Performance Evaluation of Marine Zoning in the Florida Keys National Marine Sanctuary

CRCP Progress Report Year 3

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Florida Fish and Wildlife Conservation Commission

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Progress Report Submission

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Abstract
This project uses a multi-tiered approach to evaluate Marine Protected Areas (MPAs) in the Florida Keys National Marine Sanctuary (FKNMS). Spatial and temporal rates of movement of acoustically tagged snappers and groupers will continue to be measured in the Tortugas region, including annual spawning migratory movements between Riley's Hump (RH), the Tortugas Ecological Reserves (TERs) and the Dry Tortugas National Park (DRTO), including the Research Natural Area (RNA). In addition, key issues regarding the effectiveness of the Western Sambo Ecological Reserve (WSER) for protecting essential fish habitat, population structure, species diversity and connectivity of exploited predatory reef fishes and spiny lobsters will be addressed. Results will be used to assess the importance of habitat linkages between adjacent MPAs and provide information for an ecosystem-based approach to reef fisheries management.

Background
This project uses a multi-tiered approach to evaluate Marine Protected Areas (MPAs) in the Florida Keys National Marine Sanctuary (FKNMS). The FKNMS MPAs were established to protect critical reef habitats from overexploitation, and to insure the sustainability of valuable marine resources. In past years, our research focused on the efficacy of one of the largest ecological reserves in the FKNMS, the Western Sambo Ecological Reserve (WSER). We continue to evaluate the efficacy of this reserve design relative to habitat use, population structure and animal movement, recognizing the potential need to alter MPA boundaries to include additional habitat for spawning of indicator species such as lobsters, snappers and groupers. In addition, the present project builds on past research and monitoring in the FKNMS by Florida Fish and Wildlife Conservation Commission and focuses on connectivity between the network of marine reserves in the Dry Tortugas region, including the connections between populations of fish in the Dry Tortugas National Park (DRTO), the DRTO Research Natural Area (RNA), the Tortugas North Ecological Reserve (TNER) and spawning habitat at Riley's Hump (RH), located within the Tortugas South Ecological Reserve (TSER). The following comprises the annual report for all phases of the project for October 2007 to October 2008. This submission summarizes our progress for FY08 in two parts: 1) the Dry Tortugas finfish project and 2) the WSER lobster project.

DRY TORTUGAS FINFISH
Introduction
The TSER, TNER and RNA create a network of no-take reserves that protect 600 km^2 of coral reef habitat, adjacent to and within the DRTO, 70 miles west of Key West, FL (Figure 1). The Dry Tortugas coral reef ecosystem is unique in terms of the variety and complexity of available habitat, the diversity of biological resources, and the presence of key spawning locations that hypothetically supply larval/juvenile recruits to the Florida Keys and south Florida (Domeier, 2004; Burton et al., 2005; Ault et al., 2006). The TERs were established in the Tortugas region in 2001 and the no-take RNA was established within the DRTO in 2007. The established marine reserves and adjacent open fished areas of the Tortugas region provide an excellent system for empirical studies on habitat

utilization, spillover, broad scale movements, residence times on aggregation sites and the efficacy of a network of MPAs in protecting marine fisheries and conserving marine biodiversity.

This network is designed to enhance biodiversity and sustainability throughout the Tortugas and the Florida Keys coral reef ecosystem by creating refuge for various life history stages of numerous exploited fishery resources, including snappers and groupers. The purpose of our CRCP telemetry project is to determine regional connectivity and test the hypothesis that fish move from foraging grounds (RNA, TNER, and DRTO) to spawning sites in the TSER. In addition, we will determine residence times and behavior of snappers and groupers in the spawning aggregation area. This data will be used to assess the size, shape and site selection of the Tortugas marine reserves and their efficacy as a fishery management tool. For example, changes in reserve boundaries may be implemented to enhance or reduce spillover of key species, based on observed home ranges and movement patterns of snappers and groupers during the spawning season.

Snappers and groupers migrate long distances to specific sites to form spawning aggregations of 100s of individuals at specific times of the year (Sadovy and Eklund, 1999). Spawning aggregation behavior makes these species vulnerable to fishing pressure and, as a result, many aggregating reef fish species have declined or disappeared throughout the Caribbean (Sadovy and Domeier, 2005). The relationship between reproductive output and adult population size is an important issue for fisheries biologists and managers. Recent changes in fishery regulations place greater emphasis on MPAs to preserve reef habitat, enhance reef fish production, conserve functional ecosystem processes, and protect a certain proportion of the population. The TSER was established to protect the most important known multi-species aggregation site in the southeastern United States (Lindeman et al., 2000). The re-formation of mutton snapper spawning aggregations at RH since the closure of the TSER to fishing was documented by Burton et al. (2005). However little is known about aggregation site fidelity or adult reef fish migratory movements in the region.

Materials and Methods

Finfish – Acoustic Array

An acoustic receiver array was activated in May 2008 in the Tortugas. The majority of receivers, 56 Vemco VR2s and VR2Ws, were deployed by a team of 4 scientific divers from a small research vessel (8 m). In addition, nine receivers at RH were deployed from a larger research vessel (30 m) because of the remote location and depth of RH. The receivers were housed on a concrete ballasted PVC stand that positioned the receiver "tip up" approximately 1 meter above the seafloor. Each receiver tip was protected by a coat of antifouling paint and secured within a 2.5" or 3" diameter PVC pipe by a tie wrap. An 8 m subsurface buoy was attached to the base of the receiver stand if the water depth was > 12 m. Prior to deployment, each VR2 sonic receiver was initialized in the laboratory using a computer and software provided by the manufacturer (VEMCO; AMIRIX Systems Inc.). Receiver sites were preselected based on reef fish population structure, habitat type, rugosity, depth and reserve boundary locations. The receiver stand and VR2 were released together from the research vessel when it was determined by a fathometer

reading that the vessel was over sand substrate and site coordinates were immediately recorded upon deployment. A team of divers confirmed the position and placement of the receiver stand on the seafloor. During maintenance, when receivers were checked and serviced, data was downloaded in the field using the same equipment and software as in the laboratory. If the receiver required a battery replacement or if the receiver's data capacity was more than 1/3 full, the receiver was reinitialized.

The acoustic receiver array was deployed in three phases between May and July 2008 (Table 1). The array covers approximately 800 km^2 and is designed to capture small scale movement and long range migrations of fishes in water 5 – 50 meters deep. In the first phase, 33 VR2 receivers were placed within the Dry Tortugas National Park (DRTO), including within and outside the borders of the Research Natural Area (RNA). This work was funded by our USGS research grant: *Efficacy of a newly-established RNA for protecting coral reef fishes within DRTO*, but is complimentary to the objectives of our CRCP grant. The second phase was completed in June 2008, with an additional 23 acoustic receivers placed throughout DRTO, the Tortugas North Ecological Reserve (TNER) and open use areas of the Florida Keys National Marine Sanctuary (FKNMS). The final nine receivers were set up in July 2008 in the Tortugas South Ecological Reserve (TSER) at Riley's Hump. The coverage of our array is complimented by four collaborative acoustic projects (~ 40 VR2s): the University of Miami's telemetry reef fish project (PI: Jerry Ault), Mote Marine Laboratory's Nurse shark project (PI: Wes Pratt); USGS sea turtle study (PI: Kristen Hart) and our FWC/USGS RNA study.

Receivers were serviced and downloaded this fall (Oct 2008). Hurricane Ike knocked over many of our receivers, but we only lost a few and only at shallow sites exposed to the southeast. We anticipate recovering some of these that were simply covered by sand. The portion of the RNA array along the southern boundary was repositioned into deeper water, along the reef line to the south of Bird Key. All VR2s are currently in deeper water (>15 m) to avoid storm surge in the future.

Finfish – Acoustic Tagging

All fish captured at RH were surgically implanted with VEMCO V16-4H coded transmitter tags *in-situ* at 33 – 40 m. This avoided exposure of fish to barotrauma induced mortality associated with capture from relatively deep water. Fish were captured with fish traps baited with threadfin herring and sardines and soaked 3 – 12 hrs. Traps were set on the south slope of RH in an area identified by Burton et al. (2005) as the focal point of the aggregation zone. Rather than hauling traps to the surface, fish were transferred from a trap to a catch bag by divers at depth. Fish were anaesthetized with 500 ppm clove oil/seawater mixture delivered by a 60 ml syringe and then transferred to the surgical station. Each fish was placed ventral side up in the surgery station and a 2.5 cm incision was made along the midline, posterior to the pelvic girdle. Scales were removed on either side of the incision to expose the skin. The tag was implanted within the peritoneal cavity and the incision was closed with three hand tied sutures. Sterile synthetic absorbable braided sutures (VICRYL Plus; Ethicon, Inc.) with an antibacterial coating and a size 0 cutting needle were used. The entire underwater surgical procedure

took approximately 3 – 6 minutes. Standard, fork and total lengths were recorded and the fish were immediately released.

Fish captured in the DRTO were caught by traps or hook and line and implanted with Vemco V16-4H or V9-2L coded transmitters. The DRTO collection sites were relatively shallow (< 10 – 15 m), therefore the risk of barotrauma related mortality was greatly reduced. These fish were captured and placed into a holding/recovery tank fitted with aeration and flow-through ambient sea water on the research vessel. Fish were anaesthetized for approximately 3 minutes in an aerated 40 L seawater tank containing 50 ppm clove oil and then transferred to the surgical station. The surgical procedure was identical to the underwater methods except running ambient seawater was pumped through the mouth and over the gills. Fish required a 1 – 2 hour recovery period in the holding tank and were released by a team of divers near the seafloor.

Progress and Results

Finfish – Acoustic Tagging

We captured and acoustically tagged select reef fishes on three seasonal research trips to the Tortugas during 2008 (Table 2). During trips in May and October, 17 mutton snapper, *Lutjanus analis,* 8 black grouper, *Mycteroperca bonaci*, 10 yellowtail snapper, *Ocyurus chrysurus*, and 5 white grunt, *Haemulon plumierii*, were acoustically tagged within the DRTO and in open fished areas south of the DRTO. In addition, eight mutton snapper, and 3 groupers (2 red grouper, *Epinephulus morio* and 1 Nassau grouper, *E. striatus*) were tagged in the TSER (Riley's Hump). Approximately 124,000 transmitter detections have been recorded by the array since May 2008. Preliminary analyses indicate that all mutton snapper tagged at RH, left RH by the end of Aug 2008, with 2 fish moving north onto the Tortugas Bank. One mutton snapper tagged inside the RNA migrated offshore (25 km) during a 10-d period around the June 2008 full moon. This fish returned to the RNA after it was detected on a receiver approximately 6 km from RH (Figure 2).

Future Work

Finfish

Our Tortugas Regional Array covering TNER, TSER, RNA, DRTO and open use areas of the FKNMS is continuously collecting data. We will continue to coordinate with other regional telemetry projects (Ault-DRTO; FWC/USGS-RNA; Pratt-DRTO; Hart-DRTO) by sharing information collected by all our arrays. These concurrent studies provide additional receiver coverage along the north side and central portion of the RNA. Fishes that are tagged at the spawning aggregation site may be detected at stations established by these research groups and vice versa, providing invaluable data on the connectivity of this coral reef ecosystem.

All VR2s, except at TSER, will be serviced and downloaded seasonally (early summer 2009 & fall 2009). This data will include fish tagged in FY09 as well as FY08. In addition the VR28, a tracking 4-channel receiver that provides transmitter position and bearing, will be towed from a small boat and used to expand spatial coverage of the VR2s. The remaining VR2s at RH will be downloaded, serviced and redeployed during a

collaborative research trip with M. Burton (NOAA) during July 2009. Specific areas to be covered by the VR28 include the deep water TSER habitat (Miller's Ledge) and deeper water west of RH.

A cruise to RH will be scheduled for June 2009 (peak spawning period) to acoustically tag mutton snapper (n = 20) in the aggregation and tagging efforts will expand to include fish captured from the TNER. Fish will be surgically implanted *in-situ* with V16 coded transmitters that use a single-frequency coding scheme. *In-situ* implant methodology avoids exposure of fish to barotrauma induced mortality associated with capture from deep water. Ten of these transmitters will be equipped with a depth sensor and all transmitters will last the duration of the study. During the CRCP timeframe, we will continue to tag the snapper/grouper complex of fish on our RNA project (FWC/USGS), which focuses on immigration and emigration of targeted reef fishes in the RNA, potentially contributing to information collected at RH. Data downloaded will yield time, location and depth and will provide species-specific information on fish movement rates and spawning activities. This information will be analyzed to examine movement and core utilization areas of snappers/groupers in association with specific habitat features as well as assess movement between MPAs. All data collected will be entered into an FWC Access data base with statistical analyses using SPSS or SAS. Spatial and temporal data will be processed using Arcview GIS and Tracking Analysis software to examine movement patterns in association with habitats and MPA boundaries.

WESTERN SAMBO ECOLOGICAL RESERVE - LOBSTER

Introduction

Lobsters were re-surveyed in WSER, Eastern Sambo Ecological Reserve (ESER), Middle Sambo and Pelican Shoal during 2008. Both WSER and ESER are no-take reserves and Middle Sambo and Pelican Shoal are open fished zones. We used size distribution surveys and 500 m^2 belt transect surveys of spiny lobsters inside marine reserve zones and their exploited reference areas in FKNMS during the closed fishing season to determine lobster size, sex, and abundance. Sampling was designed to test the hypothesis that no-take zones would sufficiently protect lobsters so that lobsters in these areas would become larger and more abundant than those in unprotected areas.

Methods

Lobster - Size distribution surveys

Three hundred and sixty seven lobsters were captured for size distribution estimates (Table 3 and 4). These lobsters were also examined for molt condition, sex, reproductive status (females), and evidence of disease. Very poor visibility and weather severely hampered our ability to work in Hawk Channel (patch reef) and thus patch reef size distribution lobsters were only collected from Pelican Shoals. We stratified sampling by habitat type because we expected each habitat to shelter a different size range of spiny lobsters (Hunt et al., 1991). Strata included forereef, backreef and offshore patch reef.

Lobster Monitoring - Area Surveys

In addition to size distribution surveys, we searched for lobsters in reserves (WSER and ESER) and reference (Pelican Shoal and Middle Sambo) zones using area-based surveys. Divers counted and estimated size of all lobsters in 139 transects (500 m^2) on the forereef and backreef of reserve and reference areas. Divers searched a 5 m wide area on each side of a 50 m tape and replicated this measure in each habitat.

Lobster Monitoring - Statistics

Mean size of lobster comparisons were performed using ANOVA with a Hochberg post hoc test and by using the General linear model (GLM) for interactions due to unequal sampling of males and female lobsters (ANCOVA). We used the Hochberg post hoc test during the ANCOVA to account for unequal sample sizes. Tests of sexual dimorphism (male - female size) for the fore and back reef within and outside the reserve were conducted using a multiple T-test assuming unequal variance due to the unequal sample sizes.

Results

Lobster - Inside and outside the Marine Reserves

The GLM controlling for sex as a covariate (ANCOVA) revealed a strong significant interaction therefore, to analyze size differences inside and outside the Eastern and Western Sambo reserves, male and female lobsters were analyzed separately. Post hoc tests conducted for all fore reef and back reef regions revealed three homogeneous groups among females (with moderate overlapping) and no groups among male lobsters (Table 5).

In general, the mean size of male and female lobsters increased from Pelican Shoal (outside WSER) through Middle Sambo (adjacent to WSER) to WSER itself. Although the Eastern Sambo Research Reserve is technically a lobster no take zone, the small size of this reserve provides no practical protection for those resident lobsters. Even though male lobsters within the Western Sambo Ecological Reserve were nearly 10 mm CL larger than male lobsters elsewhere, the high variance in size coupled with a relatively low sample size, cause a lack of statistical significance in size between the reserves and the fishery. When the fore and back reef samples are pooled and the analysis repeated, the difference in size among the males at Pelican Shoal and Western Sambo becomes statistically significant ($p<0.05$).

Lobster - Sexual dimorphism

A comparison of mean carapace size (CL) between male and female lobsters is presented in Table 6. Size differences between male and female lobsters were greatest inside the WSER where the differences exceeded 10 mm CL. In the fished area, the size differences were greatest at Pelican Shoal and those differences were approximately half the WSER differences. Statistically significant differences in size were found at the WSER backreef and Pelican Shoal backreef. Western Sambo forereef difference was nearly significantly different; however, the relative lack of males in the sample here greatly reduced the power of the statistical test. Although the Eastern Sambo forereef is within a marine reserve, its small size $<1km^2$ compared to typical lobster movement (> 1km/day) preclude it from affording protection for resident lobsters.

Lobster - Density

Lobster densities per 500 m^2 transect are reported in Table 7 – 9.

Future Work

Lobster

We will continue annual surveys of spiny lobster in and adjacent to the WSER and incorporate sonic tagging of spiny lobsters in the Tortugas region. We will continue to use a combination of belt-transects and the capture, measurement and release of at least 50 spiny lobsters per stratum to estimate abundance and size structure inside and outside the ERs.

References

Ault, J.S., Smith, S.G., Bohnsack, J.A., Luo, J., Harper, D.E. and McClellan, D.B. (2006) Building sustainable fisheries in Florida's coral reef ecosystem: positive signs in the Dry Tortugas. Bull. Mar. Sci. 78(3):633-654.

Burton, M.L., Brennan, K.J., Munoz, R.C., Parker, Jr. R.O. (2005) Preliminary evidence of increased spawning aggregations of mutton snapper (*Lutjanus analis*) at Riley's Hump two years after the establishment of the Tortugas South Ecological Reserve. Fish. Bull. 103:404-410.

Domeier, M.L. (2004) A potential larval recruitment pathway originating from a Florida marine protected area. Fish. Oceanogr. 13(5):287-294.

Lindeman, K.C., Pugliese, R., Waugh, G.T. and Ault, J.S. (2000) Developmental patterns within a multispecies reef fishery: management applications for essential fish habitats and protected areas. Bull. Mar. Sci. 66(3):929-956.

Sadovy, Y. and Domeier, M. (2005) Are aggregation-fisheries sustainable? Reef fish fisheries as a case study. Coral Reefs 24:254-262, DOI 10.1007/s00338-005-0474-6

Sadovy, Y.A. and Eklund, A. (1999) Synopsis of the biological information on *Epinephelus striatus* (Bloch, 1792) the Nassau grouper and *E. itajara* (Lichtenstein, 1822) the jewfish. NOAA Tech. Rep. NMFS 146:1-65.

Figure 1. The TSER, TNER, DRTO and RNA create a network of no-take reserves that protect 600 km^2 of coral reef habitat in the Dry Tortugas.

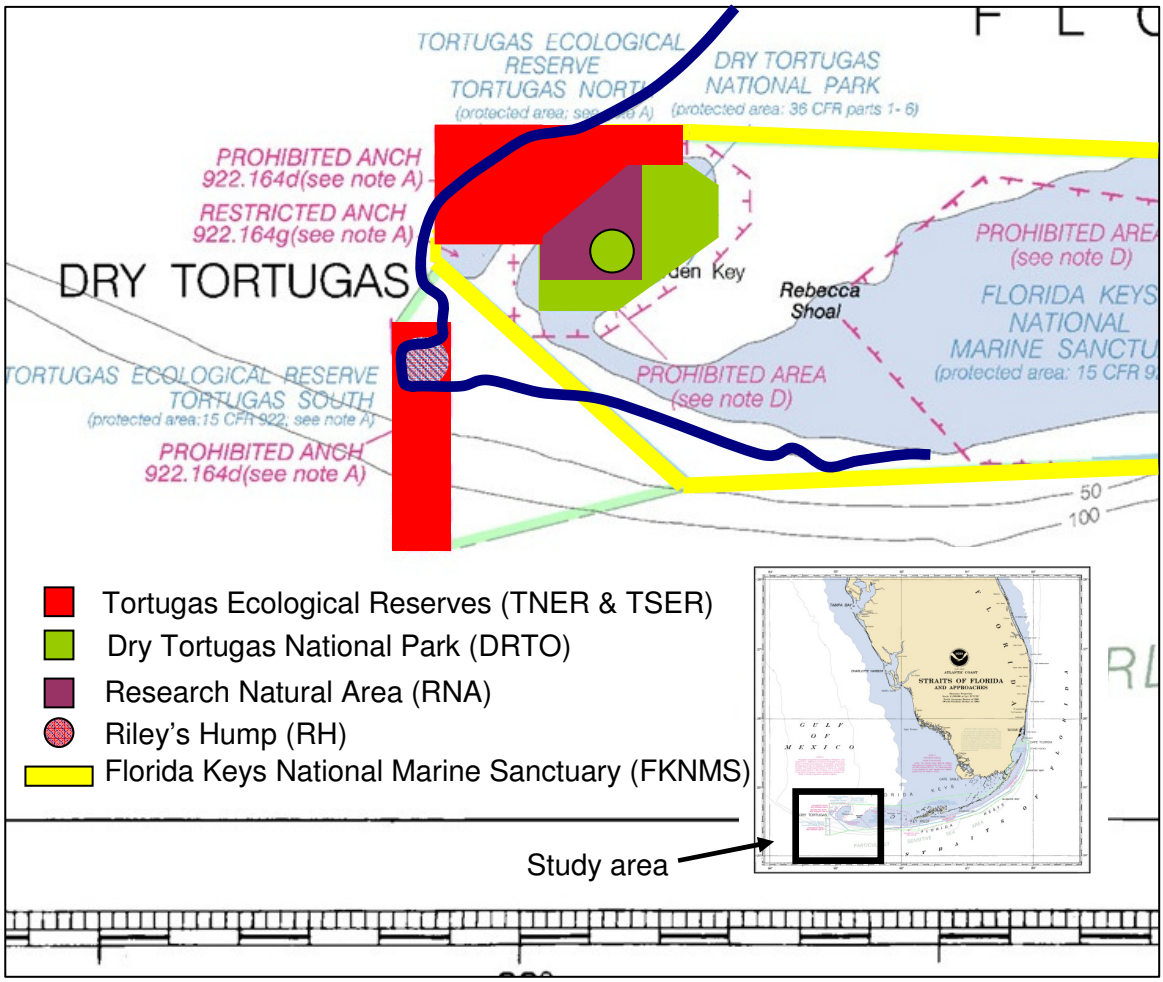

Figure 2. VR2 array, tagging sites and preliminary migratory movements of mutton snapper in the Dry Tortugas. The FWC acoustic array is complimented by three collaborative acoustic telemetry projects in the region (~ 40 VR2s): University of Miami telemetry reef fish project (PI: Dr. Jerry Ault); Mote Marine Laboratory nurse shark project (PI: Dr. Wes Pratt) and USGS sea turtle project (PI: Dr. Kristen Hart).

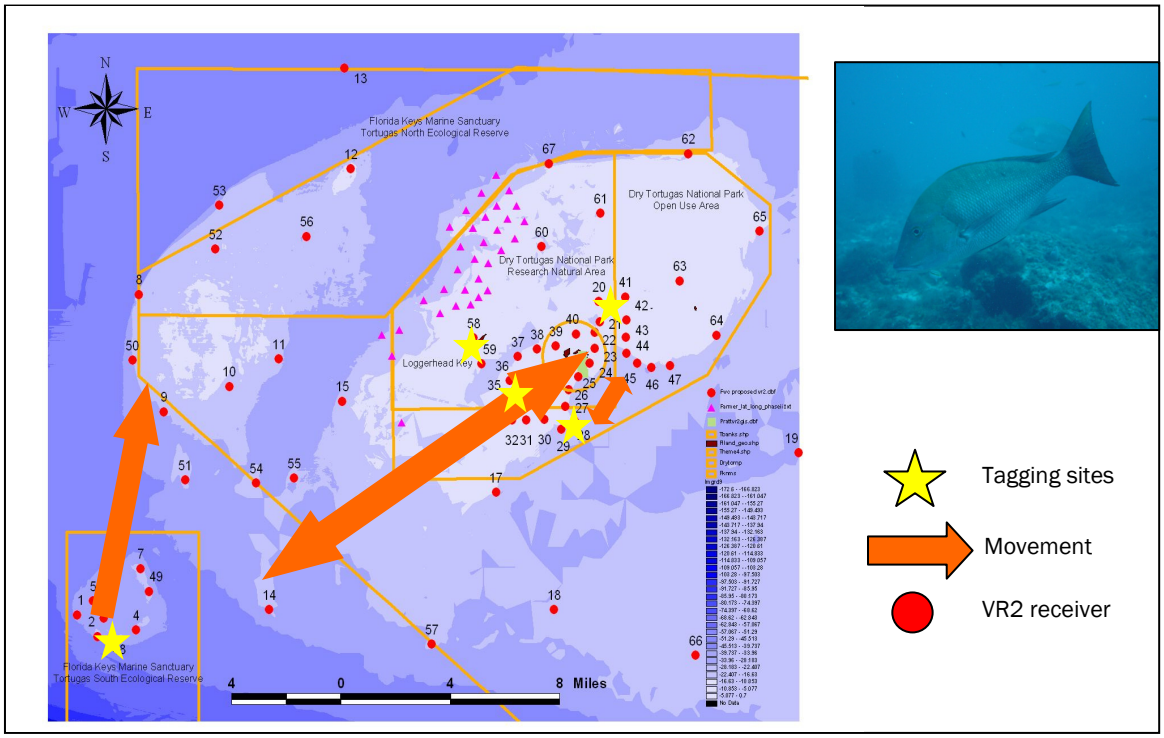

Table 1. Location of VR2 receivers in the Dry Tortugas region.

STATION	LATD	LATM	LOND	LONM	DEPTH (m)	ZONE	VR2 #
41	24	39.366	82	50.676	6.1	DRTO	2330
63	24	39.783	82	48.822	5.2	DRTO	2314
64	24	38.081	82	47.690	21.3	DRTO	2331
47	24	37.387	82	49.150	23.2	DRTO	2321
46	24	37.293	82	49.749	24.4	DRTO	2311
45	24	37.425	82	50.106	22.9	DRTO	2315
44	24	37.637	82	50.521	21.9	DRTO	2326
43	24	38.158	82	50.540	11.0	DRTO	2329
42	24	38.694	82	50.500	9.8	DRTO	2324
20	24	39.185	82	51.348	14.6	RNA	2313
21	24	38.648	82	51.336	12.2	RNA	2318
22	24	38.314	82	51.512	14.3	RNA	2325
40	24	38.234	82	52.086	13.7	RNA	2319
39	24	37.810	82	52.679	12.8	RNA	2312
38	24	37.807	82	53.355	16.8	RNA	2317
37	24	37.647	82	53.980	19.2	RNA	2320
36	24	36.896	82	54.114	6.1	RNA	2328
35	24	36.384	82	54.148	6.1	RNA	2327
34	24	36.350	82	53.622	2.7	RNA	6030
33	24	36.329	82	53.041	8.5	RNA	7152
30	24	35.795	82	53.102	4.0	DRTO	7154
31	24	35.782	82	53.692	3.4	DRTO	5922
32	24	35.751	82	54.123	4.6	DRTO	4210
59	24	37.313	82	55.082	21.6	RNA	6024
23	24	37.807	82	51.383	12.2	RNA	2323
24	24	37.403	82	51.662	4.6	RNA	6029
25	24	36.991	82	52.000	19.8	RNA	7245
26	24	36.572	82	52.246	21.6	RNA	7441
27	24	36.198	82	52.366	21.0	RNA	7247
28	24	35.638	82	52.200	21.3	DRTO	7151
29	24	35.462	82	52.619	22.6	DRTO	7155
65	24	41.251	82	46.291	21.0	DRTO	103206
62	24	43.477	82	48.530	16.2	DRTO	103202
61	24	41.786	82	51.397	14.9	RNA	5121C
60	24	40.814	82	53.187	17.1	RNA	100454
67	24	43.217	82	52.946	29.6	RNA	103208
12	24	42.994	82	59.301	15.8	TNER	103196
56	24	41.128	83	0.546	21.3	TNER	4207C
53	24	42.242	83	3.407	32.0	TNER	103201
58	24	38.345	82	55.275	4.3	RNA	2316C
17	24	34.115	82	55.638	12.8	FKNMS	103203
66	24	31.710	82	56.535	17.1	FKNMS	7150C
57	24	29.234	82	56.686	24.1	FKNMS	5124C
19	24	28.997	82	58.463	29.3	OPEN	4208C
14	24	30.222	83	1.852	26.2	OPEN	103207
18	24	31.424	83	1.927	24.1	FKNMS	7249C
54	24	33.986	83	2.295	24.7	FKNMS	7248C

Table 1. (cont)

STATION	LATD	LATM	LOND	LONM	DEPTH (m)	ZONE	VR2 #
55	24	34.076	83	1.046	25.0	FKNMS	5120C
16	24	33.551	82	57.880	19.2	FKNMS	6025C
15	24	35.839	82	59.420	17.4	FKNMS	7149C
11	24	37.673	83	1.838	16.5	FKNMS	5116C
10	24	36.824	83	3.525	19.8	FKNMS	7246C
51	24	33.984	83	4.512	25.3	FKNMS	6023C
9	24	36.036	83	5.371	28.7	OPEN	5123C
50	24	37.387	83	6.165	32.9	OPEN	4209C
8	24	39.520	83	5.966	23.2	TNER	5118C
52	24	40.172	83	4.219	20.4	TNER	7160C
2	24	29.435	83	7.291	30.8	TSER	103198
48	24	29.346	83	6.878	28.7	TSER	7250
4	24	29.631	83	6.065	32.6	TSER	103205
3	24	29.968	83	7.103	30.5	TSER	103209
1	24	30.077	83	7.943	31.4	TSER	103197
5	24	30.478	83	7.431	32.3	TSER	103200
6	24	31.408	83	6.732	28.7	TSER	103195
7	24	31.422	83	5.926	27.4	TSER	103199
49	24	30.762	83	5.647	25.6	TSER	103204
30A	24	35.182	82	53.185	22.3	DRTO	7245
31A	24	34.662	82	53.257	22.3	DRTO	6024
32A	24	34.441	82	53.863	23.8	DRTO	5115
33A	24	34.878	82	54.95	17.7	DRTO	103571
34A	24	35.764	82	54.858	17.1	DRTO	7152
36A	24	37.274	82	54.23	13.4	RNA	2320
40A	24	38.719	82	52.321	18.9	RNA	2316
24A	24	37.467	82	51.426	21.3	RNA	7150c
35A	24	36.377	82	54.195	14.3	RNA	2314
37B	24	38.549	82	53.753	20.1	RNA	2325
68	24	37.531	82	56.610	6.1	RNA	103567

* Stations denoted with an “A” or “B” represent relocation to adjacent deeper water.

Table 2. All acoustically tagged fish captured and released in the Dry Tortugas between May 2008 - October 2008.

Species	**Date**	**Zone**	**Depth (m)**	**TL (mm)**	**Code**	**Tag type**
Epinephelus morio	7/3/2008	TSER	26.8	584	2166	V16-4H
Epinephelus morio	7/3/2008	TSER	25.9	686	2153	V16-4H
Epinephelus morio	7/6/2008	TSER	37.5	406	2154	V16-4H
Epinephelus striatus	7/5/2008	TSER	33.5	584	49585	V16-4H
Haemulon plumierii	5/19/2008	DRTO	6.4	289	49601	V9-2L
Haemulon plumierii	5/27/2008	RNA	4.6	272	49602	V9-2L
Haemulon plumierii	5/27/2008	RNA	10.1	253	49595	V9-2L
Haemulon plumierii	5/30/2008	RNA	9.8	282	49603	V9-2L
Haemulon plumierii	5/30/2008	RNA	9.8	263	49604	V9-2L
Lutjanus analis	5/16/2008	DRTO	9.8	648	2170	V16-4H
Lutjanus analis	5/17/2008	DRTO	8.5	551	2176	V16-4H
Lutjanus analis	5/17/2008	DRTO	8.5	610	2175	V16-4H
Lutjanus analis	5/22/2008	RNA	12.2	468	2174	V16-4H
Lutjanus analis	5/24/2008	DRTO	14.8	610	2185	V16-4H
Lutjanus analis	5/26/2008	RNA	4.6	566	2168	V16-4H
Lutjanus analis	5/30/2008	RNA	7.3	645	2177	V16-4H
Lutjanus analis	5/30/2008	RNA	7.3	692	2167	V16-4H
Lutjanus analis	7/1/2008	TSER	29.0	610	49591	V16-4H
Lutjanus analis	7/1/2008	TSER	29.0	508	49589	V16-4H
Lutjanus analis	7/1/2008	TSER	32.6	635	49590	V16-4H
Lutjanus analis	7/2/2008	TSER	27.4	470	13675/ 55	V16P-4H
Lutjanus analis	7/5/2008	TSER	36.6	457	13674/ 54	V16P-4H
Lutjanus analis	7/5/2008	TSER	33.5	483	13678/ 58	V16P-4H
Lutjanus analis	7/5/2008	TSER	36.6	483	13677/ 57	V16P-4H
Lutjanus analis	7/5/2008	TSER	33.5	578	13679/ 59	V16P-4H
Lutjanus analis	10/13/2008	RNA	4.3	718	49588	V16-4H
Lutjanus analis	10/13/2008	RNA	4.3	591	2200	V16-4H
Lutjanus analis	10/13/2008	RNA	4.3	572	2201	V16-4H
Lutjanus analis	10/13/2008	RNA	4.3	603	2198	V16-4H
Lutjanus analis	10/13/2008	RNA	4.3	591	49587	V16-4H
Lutjanus analis	10/15/2008	RNA	11.0	743	52503	V16-4H
Lutjanus analis	10/15/2008	RNA	11.0	705	52504	V16-4H
Lutjanus analis	10/15/2008	RNA	11.0	533	52505	V16-4H
Lutjanus analis	10/14/2008	DRTO	2.1	616	52502	V16-4H

Table 2. (cont)

Species	Date	Zone	Depth (m)	TL (mm)	Code	Tag type
Mycteroperca bonaci	5/21/2008	RNA	10.7	609	2173	V16-4H
Mycteroperca bonaci	5/26/2008	RNA	6.1	438	2169	V16-4H
Mycteroperca bonaci	5/29/2008	DRTO	10.1	618	2171	V16-4H
Mycteroperca bonaci	5/29/2008	RNA	8.5	548	2172	V16-4H
Mycteroperca bonaci	5/30/2008	DRTO	9.1	562	2184	V16-4H
Mycteroperca bonaci	6/3/2008	DRTO	14.9	640	2165	V16-4H
Mycteroperca bonaci	10/11/2008	RNA	7.3	432	49586	V16-4H
Mycteroperca bonaci	10/14/2008	DRTO	1.5	667	52506	V16-4H
Ocyurus chrysurus	5/16/2008	DRTO	9.8	432	49599	V9-2L
Ocyurus chrysurus	5/17/2008	DRTO	8.5	432	49598	V9-2L
Ocyurus chrysurus	5/17/2008	DRTO	8.5	381	49597	V9-2L
Ocyurus chrysurus	5/19/2008	DRTO	6.1	401	49600	V9-2L
Ocyurus chrysurus	5/19/2008	DRTO	6.1	376	49596	V9-2L
Ocyurus chrysurus	10/10/2008	DRTO	10.4	445	52521	V9-2L
Ocyurus chrysurus	10/10/2008	DRTO	10.4	406	52520	V9-2L
Ocyurus chrysurus	10/10/2008	DRTO	10.4	438	52519	V9-2L
Ocyurus chrysurus	10/11/2008	RNA	7.3	514	52518	V9-2L
Ocyurus chrysurus	10/11/2008	RNA	7.3	419	52517	V9-2L

Table 3. Number of lobsters collected for size distribution analysis by region and habitat (males/females).

Region	Habitat			Total
	Fore reef	Back reef	Patch reef	
Middle Sambo	45 (12/33)			45 (12/33)
Pelican Shoal	55 (18/37)	59 (24/35)	22 (9/13)	136 (51/85)
Western Sambo (ER)	51 (12/39)	61 (24/37)		112 (36/76)
Eastern Sambo (RR)	74 (18/56)			74 (18/56)
Total	225 (60/165)	120 (48/72)	22 (9/13)	367 (117/250)

Table 4. Mean size of lobster by sex, habitat, and region.

Habitat	Region	Males Mean±SD	Females Mean±SD	Overall Mean±SD
Fore reef	Pelican Shoal	81.6±10.5	76.7±6.7	78.3±8.4
	Middle Sambo	82.0±10.1	80.2±6.3	80.6±7.4
	Eastern Sambo RR	82.8±13.6	82.7±6.4	82.7±8.6
	Western Sambo ER	91.0±16.5	80.9±5.3	83.3±10.0
Back reef	Pelican Shoal	81.1±10.2	74.4±5.5	77.1±8.3
	Western Sambo ER	92.0±13.5	80.7±6.2	85.1±11.2
Patch reef	Pelican Shoal	77.3±11.9	73.2±10.9	74.9±11.2
	Overall	84.8±13.0	78.3±7.0	80.5±9.9

Table 5. Results of ANCOVA on the effect of marine reserves on male and female lobster size.

Females

Post hoc test Hochberg [a,b]	Reserve status	Region, Habitat	N	Homogeneous subsets (α = 0.05) 1	2	3
	Outside Reserves	Pelican Shoal Back reef	35	74.43		
		Pelican Shoal Fore reef	37	76.73	76.73	
		Middle Sambo Fore reef	33		80.15	80.15
	Within Reserves	Western Sambo Back reef	37		80.70	80.70
		Western Sambo Fore reef	39			80.92
		Eastern Sambo Fore reef	56			82.71
		Significance of group		0.787	0.068	0.641

Males

Post hoc test Hochberg [a,b]	Reserve status	Region, Habitat	N	Homogeneous subsets (α = 0.05) 1
	Outside Reserves	Pelican Shoal Back reef	24	81.08
		Pelican Shoal Fore reef	18	81.56
		Middle Sambo Fore reef	12	82.00
	Within Reserves	Eastern Sambo Fore reef	18	82.83
		Western Sambo Fore reef	12	91.00
		Western Sambo Back reef	24	92.00
		Significance of group		0.172

Means for groups in homogeneous subsets are displayed.

[a] Uses Harmonic Mean Sample Size = 36.083 for females and 16.364 for males.

[b] Group sizes unequal. Harmonic mean of the group sizes used. Type I error levels are not guaranteed.

Table 6. Results of multiple T-tests comparing mean size (CL) of male and female lobsters.

Location (**bold**=Marine reserve)	t	df	Sig. (2-tailed)	Mean Difference
Eastern Sambo forereef	0.04	19.44	0.972	0.1
Middle Sambo forereef	0.59	14.19	0.562	1.8
Pelican Shoal forereef	1.78	24.04	0.088	4.8
Pelican Shoal backreef	2.92	32.21	**0.006**	6.7
Pelican Shoal patch reef	0.82	16.36	0.422	4.1
Western Sambo forereef	2.09	11.71	0.059	10.1
Western Sambo backreef	3.83	29.38	**0.001**	11.3

Table 7. Number of transect ($500m^2$) surveys conducted by region (note: Patch reef transects were stratified equally into 10 top and 10 side transects).

Region	Fore reef	Back reef	Patch reef
Pelican Shoal	20	20	20
Middle Sambo	10		
Eastern Sambo	10		
Western Sambo	19	20	20

Table 8. Number of lobsters per $500m^2$.

		Fore reef Mean ±S.D.	Back reef Mean ±S.D.	patch reef Mean ±S.D.	Overall Mean ±S.D.
Fishery	Pelican Shoal	2.2 ±2.1	1.3 ±1.9	0.6 ±1.2	1.3 ±1.9
	Middle Sambo	3.1 ±3.2	. .	. .	3.1 ±3.2
Protected	Eastern Sambo	3.2 ±4.4	. .	. .	3.2 ±4.4
	Western Sambo	1.9 ±1.9	4.5 ±6.0	1.1 ±1.4	2.5 ±4.0
Overall		2.4 ±2.7	2.9 ±4.7	0.8 ±1.3	2.1 ±3.3

Table 9. Results from ANOVA on density of lobsters per $500m^2$ transect.

ANOVA
Density

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	220.44	7	31.49	3.32	0.003
Within Groups	1242.15	131	9.48		
Total	1462.59	138			