately larger percentage of the adult spawners in 2008–2010 for four of the five fishery species, ranging from 32 to 52%.

Performance Measure Evaluation

The visual survey enabled evaluation of changes in reef fish populations in the Tortugas region during the 1999–2011 time period. Key management and environmental events occurring during these years were implementation of the TNER in 2001, intense hurricanes in 2004–2005, and implementation of the RNA in 2007. A complementary trap survey provided additional information for evaluating changes in reef-fish population metrics between the NCZ and RNA zones during 2008–2011.

For five principal fishery species (red and black grouper, mutton and yellowtail snapper, and hogfish), visual surveys showed an increase in the density and abundance of fish at and above the legal size of capture in both the TNER and DRTO between the baseline years 1999–2000 and 2010, post-implementation of the TNER and RNA. These increases in density were generally accompanied by increases in both the occupancy rate and the size of fishes in the exploited life stage. In contrast, density, occupancy rate, and sizes of these fishery species either remained the same or decreased in the TBO during the same time period. This same spatial pattern of change also was observed for goliath grouper, a species under a fishing moratorium in U.S. (Florida) waters since 1994. Density and occupancy rates for a suite of non-target reef fishes showed a different spatial pattern of change during the 1999–2010 period, with fluctuations above and below baseline levels occurring in each management zone depending on the species.

Within DRTO, the visual survey detected some increases in density and occurrence for principal fishery species before (2006) and after (2008–2011) implementation of the RNA; however, these increases occurred in the NCZ and RNA zones with equal frequency. The focused trap study conducted during 2008–2011 also detected no consistent pattern of differences in relative abundance or size structure between the NCZ and RNA zones for three fishery species: red grouper, yellowtail snapper, and white grunt. Acoustic tagging studies of fish movement (Farmer and Ault 2011; Chapters 3 and 4, this volume) show that the principal fishery species move freely between the NCZ and RNA zones, both of which comprise a similar mix of reef habitat types (Fig. 1) and depths. Taken together, results from the visual and trap surveys and tagging studies indicate that there has been no dramatic displacement of fishing effort from the RNA to the NCZ post-implementation of the RNA. From a broader fishing perspective, more and larger reef fish are available for capture by recreational anglers in the NCZ at present (2011) compared to 1999 before implementation of the TNER and RNA.

Visual surveys showed an increase in the density and abundance of mutton snapper in both the TNER and DRTO between the baseline years 1999–2000 and 2010, post-implementation of the TNER and RNA. Photo by Douglas Morrison, NPS.

Visual surveys conducted concurrently in the Dry Tortugas and Florida Keys regions (Ault et al. 2006; Smith et al. 2011) provide a unique perspective on the ecological role of DRTO in both the Tortugas region and in the larger Florida Keys/Dry Tortugas reef ecosystem. DRTO comprises 60% of the coral reef habitat in the Tortugas region, yet it harbors a disproportionately greater number (62–93%) of juveniles of principal fishery species in the region. This is likely attributed to the wider range of depths and reef habitats present in DRTO as compared to Tortugas Bank, as well as the presence of shallow seagrass habitats in DRTO, which are known nursery areas for juvenile reef fishes (Chapter 2, this volume). DRTO also contains a disproportionately greater number of adult spawners (>60% in most cases) of fishery species in the region, likely owing to the combination of favorable adult reef habitats in DRTO as well as the restrictions on fishing to recreational angling only.

Viewed from the perspective of the southern Florida coral reef ecosystem, the role of DRTO with respect to reef fish spawning stock is even more striking. Although DRTO accounts for 22% of the total reef habitat area, it contains one-third to one-half of the adult spawners for four of the five principal species analyzed, and this proportion has generally increased from 1999 to 2010. These results, combined with studies of regional connectivity, oceanography, and larval transport (Chapters 3 and 11, this volume) strongly indicate that DRTO is perhaps the major source point providing production of newborn recruits to populations of principal reef fishery species in the Tortugas region, but also the Florida Keys and southeast Florida reef tract, and the West Florida shelf. Setting aside the RNA within DRTO as a place of refuge for juveniles and adults of principal reef fishery species to live, grow, and reproduce with minimal human impacts is thus beneficial for the future sustainability of these economically and ecologically important fishery resources in Florida, particularly in light of the ever-increasing human population, environmental changes, and accompanying increases in recreational boaters and anglers using the Florida coastal marine ecosystem.

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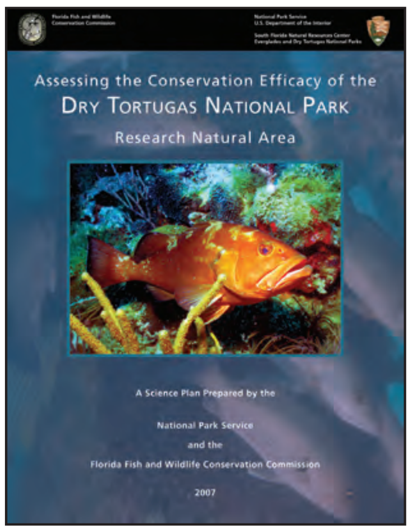

Science activities in the Dry Tortugas National Park Research Natural Area are guided by the science plan prepared in 2007 by the National Park Service and the Florida Fish and Wildlife Conservation Commission. All reports are available online at: http://www.nps.gov/ever/naturescience/technicalreports.htm

Comments and Questions on the RNA Science Plan, 3-Year Report, and 5-Year Report:

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