NOAA Coral Reef Conservation Program
Final Report

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

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Abstract
This multi-year project has used a multi-tiered approach to evaluate Marine Protected Areas in the Florida Keys National Marine Sanctuary. During the Federal Fiscal Year 11 (Oct. 2010-Sept. 2011), spatial and temporal rates of movement of acoustically tagged snappers and groupers were measured in the Tortugas region, including annual spawning migratory movements between Tortugas South Ecological Reserve (Riley's Hump) and the Tortugas North Ecological Reserve, and the Dry Tortugas National Park, including the Research Natural Area. In addition, the abundance and size-structure of spiny lobsters in and adjacent to the Western Sambo Ecological Reserve were surveyed and spiny lobsters were tagged with acoustic tags north of the lower Keys to evaluate their movement patterns. Results will be used to assess the importance of habitat linkages between adjacent marine protected areas and provide information for an ecosystem-based approach to management of marine resources.

Background
This multi-year 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 resolve user conflicts, to protect critical coral reef ecosystems from exploitation, 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 species such as lobsters, snappers and groupers. The present project builds on past research and monitoring in the FKNMS by the 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), including the DRTO Research Natural Area (RNA, a type of marine reserve), the Tortugas North Ecological Reserve (TNER) and spawning habitat at Riley's Hump (RH), located within the Tortugas South Ecological Reserve (TSER). The following submission summarizes annual progress on the *Performance Evaluation of Marine Zoning in the Florida Keys National Marine Sanctuary* project for October 2010 to October 2011 in three parts: 1) Dry Tortugas Finfish project; 2) Western Sambo Ecological Reserve lobster project and 3) Florida Keys Lobster project.

DRY TORTUGAS FINFISH PROJECT

Summary report

During 2008-11, we tagged 120 fishes including: 28 mutton snapper and 10 black grouper at Riley's Hump (RH) and 27 mutton snapper and 15 black grouper within DRTO. We also tagged

small numbers of red grouper, Nassau grouper, yellowfin grouper, goliath grouper, and white grunt. Currently, we are maintaining 64 acoustic receivers. We found large mutton snapper spawning aggregations during 2009 and 2010 and observed spawning 1–5 days after full moon during June 2009. We observed individual mutton snappers making up to 3 repetitive spawning round trips between May and August. Individuals stayed on the spawning grounds up to 10 days around full moon before returning to DRTO/RNA. These results have been provided to FKNMS managers for management review.

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 likely supply larval/juvenile recruits to the Florida Keys and south Florida (Domeier, 2004; Burton et al., 2005; Ault et al., 2006). The TSER and TNER were established 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 resources 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 was to determine regional connectivity and test the hypothesis that fish move from foraging grounds (RNA, TNER, and DRTO) to spawning sites in the TSER. Data will be used to assess the size, shape and site selection of the Tortugas marine reserves and their efficacy as an ecosystem-based 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.

In addition, we began the effort to determine residence times and behavior of snappers and groupers in spawning aggregation areas. Snappers and groupers migrate long distances to specific sites to form spawning aggregations of 100 – 1000s of individuals at specific times of the year. Unfortunately, traditional fishery management strategies have not always accounted for the vulnerable nature of spawning events and these prime fishery targets are often heavily fished. Recent changes in fishery regulations have placed greater emphasis on marine protected areas to preserve reef habitat, enhance reef fish production, conserve functional ecosystem processes, and protect a certain proportion of the population. After years of overexploitation, the TSER was

established to protect the most important known multi-species aggregation site in the southeastern United States (Lindeman et al., 2000). Re-formation of the mutton snapper spawning aggregation has been documented since closure of the TSER to fishing, but little is known about adult reef fish movements in the region or the characterization of transient reef fish spawning aggregations at Riley's Hump.

Additionally, scientists from the Florida Fish and Wildlife Conservation Commission (FWC) and the Caribbean Coral Reef Institute (CCRI) of the University of Puerto Rico (UPR) embarked on a five day mission aboard the M/V Spree during March 2011 to study and identify black grouper spawning aggregations at Riley's Hump (RH), located within the Tortugas South Ecological Reserve (TSER). An additional objective of the mission was to examine the connectivity between shallow and deeper habitats in RH. The scientists conducted visual censuses using open-circuit scuba (i.e., air, Nitrox systems) and closed-circuit rebreather (CCR-Trimix) diving, a remote operating vehicle (ROV) and acoustic sonar (split-beam echosounder) surveys. These activities were used to enhance our knowledge in the use and the distribution of snappers and groupers in deep water reefs of Riley's Hump and better design future arrays of our VR2 receivers to collect information on black grouper. A detail synopsis of this cruise is provided in Appendix 1.

Materials and Methods

Finfish – Acoustic Array

The acoustic receiver array was first deployed in three phases between May and July 2008. 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 DRTO, including within and outside the borders of the 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 complementary 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 TNER and open use areas of the FKNMS. The final nine receivers were set up during July 2008 at RH in the TSER. The coverage of our array is complemented by two collaborative acoustic projects: Mote Marine Laboratory's Nurse shark project (PI: Wes Pratt) and a USGS sea turtle study (PI: Kristen Hart).

The receivers were secured to a PVC stand attached to a concrete platform that functioned as ballast and provided stability. The VR2 receivers were positioned "tip up" approximately 1 meter above the seafloor inside a PVC pipe sleeve (63.5 or 76.2 mm) and secured by a tie wrap. Each receiver tip was protected by a coat of antifouling paint. A 3 m subsurface buoy was attached to a stainless steel I-bolt at the base of each receiver stand with a 6.35 mm polypropylene line. Prior

to deployment, each VR2 sonic receiver was initialized in the laboratory with a personal computer and VUE 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 VR2 receiver stand and a surface marker were dropped 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 immediately confirmed the position and placement of the receiver stand on the seafloor. Receivers were serviced for maintenance twice per year in the field. Individual receivers were brought to the surface and data was uploaded to a personal computer using VUE software with an upload cable or by Bluetooth® technology. If the receiver required a battery replacement, the battery was replaced and the receiver was reinitialized. In addition, the subsurface buoy and line were scraped clean of fouling organisms.

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 the capture of fish from relatively deep water. Fish were caught in fish traps baited with threadfin herring and sardines 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. Each fish was positioned ventral side up in a V-cradle 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.

Progress and Results

Finfish

During FY 2011, VR2 receivers were successfully downloaded, redeployed and remain operational on or near their original locations (Figure 1). All receivers were serviced during March 2011, July/August 2011 and December 2011**.** Sixty-four VR2 stations have recorded more than 1.3 million detections since May 2008 (Table 1). Stations 20, 35, 35A, and 37B have large numbers of detections (> 50,000) because of one or two fish in residence near these inshore sites. The numerous detections at stations 2 and 48 are from multiple individual fish because of the proximity of these stations to spawning habitat along the southern slope of RH. One Hundred-twenty (120) fish were tagged from May 2008 through July 2011 with approximately, 2.2 million

detections recorded by the FWC array during that time. Time-at-liberty for FWC tagged snappers and groupers determined by the array ranged from 114-1115 d with mean (± SE) of 754±35 d for mutton snapper (n=51), 411±7 d for yellowtail snapper (n=18), 452±47 d for black grouper (n=27), 482±237 d for red grouper (n=4), 666±292 d for Nassau grouper, *Epinephelus striatus* (n=3), and 415±0 d for goliath grouper, *Epinephelus itajara* (n=2).

During March 2011, seven fish were tagged aboard the Anabel C Charter vessel. Four black grouper were tagged inside TNER and one in the OPEN region west of the RNA, one mutton snapper was tagged inside the DRTO, and one Nassau grouper was acoustically tagged in the OPEN region near the southwest tip of the TNER **(**Table 3). Approximately 40 % of fish tagged within the TSER have been successfully tracked greater than 20 days since the inception of the study. Results of our research was presented at the Florida Keys National Marine Sanctuary, Advisory Council, Key West, Florida (December 2011).

Mutton Snapper

Mutton snapper (45.7-89.7 cm) were acoustically tagged offshore at the RH FSA (n=28) and inshore within the RNA and DRTO (n=27). A total of 1.4 million mutton snapper tag detections were recorded by the array between May 2008 and August 2011. Sixty-eight detections were recorded on the Tortugas Bank and the remaining detections were recorded at Riley's Hump (33,460) and on or near the Dry Tortugas. Individual mutton snapper (n=51) were tracked an average (mean±sd) of 315±338 days (d) with a range of 3 -1056 d.

Exploited-phase mutton snapper crossed reserve boundaries several times annually, especially during the spring/summer spawning season. Results indicate a migratory pathway exists for the seasonal movements of mutton snapper between the DRTO/RNA and the TSER, providing connectivity between marine protected areas and spawning activities (Figure 2). Currently, fifteen individual mutton snapper have been tracked making repeated migratory round trips (≤ 4 trips/fish/season) up to 62 km to RH. Kernel density estimates (Hawth's Analysis Tools for ArcGIS) of home range indicated 12 of these mutton snapper were residential fish of the RNA or migrated through the RNA. Daily transmitter detection frequency peaked at RH on the full moon during the spawning season (May to August) (Figure 3). Mean residence time on the spawning grounds was 7±3 d. The mean day of arrival relative to the full moon (+1±3 d) varied significantly ($p=0.002$), however the mean day of departure (+7±1 d; $p=0.06$) did not vary significantly over seven distinct spawning periods (Figure 4).

Black grouper

Grouper movements were small and infrequent, whereas mutton snapper and other species tagged moved more frequently. The majority of black grouper detections were picked up by a single VR2 receiver, but vary substantially in frequency across seasons. Detection frequency for the 3 RH groupers was lowest during the summer period of July to September and highest during

the period of October to March. Detection frequency drops drastically in early July for the largest fish (#21, 1069mm) and increases dramatically in early October, (sta.2, top figure), while detection of grouper #29 (sta. 2, 3, &48) is a more gradual decline, also beginning in early July, and like #21, frequency dramatically increases in October. Detection of grouper #23 at station 4 is more frequent during the same summer period without a dramatic decline, but detections do increase rapidly in early September. The pattern of detection frequency may suggest vertical movement, possibly indicating preference for cooler temperature and/or change in food availability. The smaller DRTO grouper does not show an obvious pattern. To date, no black grouper have been detected moving across reserve boundaries. Four large grouper tagged in the TNER and RNA last October were the first large adult black grouper to be tagged outside of RH, and may be more likely to be detected by the array while moving to and from the shallower reefs, and possibly to RH during the winter/spring spawning period. The estimated mean home range was 0.42 km^2 with 36.1% of this home range within the RNA (Table 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 and share data with other regional telemetry projects (Pratt-Mote; Hart-USGS). 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 will be serviced and downloaded during May 2012 & October 2012. These data will include fish tagged in 2008, 2009, 2010, 2011 and those to be tagged in 2012.

A cruise to RH will be scheduled for March 2012 (peak spawning period for black grouper) to search for deep water snappers and groupers at RH. During this trip we will pair with the University of Puerto Rico (UPR) Coral Reef Institute to conduct surveys in deeper water (>150'). Technical divers from UPR will set VR2 stations in deeper waters and conduct video transects of reef fishes in this area of RH. A group of shallow divers (100') will download and service the nine VR2 set in RH. In addition, we will use a remotely operated vehicle (ROV) to survey for coral and hard bottom areas at RH at depths of 45 to 200 feet. Specific areas to be covered by the technical divers and ROV include the deep water TSER habitat (Miller's Ledge) and deeper water west of RH.

During the CRCP timeframe, we will continue monitoring the snapper/grouper complex of fish on our RNA project (FWC/USGS), which focuses on immigration and emigration of targeted reef fishes in and near 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 habitat utilization areas of snappers/groupers and determine long range 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. A peer review manuscript using all the data downloaded up to December 2011 is currently underway. Dr. Feeley is leading this task.

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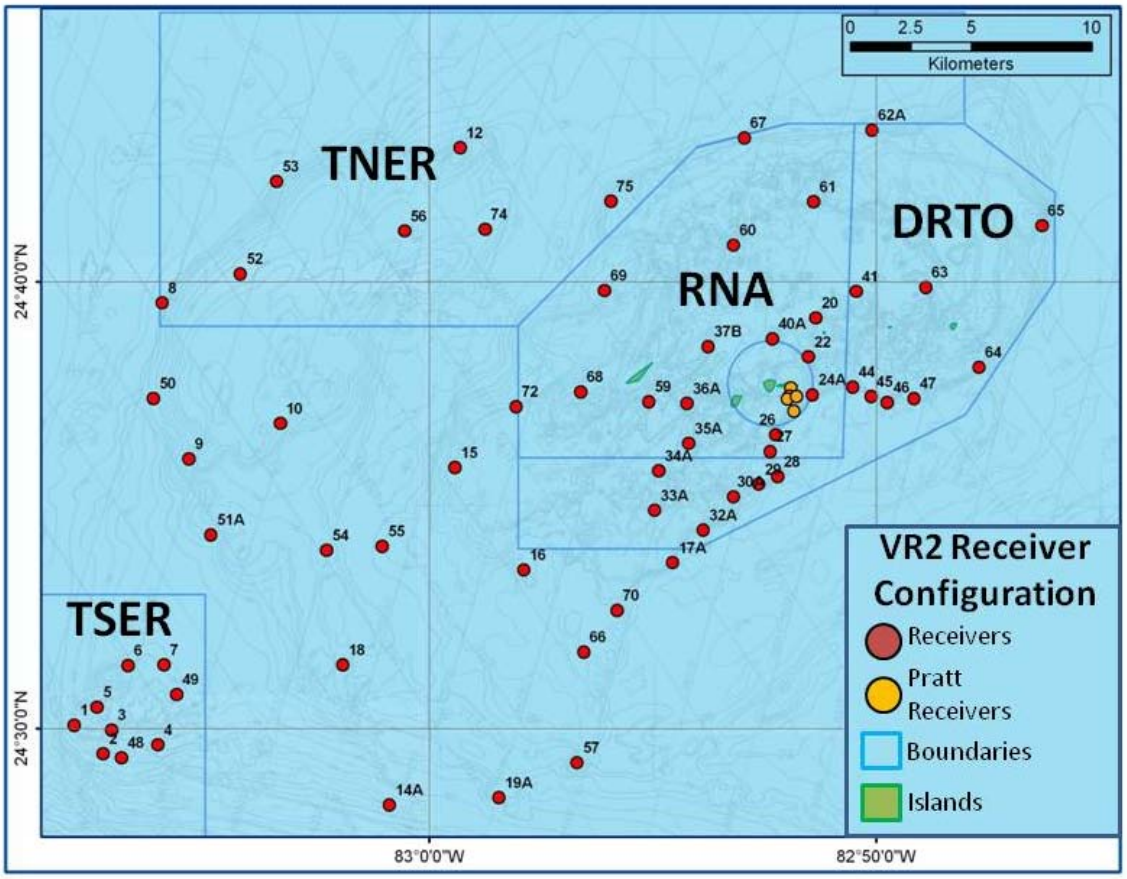

Figure 1. The TSER, TNER, DRTO and RNA create a network of no-take reserves that protect 600 km^2 of coral reef habitat in the Dry Tortugas. Location of FWC VR2 receivers are indicated for FY 2009. The FWC array is complemented by two collaborative telemetry projects: the Mote Marine Laboratory nurse shark project (PI: Dr. Wes Pratt) and USGS sea turtle project (PI: Dr. Kristen Hart).

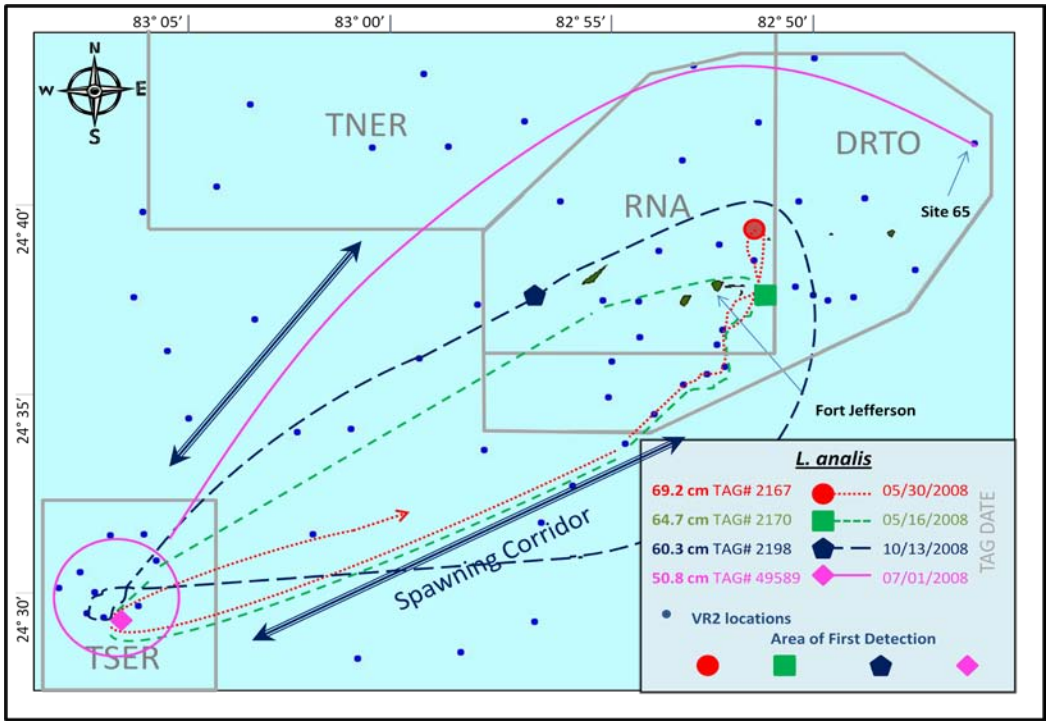

Figure 2. Tagging sites and preliminary spawning migratory movements of four mutton snapper in the Dry Tortugas.

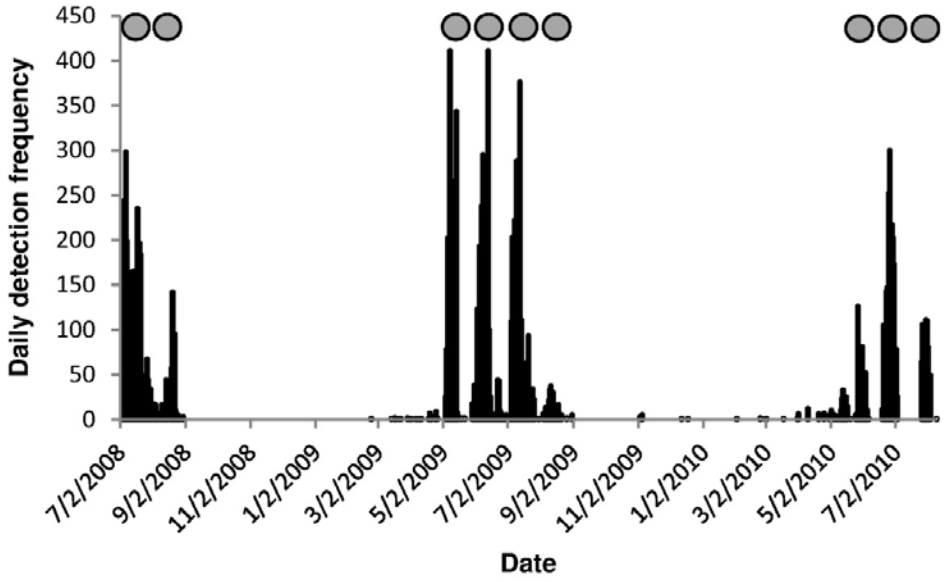

Figure 3. The daily frequency of mutton snapper transmitter detections from the south slope receiver in the Tortugas South Ecological Reserve on Riley's Hump relative to the full moon phase.

Table 1: Location of VR2 receivers in the Dry Tortugas region (September 2010). The management zone and cumulative number of detections is included for each station. Tortugas South Ecological Reserve (TSER), Tortugas North Ecological Reserve (TNER), Dry Tortugas National Park (DRTO), Research Natural Area (RNA), Florida Keys National Marine Sanctuary (FKNMS) and open waters (OPEN).

STATION	LATD	LATM	LOND	LONM	DEPTH (M)	ZONE	Number of Detections
1	24	30.077	83	7.943	2.4	TSER	2661
2	24	29.435	83	7.291	2.2	TSER	237747
3	24	29.968	83	7.103	2.2	TSER	6445
4	24	29.631	83	6.065	1.8	TSER	57796
5	24	30.478	83	7.431	2.3	TSER	29
6	24	31.408	83	6.732	2.1	TSER	1510
7	24	31.422	83	5.926	1.8	TSER	1142
8	24	39.520	83	5.966	1.8	TNER	143
9	24	36.036	83	5.371	1.6	OPEN	252
10	24	36.824	83	3.325	1.0	FKNMS	115
12	24	42.994	82	59.301	18.1	TNER	723
15	24	35.839	82	59.420	18.1	FKNMS	533
16	24	33.551	82	57.880	17.6	FKNMS	28
17A	24	33.710	82	54.547	16.6	FKNMS	495
18	24	31.424	83	1.927	0.6	FKNMS	77
19A	24	28.452	82	58.434	17.8	OPEN	3
20	24	39.185	82	51.348	15.7	RNA	127158
22	24	38.316	82	51.514	15.7	RNA	1594
26	24	36.572	82	52.246	15.9	RNA	4345
27	24	36.198	82	52.366	16.0	RNA	17425
28	24	35.638	82	52.200	15.9	DRTO	11133
29	24	35.462	82	52.619	16.0	DRTO	22402
41	24	39.778	82	50.450	15.4	DRTO	453
44	24	37.642	82	50.522	15.4	DRTO	6211
45	24	37.428	82	50.112	15.3	DRTO	32395
46	24	37.293	82	49.749	15.2	DRTO	9589
47	24	37.387	82	49.150	15.0	DRTO	761
48	24	29.346	83	6.878	2.1	TSER	56283
49	24	30.762	83	5.647	1.7	TSER	4543
50	24	37.387	83	6.165	1.9	OPEN	207
51A	24	34.332	83	4.879	1.5	OPEN	New Station
52	24	40.172	83	4.219	1.3	TNER	85
53	24	42.242	83	3.407	1.0	TNER	153
54	24	33.986	83	2.295	0.7	FKNMS	56
55	24	34.076	83	1.046	0.3	FKNMS	40
56	24	41.128	83	0.546	0.2	TNER	138
57	24	29.234	82	56.686	17.3	FKNMS	167
59	24	37.313	82	55.082	16.8	RNA	6005
60	24	40.814	82	53.187	16.2	RNA	42781

Table 1. (continued).

61	24	41.786	82	51.397	15.7	RNA	6539
62A	24	43.393	82	50.089	15.3	DRTO	895
63	24	39.872	82	48.885	14.9	DRTO	507
64	24	38.083	82	47.692	14.5	DRTO	1171
65	24	41.251	82	46.291	14.1	DRTO	3178
66	24	31.710	82	56.535	17.2	FKNMS	151
67	24	43.217	82	52.946	16.1	RNA	1328
68	24	37.533	82	56.605	17.3	RNA	10513
69	24	39.800	82	56.073	17.1	RNA	43
70	24	32.642	82	55.796	17.0	OPEN	132
24A	24	37.467	82	51.426	15.7	RNA	3925
30A	24	35.182	82	53.185	16.2	DRTO	9326
32A	24	34.441	82	53.863	16.4	DRTO	1305
33A	24	34.878	82	54.950	16.7	DRTO	80
34A	24	35.764	82	54.858	16.7	DRTO	308
35A	24	36.377	82	54.195	16.5	RNA	306798
36A	24	37.274	82	54.230	16.5	RNA	486
37B	24	38.549	82	53.753	16.4	RNA	330845
40A	24	38.719	82	52.321	15.9	RNA	549
14A	24	28.287	83	0.885	0.3	OPEN	1777
71	24	25.878	81	55.865	17.0	OPEN	1
72	24	37.202	82	58.051	17.7	OPEN	92
73	24	25.291	82	26.511	8.1	OPEN	70
74	24	41.168	82	58.748	17.9	TNER	New Station
75	24	41.803	82	56.943	17.4	TNER	New Station

Table 2. kernel density estimates (KDE) of home ranges (± standard error) for tagged fish.

Florida Fish and Wildlife Conservation Commission			
Species	Number tagged	Total length (cm)	KDE home range (km^2)
mutton snapper	23	46-90	30.86±10.53
yellowtail snapper	10	40-51	1.60±0.90
black grouper	17	46-122	0.12±0.04

Table 3. All acoustically tagged fish captured and released in the Dry Tortugas between May 2008 - March 2011.

Pinger code	Species	Date Tagged	Zone	Latitude	Longitude	Depth ft	TL inches	TL mm	Tag life days	Days of Tag Activity	% of Days Detected	Total Detections
27	*Epinephelus itajara*	6/13/2009	TNER	24 46.002	82 59.433	158	58.465	1485.0	480	480	0.00	0
2577	*Epinephelus itajara*	6/13/2009	TNER	24 46.002	82 59.433	158	77.835	1977.0	520	520	0.00	0
2576	*Epinephelus itajara*	6/1/2010	TSER	24 29.435	83 7.291	114	65.200	1656.1	520	415	10.84	2884
2572	*Epinephelus itajara*	6/1/2010	TSER	24 29.435	83 7.291	114	49.400	1254.8	520	415	23.86	3214
2153	*Epinephelus morio*	7/3/2008	TSER	24 29.367	83 6.863	85	27.000	685.8	150	150	99.33	51767
2166	*Epinephelus morio*	7/3/2008	TSER	24 29.543	83 7.349	88	23.000	584.2	470	470	2.55	56
56749	*Epinephelus morio*	5/8/2009	DRTO	24.6239	82.8312	34	22.500	571.5	1157	804	0.87	216
2154	*Epinephelus morio*	7/6/2008	TSER	24 29.432	83 7.288	123	16.000	406.4	150	151	100.00	63187
49585	*Epinephelus striatus*	7/5/2008	TSER	24 29.43	83 7.322	110	23.000	584.2	1160	1111	3.96	3715
52510	*Epinephelus striatus*	6/11/2009	TSER	24 29.438	83 7.298	105	26.000	660.4	1157	770	81.17	76278
56739	*Epinephelus striatus*	3/27/2011	OPEN	24.6449	-83.1030	75	31.000	787.4	1157	116	7.76	60
49603	*Haemulon plumieri*	5/30/2008	RNA	24.6209	82.8618	32	11.102	282.0	370	370	4.32	257
49601	*Haemulon plumieri*	5/19/2008	DRTO	24 38.553	82 48.909	21	11.378	289.0	370	370	0.00	0
49595	*Haemulon plumieri*	5/27/2008	RNA	24 37.758	82 52.981	33	9.961	253.0	370	370	0.00	0
49602	*Haemulon plumieri*	5/27/2008	RNA	24 37.75	82 52.949	15	10.709	272.0	370	370	0.00	0
2170	*Lutjanus analis*	5/16/2008	DRTO	24 35.583	82 52.687	32	25.500	647.7	470	470	38.94	11985
2175	*Lutjanus analis*	5/17/2008	DRTO	24 35.628	82 52.674	28	24.000	609.6	470	470	5.11	632
2176	*Lutjanus analis*	5/17/2008	DRTO	24 35.625	82 52.673	28	21.700	551.2	470	470	11.91	2238
2174	*Lutjanus analis*	5/22/2008	RNA	24 34.332	82 54.639	40	18.425	468.0	470	470	0.00	0
2185	*Lutjanus analis*	5/24/2008	DRTO	24 36.138	82 56.951	49	24.016	610.0	470	470	1.49	988
2168	*Lutjanus analis*	5/26/2008	RNA	24 36.384	82 54.141	15	22.283	566.0	470	470	80.85	443749
2167	*Lutjanus analis*	5/30/2008	RNA	24 38.853	82 51.419	24	27.244	692.0	470	470	64.89	127088
2177	*Lutjanus analis*	5/30/2008	RNA	24 38.853	82 51.419	24	25.394	645.0	470	470	62.13	7482
49589	*Lutjanus analis*	7/1/2008	TSER	24 29.475	83 7.264	95	20.000	508.0	1160	1115	2.78	958
49590	*Lutjanus analis*	7/1/2008	TSER	24 29.45	83 7.307	107	25.000	635.0	1160	1115	3.95	1099
49591	*Lutjanus analis*	7/1/2008	TSER	24 29.475	83 7.264	95	24.000	609.6	1160	1115	2.87	1933
13675/ 55	*Lutjanus analis*	7/2/2008	TSER	24 29.492	83 7.25	90	18.500	469.9	1160	1114	0.27	31
13674/54	*Lutjanus analis*	7/5/2008	TSER	24 29.432	83 7.288	120	18.000	457.2	1160	1111	1.80	405
13677/ 57	*Lutjanus analis*	7/5/2008	TSER	24 29.432	83 7.288	120	19.000	482.6	1160	1111	22.14	1900
13678/58	*Lutjanus analis*	7/5/2008	TSER	24 29.43	83 7.322	110	19.000	482.6	1160	1111	5.13	1509

13679/ 59	*Lutjanus analis*	7/5/2008	TSER	24 29.43	83 7.322	110	22.750	577.9	1160	1111	1.98	667
2198	*Lutjanus analis*	10/13/2008	RNA	24 37.437	82 56.51	14	23.750	603.3	820	820	20.85	4371
2200	*Lutjanus analis*	10/13/2008	RNA	24 37.437	82 56.51	14	23.250	590.6	820	820	0.37	213
2201	*Lutjanus analis*	10/13/2008	RNA	24 37.437	82 56.51	14	22.500	571.5	820	820	27.44	2768
49587	*Lutjanus analis*	10/13/2008	RNA	24 37.449	82 56.509	14	23.250	590.6	1160	1011	0.20	8
49588	*Lutjanus analis*	10/13/2008	RNA	24 37.437	82 56.51	14	28.250	717.6	1160	1011	4.95	1179
52502	*Lutjanus analis*	10/14/2008	DRTO	24 37.229	82 52.161	7	24.250	616.0	1157	1010	88.12	85379
52503	*Lutjanus analis*	10/15/2008	RNA	24 38.51	82 53.77	36	29.250	743.0	1157	1009	0.40	36
52504	*Lutjanus analis*	10/15/2008	RNA	24 38.51	82 53.77	36	27.750	704.9	1157	1009	43.11	120562
52505	*Lutjanus analis*	10/15/2008	RNA	24 38.51	82 53.77	36	21.000	533.4	1157	1009	98.12	519270
56742	*Lutjanus analis*	5/9/2009	RNA	24 38.693	82 51.074	28	20.500	520.7	1157	417	0.24	7
52507	*Lutjanus analis*	5/12/2009	RNA	24 37.55	82 56.207	15	24.000	609.6	1157	800	59.38	9790
52508	*Lutjanus analis*	5/12/2009	RNA	24 37.55	82 56.207	15	23.000	584.2	1157	800	37.63	2375
52509	*Lutjanus analis*	5/13/2009	RNA	24 38.687	82 51.08	31	25.500	647.7	1157	799	0.00	0
14805/131	*Lutjanus analis*	6/9/2009	TSER	24 29.399	83 7.24	112	24.000	609.6	1122	772	0.26	28
13676/ 56	*Lutjanus analis*	6/9/2009	TSER	24 29.438	83 7.298	105	25.000	635.0	1160	772	1.81	259
13680/ 60	*Lutjanus analis*	6/9/2009	TSER	24 29.438	83 7.298	105	25.000	635.0	1160	772	0.91	371
13682/ 62	*Lutjanus analis*	6/9/2009	TSER	24 29.438	83 7.298	105	28.000	711.2	1160	772	2.46	455
13683/ 63	*Lutjanus analis*	6/9/2009	TSER	24 29.399	83 7.24	112	24.000	609.6	1160	772	2.59	90
52515	*Lutjanus analis*	6/10/2009	TSER	24 29.438	83 7.298	105	24.000	609.6	1157	771	2.08	461
52511	*Lutjanus analis*	6/11/2009	TSER	24 29.458	83 7.384	120	18.500	469.9	1157	770	9.48	5035
52512	*Lutjanus analis*	6/11/2009	TSER	24 29.438	83 7.24	105	26.000	660.4	1157	770	0.39	29
52513	*Lutjanus analis*	6/11/2009	TSER	24 29.438	83 7.24	105	24.500	622.3	1157	770	0.13	19
52514	*Lutjanus analis*	6/11/2009	TSER	24 29.399	83 7.24	112	29.000	736.6	1157	770	32.73	7874
52516	*Lutjanus analis*	6/11/2009	TSER	24 29.438	83 7.24	105	23.000	584.2	1157	770	13.51	2695
13681/ 61	*Lutjanus analis*	6/11/2009	TSER	24 29.438	83 7.298	105	26.500	673.1	1160	770	0.13	1
56746	*Lutjanus analis*	6/12/2009	TSER	24 29.458	83 7.384	120	26.500	673.1	1157	769	0.39	35
56747	*Lutjanus analis*	6/12/2009	TSER	24 29.438	83 7.298	105	28.500	723.9	1157	769	1.04	60
56748	*Lutjanus analis*	6/12/2009	TSER	24 29.438	83 7.298	105	28.000	711.2	1157	769	3.51	809
56744	*Lutjanus analis*	9/25/2009	RNA	24 40.583	82 53.208	41	30.000	762.0	1157	664	21.69	1298
14806/132	*Lutjanus analis*	9/27/2009	RNA	24 37.868	82 55.025	15	30.000	762.0	1122	662	0.00	0
14802/128	*Lutjanus analis*	9/28/2009	RNA	24 40.281	82 53.343	39	22.250	565.2	1122	661	0.45	29
14803/129	*Lutjanus analis*	9/29/2009	RNA	24 37.401	82 56.574	14	29.000	736.6	1122	660	0.00	0
14804/130	*Lutjanus analis*	9/30/2009	RNA	24 37.446	82 56.564	19	24.500	622.3	1122	659	31.26	1295
61851	*Lutjanus analis*	5/30/2010	TSER	24 29.435	83 7.291	114	28.000	711.2	1157	417	97.60	68149

61849	*Lutjanus analis*	5/31/2010	TSER	24 29.435	83 7.291	114	28.000	711.2	1157	416	1.68	52
61853	*Lutjanus analis*	5/31/2010	TSER	24 29.435	83 7.291	114	29.500	749.3	1157	416	10.10	600
61852	*Lutjanus analis*	5/31/2010	TSER	24 29.435	83 7.291	114	27.000	685.8	1157	416	1.92	305
62115/6	*Lutjanus analis*	6/1/2010	TSER	24 29.435	83 7.291	114	35.300	896.6	1122	415	5.78	355
61848	*Lutjanus analis*	3/29/2011	DRTO	24.5925	82.8774	39	30.512	775.0	1157	114	57.02	2383
2173	*Mycteroperca bonaci*	5/21/2008	RNA	24 39.027	82 51.022	35	23.976	609.0	470	470	0.00	0
2169	*Mycteroperca bonaci*	5/26/2008	RNA	24 36.38	82 54.05	20	17.244	438.0	470	470	1.49	259
2171	*Mycteroperca bonaci*	5/29/2008	DRTO	24 35.6	82 52.695	33	24.331	618.0	470	470	51.70	8836
2172	*Mycteroperca bonaci*	5/29/2008	RNA	24 36.418	82 54.156	28	21.575	548.0	470	470	9.15	2874
2184	*Mycteroperca bonaci*	5/30/2008	DRTO	24 35.824	82 52.199	30	22.126	562.0	470	470	1.28	146
2165	*Mycteroperca bonaci*	6/3/2008	DRTO	24 35.513	82 52.372	49	25.197	640.0	470	470	0.64	421
49586	*Mycteroperca bonaci*	10/11/2008	RNA	24 38.912	82 51.003	24	17.000	431.8	1160	1013	0.30	29
52506	*Mycteroperca bonaci*	10/14/2008	DRTO	24 37.229	82 52.161	5	26.250	666.8	1157	1010	73.56	30060
56751	*Mycteroperca bonaci*	5/8/2009	DRTO	24 37.433	82 49.872	34	21.000	533.4	1157	804	43.41	6743
56730	*Mycteroperca bonaci*	5/9/2009	DRTO	24 37.439	82 49.889	34	15.000	381.0	417	803	0.50	5
56731	*Mycteroperca bonaci*	5/9/2009	DRTO	24 37.439	82 49.889	34	18.500	469.9	417	803	0.00	0
56736	*Mycteroperca bonaci*	5/10/2009	DRTO	24 37.376	82 49.948	46	20.500	520.7	1157	802	86.16	53908
21	*Mycteroperca bonaci*	6/10/2009	TSER	24 29.529	83 7.239	90	42.087	1069.0	480	480	62.92	40190
23	*Mycteroperca bonaci*	6/10/2009	TSER	24 29.631	83 6.065	110	36.260	921.0	480	480	56.46	48075
28	*Mycteroperca bonaci*	6/10/2009	TSER	24 29.631	83 6.065	110	36.260	921.0	480	480	0.42	2
29	*Mycteroperca bonaci*	6/10/2009	TSER	24 29.399	83 7.24	112	38.386	975.0	480	480	51.25	29
56741	*Mycteroperca bonaci*	9/26/2009	RNA	24 40.583	82 53.21	42	18.000	457.2	1157	663	50.38	3494
61850	*Mycteroperca bonaci*	5/31/2010	TSER	24 29.435	83 7.291	114	29.000	736.6	1157	416	70.43	30220
61854	*Mycteroperca bonaci*	5/31/2010	TSER	24 29.435	83 7.291	114	26.500	673.1	1157	416	63.22	4078
24	*Mycteroperca bonaci*	6/1/2010	TSER	24 29.435	83 7.291	114	47.900	1216.7	480	415	10.36	846
22	*Mycteroperca bonaci*	6/1/2010	TSER	24 29.435	83 7.291	114	38.500	977.9	480	415	19.52	9734
2571	*Mycteroperca bonaci*	6/1/2010	TSER	24 29.435	83 7.291	114	42.100	1069.4	520	415	61.20	11675
2575	*Mycteroperca bonaci*	6/1/2010	TSER	24 29.435	83 7.291	114	42.100	1069.4	520	415	11.33	1178
62112/3	*Mycteroperca bonaci*	10/10/2010	RNA	24 38.478	82 51.092	26	24.000	609.6	1122	284	1.06	14
62111/2	*Mycteroperca bonaci*	10/10/2010	DRTO	24 38.922	82 50.992	21	22.500	571.5	1122	284	0.00	0
61858	*Mycteroperca bonaci*	10/11/2010	TNER	24 42.56	82 59.427	40	36.500	927.1	1157	283	0.00	0
61857	*Mycteroperca bonaci*	10/11/2010	TNER	24 43.055	82 59.513	60	28.000	711.2	1157	283	1.06	13
56737	*Mycteroperca bonaci*	3/27/2011	TNER	24.6624	-83.0974	79	25.984	660.0	1157	116	75.86	1995
56745	*Mycteroperca bonaci*	3/27/2011	OPEN	24.6547	-83.1014	77	25.984	660.0	1157	117	100.00	14547
56738	*Mycteroperca bonaci*	3/27/2011	TNER	24.6547	-83.1014	77	25.984	655.0	1157	116	4.31	296

61846	*Mycteroperca bonaci*	3/28/2011	TNER	24.7107	-82.9975	63	27.165	690.0	1157	115	2.61	12
56740	*Mycteroperca bonaci*	3/29/2011	OPEN	24.6315	-82.9679	52	21.654	550.0	1157	114	3.51	410
61855	*Mycteroperca venenosa*	10/11/2010	OPEN	24 39.392	83 6.016	72	28.000	711.2	1157	283	0.00	0
49599	*Ocyurus chrysurus*	5/16/2008	DRTO	24 35.583	82 52.687	32	17.008	432.0	370	370	38.11	2129
49597	*Ocyurus chrysurus*	5/17/2008	DRTO	24 35.625	82 52.673	28	15.000	381.0	370	370	1.89	158
49598	*Ocyurus chrysurus*	5/17/2008	DRTO	24 35.625	82 52.673	28	17.008	432.0	370	370	6.49	148
49596	*Ocyurus chrysurus*	5/19/2008	DRTO	24 37.017	82 49.509	20	14.803	376.0	370	370	0.00	0
49600	*Ocyurus chrysurus*	5/19/2008	DRTO	24 37.017	82 49.509	20	15.787	401.0	470	470	0.21	1
52519	*Ocyurus chrysurus*	10/10/2008	DRTO	24 35.589	82 52.683	34	17.250	438.2	417	417	45.80	8736
52520	*Ocyurus chrysurus*	10/10/2008	DRTO	24 35.589	82 52.683	34	16.000	406.4	417	417	19.42	245
52521	*Ocyurus chrysurus*	10/10/2008	DRTO	24 35.589	82 52.683	34	17.500	444.5	417	417	12.47	190
52517	*Ocyurus chrysurus*	10/11/2008	RNA	24 38.912	82 51.003	24	16.500	419.1	417	417	0.00	0
52518	*Ocyurus chrysurus*	10/11/2008	RNA	24 38.912	82 51.003	24	20.250	514.4	417	417	2.88	601
56732	*Ocyurus chrysurus*	5/7/2009	DRTO	24 35.611	82 52.759	31	15.800	401.3	417	417	46.28	1284
56733	*Ocyurus chrysurus*	5/7/2009	DRTO	24 35.611	82 52.759	31	16.800	426.7	417	417	57.07	4057
56734	*Ocyurus chrysurus*	5/7/2009	DRTO	24 35.611	82 52.759	31	14.750	374.7	417	417	0.72	7
61844	*Ocyurus chrysurus*	9/24/2009	DRTO	24 35.509	82 52.628	39	17.300	440.0	417	417	47.48	4743
61845	*Ocyurus chrysurus*	9/24/2009	DRTO	24 35.509	82 52.628	39	16.000	406.4	417	417	95.20	15990
61843	*Ocyurus chrysurus*	9/25/2009	RNA	24 40.583	82 53.208	41	20.000	508.0	417	417	0.00	0
61841	*Ocyurus chrysurus*	9/25/2009	RNA	24 40.583	82 53.208	41	16.000	406.4	417	417	0.96	22
61842	*Ocyurus chrysurus*	9/25/2009	RNA	24 40.523	82 53.149	29	17.000	431.8	417	417	1.68	10

WESTERN SAMBO ECOLOGICAL RESERVE – LOBSTER PROJECT

Introduction

Lobsters were re-surveyed in WSER, Eastern Sambo Special Use Area (ESSUA), Middle Sambo, and Pelican Shoal during 2011. Both WSER and ESSUA are no-take reserves and Middle Sambo and Pelican Shoal are open to fishing. Additionally, for a third year we surveyed lobsters in the outlier reef just beyond the WSER boundaries, where lobsters appear to release their eggs (Bertelsen et al. 2010) To determine lobster size, sex, and abundance inside FKNMS marine reserve zones and their exploited reference areas, we used size distribution surveys and 500 m^2 belt transect surveys during the closed fishing season. Sampling was designed to test the hypothesis that currently established no-take zones sufficiently protect lobsters so that lobsters in these areas become larger and more abundant than those in unprotected areas.

Methods

Lobster - Size distribution surveys

Six hundred sixty-four lobsters were captured for size structure estimates (Tables 4 and 5). We measured lobsters and examined them for molt condition, sex, reproductive status (females), and evidence of disease. We stratified sampling by habitat type because we expected each habitat to shelter a different size range and sex ratio of spiny lobsters (Hunt et al., 1991). Strata included reef crest, patch reef, and outlier reef. We attempted to capture at least 50 spiny lobsters per stratum in the reserves and at reference areas.

Lobster Monitoring - Area Surveys

To compare abundance, we searched for lobsters in reserves (WSER and ESSUA) and reference areas (Pelican Shoal and Middle Sambo) using area-based surveys. Divers counted all lobsters in 187 transects (500 m2) on the reef crest, outlier reef (no reference area), and patch reefs of reserve and reference areas (Table 6). Divers searched a 5 m wide area on each side of a 50 m tape and replicated this measure at each site. On the reef crest we targeted sites with complex habitat where lobsters are more likely to reside, so that we would be more likely to see differences in lobster abundance between reserves and reference sites. Targeting high quality habitat should result in higher abundance because high quality habitat contains more potential dens for lobsters. Survey sites at patch reefs and at the outlier reef were randomly selected because we had not yet completed a sufficient number of surveys at those habitat stratum to determine where the high quality habitat exists.

Lobster Monitoring - Statistics

Mean size of lobsters from the reef crest was compared using ANOVA. Size data on males and females were separated to control for the different ratios of males to females in our samples, since females are often more abundant and males are usually larger. The mean size for both males and females on the patch reef sites were compared with independent samples t-tests. We did not include the outlier reef since it did not have a comparable reference area. Differences in lobster size between habitat types were compared using ANOVA, a Mann-Whitney test, and a Kruskal-Wallis test. Tests of sexual dimorphism (male - female size) for the reef crest comparing

reserves to reference areas were conducted using a multiple t-test assuming unequal variance due to the unequal sample sizes. Differences in lobster density between regions were evaluated using ANOVA and independent samples t-test. Again, we did not include the outlier reef, since it did not have a reference area. Differences in lobster density between habitat types were evaluated using a Kruskal-Wallis test.

Results and discussion

Lobster - Inside and outside the Marine Reserves

There were significant differences in size of both male and female lobsters from the reef crest regions (Pelican Shoal, WSER, Middle Sambo and ESSUA) (Table 5, males: ANOVA, d.f. = 3, F = 2.88, P = 0.037, females: ANOVA, d.f. = 3, F = 3.90, P = 0.009). For both males and females, lobsters from WSER were significantly larger than lobsters from Pelican Shoal. There were no other significant differences in size between regions.

For patch reefs there was no difference in the size of females between regions (*t* test, d.f. = 42, *t* = -1.393, *P* =0.171), but there was a difference in the size of males between regions (*t* test, d.f. = 65, *t* = -4.058, *P* =0.000). Males from patch reefs in WSER were larger than males from patch reefs near Pelican Shoal. It is not unusual for there to be a significant difference in size between regions for males but not for females, because female growth slows down upon maturation (Lipcius and Herrnkind 1987; Bertelsen et al. 2004). This year's size distribution data were more consistent with previous year's results, whereas last year the males were unusually small. The aberration in the size data last year appeared to be a result of an influx of new recruits, and should not be interpreted as a marine protected area that is ineffective at retaining large male lobsters.

Lobster- habitat type

There were significant differences in lobster size between habitat types for male lobsters at Pelican Shoal (Table 5, males: *Mann-Whitney Test*, *Z* = -2.372, *P* =0.018) but no differences in size between habitat types for females (*Mann-Whitney Test*, *Z* = -.368, *P* =0.713). Male lobsters on the Pelican Shoal reef crest were larger than those on nearby patches. There were no differences in size of lobster between habitat types for male or female lobsters at WSER (females: Kruskal-Wallis Test, χ^2 = 2.61, d.f. = 2, *P* = 0.271; males: ANOVA, d.f. = 2, F = .932, P = 0.397).

Lobster - Sexual size dimorphism

A comparison of mean carapace length (CL) between male and female lobsters is presented in Table 7. A functional marine protected area should retain mature animals, and since adult male lobsters are likely growing faster than adult female lobsters (Lipcius and Herrnkind 1987, Bertelsen et al. 2004), significant differences in size between males and females should be an indicator of an effective marine protected area. The average size difference between sexes for the past 6 years indicates sexual size dimorphism is generally greatest in the large reserve, WSER, and decreases with distance from WSER (Maxwell et al. 2010). This year there were significant differences in size between sexes at all of the reef crest locations, and the greatest differences were found in the reserves. At the patch reefs, there were differences in size between sexes at

WSER, but not at Pelican. And there were no significant size differences between males and females at the Western Sambo outlier reef.

Lobster - Density

Lobster densities per 500 m2 transect are reported in Table 8. There were no differences in density of lobsters between any of the reef crest locations (Pelican Shoal, WSER, Middle Sambo and Eastern Sambo) (ANOVA, d.f. = 3, F = .256, P = 0.857) or patch reef locations (Pelican Shoal and WSER) (*t* test, d.f. = 38, *t* = -1.226, *P* =0.228). However, there were significant differences in density between habitat types (Kruskal Wallis, d.f. = 2, Chi-Square = 30.075, P = 0.000). There were more lobsters on the reef crest than at patch reefs. As expected, using our new site selection method, lobster densities were higher at reef crest sites, but unexpected was the lack of resolvable differences in densities between regions.

Lobster – Outlier reef

Similar to the previous two years, the sex ratio at the outlier reef was more skewed towards females than at other locations (Table 4). This result is consistent with FWC's observations of lobsters tagged with sonic tags. The outlier reef appears to be where a number of females go to release their eggs (Bertelsen et al. 2010). The influx of migrating females could account for the skewed sex ratio during the breeding season (Mar-Sept).

Future Work

Lobster

With reduced funding next year, we will still endeavor to continue the annual lobster abundance and size structure surveys in and adjacent to WSER using state funding sources. We will continue these important lobster studies because of our commitment to the management of NOAA's Florida Keys National Marine Sanctuary.

Additionally, in future surveys we will continue to incorporate habitat assessments into our surveys so that we can select survey sites stratified by habitat quality, similar to the stratified random sampling design used for the Keys-wide visual reef fish surveys (Brandt et al. 2009). This methodology will allow us to relate lobster size and abundance to habitat quality. Differences in the surveyed habitat could explain some of the annual variability in lobster size and abundance.

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Jessica Snook, FWC

Table 1. Number of lobsters collected for size distribution analysis by region and habitat (males/females).

		Habitat		
Region **(Bold = reserve)**	Reef crest	Outlier reef	Patch reef	Total
Pelican Shoal	164 (57/107)		46 (33/13)	210(90/120)
Eastern Sambo (SUA)	68 (29/39)			68 (29/39)
Middle Sambo	105 (37/68)			105 (37/68)
Western Sambo (ER)	175 (65/110)		65 (34/31)	240(99/141)
Western Sambo		41 (8/33)		41 (8/33)
Total	512(188/324)	41 (8/33)	111(67/44)	664(263/401)

Table 2. Mean size of lobster by sex, habitat, and region.

Habitat	Region (**Bold = reserve**)	Males	Females	Overall
		Mean ±SD	Mean ±SD	Mean ±SD
Reef crest	Pelican Shoal	82.6±9.0	75.7±6.0	78.1±7.9
	Eastern Sambo SUA	86.7±9.9	77.8±7.5	81.6±9.6
	Middle Sambo	83.1±9.2	77.5±8.6	79.4±9.2
	Western Sambo ER	88.0±14.8	79.1±7.2	82.4±11.5
Patch reef	Pelican Shoal	70.8±18.6	70.8±17.4	70.8±18.1
	Western Sambo ER	88.1±16.1	76.7±10.5	82.7±14.8
Outlier reef	Western Sambo	80.6±4.3	77.2±4.9	77.9±5.0
	Overall	83.6±14.1	77.2±8.0	79.7±11.3

Table 3. Number of transect (500m2) surveys conducted by region (note: Patch reef transects were stratified equally into 10 top and 10 side transects).

	Habitat			
Region **(Bold = reserve)**	Reef crest	Outlier reef	Patch reef	Total
Pelican Shoal	39		22	61
Eastern Sambo (SUA)	19			19
Middle Sambo	21			21
Western Sambo (ER)	38		18	56
Western Sambo		30		30
Total	117	30	40	187

Table 4. Results of multiple t-tests comparing mean size (CL) of male and female lobsters. Although not all of the results are significant, the mean male size was always larger than the mean female size.

Location(**bold = reserve**)	t	df	Sig. (2 tailed)	Mean difference
Pelican Shoal reef crest	5.13	83.24	0.00	6.8 mm CL
Eastern Sambo SUA reef crest	4.19	66.00	0.000	8.8 mm CL
Middle Sambo reef crest	3.08	103.00	0.003	5.6 mm CL
Western Sambo ER reef crest	4.57	82.02	0.000	9.0 mm CL
Pelican Shoal patch	.013	44.00	0.990	0.08 mm CL
Western Sambo ER patch	3.35	63.00	0.001	3.4 mm CL
Western Sambo outlier reef	1.81	39.00	0.078	3.4 mm CL

Table 5. Number of lobsters per 500m2.

Region **(Bold = reserve)**	**Habitat**			
	Reef crest Mean±SD	Outlier reef Mean±SD	Patch reef Mean±SD	Overall Mean±SD
Pelican Shoal	4.85±7.09		1.14±2.29	3.51±6.08
Eastern Sambo (SUA)	3.84±2.95			3.84±2.95
Middle Sambo	5.43±4.77			5.43±4.77
Western Sambo (ER)	4.82±5.86		2.00±2.11	3.91±5.12
Western Sambo		1.40±1.54		1.40±1.54
Total	4.78±5.74	1.40±1.54	1.53±2.23	3.54±4.95

FLORIDA KEYS LOBSTER PROJECT.

Lower Keys Gulf side acoustically tagged lobsters (May 25, 2011 to July 26, 2011)

Executive Summary

On May 25th, we tagged 31 lobsters north of Sawyer Key within a grid of 17 VR2 receivers and an emigration ring 5 km in diameter around the grid (Figure 1). By Jun 16th, divers making routine inspections of casitas had recovered three tags from molted lobsters. On Jun 21st, we tagged an additional 3 lobsters with those tags. Two tags failed at the outset, one apparently fell off and another lobster likely died after tagging. Therefore, in effect, we tagged a net of 32 lobsters.

Summarized results and conclusions

1) There is no appreciable difference in emigration rates of Lower Keys Gulfside lobster than emigration rates reported the literature.

2) There is no significant difference in the rates of daily location shifts (i.e.; a location shift greater than 300 m) of Lower Keys Gulfside lobsters than daily location shifts of WSER lobsters although our estimate is lower for the Gulfside. Problems with the tracking grid lower the confidence of the estimated rate.

3) Although only two egg bearing females were tagged, neither showed any evidence of a reproductive migration such as exhibited by an overwhelming majority of WSER females.

4) The most striking difference between Lower Keys Gulfside lobsters and WSER lobsters is that Gulfside lobsters emigrate to the west and WSER lobsters emigrate in all directions.

Methods

On May 24-25, we deployed 38 VR2 acoustic receivers north of Sawyer Key (Figure 1) in 25 to 35 ft of water. Seventeen receivers were configured into a tracking grid 300m apart (Figure 2). The remaining receivers formed a ring 5km wide around the tracking grid (Figure 2). Within the grid and on 4 different casitas, we tagged a total of 31 lobsters. On subsequent dives, divers found three molts with acoustic tags. On June 21, we retagged three lobsters with those tags. On July 26, we retrieved all the receivers and downloaded the data into an Access database.

Results and Discussion

We could only estimate positions of lobsters within the tracking grid to a resolution of 300 m rather than the planned 30-50 m because the listening range of the receivers was reduced at night

for reasons unknown. Range testing of the tags was conducted during daylight. The loss of acoustic clarity could be due to nocturnal activity of snapping shrimp and/or other factors that severely reduced the range of the receivers. However, many emigrations were detected and every emigration was to the west.

The fate of each tagged lobster is catalogued in Table 1.

Emigration was defined by examining the pattern of transmissions detected by receivers. When a lobster's transmissions end on the tracking grid, then are briefly detected on the 5km wide emigration ring, this pattern is interpreted as emigration. One lobster that was detected on the emigration ring, returned to the grid the night later. This was not scored as emigration. Another lobster "wandered" off the grid to the NNW over the course of several days. This too was not scored as an emigration because the movement pattern resembled a series of "den shifts" which we have seen in other studies. One rapid departure to the west was not subsequently detected by the emigration ring. This was scored as a likely emigration.

When a lobster's transmissions become fixed on one receiver and are relatively constant throughout the day, this is scored as a molted lobster.

Overall, there were 12 identifiable migration events from 34 tagged lobsters (35%). All migrations were westward (between 225^{o} and 295^{o}). There were also 11 events that I interpret as molting. Three molts were confirmed by divers.

The overall daily emigration rate is estimated at 1.4% through 62 days (equal to the number of migrations divided by the sum of the number of tagdays [sum of the number of days each tag is dectected]).

These emigration rates are in line with published results. Olsen et al. (1972) reported daily emigration rates and 0.6% and 2.6% at two sites. Bertelsen and Hornbeck (2009) reported an overall emigration for male lobsters at WSER at 25% over thirty days. The Olsen et al. (1972) extrapolates to 34% at 30 days.

Another measure of movement I measured was the changes in the daytime positions of lobsters. This was determined by accumulating the latitude and longitude of all transmissions of a given lobster recorded between 8am and 6pm, then calculating a centroid. Because the tracking resolution of this grid was very poor, I looked only at frequencies of daytime position changes that were greater than 300m and compared that to frequencies of daytime position change greater than 300m in the WSER lobsters.

Overall, the frequency of changes in daily position greater than 300m was 9% (43 of 478) in this study. In the earlier WSER study, we found the frequency of daily position changes greater than 300m ranged between 10% to 35% depending on size class (larger lobsters change positions less

frequently). The 9% estimate for Gulfside lobsters is within line of large (90-110mm CL) WSER lobsters (10%) but is lower than medium sized (75-90 mm CL)WSER lobsters at 25%. The lower rate of large shifts (>300m) in daily position of Gulfside lobsters could be due to several factors; (1) the tracking grid on the Gulfside did not work as well as WSER and therefore large shifts were difficult to detect and (2) The gulfside is much more structurally simple with far fewer large den complexes for lobsters to choose and therefore lobsters shift dens with less frequency on the gulfside.

Conclusions

1. Acoustic data reveal an unambiguous westward motion of a portion of the gulfside resident lobsters. The movement is similar in magnitude to nomadic movements of oceanside resident lobsters however oceanside residents move in all directions. The destination of this westward migration is unknown.

2. Den shifting and movement between casitas occurs at a rate similar but smaller than patch reef shifting of oceanside residents. The overall smaller rate of den shifting in gulfside residents may be due to the lower number of large suitable shelters on the gulfside.

3. Although only two females with eggs were tagged, neither exhibited any evidence of a reproductive migration as seen in oceanside residents. This may be a consequence of the extreme rarity of reproductive activity on the gulfside and because deepwater habitat (the destination of oceanside females) is too far away (i.e.; the 60 ft contour is 25 to 50 kilometers from the study site).

Future plans

This initial study establishes a clear and unambiguous direction for adult and subadult migration of gulfside resident lobsters. One important goal is to determine the ultimate destination(s) of these lobsters and determine the location of their breeding grounds. A followup study is proposed to determine the direction of travel occurring north of Key West. Possibilities include (1) an Oceanside movement through channels near Key West or Marquesas, (2) a continuous westward migration in the direction of the Dry Tortugas, and (3) dispersal into deeper Gulfside waters. An Oceanside movement would establish connectivity between Gulf and Oceanside residents.

Literature Cited

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Olsen D.A., W.F. Hernnkind and I.G. Koblick. 1972. Ecological study for the development of lobster management techniques. Puerto Rico Inter-National Undersea Laboratory special report 1, Sea Grant study. 101 p.

Acoustic Lobster Team

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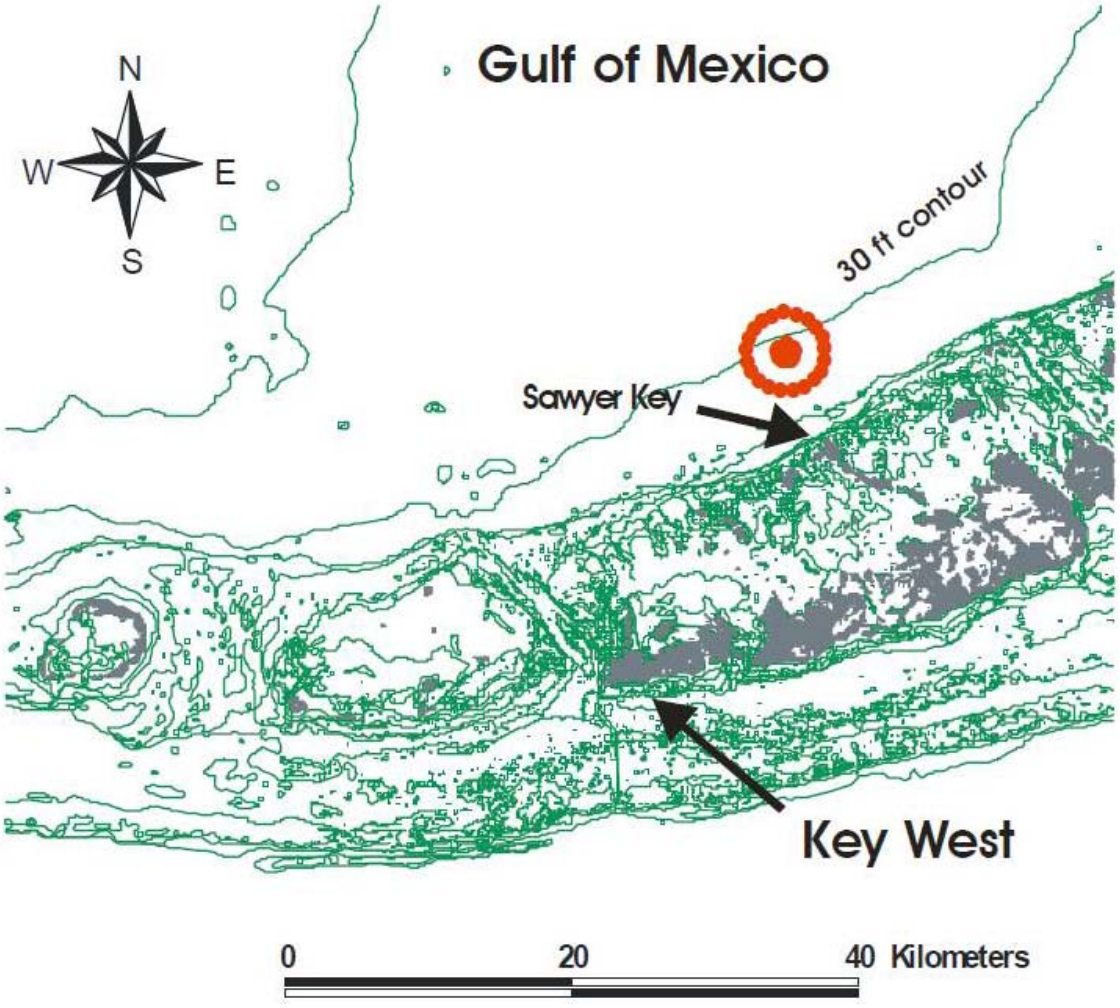

Figure 1. Location of study

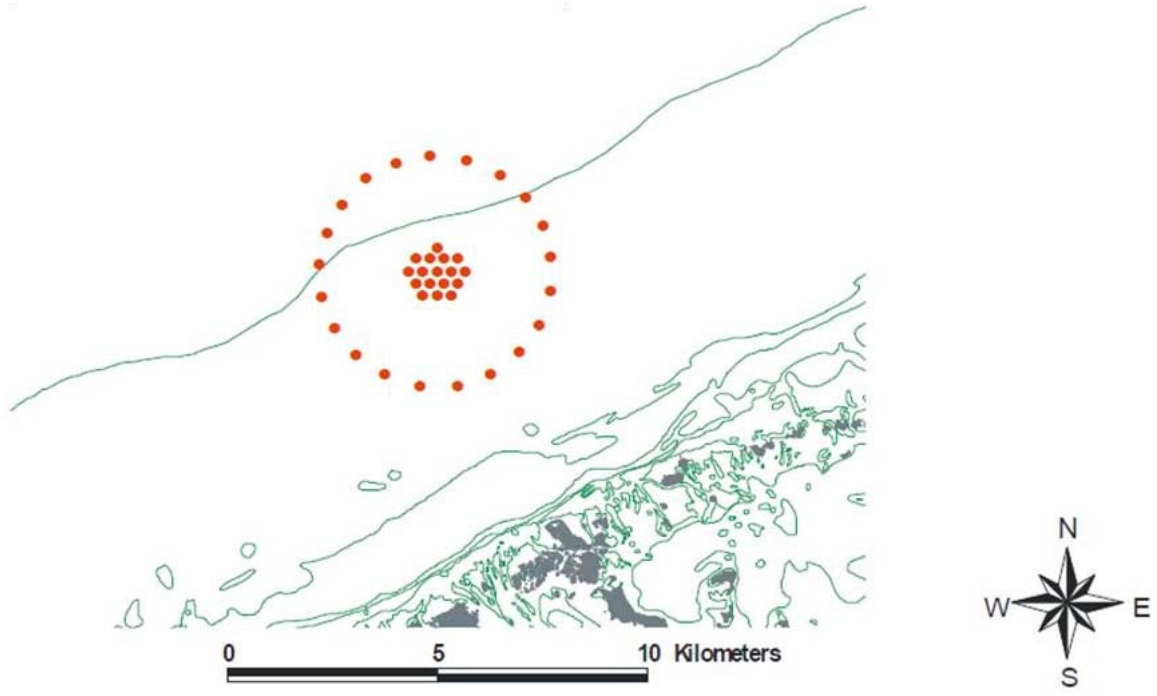

Figure 2. A. The inner VR2s tracking grid (300m inter-receiver distance) and emigration ring (5km diameter, 750 m inter-receiver distance).

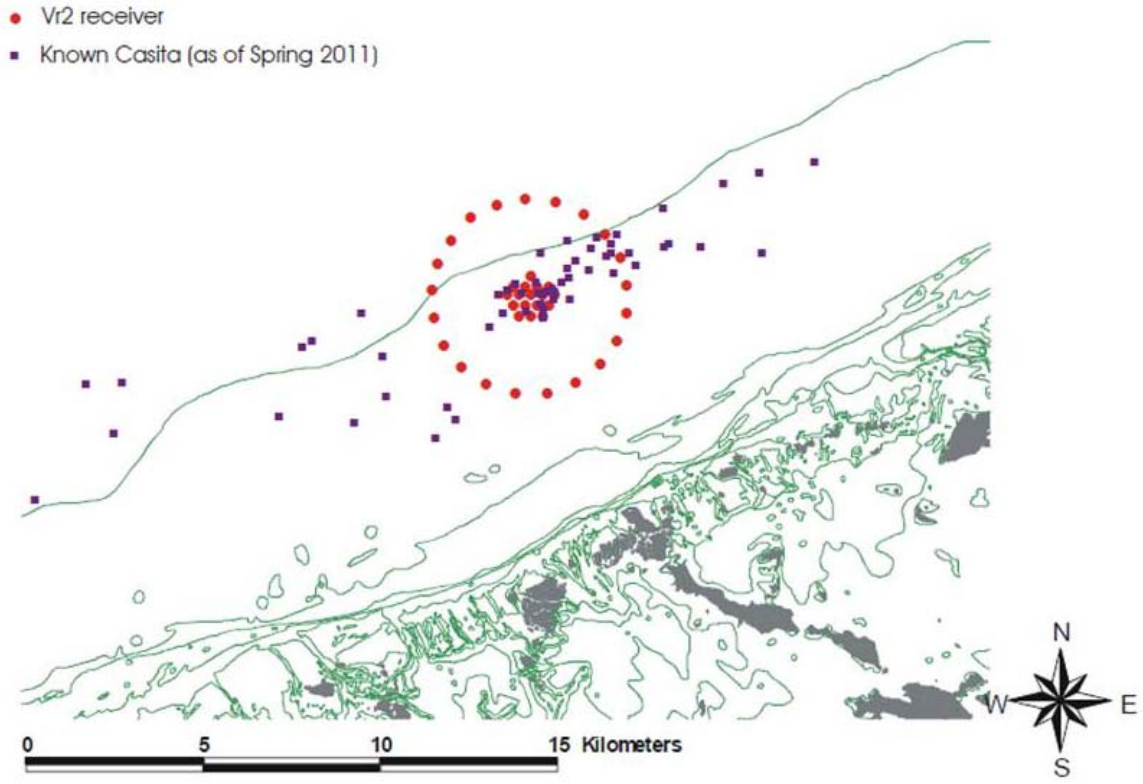

Figure 2. B. Wider view showing location of mapped casitas as of spring 2011.

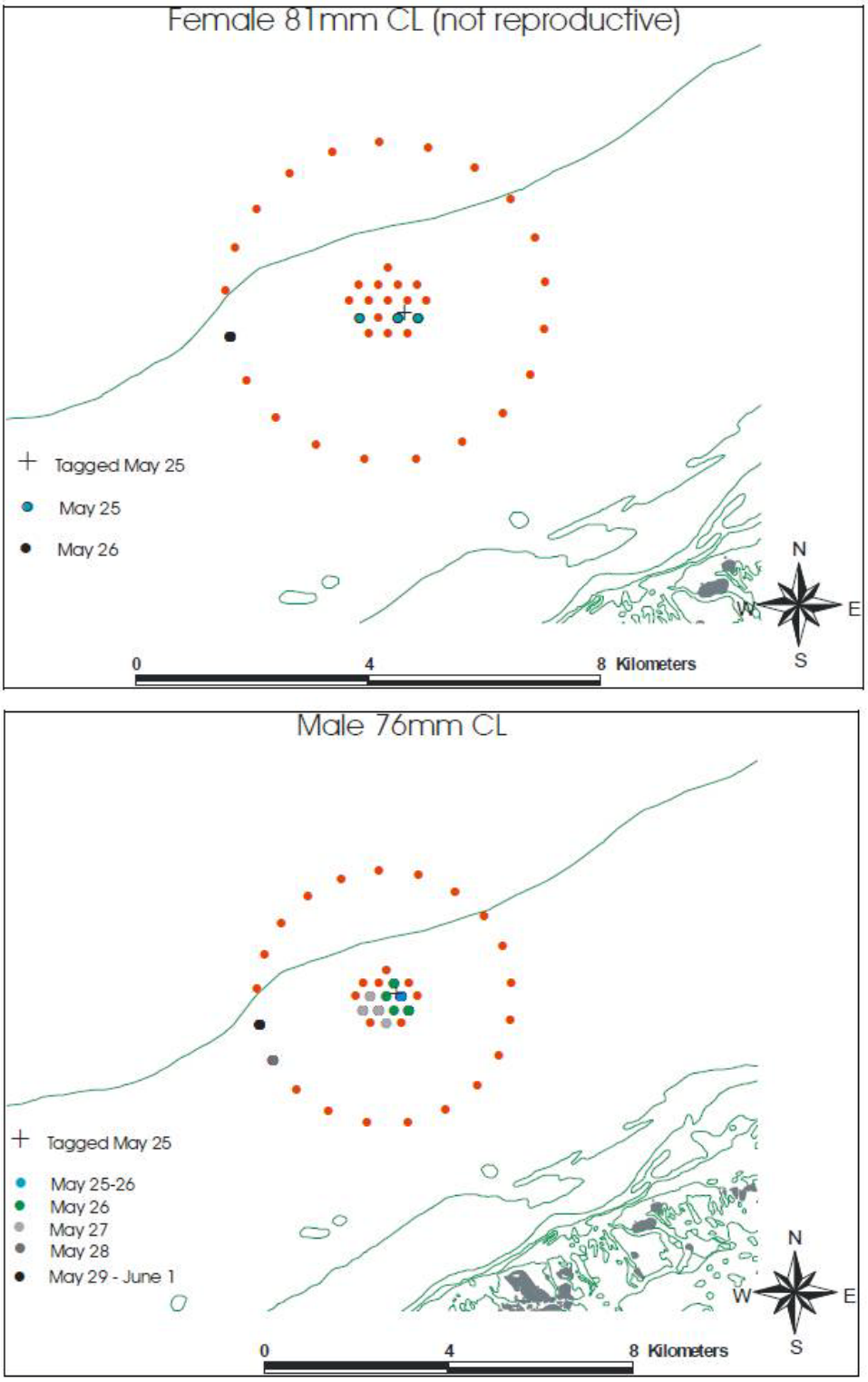

Figure 3. Sample emigration tracks males and females.

Table 1. Fate summary of each tagged lobster (two pages). EOS = status of Eggs (N=none, B=brown), Ovaries (N=not ripe), Spermatophore (N=none, E=eroded). First day=tagging date. Last day=date of last detection. At large = number of days of detection. Adjusted at large = censured to exclude days after when I believe the lobster has molted or died. N of VR2 contacts = number of unique VR2s that detected a given tag. Fate = description of fate of each lobster as interpreted from the VR2 record.

code	sex	Size (mm)	(EOS)	First day	Last day	At large(days)	Adjusted at large	Transmissions	N of VR2 contacts
15403	M	96		25-May-11	25-Jul-11	61	0	1288	2
15422	M	92		26-May-11	16-Jun-11	1	0	2943	3
15405	F	81	NNN	25-May-11	26-May-11	1	1	34	4
15406	F	78	BNE	25-May-11	26-May-11	1	1	33	7
15420	F	81	NNN	25-May-11	26-May-11	1	1	102	3
15419	F	76	NNN	25-May-11	2-Jun-11	8	1	18	4
15413	F	83	NNN	25-May-11	29-May-11	4	4	70	4
15418b	M	81		21-Jun-11	25-Jun-11	4	4	103	4
15402	F	78	NNN	25-May-11	30-May-11	5	5	78	6
15408	M	76		25-May-11	1-Jun-11	7	7	376	11
15415	F	81	NNN	25-May-11	3-Jun-11	8	8	461	3
15404	M	95		25-May-11	4-Jun-11	10	10	3336	5
15426	F	77	NNN	25-May-11	26-Jul-11	62	10	10111	6
15416	F	84	NNN	25-May-11	5-Jun-11	11	11	30	5
15424	M	85		25-May-11	26-Jul-11	62	15	8002	4
15409	F	77	NNN	25-May-11	11-Jul-11	47	16	1857	6
37260	F	80	NNN	25-May-11	26-Jul-11	62	16	1270	6
15418	M	90		26-May-11	15-Jun-11	21	21	214	4
15417	F	81	NNN	25-May-11	22-Jul-11	58	22	3377	9
15423	F	78	NNN	25-May-11	26-Jul-11	62	24	4545	4
37266	F	89	NNN	25-May-11	26-Jul-11	62	25	2306	5
37262	M	84		25-May-11	26-Jul-11	62	28	9107	7
15415b	M	94		21-Jun-11	26-Jul-11	36	36	877	3
15422b	M	83		21-Jun-11	26-Jul-11	36	36	3182	10
15421	F	79	NNN	25-May-11	19-Jul-11	55	37	1224	6
15411	M	86		26-May-11	26-Jul-11	61	37	4980	7
15410	F	80	NNN	25-May-11	11-Jul-11	47	47	684	10
15412	F	85	NNN	25-May-11	17-Jul-11	53	53	11567	5
15414	F	86	NNN	26-May-11	20-Jul-11	55	55	500	3
15407	F	89	NNN	25-May-11	20-Jul-11	56	56	1807	5
15399	M	81		25-May-11	21-Jul-11	57	57	1264	3
15425	F	91	NNN	25-May-11	25-Jul-11	61	61	1196	8
37259	F	85	BNN	25-May-11	26-Jul-11	62	62	2215	14
37268	F	83	NNN	25-May-11	26-Jul-11	62	62	3557	6

code	Fate
15403	Likely died during tagging, no movement
15422	appears to have lost the tag on the first day
15405	Emigrated to the west on the second day
15406	Very likely emigrated west on the second day, not detected by ring
15420	Emigrated to WSW on second day
15419	Emigrated to WNW on 2nd day, spurious single ping on 2-Jun in mid-grid
15413	"Wanders" off to the northwest off the grid in four days
15418b	Stayed on grid through Jun 25, may have emigrated to the west on that day
15402	Emigrated to west on 5th day (W)
15408	Emigrated to west on 11th day (WSW)
15415	stayed, likely molted on Jun 3
15404	stayed near vr2 next to casita, then moved off grid NNW on night of June 3-4
15426	stayed on grid, may have molted by Jun 4th
15416	Emigrated to west on 5th day (WSW)
15424	stayed on grid, probably molted Jun 9th
15409	stayed on grid through Jun 10th, then perhaps molted near the center of the grid
37260	stayed on grid, likely molted around jun 10th
15418	stayed on grid, unsure about time of molting
15417	remained on grid, may have molted on Jun 16th
15423	stayed on grid, possibly molted around Jun 18th
37266	stayed on grid, may have molted by Jun 19
37262	stayed on grid, likely molted by jun 22
15415b	stayed in local area
15422b	stayed on grid, can detect a foraging pattern where the lobster repeatedly foraged for the south, then to the east
15421	stayed within or near grid; lost contact Jul 1
15411	Stayed on grid at least to July 1, then molted(?)
15410	stayed on grid through July 11, lost contact on west side of grid at that time
15412	stayed on grid
15414	stayed on grid
15407	Stayed on the grid
15399	Remained on grid
15425	stayed on grid
37259	left the grid near midnight 30 May returning to the grid on the night after midnight 1 June (about 26 hours later).
37268	stayed on grid,

Appendix 1.

Synoptic Cruise Report
20 April 2011

Performance evaluation of marine zoning in the Florida Keys National Marine Sanctuary: Black grouper spawning aggregation Cruise 2011; assessment of Riley's Hump deep ecosystem by *in situ* and remote sampling techniques

INTRODUCTION

Reef habitats occupying areas deeper than 35 m (115 ft) are generally considered deep habitats and occur throughout the tropics and in many areas of the Florida Keys and the Dry Tortugas region. However, these refugia have been poorly documented compared with more easily accessible shallow-water reefs. An understanding of deep reef fish communities is vital as these ecosystems support commercially important fish and invertebrate species. Current knowledge of deep reef areas have been limited due to logistical difficulties and expenses associated with sampling these areas. Fish abundance data must be collected using specialized technical divers to increase bottom time, remote sampling units such as ROV or autonomous underwater vehicles (AUV).

In March, 2011, scientists from the Florida Fish and Wildlife Conservation Commission (FWC) and the Caribbean Coral Reef Institute (CCRI) of the University of Puerto Rico (UPR) embarked on a five day mission aboard the M/V Spree to study and identify black grouper spawning aggregations at Riley's Hump (RH), located within the Tortugas South Ecological Reserve (TSER). This was the fourth expedition by staff of the FWC South Florida Regional Laboratory and partner agencies to assess and monitor spawning aggregations of snappers and groupers in this important multi-species aggregation site, and the first expedition with members of the technical diving team of CCRI.

In the past, efforts have been directed at the study of mutton snapper spawning aggregations in this region during the spring and summer months. Data from acoustically tagged snappers and groupers has demonstrated connectivity between the network of marine reserves existing in the Dry Tortugas region (Figure 1). Advantageous conditions exist to learn about the habitat and depth occupied by these fish other than during periods when tagged fish were being detected by relatively shallow acoustic receivers. The exceptional number of fish, short distances between shallow (28 m ~90 ft.) and deep (45 m ~150 ft.) habitat, and the proportionally comprehensive receiver coverage, have made Riley's Hump an ideal location for documenting the exchange of reef fishes between these habitats. The present mission provided a unique opportunity to identify and record sites for winter spawning groupers and to document the presence and abundance of groupers and snapper at depth not accessible by FWC scuba ranges of about 100 – 115 ft (30 – 35 meters).

The present project has aimed to build on past research and monitoring in the Florida Keys National Marine Sanctuary (FKNMS) by FWC and focused 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, a type of marine reserve), the Tortugas North Ecological Reserve (TNER) and spawning habitat at Riley's Hump, located within the TSER. Recent diver surveys have successfully identified spawning aggregations in Riley's Hump and demonstrated the spatial connectivity among these reserves. Still, an important knowledge gap exists concerning the connectivity of snappers and groupers in the area. This has led to the question regarding the exchange of reef fishes between deep and shallow water habitat. To examine this connectivity, the project conducted visual censuses using open-circuit scuba (i.e., air, Nitrox systems) and closed-circuit rebreather (CCR-Trimix) diving, a remote operating vehicle (ROV) and acoustic sonar (split-beam echosounder) surveys. These activities were used to enhance our knowledge in the use and the distribution of snappers and groupers in deep water reefs of Riley's Hump.

Under the direction of Chief Scientists Alejandro Acosta, (FWC) and Dr. Richard Appeldoorn (CCRI), a team of three scuba divers (Milton Carlo, Michael Nemeth and Yvonne Bejarano) using closed-circuit re-breather (CCR-Trimix) systems conducted visual censuses in deeper parts of the hump. In addition, shallow divers (David Eaken, Paul Barbera, Michelle Dancy, Marie Tellier, Ben Binder and Danielle Morley) downloaded the VR2 receivers located at Riley's Hump using open-circuit scuba (i.e., air, Nitrox). Dr. Richard Appeldoorn and Dr. Francisco Pagan (CCRI), deployed and conducted the remotely operated vehicle (ROV) over the deep habitat to complement the information collected by the technical divers. Danielle Morley led the split beam sonar mission to map the new areas surveyed by the divers and the ROV. Paul Barbera led the selection of new sampling sites based on the existing bathymetric charts of the area. Marie Tellier kept the day to day log of the cruise. David Eaken and Milton Carlo were the dive safety officers for this cruise.

OBJECTIVES

1) Determine the connectivity between shallow portions of Riley's Hump (<120 feet) and deep reef habitats at Riley's Hump (>120 feet) by documenting the presence, abundance and movement of reef fishes and describing coral reef habitat in this area.

> a) Conduct visual censuses of fish and associated habitat in the deeper waters of Rileys Hump. The censuses was conducted using open-circuit scuba (i.e., air, Nitrox) and closed-circuit rebreather (CCR-Trimix) diving. Each diver conducted one dive per day for a total of 4 dives. High-definition video was taken of the seafloor, and all fish species were identified, counted and measured. Although finfish were the predominate focus of the project, video data collected could also be used to assess biotic cover, invertebrates, and other habitat metrics.

b) Fish populations were surveyed using a Remote Operating Vehicle (ROV) supplied by the University of Puerto Rico. ROV surveys were conducted in waters deeper than the maximum diving depth planned for this mission (200 ft). ROV surveys were also conducted where SCUBA divers previously surveyed, so that the two methods could be compared.

2) Deploy acoustic receivers (VR2), and associated stands in deeper (150') water of Riley's Hump. Four VR2 stands will be deployed if determined necessary with a mid-water buoy attached to each stand.

METHODS

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Richard Appeldoorn	ROV Operator			CCRI/UPR
Francisco Pagán	ROV Operator			CCRI/UPR
Michael Nemeth	Mixed gas			CCRI/UPR
Yvonne Bejarano	Rebreathers			CCRI/UPR
Milton Carlo	DSO			CCRI/UPR

STUDY AREA

The Tortugas Ecological Reserves (TSER & TNER) and the Research Natural Area (RNA) are no-take marine reserves located adjacent to and within the Dry Tortugas National Park (DRTO), 70 miles west of Key West, FL, USA (Figure 1). These reserves (600 km2) protect a variety of habitat including: shallow sea grass and hard bottom nursery grounds, Riley's Hump (RH) (30 m), an offshore reef fish spawning aggregation site, and deepwater habitat > 600 m. This network of reserves is designed to enhance sustainability and biodiversity throughout the Tortugas and the Florida Keys coral reef ecosystem by creating a refuge for numerous exploited fishery resources, including snappers and groupers.

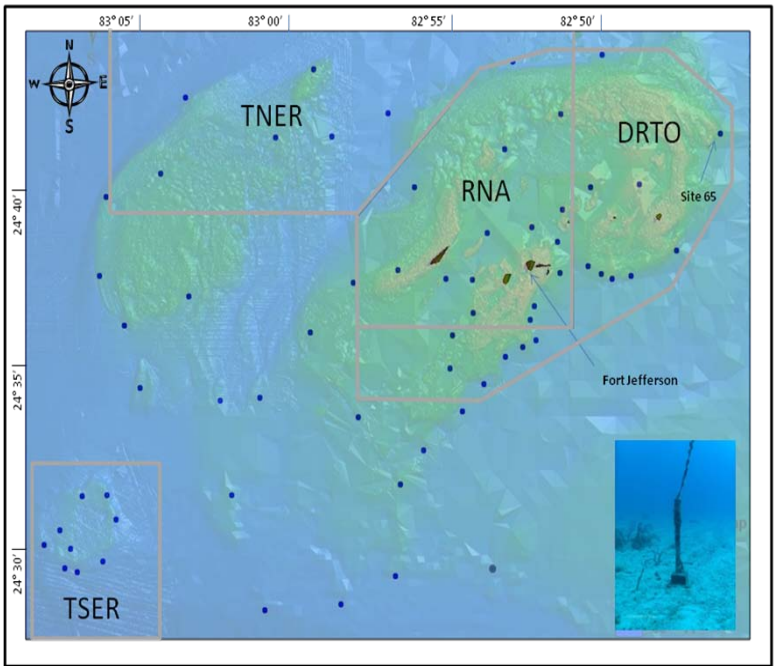

Figure 1. Location of Acoustic Receivers (VR2) in the Dry Tortugas Region

SAMPLING PLATFORM

The M/V Spree is a 100-ft liveaboard vessel based in Key West, Florida. The vessel was used as the sampling platform for this cruise (Figure 2). The "Spree" is designed for open ocean diving and offers rebreather support during tech trips. Additionally, the ship is fitted with a boom arm to connect the sonar transducer.

Figure 3. The M/V Spree.

REMOTELY OPERATED VEHICLE

The high quality video and digital still imaging capabilities of the Seabotix ROV (Figure 3) was used to estimate the distribution and abundance of fish and invertebrates at each study site.

Figure 3. The CCRI/ University of Puerto Rico Seabotix ROV and crew working the cable.

CLOSED-CIRCUIT REBREATHER (CCR-TRIMIX) DIVING

Three closed-circut rebreather divers conducted fish visual censuses as well as photo and video transects in deeper waters of Riley's Hump (Figure 4).

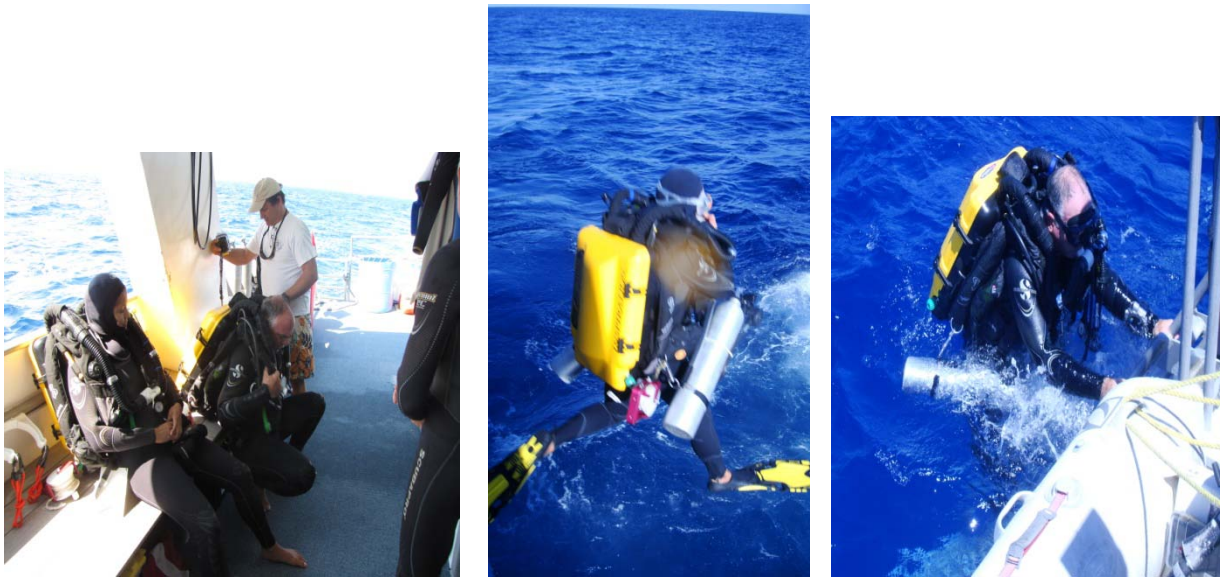

Figure 4. Rebreather divers checking equipment and entering the water and returning from the dive.

ROV and Rebreathers Data Analysis

Video Tape Analysis – All fish observed during the two minute transects were tabulated and identified (to species when possible). Sessile epifauna greater than 2 cm in height (e.g., gorgonians, sponges, black corals, crinoids) observed in the video frame during each transect were also quantified. Epifauna was identified to lowest possible taxa, and grouped into functional categories (i.e., see fans, branching corals). Navigational logging of the ROV provided by the Spree was used to determine the approximate length of each transect. When possible, average density (individuals/m^2), of fish was estimated. The ROV operation video and images were stored at the FWRI South Florida Regional Lab(SFRL), Marathon, Florida.

BENTHIC MAPPING

The use of single-beam sonar technology generated acoustic bathymetric and habitat maps of Fish Spawning Aggregation (FSA) sites.

Figure 5. Transducer and pole on the M/V Spree

PRELIMINARY RESULTS

Sampling Stations

Nine VR2 stations located in Riley's hump were visited and serviced (Figure 6). The VR2 receivers were brought back onto the boat, their data downloaded and their respective batteries changed and then re-deployed.

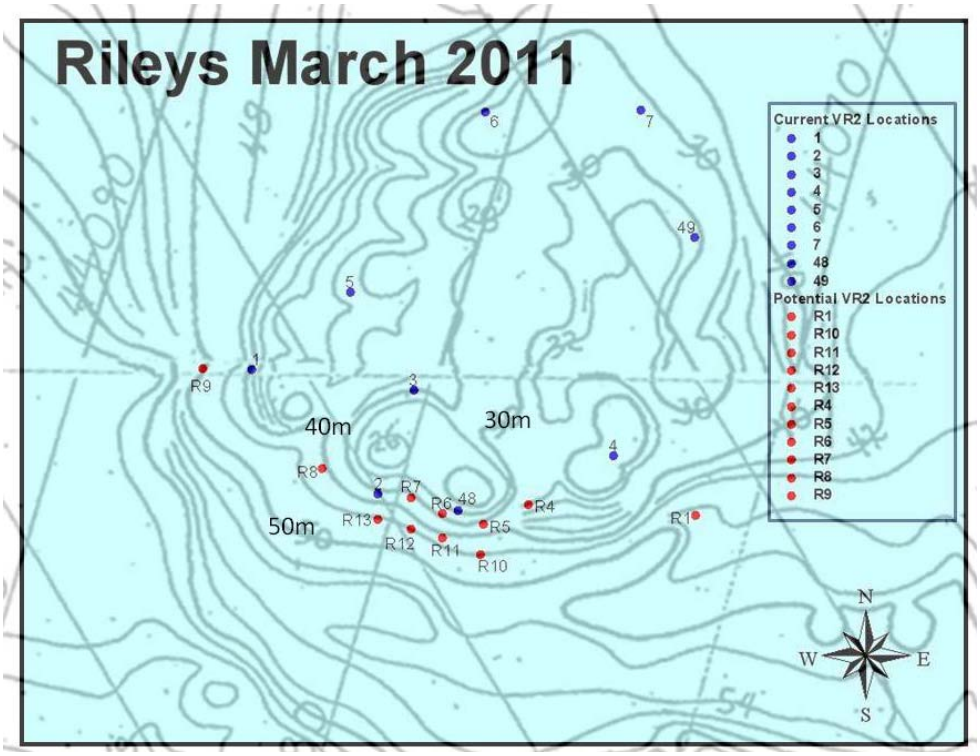

Figure 6. Location of current acoustic receivers VR2 and potential future deployment in deeper areas of Riley's Hump.

Remotely Operated Vehicle (ROV)

Four ROV dives were completed with over 2.5 hours of video footage collected. Figure 7 shows the tracks of the ROV dives. These dives were conducted at depths ranging from 27 meters to 64 meters. Selection of the ROV tracks was based on previous fish tagging data and bottom geomorphology. The video images demonstrated the presence of large groupers and mutton snapper in deeper waters of the hump. The presence of juvenile and adult lionfish sharing the same ledge as larger groupers was also noted. Over 39 different fish species (Appendix A) were observed during the three ROV dives. A summary of the observations of commercial fish species from the ROV videos is presented in Table 1. Strong winds (15 to 17 knots) precluded the smooth operation of the ROV. In many instances the ROV was dragged by the boat and the unit was not able to descend.

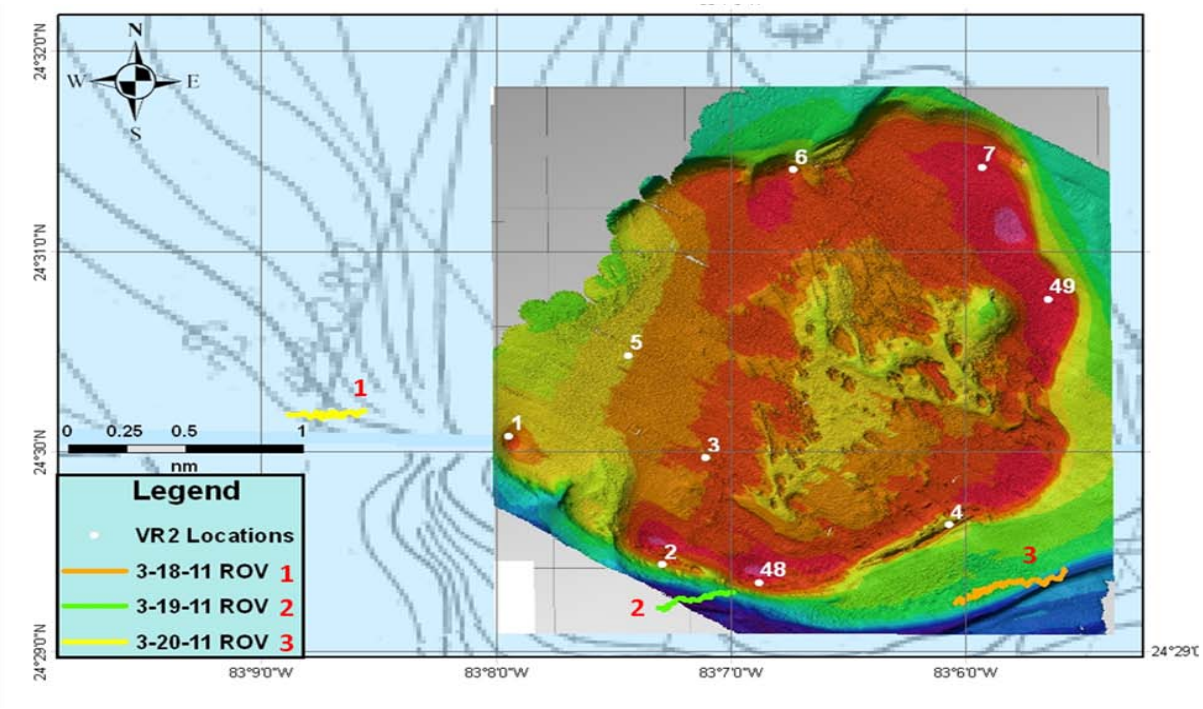

Figure 7. Track for three ROV dives conducted at Riley's Hump during March 2011.

Table 1. Commercial Fish species observed during ROV dives.

Date		Latitude	Longitude	Depth	Commercial Fish Species	Common Name	No. of Specimens
########	start	24.4902	-83.09302	31 - 49m	*Carcharhinus limbatus*	Blacktip Shark	1
	end	24.5254	-83.06067		*Carcharhinus perezzi*	Reef Shark	1
					Epinephelus morio	Red Grouper	2
					Ginglymostoma cirratum	Nurse Shark	1
					Lachnolaimus maximus	Hogfish	3
					Lutjanus analis	Mutton Snapper	38
					Mycteroperca bonaci	Black Grouper	1
					Pterois volitans	Lionfish	1
					Scomberomorus cavalla	King Mackeral	1
					Seriola rivoliana	Almaco Jack	1
########	start	24.4883	-83.11652	33 - 52m	*Carcharhinus limbatus*	Blacktip Shark	1
	end	24.5068	-83.08894		*Epinephelus morio*	Red Grouper	1
					Lachnolaimus maximus	Hogfish	1
					Lutjanus analis	Mutton Snapper	3
					Pterois volitans	Lionfish	7
########	start	24.503	-83.14523	59 - 65m	*Lutjanus analis*	Mutton Snapper	2
	end	24.5031	-83.14809		*Pterois volitans*	Lionfish	1

Technical Diving

A total of eight technical dives were conducted during the cruise (2 dives /day). Figure 8 shows the entry and exit points of the divers. Dives were conducted to depths ranging from 47 meters to 60 meters. Selections of the dive sites were based on previous fish data from the tagging experiment and bottom geomorphology. The divers observed elevated densities of adult black grouper, mutton and cubera snapper in deeper waters. Divers also noticed the presence of juvenile and adult lionfish sharing the same ledge as larger groupers. Over 34 different fish species (Appendix B) were observed during the technical dives. A summary of the observations of commercial fish species from the technical dive videos is presented in Table 2.

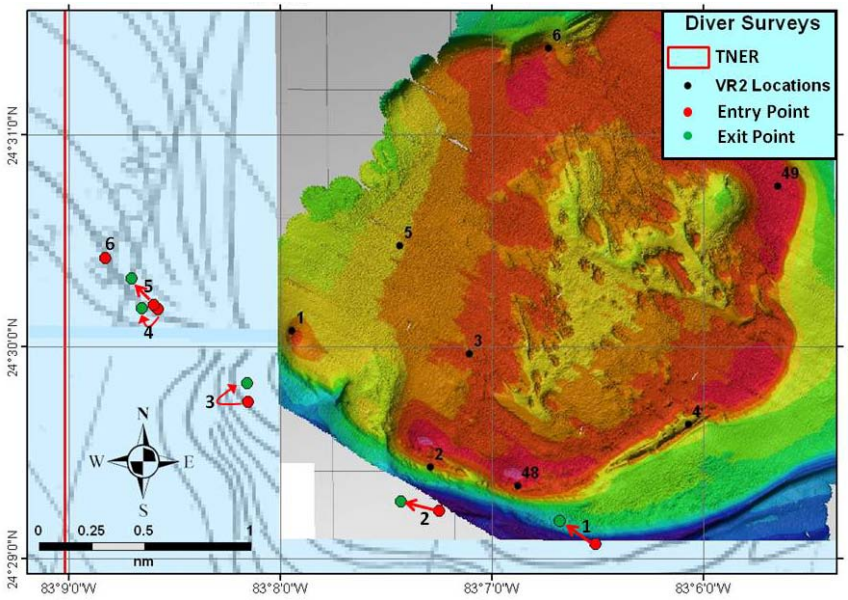

Figure 8. Track for technical dives conducted at Riley's Hump during March 2011.

Table 2. Location for technical dives conducted at Riley's Hump during March 2011.

Date	Dive No.	Down/Up	Latitude	Longitude	Max Depth (m)
3/18/2011	1	Down	24.29.069	-83.06.508	52
		Up	24.29.176	-83.06.677	
3/19/2011	1	Down	24.29.225	-83.07.250	51
		Up	24.29.271	-83.07.429	
3/19/2011	2	Down	24.29.739	-83.08.156	47
		Up	24.29.828	-83.08.157	
3/20/2011	1	Down	24.30.180	-83.08.582	60
		Up	24.30.181	-83.08.653	
3/21/2011	1	Down	24.30.199	-83.08.600	58
		Up	24.30.322	-83.08.702	

Table 3. Commercial Fish species observed during the technical dives conducted at Riley's Hump during March 2011.

Date	Dive No.	Commercial Fish Species	Fish Species	Count	Size (cm)
3/18/2011	1	*Seriola rivoliana*	Almaco Jack	7	45
		Cephalopholis cruentata	Graysby	1	12
		Epinephelus itajara	Goliath Grouper	2	120
		Bodianus rufus	Spanish Hogfish	1	
		Lachnolaimus maximus	Hogfish	5	50 - 60
		Lutjanus jocu	Dog Snapper	1	
		Lutjanus analis	Mutton Snapper	5	45 - 60
		Seriola dumerili	Greater Amberjack	1	90
		Pterois volitans	Lionfish	7	10 - 18
3/19/2011	1	*Lutjanus analis*	Mutton Snapper	6	60- 65
		Epinephelus morio	Red Grouper	2	80, 75
		Cephalopholis cruentata	Graysby	1	30
		Lachnolaimus maximus	Hogfish	4	80,70
		Bodianus pulchellus	Spotfin hoghfish		
		Bodianus rufus	Spanish Hogfish	1	
		Pterois volitans	Lionfish	8	15 - 17
	2	*Haemulon album*	White margate	2	
		Lutjanus analis	Mutton Snapper	34	60
		Epinephelus morio	Red Grouper	3	80
		Bodianus pulchellus	Spotfin hoghfish	1	
3/20/2011	1	*Lutjanus analis*	Mutton Snapper	7	60 - 70
		Mycteroperca bonaci	Black Grouper	14	90 - 100
		Lutjanus jocu	Dog Snapper	2	60, 70
		Mycteroperca phenax	Scamp	11	80
			Scamp	2	20
		Seriola rivoliana	Almaco Jack	1	60
		Bodianus rufus	Spanish Hogfish	1	
		Pterois volitans	Lionfish	23	15 - 17
3/21/2011	1	*Mycteroperca bonaci*	Black Grouper	2	100
		Mycteroperca phenax	Scamp	1	80
		Lutjanus jocu	Dog Snapper	1	80
		Seriola rivoliana	Almaco Jack	68	60
		Seriola dumerili	Greater Amberjack	2	70
		Lutjanus analis	Mutton Snapper	1	90
		Pterois volitans	Lionfish	5	15
	2	*Lachnolaimus maximus*	Hogfish	1	
		Seriola rivoliana	Almaco Jack	50	60
		Mycteroperca bonaci	Black Grouper	6	80-110
		Mycteroperca phenax	Scamp	18	80
		Lutjanus analis	Mutton Snapper	2	70, 90
		Lutjanuscyanopterus	Cubera Snapper	70	80
		Pterois volitans	Lionfish	2	15

Bottom Mapping:

Acoustic seafloor mapping using split-beam (SIMRAD EK-60) sonar systems was performed during three days of the five day cruise. Rough sea conditions prevented sonar mapping during the other two days of the cruise. During the first day, one of the Spawning aggregation stations (silver route) monitored by Mike Burton was mapped. On day two, the approach was changed and the 35-40 meter contour around the hump was mapped, in an attempt to identify areas of elevated fish density and/or promising bathymetric features (Figure 9 – green line). During the final day, an area recommended by the captain based on past observations, was also mapped. This area showed interesting benthos with many features and technical divers were sent to investigate this habitat. The divers confirmed the presence of large grouper, mutton and cubera snappers. Mapping was conducted for a total of approximately 5 hours.

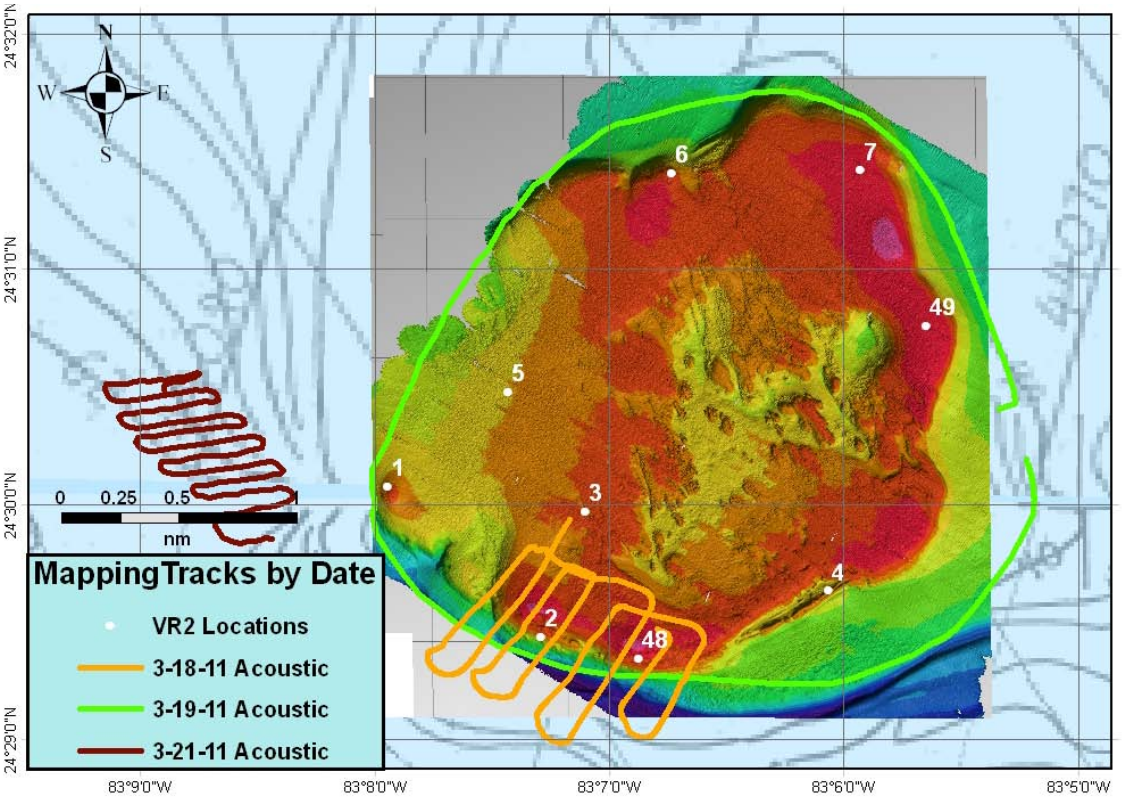

Figure 9. Mapping tracks for the three sites visited during March 2011 cruise.

Summary and Future Perspectives

The results from the technical and ROV dives have proven beneficial to the ongoing studies regarding the potential of grouper spawning aggregations sites within the Dry Tortugas system of protected areas. This cruise was a major step towards the understanding of the species composition, behavior and abundance in a multi-species aggregation site at Riley's Hump. Although we were not able to observe spawning of black grouper, multiple mature black grouper displayed spawning behavior. In addition, the divers observed a considerable number of cubera snapper that presented spawning behavior. The initial research questions were well addressed and the methodology proved effective. The technology used was successfully implemented and will provide an easily replicated procedure for future researchers. The cruise demonstrated that high quality digital videos provided by the ROV and divers can be used to characterized fish species composition as well as benthic habitats present at depths greater than 30 meters. Information from the technical divers and the ROV dives provided comparable descriptions of fish composition and benthic characteristics of the area. Technical divers were able to provide additional insight to the behavior and ecological processes pertaining to the species of interest that were not observed in the ROV data. The full potential of the ROV and mapping operations were not realized due to adverse weather and water conditions.

Acoustic tagging of black grouper and cubera snappers in deeper waters and the deployment of VR2 receivers in these areas are of future interest. These activities require technical diving expertise not available within the FWC team. Researchers from the CCRI expressed interest in continued cooperation with FWC on future missions to this area.

Additional ROV dives and mapping of the areas adjacent to Riley's Hump and between RH and the DRTO are needed to extend estimations of species abundance. Additionally, better mapping of the habitat features would be beneficial.

Acknowledgement

We thank Captain Frank Wasson and the crew of the M/V Spree for their support during all the phases of this cruise. Captain Frank's expertise and knowledge of the area was instrumental in the success of this operation. To the CCRI crew and FWC crew for their high level of dedication and professionalism demonstrated during this cruise. To the office staff of CCRI from UPR and FWC for helping with all the paper work. Funding for this project is provided by NOAA /Coral Reef Conservation Program.

Appendix A. Species composition observed during ROV dives conducted in Riley's Hump during March 2011. Commercial species are presented in Table 1.

Species	**Common Name**
Acanthostracion polygonia	Honneycomb Cowfish
Acanthurus bahianus	Ocean Surgeonfish
Acanthurus coeruleus	Blue Tang
Aluterus monoceros	Unicorn Filefish
Calamus calamus	Saucereye Porgy
Canthidermis sufflamen	Ocean Triggerfish
Caranx ruber	Bar Jack
Centropyge argi	Cherubfish
Chaetodon sedentarius	Reef Butterflyfish
Chromis enchrysurus	Yellowtail Reeffish
Halichoeres bivattatus	Slippery Dick
Halichoeres garnoti	Yellowhead Wrasse
Holocanthus bermudensis	Blue Angelfish
Holocanthus townsend	Townsend Angelfish
Holocentrus adscensionis	Squirrelfish
Malacanthus plumieri	Sand Tilefish
Pomacanthus arcuatus	Grey Angelfish
Pomacanthus paru	French Angelfish
Pomacanthus tricolor	Rock Beauty
Serranus tortugarum	Chalk Bass
Sparisoma viride	Stoplight Parrotfish
Stegastes partitus	Bicolor Damselfish
Thalassoma bifasciatum	Bluehead
Bodianus pulchellus	Spotfin Hogfish
Carcharhinus limbatus	Blacktip Shark
Carcharhinus perezzi	Reef Shark
Epinephelus morio	Red Grouper
Ginglymostoma cirratum	Nurse Shark
Lachnolaimus maximus	Hogfish
Lutjanus analis	Mutton Snapper
Mycteroperca bonaci	Black Grouper
Pterois volitans	Lionfish
Scomberomorus cavalla	King Mackeral
Seriola rivoliana	Almaco Jack
Haemulon album	White Margate
Holocanthus ciliaris	Queen Angelfish
Hypoplectrus sp.	Hamlet hybrid
Ptereleotris calliurus	Blue Dartfish

Appendix B. Fish species composition observed during technical dives conducted in Riley's Hump during March 2011. Commercial species are presented in Table 2.

Scientific Name	**Common Name**
Stegastes partitus	Bicolor Damselfish
Holocanthus bermudensis	Blue Angelfish
Chromis cyanea	Blue Chromis
Ptereleotris calliurus	Blue Dartfish
Acanthurus coeruleus	Blue Tang
Thalassoma bifasciatum	Bluehead
Chromis multilineata	Brown Chromis
Hypoplectrus unicolor	Butter Hamlet
Serranus tortugarum	Chalk Bass
Halichoeres maculipinna	Clown Wrasse
Haemulon flavolineatum	French Grunt
Pomacanthus arcuatus	Grey Angelfish
Serranus tigrinus	Harlequin Bass
Halichoeres radiatus	Puddingwife
Chromis scotti	Purple Reeffish
Holacanthus ciliaris	Queen Angelfish
Chaetodon sedentarius	Reef Butterflyfish
Holacanthus tricolor	Rock Beauty
Malacanthus plumieri	Sand Tilefish
Canthigaster rostrata	Sharpnose Pufferfish
Halichoeres bivittatus	Slippery Dick
Bodianus rufus	Spanish Hogfish
Chaetodon ocellatus	Spotfin Butterflyfish
Bodianus pulchellus	Spotfin Hogfish
Holocentrus adscensionis	Squirrelfish
Chromis insolata	Sunshinefish
Stegastes planifrons	Threespot Damselfish
Apogon pseudomaculatus	Two Spot Cardinalfish
Haemulon album	White Margate
Liopropoma eukrines	Wrasse Basslet
Mulloidichthys martinicus	Yellow Goatfish
Halichoeres garnoti	Yellowhead Wrasse
Chromis enchrysura	Yellowtail Reeffish

Appendix C. Scientific and boat crew for the Riley's Hump, March 2011 cruise.


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