Characterization of Navassa National Wildlife Refuge: A preliminary report for NF-06-05 (NOAA ship *Nancy Foster*, April 18-30, 2006)

NOAA Technical Memorandum NOS NCCOS #38

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Abstract

Navassa is a small, undeveloped island in the Windward Passage between Jamaica and Haiti. It was designated a National Wildlife Refuge under the jurisdiction of the U.S. Fish and Wildlife Service in 1999, but the remote location makes management and enforcement challenging, and the area is regularly fished by artisanal fishermen from Haiti. In April 2006, the NOAA Center for Coastal Fisheries and Habitat Research conducted a research cruise to Navassa. The cruise produced the first high-resolution multibeam bathymetry for the area, which will facilitate habitat mapping and assist in refuge management. A major emphasis of the cruise was to study the impact of Haitian fishing gear on benthic habitats and fish communities; however, in 10 days on station only one small boat was observed with five fishermen and seven traps. Fifteen monitoring stations were established to characterize fish and benthic communities along the deep (28-34 m) shelf, as these areas have been largely unstudied by previous cruises. The fish communities included numerous squirrelfishes, triggerfishes, and parrotfishes. Snappers and grouper were also present but no small individuals were observed. Similarly, conch surveys indicated the population was in low abundance and was heavily skewed towards adults. Analysis of the benthic photoquadrats is currently underway. Other cruise activities included installation of a temperature logger network, sample collection for stable isotope analyses to examine trophic structure, and drop camera surveys to ground-truth habitat maps and overhead imagery.

Introduction and Cruise Objectives

Navassa is a small (~5 km^2) undeveloped, uninhabited island 35 mi west of Haiti that has been a National Wildlife Refuge under the jurisdiction of the U.S. Fish and Wildlife Service (USFWS) since 1999. Although a USFWS special access permit is required for entry into the refuge (Appendix 1), the remote location of the island makes enforcement challenging and Navassa's coastal waters are intensively fished by artisanal fishermen from Haiti. The coral reefs around the island may be particularly vulnerable to exploitation, as there is no traditional nursery habitat (reef flat, mangroves, seagrass beds) typically associated with coral reefs to sustain the local population. The marine resources around Navassa have not been extensively studied; the most detailed work to date is an ongoing, long-term monitoring program led by the NOAA Southeast Fisheries Science Center (SEFSC, Miami, Florida) (Miller, 2003). Preliminary results describe a relatively healthy coral reef habitat, but fish communities appear to be changing as a result of the artisanal fishing pressure.

In an effort to better characterize resource dynamics and fishing pressure in Navassa, the NOAA Center for Coastal Fisheries and Habitat Research (CCFHR, Beaufort, North Carolina) organized this research cruise aboard the NOAA ship *Nancy Foster* (cruise number NF-06-05). The goals of this cruise were to provide information complementary to that of the SEFSC effort, and to generate targeted research products to assist with the management of Navassa. In addition, the interesting combination of resources (deep reefs with little influence from terrestrial development) and management issues (remote location and fishing pressure) at Navassa provide a broad comparison for similar locations such as the Tortugas Ecological Reserve (TER), where CCFHR has an ongoing monitoring program (Fonseca et al., 2005).

The primary objectives of the cruise were to:

1) Characterize benthic and fish communities on the deep (28-34 m) nearshore shelf of Navassa. Monitoring programs currently exist for some of Navassa's shallower resources, but the deeper portions of the reef are not well-characterized. The *Nancy Foster*'s nitrox capabilities allow scuba divers increased bottom time at depth, enabling the investigation of areas beyond those reachable by previous research cruises.

2) Conduct high-resolution multibeam surveys for Navassa. The resulting bathymetry and backscatter maps will provide context for habitat assessment work and give the refuge managers a better idea of resources within the refuge.

3) Assess the effects of artisanal fishing around Navassa. A gear impact study would document the number and type of gear deployed and the type of habitat targeted. In addition, the population status of newly exploited species (e.g. conch) would be assessed. Previous research has provided qualitative and socioeconomic information on the artisanal fishery (Jean Wiener, personal communication), but the intent here is to document gear/habitat interactions.

A number of secondary objectives were pursued as time allowed. These were:

1) Collection of biological samples for stable isotope analysis to elucidate food web structure around Navassa. The island lacks nursery habitats typical of other tropical marine systems and may support an atypical trophic structure.

2) Installation of a temperature sensor network to evaluate the potential for thermal bleaching events at Navassa and to ground-truth sea surface temperature from satellites.

3) Collection of georeferenced photography (still and video) for ground-truthing mapping efforts (bathymetry, habitat maps, satellite imagery) by other scientists from NOAA and the University of Miami.

This multidisciplinary research cruise included 14 scientists, representing two federal agencies (including four NOAA offices) and three private or nongovernmental organizations. Table 1 provides a complete list of cruise participants.

Table 1. Scientific party for NF-06-05.

Name	**Affiliation**	**Primary role**
Addison, Christine	NOAA CCFHR	lead conch and lead fish surveys
Degan, Brian	NOAA CCFHR	lead fish surveys
Foust, Will	NOAA Public Health Service	diving medical officer
Hilmer, Dave	NOAA CSCOR	diver
Kelty, Ruth	NOAA NCCOS	diver
Marr, John	Perry Institute for Marine Science	diver
Moneysmith, Shelby	Biscayne National Park	diver
Piniak, Greg	NOAA CCFHR	chief scientist
Poray, Abigail	NOAA CCFHR	data management, camera supervisor
Stecher, Mike	Solmar Hydro	lead multibeam surveys
Uhrin, Amy	NOAA CCFHR	lead gear impact surveys
Vander Pluym, Jenny	NOAA CCFHR	diver
Whitfield, Paula	NOAA CCFHR	diver
Wiener, Jean	Fondation pour la Protection de la Biodiversite Marine (FoProBiM)	interpreter for interviews with artisanal fishermen

Methods and Results

The general daily plan for the cruise was to conduct habitat/fish survey dives at ~0800 and ~1700. Between these dives, the survey launches were used for gear impact studies, conch surveys, and miscellaneous dive operations, while the *Nancy Foster* ran multibeam survey lines. A brief methodology and summary of each research activity follows.

Habitat and Fish Surveys

The basic methodology for the habitat and fish surveys was adapted from CCFHR's ongoing monitoring program in Tortugas Ecological Reserve (Fonseca et al., 2005). The most significant difference is that the Tortugas protocol utilizes single transects for replicate sites within a level of resource protection (reserve, park, unprotected) whereas this cruise used replicate transects for individual sites selected solely by depth.

Site Selection

Site selection was based on bathymetry data collected on a previous research cruise using the QTC VIEW™ seabed classification system and a 50 kHz single-beam fathometer (Art Gleason, University of Miami, personal communication). Bathymetry data were imported into ArcMap 9.1. The Navassa area was divided into three strata (north, east, and south), and a sampling universe within each strata was defined by depth (28-34 m, or 90-110 ft). For each area, sampling sites were randomly generated using the Hawth's Tools extension in ArcGIS, with a minimum distance of 100 m between sites. The random sites were assigned a three-digit identification number to reflect strata (1 = south, 2 = north, 3 = east) and site number (01-15). Sites were selected for depth only, and no specific habitat was targeted. Each day's working sites were selected from the predetermined list of random sites based on accessibility and weather (Figure 1, Table 2). Water depth was confirmed with the ship's fathometer, and sites that were too deep were eliminated from the database. If the correct depth was confirmed and the sea state was acceptable, the site was marked with a buoy so divers could return to the site from small launches.

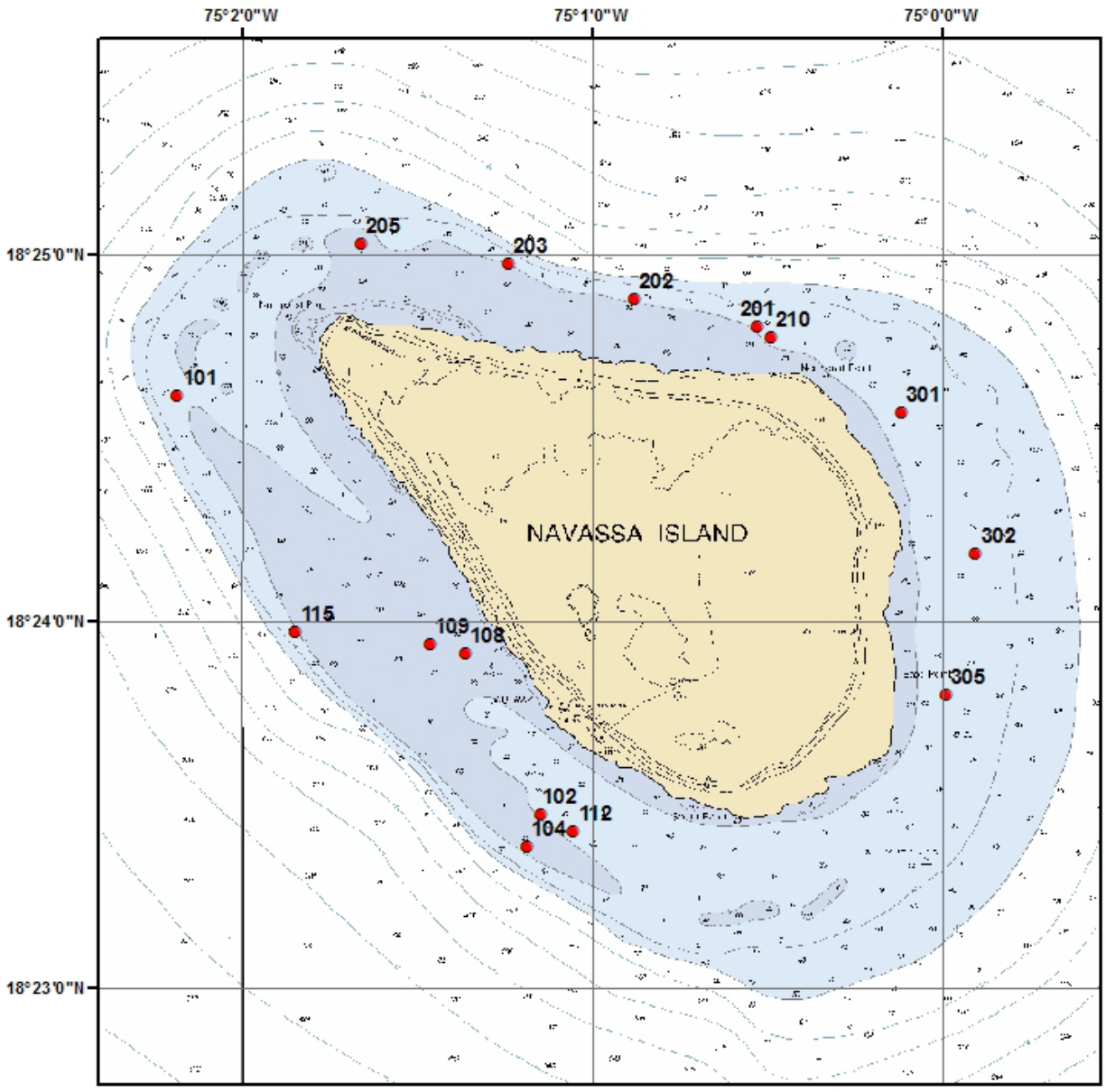

Figure 1. Sites for habitat and fish surveys.

Table 2. Location and depth for habitat/fish survey dive sites. Depths are the maximum depths reached by divers.

Site	Strata	Latitude	Longitude	Depth (ft)	Habitat found
101	south	18° 24.615' N	75° 02.184' W	110	colonized hard bottom (sponge/soft coral)
102	south	18° 23.471' N	75° 01.147' W	110	patchy reef
104	south	18° 23.387' N	75° 01.185' W	104	patchy reef, sand with sponge/soft coral
108	south	18° 23.912' N	75° 01.362'W	110	rubble and reef
109	south	18° 23.938' N	75° 01.464' W	105	sand plain with patch reefs
112	south	18° 23.427' N	75° 01.055' W	104	low-relief spur/groove
115	south	18° 23.969' N	75° 01.848' W	109	patch reef
201	north	18° 24.804' N	75° 00.527' W	110	colonized hard bottom
202	north	18° 24.879' N	75° 00.878' W	110	colonized hard bottom
203	north	18° 24.976' N	75° 01.241' W	104	colonized hard bottom
205	north	18° 25.230' N	75° 01.661' W	105	colonized hard bottom
210	north	18° 24.776' N	75° 00.488' W	105	low-relief spur/groove
301	east	18° 24.675' N	75° 00.117' W	106	colonized pavement
302	east	18° 24.184' N	74° 59.904' W	106	colonized pavement
305	east	18° 23.798' N	74° 59.989' W	110	colonized pavement/rubble field

Survey Methodology

Three survey teams were deployed at each site using survey launches. All dives were completed using 32% nitrox to allow for sufficient bottom time while working at deeper depths (target depths were 90 – 110 ft). One diver conducted visual fish surveys, while a second diver was responsible for benthic photography. A third diver was typically included for safety and to assist with miscellaneous tasks. Entry of dive teams into the water was staggered by approximately 10 minutes to minimize interference between teams. Divers descended along the buoy line and upon reaching the bottom dispersed from the anchor at pre-determined random compass bearings for a pre-determined random number of fin kicks (0-20). Each dive team carried a 30 m transect tape with a small dive weight clipped to the end. The fish diver surveyed the transect continuing the original random compass bearing, swimming at a constant speed and counting fish (see Appendix 2 for a sample fish data sheet). Large fish were counted to the limit of visibility (~25 m), while smaller resident fish were enumerated along a belt transect extending

2 m to either side of the transect tape (total belt width = 4 m) (see Appendix 3 for a complete list of targeted species). Other species of interest (lobster, conch, turtles, eels) encountered along the transect were also noted. Fish sizes were not collected due to time restrictions and the inability to calibrate diver estimates (but were noted by some fish counters).

The benthic diver followed along behind the fish diver, taking digital still photos at a fixed distance perpendicular to the bottom at each meter mark from 0 to 30m along the transect (31 images total). Camera settings and equipment setup are described in Appendix 4. In addition to high resolution habitat photos, general habitat classifications were made when swimming to the transect start. An overall site classification (continuous reef, patchy reef, pavement, rubble, sand) and an estimation of site elevation (low (<1m), medium (1-3m), high (>3m)) were identified. Additionally, divers categorized each site's substrate type in more detail using five habitat types (sand, reef, rock, rubble, and pavement) and estimated percent cover of the top three habitat types. Divers then classified benthic cover by selecting the top three benthic cover types (coral, soft coral, sponge, algae, sand) and estimated coverage of each type throughout their transect. Upon completing the transect, the fish diver rolled up the transect tape and the team returned to the buoy for ascent. The last dive team to leave the bottom would typically send the buoy anchor to the surface using a lift bag to avoid reef damage, followed by a signal float for a free ascent. A total of 45 habitat transects (15 sites x 3 transects per site) were surveyed. Statistics for these habitat dives and all other miscellaneous dive operations are provided in Appendix 5.

Data Processing and Results

Benthic Photoquadrats

Benthic habitat photos were imported into Coral Point Count with Excel extensions, developed by the National Coral Reef Institute at Nova Southeastern University Oceanographic Center (Kohler and Gill, in press). This program randomly generates a pre-selected number of points per image and allows the user to identify the organism or substrate under the sampling point; the resulting information is used to calculate the percent cover and diversity of benthic macroalgae, corals, and other invertebrates. A random subset of these transects will be included in a power analysis to determine the number of points per frame necessary for cover and diversity calculations to stabilize.

Habitat Analysis

Detailed analysis of the benthic habitat photos is currently in progress. Data presented here are from coarse habitat (abiotic) and benthic cover (biotic) classifications recorded during the fish census. Although these strata differ from previous studies, substrate type (Figure 2) and benthic cover (Figure 3) percentages recorded during this cruise are comparable to those

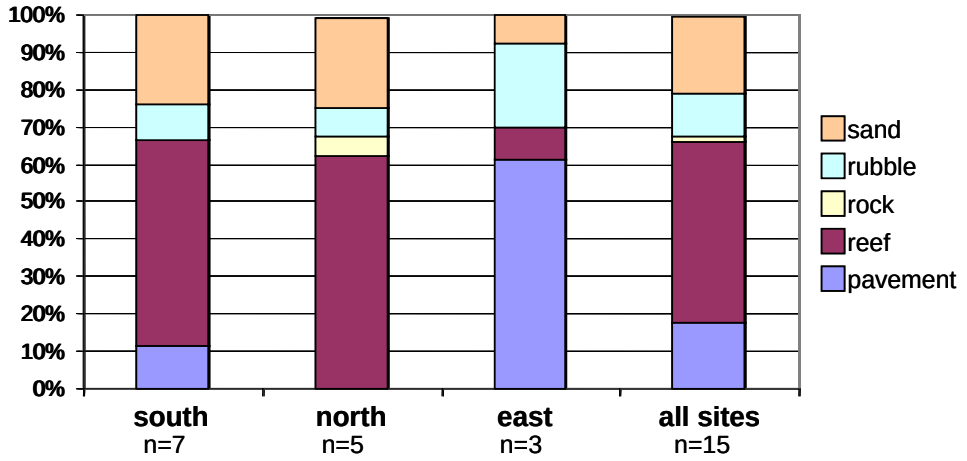

Figure 2. Percent cover by substrate type for surveys completed at Navassa in April 2006.

recorded by previous investigators at Navassa (McClellan and Miller, 2003). Substrate types for north and south sample strata are similar with reef as the dominant habitat type. The east stratum is a low relief pavement-rubble habitat, lacking large expanses of rock or reef structure (Table 3). Despite its low relief, the total numbers of fish recorded on the east side were comparable to those of the other two sampled strata (Table 3).

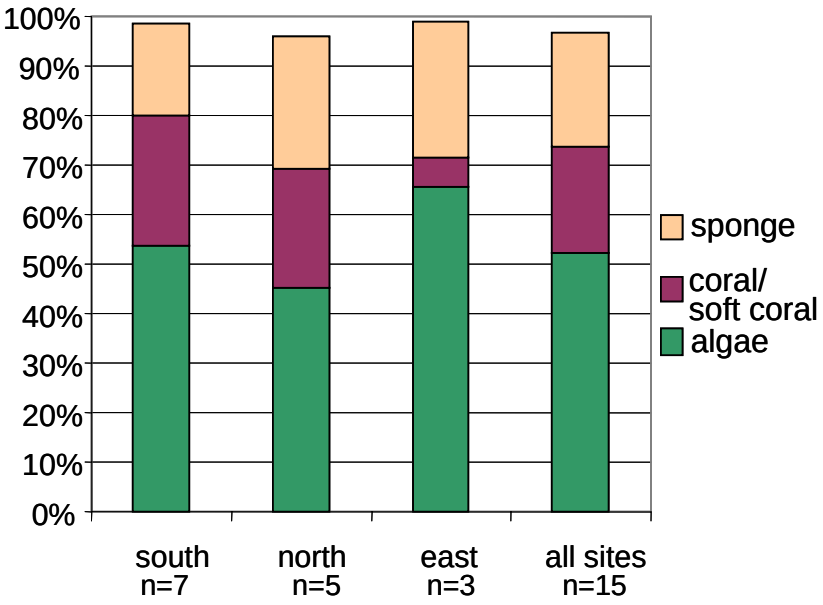

Figure 3. Percent cover of habitat type by sample strata from Navassa in April 2006.

Table 3. Summary table of general site classifications, total number of fish, average number of fish, and total number of fish species observed by site and within each strata. *Summary statistics for Site 202 do not include the solitary school of ~400 scad observed; this species was included in the total number of fish species data field.

Strata	Site	Elevation	Substrate category	Depth (ft)	Total fish	Average number of fish	Number of fish species
east	301	low	pavement	106	154	51.33	19
	302	low	pavement	106	149	49.67	22
	305	low	rubble	110	80	26.67	16
east total				**107.3**	**383**	**127.67**	**19**
north	201	medium	patchy reef	110	180	60	28
	202	medium	patchy reef	110	156*	52*	23
	203	medium	patchy reef	104	181	60.33	28
	205	medium	patchy reef	105	237	79	24
	210	high	patchy reef	105	182	60.67	28

Strata	Site	Elevation	Substrate category	Depth (ft)	Total fish	Average number of fish	Number of fish species
north total				**106.8**	**936***	**187.2***	**26.2**
south	101	low	pavement	110	118	39.33	14
	102	medium	patchy reef	110	161	53.67	25
	104	medium	patchy reef	104	171	57	33
	108	high	patchy reef	110	111	37	21
	109	high	patchy reef	105	113	37.67	18
	112	medium	patchy reef	104	181	60.33	22
	115	high	patchy reef	109	139	46.33	21
south total				**107.4**	**994**	**142**	**22**
grand total				**107.2**	**2713**	**180.86**	**total: 60 mean: 22.8**

Fish Surveys

Fish census data are currently being entered for data analysis; the data presented here are a preliminary analysis only. A total of 2,679 fish and invertebrates, comprised of sixty different species from 22 different families, were counted during the fish surveys. An additional four species of fish were observed off transect (lesser electric ray, black jack, wahoo, and greater soapfish). Table 4 is a preliminary inventory of fish observed from the predetermined species list (see Appendix 3). Although the methodology differs from that of previous investigators, similar fish assemblages were observed. Noteworthy observations of fish communities include:

- large aggregates of ocean triggerfish and herbivores
- within the Family Haemulidae, only French grunts were observed at five sites
- large (>30 cm) Nassau grouper observed at multiple sites on the south and east side of island
- excluding graysby and coney, few small (<30 cm) snapper or grouper were observed

Table 4. Fish species observed in visual censuses at Navassa.

Family name	Scientific name	**Family common name**	Species common name
Torpendinidae	*Narcine brasiliensis*	**Electric rays**	lesser electric ray
Urolophidae	*Urobatis jamaicensis*	**Round stingrays**	yellow stingray
Muraenidae	*Gymnothorax moringa*	**Morays**	spotted moray
Holocentridae	*Holocentrus adscensionis*	**Squirrelfishes**	squirrelfish
	Holocentrus rufus		longspine squirrelfish
	Myripristis jacobus		blackbar soldierfish
	Neoniphon marianus		longjaw squirrelfish
	Sargocentron coruscum		reef squirrelfish
	Sargocentron vexillarium		dusky squirrelfish
Aulostomidae	*Aulostomus maculatus*	**Trumpetfishes**	trumpetfish
Serranidae	*Cephalopholis cruentatus*	**Sea basses**	graysby
	Cephalopholis fulva		coney
	Epinephelus guttatus		red hind
	Epinephelus striatus		Nassau grouper
	Mycteroperca interstitialis		yellowmouth grouper
	Mycteroperca tigris		tiger grouper
	Rypticus saponaceus		greater soapfish
Malacanthidae	*Malacanthus plumieri*	**Tilefishes**	sand tilefish
Carangidae	*Caranx latus*	**Jacks**	horse-eye jack
	Caranx lugubris		black jack
	Caranx ruber		bar jack
	Decapterus spp.		scad
	Elagatis bipinnulata		rainbow runner
	Seriola rivoliana		almaco jack
Lutjanidae	*Lutjanus apodus*	**Snappers**	schoolmaster
	Lutjanus jocu		dog snapper
	Ocyurus chrysurus		yellowtail snapper
Haemulidae	*Haemulon flavolineatum*	**Grunts**	French grunt
Mullidae	*Mulloidichthys martinicus*	**Goatfishes**	yellow goatfish
	Pseudopeneus maculatus		spotted goatfish
Kyphosidae	*Kyphosus sectatrix*	**Sea chubs**	Bermuda chub
Pomacanthidae	*Holacanthus ciliaris*	**Angelfishes**	queen angelfish
	Holacanthus tricolor		rock beauty
	Pomacanthus paru		French angelfish
Sphyraenidae	*Sphyraena barracuda*	**Barracudas**	great barracuda
Labridae	*Bodianus rufus*	**Wrasses**	Spanish hogfish
	Clepticus parrae		creole wrasse
	Halichoeres radiatus		puddingwife
	Lachnolaimus maximus		hogfish
Scaridae	*Scarus iserti*	**Parrotfishes**	striped parrotfish
	Scarus taeniopterus		princess parrotfish
	Scarus vetula		queen parrotfish
	Sparisoma aurofrenatum		redband parrotfish
	Sparisoma chrysopterum		redtail parrotfish
	Sparisoma rubripinne		yellowtail parrotfish
	Sparisoma viride		stoplight parrotfish

Family name	Scientific name	**Family common name**	Species common name
Acanthuridae	*Acanthurus bahianus*	**Surgeonfishes**	ocean surgeonfish
	Acanthurus chirurgus		doctorfish
	Acanthurus coeruleus		blue tang
Scombridae	*Acanthocybium solandri*	**Mackerels**	wahoo
	Thunnus atlanticus		blackfin tuna
Balistidae	*Balistes vetula*	**Triggerfishes**	queen triggerfish
	Canthidermis sufflamen		ocean triggerfish
	Melichthys niger		black durgon
	Xanthichthys ringens		Sargassum triggerfish
Monacanthidae	*Aluterus schoephfii*	**Filefishes**	orangespotted filefish
Ostraciidae	*Acanthostracion polygonia*	**Boxfishes**	honeycomb cowfish
	Acanthostracion quadricornis		scrawled cowfish
	Lactophrys triqueter		smooth trunkfish

Table 5. Summary, grouped by strata, of the three most common fish families and average number of fish per family. The percentage of each fish family is the proportion of that family to the total number observed by strata. *Solitary school of 400 scad observed at site 202 in North strata was excluded from this table.

Strata	**Family**	**% of total fish observed**	**Average # of fish per transect**
south	Scaridae (parrotfishes)	28.87 %	13.67
	Acanthuridae (surgeonfishes)	15.69 %	7.43
	Balistidae (triggerfishes)	13.98 %	6.62
north	Scaridae*	23.82 %	14.87
	Balistidae	21.47 %	13.4
	Acanthuridae	14.21 %	8.87
east	Balistidae	25.85 %	11
	Acanthuridae	17.49 %	7.44
	Serranidae (groupers)	16.19 %	6.89

The three most common fish families encountered throughout the fish surveys were Scaridae (parrotfish), Balistidae (triggerfish), and Acanthuridae (surgeonfishes) (Table 5). With an algal dominated benthic cover (Figure 3), it is not surprising that at least one of the most abundant families in each stratum were herbivores. The most common species of the most abundant families is shown plotted by strata in Figure 4. A high percentage of serranid fishes, composed primarily of a single species, the coney, was unique to the east strata (Figure 4d).

Divers observed large numbers of coneys hovering over rubble nest-like mounds, typical of the low relief and pavement-rubble type substrate of the east side (Table 4). Although squirrelfish (family: Holocentridae) were not in the three most abundant families, they were a common occurrence during fish surveys and were studied because they are a fish species targeted by Haitian fishermen (Figure 4e).

The intent for future data analysis includes: 1) comparison of these Navassa surveys to those from previous cruises (for example, McClellan and Miller, 2003); 2) comparison of species diversity within and among habitat types and trophic levels; and 3) comparison of refuge fish populations to those of other protected areas within the Caribbean and south Florida.

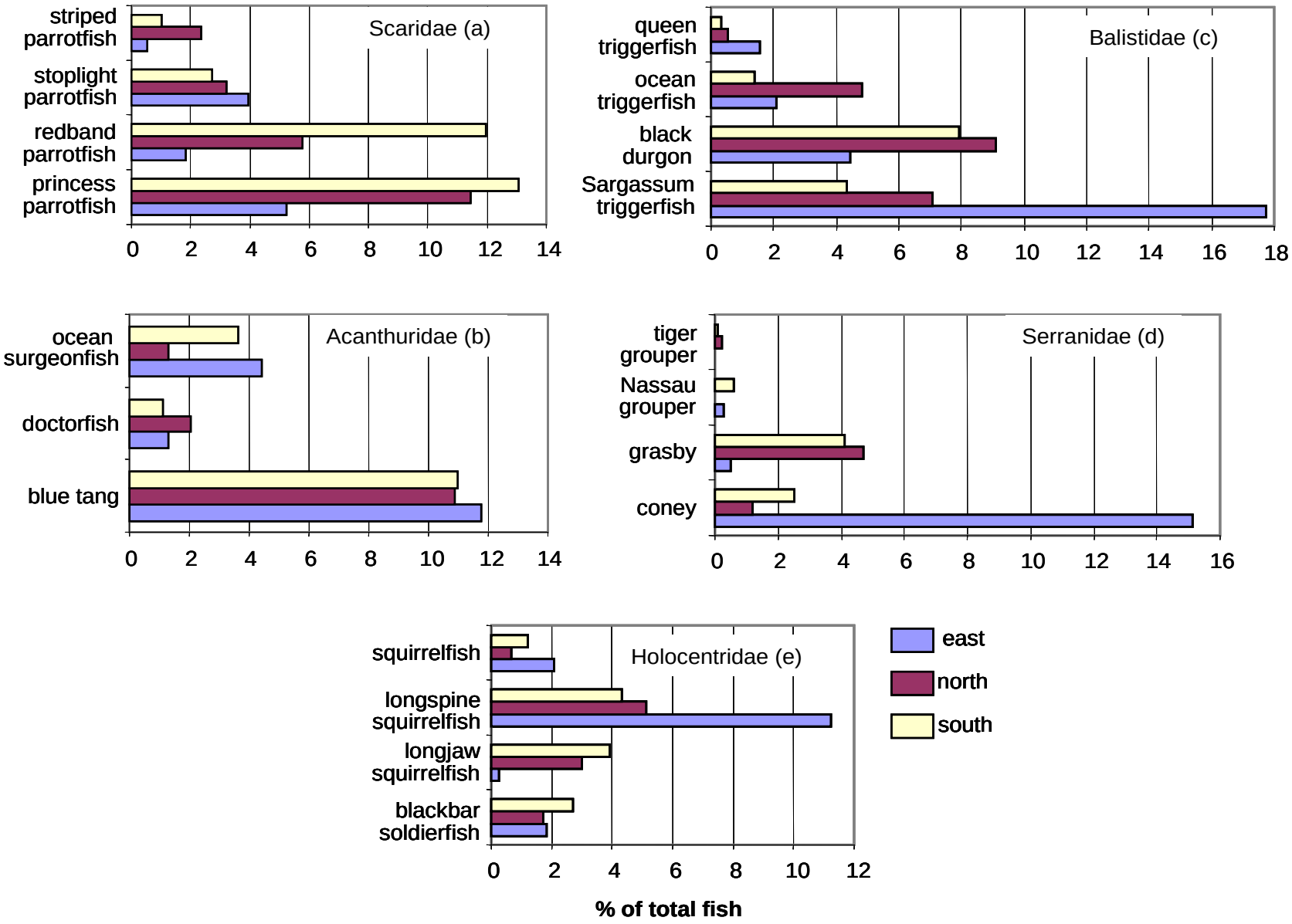

Figure 4. Percentage of total fish, by strata and family, of the common species observed.

Multibeam Mapping

The *Nancy Foster* has a hull-mounted Simrad EM 1002 multibeam system. A private firm, Solmar Hydro, was contracted to map the area around Navassa, with acquisition assistance from the *Nancy Foster*'s survey technician. Upon arrival at Navassa, differential GPS coverage was found to be insufficient for the *Nancy Foster* to provide the necessary degree of spatial information for the multibeam surveys. The services of a commercial satellite company (Fugro Chance Inc.,) were therefore retained for the duration of the survey. Although previous cruises to the area had noted significant navigational hazards from artisanal fishing gear, few fishermen were present during this cruise, so the survey obtained good coverage for the relatively shallow area near the island. A total of 330 km of survey lines around Navassa produced coverage of 102 km^2. An additional 5% of the survey distance was done perpendicular to the original survey lines to cross-check bathymetry. Post-processing is estimated to be completed by August 2006. Preliminary bathymetry for the area is included in Figures 5 and 6. Deep-sea (~1000 m) coral habitat potentially exists to the southwest of Navassa (Steven Lutz, University of Miami, personal communication); an effort was made to map this area but power surges and electronic difficulties aboard the ship required that multibeam operations be terminated before the deep-sea survey work could be initiated.

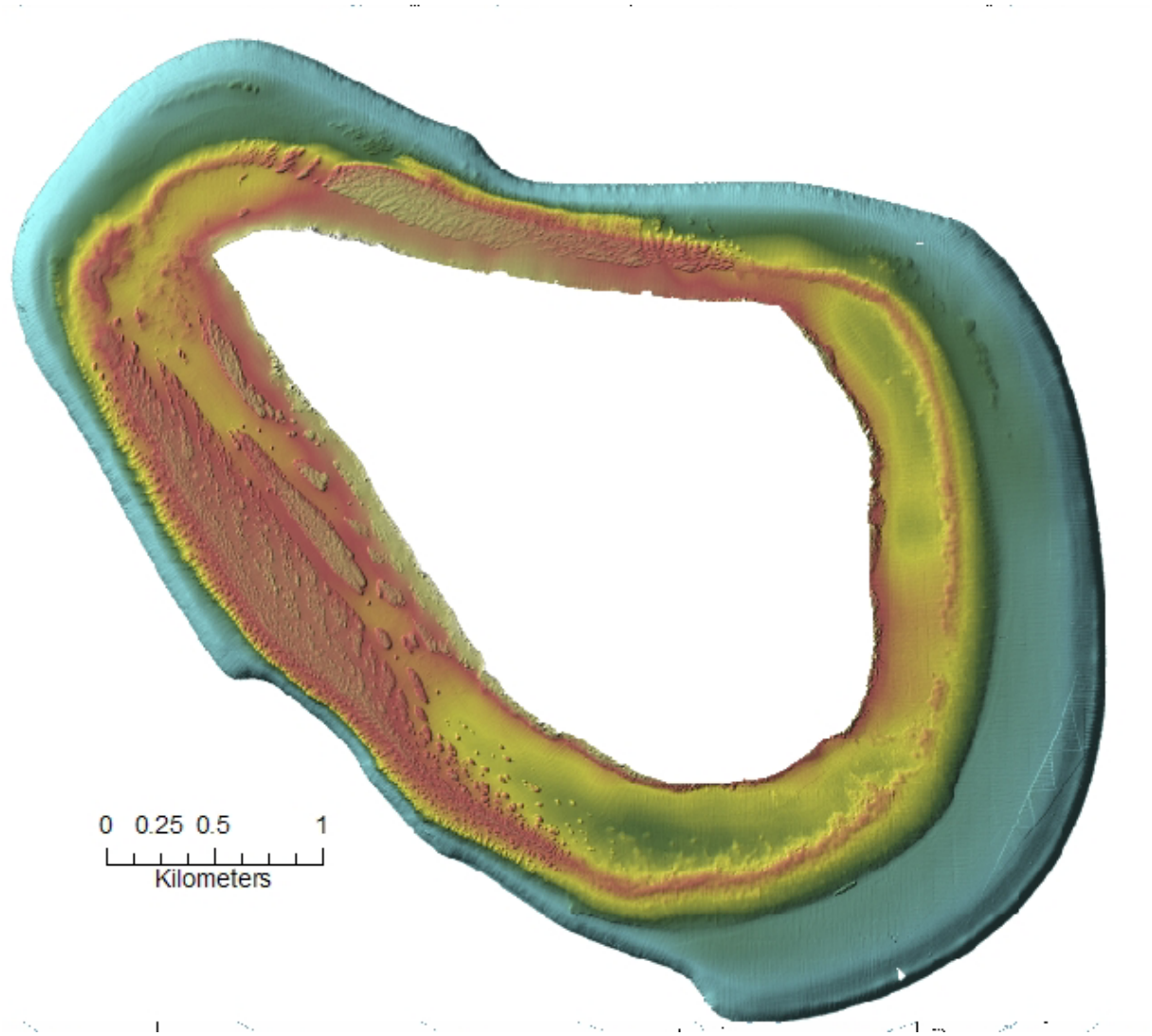

Figure 5. Preliminary near-shore bathymetry to the 50 m contour, gridded at 2 m resolution. Depth gradient from ~25 m (reds) to ~50 m (green). *(Image courtesy Solmar Hydro)*

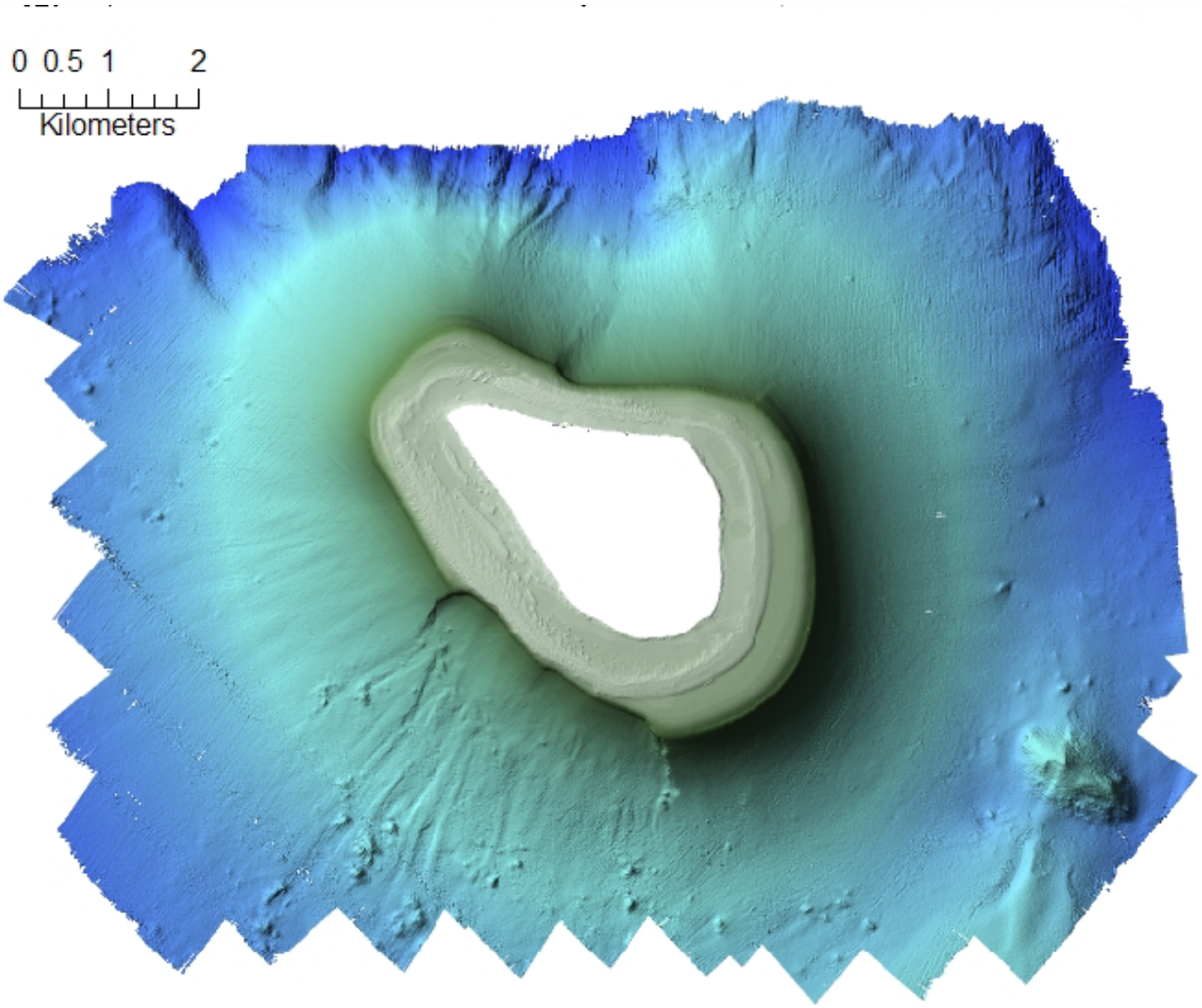

Figure 6. Bathymetry for entire Navassa survey area, gridded at 5 m resolution. Depth gradient from ~25 m (light blue) to over 1000 m (dark blue). *(Image courtesy Solmar Hydro)*

Artisanal Fishing Survey

Interviews with fishermen conducted by FoProBiM's Jean Wiener on this cruise and interviews and observations made during previous cruises by NOAA/NMFS/SEFSC (Miller et al. 2003; Wiener, 2005; Wiener, 2006) provided information on various aspects of Haitian fishing practices at Navassa. Fishermen use a combination of sails, small motors (~15 hp), and oars to navigate the 35 mile crossing to Navassa in wooden plank vessels of up to 17 ft. While five men per boat is the average, vessels have been observed to hold anywhere from 3-8 fishers (Wiener, 2005). Fishing vessels spend an average of eight days at Navassa, but may spend anywhere from 2 – 21 days at the island. Up to 24 traps may be fished by a single boat on a trip. A single ~15 ft vessel with a crew of four men was observed (Figure 7). The men arrived from Haiti on the morning

Figure 7 (above). Haitian fishermen observed during the cruise. (*Photo by Amy V. Uhrin)*

Figure 8 (below). Antillean-Z style fish trap utilized by the Haitian fishermen, seen resting on colonized hard bottom. Long axis = ~2m *(Photo by Jean Wiener)*

of April 21, 2006 and departed at dawn five days later. The trip to and from Haiti was made under sail, but while at Navassa, the fishermen used oars to navigate around the island. In addition to hand lines (monofilament), a total of seven Antillean-Z-traps were fished during the 5-day trip (Figure 8). Traps were constructed of meshed/woven bamboo (3-4 cm mesh size) with wooden cross supports and corners and have opposing funnel entrances. Rocks were used as ballast and were tied at opposite corners of the traps with bamboo strips. Six of the seven traps were observed as they were actively fished. The buoys attached to the seventh trap were pulled under by currents, and the trap could not be located, even by the fishermen. Traps were set along the more protected southwest coast terrace (Figure 9). The use of triple mesh nets has also been reported at Navassa, but the fishermen on this trip indicated a preference for traps.

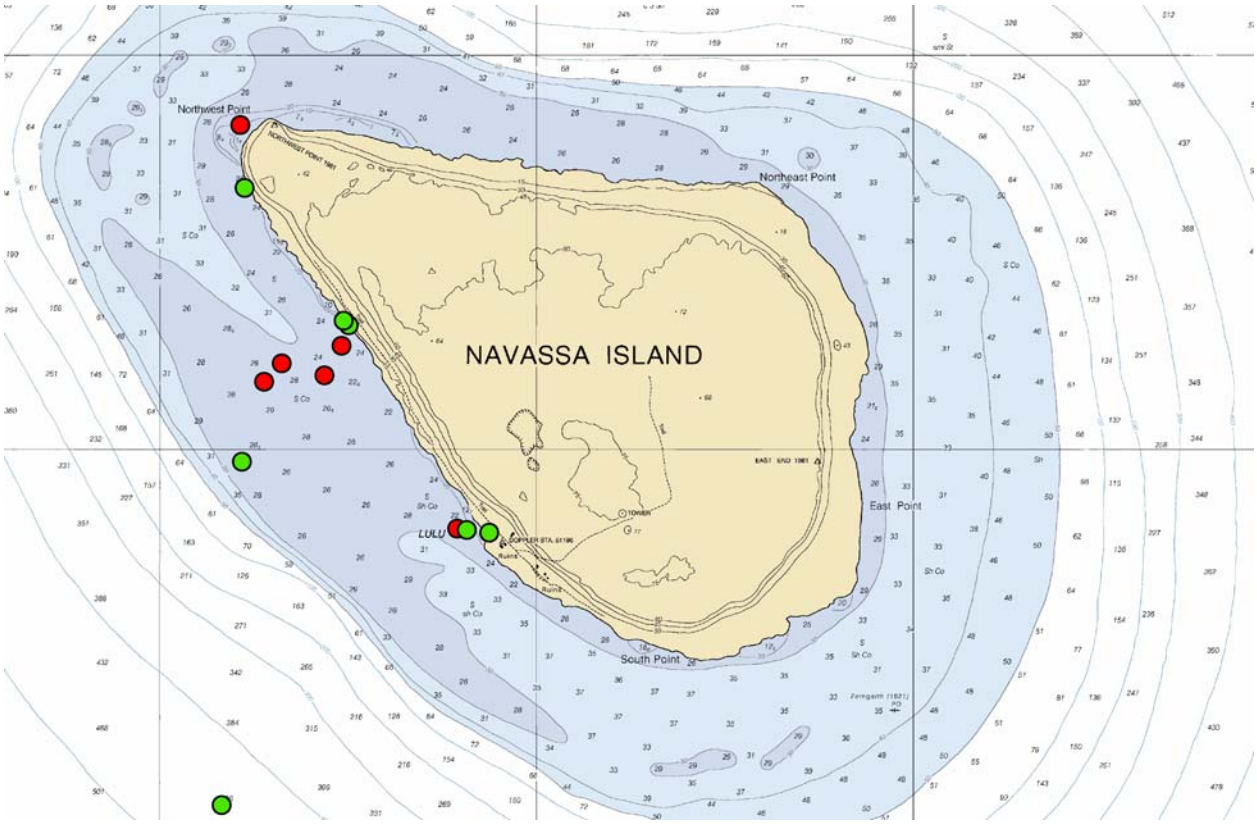

Figure 9. Location of Z-traps around Navassa observed during this cruise. Red circles indicate actively fished traps and green circles represent locations where traps were left by fishermen.

Table 6. Location, depth, and habitat targeted for all observed Antillean Z-traps.

Trap #	Date	Depth (feet)	Latitude	Longitude	Location	Habitat
Fished						
Trap 1	4/21/06	87	18º 24.264' N	75º 01.517' W	NW of Lulu Bay	colonized hard bottom
Trap 2	4/21/06	97	18º 24.173' N	75º 01.722' W	NW of Lulu Bay	bare/sandy
Trap 3	4/21/06	98	18º 24.189' N	75º 01.562' W	NW of Lulu Bay	bare/sandy
Trap 4	4/21/06	86	18º 24.220' N	75º 01.676' W	NW of Lulu Bay	colonized hard bottom
Trap 5	4/23/06	32	18º 24.825' N	75º 01.786' W	NW Point	reef
Trap 6	4/23/06	62	18º 23.800' N	75º 01.210' W	Lulu Bay	bare/sandy
Left Behind						
Trap 1	4/28/06	81	18º 23.790' N	75º 01.125' W	Lulu Bay	colonized hard bottom
Trap 2	4/28/06	82	18º 23.797' N	75º 01.185' W	Lulu Bay	sand
Trap 3	4/28/06	87	18º 23.098' N	75º 01.835' W	mid-north Lulu	colonized hard bottom
Trap 4	4/28/06	91	18º 24.317' N	75º 01.498' W	mid-north Lulu	rocky hard bottom
Trap 5	4/28/06	89	18º 24.328' N	75º 01.512' W	mid-north Lulu	colonized hard bottom
Trap 6	4/28/06	87	18º 24.665' N	75º 01.775' W	NW Point	reef
Trap 7	4/28/06	92	18º 23.970' N	75º 01.782' W	mid-north Lulu	mixed hard bottom

At each trap, a SeaViewer® Sea-Drop™ color camera (650 series) was deployed to record the type of habitat that the trap was resting on (Table 6). In addition, a coordinate was collected using DGPS to mark the location of the trap buoy, and a Speedtech SM-5 Depthmate Portable Sounder was used to determine water depth (Table 6). After the departure of the fishermen, the traps were revisited and all seven traps were located. The survey methodology described above was repeated for each trap. The traps remained *in situ* along the southwest coast (Figure 9).

Although encounters with a larger fishing fleet were anticipated, these limited observations were consistent with those reported previously for Navassa (Miller et al., 2003). Here, the Haitian fishermen deployed traps manually and preferred to set traps over bare substrate, but the size and weight of the traps made exact placement difficult. The six actively fished traps observed here targeted bare substrate and colonized hard bottom equally (Table 6). Other trap fisheries in the Caribbean likewise target low-relief colonized hardbottom and bare

substrate in roughly the same proportion (St. Thomas, U. S. Virgin Islands: Quandt, 1999; Puerto Rico: Appeldoorn, 2000; Schärer, 2004). In these cases, proximity to coral reef habitat seems to be the determining factor in trap placement. Other studies have identified algal plains as primary target habitat for trap fisheries (St. John, U. S. Virgin Islands: Garrison et al., 2004; Puerto Rico: Jean-Baptiste, 1999; Valdés-Pizzini, 1997). Although no algal plain habitat was encountered during the present cruise, high percentages of algal cover (45 – 65%) were observed along all coasts of Navassa (Figure 3) suggesting that this habitat type could be frequently targeted by trap fishing.

Although trap catches were not quantified for every haul, catches that were observed suggested squirrelfish and trunkfish as the most common taxa encountered. Other taxa included sand tilefish, rock beauty, and coney. These observations are consistent with catches reported by Miller et al. (2003). Although direct length measurements were not made, all observed fish appeared to be smaller than 20 cm, indicating that a large portion of juveniles are more than likely removed from the local population before reaching sexual maturity. The fact that these smaller animals are targeted by the fishermen supports the contention

Figure 10. Catch taken from one of the fished traps. *(Photo by Jean Wiener)*

that shifts in species composition are already occurring in this fishery (Miller et al., 2003), such as are apparent in other Caribbean nations (Koslow et al., 1988; Jeffery, 2000; Rogers and Beets, 2001).

With an estimated 70 boat trips per year made to Navassa and up to 24 traps deployed during any given trip (Wiener, 2005), the possibility exists for traps to have a negative impact on the habitat that they are resting on, particularly when the traps remain in situ at the island in between fishing trips or are lost due to storms. The actively fished traps observed during the cruise were allowed to remain on the bottom for five days; no information was gathered from the fishermen regarding the amount of time between successive fishing trips. Fish traps elsewhere in the Caribbean have been observed to inflict damage on live bottom habitats (Quandt, 1999; Appeldoorn et al., 2000) although the amount of time spent on the bottom was not reported. Similarly, spiny lobster traps resting on seagrass in the Florida Keys caused significant decreases in shoot densities after six weeks in situ (Uhrin et al., 2005). In addition to habitat modification, there is the potential for modifying fish population and hence, fishery structure as these unattended traps continue to capture fish. Although these aspects of the Navassa fishery were not directly addressed here, it is an important consideration in producing cumulative impacts, especially in areas around the island where fishing effort is concentrated.

The period of time around Easter season traditionally offers the best fishing at Navassa, according to the Haitian fishermen (Wiener, 2005; 2006). Therefore, it was surprising that only one vessel was observed throughout the duration of the cruise. The fishermen explained that although it was the appropriate season, the moon was “not bright enough”. Whether moon phase is important for navigational purposes or plays a role in fish distribution was not clarified but moon phase has been reported to affect catch rates of Antillean Z-traps in Jamaica (Munro et al.,

1971) and thus may be an important consideration when attempting to model fishing pressure at Navassa.

Given the economic importance of Navassa as a fishing ground for Haitians, the level of participation in the fishery, and the gear employed, impacts to the fishery are unavoidable. In fact, qualitative information gathered during this cruise and others before it suggests patterns of overfishing and shifts in species composition (Miller et al., 2003). In addition to direct effects of fishing pressure (i.e., resource removal), the effect of fishing gear on benthic habitats, specifically those serving as Essential Fish Habitat in this area, warrants further investigation when considering the need for fishery management strategies at Navassa.

Conch Population Surveys

Site Selection

Site selection was based on a combination of computer-based (coarse-scale) and diver-selected (fine-scale) scale techniques. Conch survey efforts were divided equally across the same north, south, and east divisions of the island used for fish and habitat surveys. Using direction strata and diveable depths (less than 110 ft) as the primary site selection criteria, surface tow tracks were created across the target areas. Once on site, snorkelers were towed on a manta board at a slow speed (less than 1 kt) across the target areas to examine benthos for suitable conch habitat (i.e., absence of high relief reef structure) and evidence of resident conch (i.e., sand tracks or shells).

Table 7. Sample locations for conch surveys.

Site	Latitude	Longitude	Depth (ft)	Strata
East 2	18° 24.753’ N	75° 00.222’ W	99	east
East 1	18° 24.083’ N	75° 00.114’ W	92	east
North Temp	18° 24.820’ N	75° 00.805’ W	91	north
NW Point	18° 24.897’ N	75° 01.846’ W	102	north
Conch 1	18° 24.173’ N	75° 01.432’ W	80	south
Lulu Bay	18° 23.710’ N	75° 01.190’ W	70	south

Survey Methodology

When a suitable habitat at appropriate depth was located, a surface marker was deployed for diver surveys. Survey methods based on a sampling design followed by the Florida Fish & Wildlife Conservation Commission (Glazer, 1999). Each site contained three 30 m transects with a belt width of 4 m. Transects originated at the drop weight and radiated outwards along a random compass bearing. When a queen or milk conch was encountered, habitat type, transect distance, age, size (if juvenile), and sexual activity (if observed) were noted. See Appendix 6 for an example of the conch survey datasheet, and Appendix 7 for conch habitat codes. A total of five sites were completed with three transects per site, at a sixth site (North Temp) only one transect was completed due to temperature logger deployment (Table 7). Presence/absence of conch was also noted by fish surveyors at 12 of the habitat sites.

Data Processing and Results

A total of 2160 m^2 of the inner shelf around Navassa was surveyed for conch. Only 10 live conch were observed on the 16 conch transects, with an additional 29 conch on the 45 fish/habitat transects (10 of the 29 were observed on a single transect). The conch observed (mostly queen conch) were very large and heavily encrusted with sponges and other biofouling organisms. Although mating pairs were seen on one of the habitat dives (site 109), no juvenile conch were observed during the entire trip. Recruitment is likely to be extremely limited. Haitian fishermen working around Navassa target conch both for market and for personal consumption while fishing. As the fishermen often overnight in Lulu Bay, a conch dive was dedicated to surveying the anchorage area for conch shells with a hole knocked in the shell, indicative of meat extraction by fishermen. The vast majority of knocked shells found were adults, although a small number of juvenile shells (n=3) were observed.

Secondary Activities

During surface intervals between survey dives or when additional bottom time was available, a number of activities were conducted to further characterize the Navassa area or to provide data or samples for collaborators.

Temperature loggers

A network of five temperature loggers was installed around the island to ground-truth satellite sea surface temperatures and to help assess the potential for coral bleaching due to elevated temperatures. The loggers (Onset HOBO Water Temp Pro V2) were launched 4/23/06 to collect hourly temperature data beginning at 1800 EST. The loggers' battery life is sufficient to collect hourly temperature data for approximately 3 years. Two spare loggers (#1, serial # 967888; #2, serial # 967891) and the affiliated software will be delivered to Dr. Margaret Miller (NOAA Southeast Fisheries Science Center) to collect and re-deploy the loggers during her cruise in November 2006. The loggers were attached via cable ties to a 10" galvanized nail pounded into non-living substrate. In some cases the nail was marked with a small cylindrical blue float on a 1-foot long wire tether; in instances where the floats could be visually located by fishermen from the surface, the floats were not used. The loggers are located as follows:

Logger 3 (serial # 967887): West Pinnacles (18° 24.331' N, 75° 01.507' W). At the base of the wall there is a large solitary pinnacle at a depth of ~83 ft, with a cluster of large rocks to the northwest (left facing the island). The logger is at the base of the solitary pinnacle and marked with a float.

Logger 4 (serial # 967885): Northwest Point (18° 24.825' N, 75° 01.786' W). The logger (Figure 11) is located in a narrow sand/rubble crevice between two large coral spurs at a depth of 36 ft, and is marked with a float.

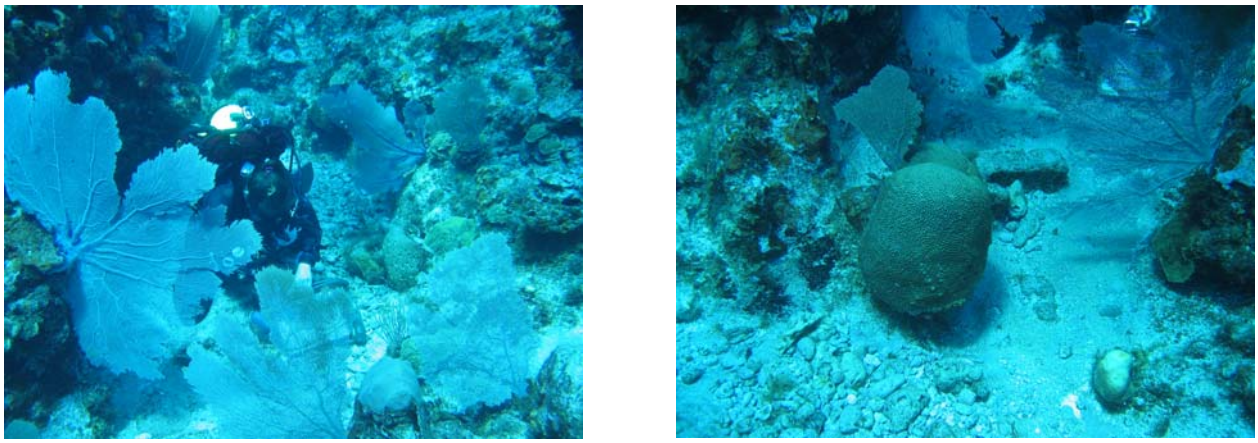

Figure 11. Diver installing the temperature logger at Northwest Point (left). Just seaward of the logger is a gorgonian growing out of a *Diploria* colony (right). (*Photos by Dave Hilmer)*

Logger 5 (serial # 967890): Conch north (18° 24.820' N, 75 °00.806' W). Logger was installed in a sandy area surrounded by larger patch reefs. Temperature logger was anchored in a small rock near the center of a large sandy space (Figure 12). The logger was marked with a blue subsurface float and was placed at a depth of approximately 91 ft.

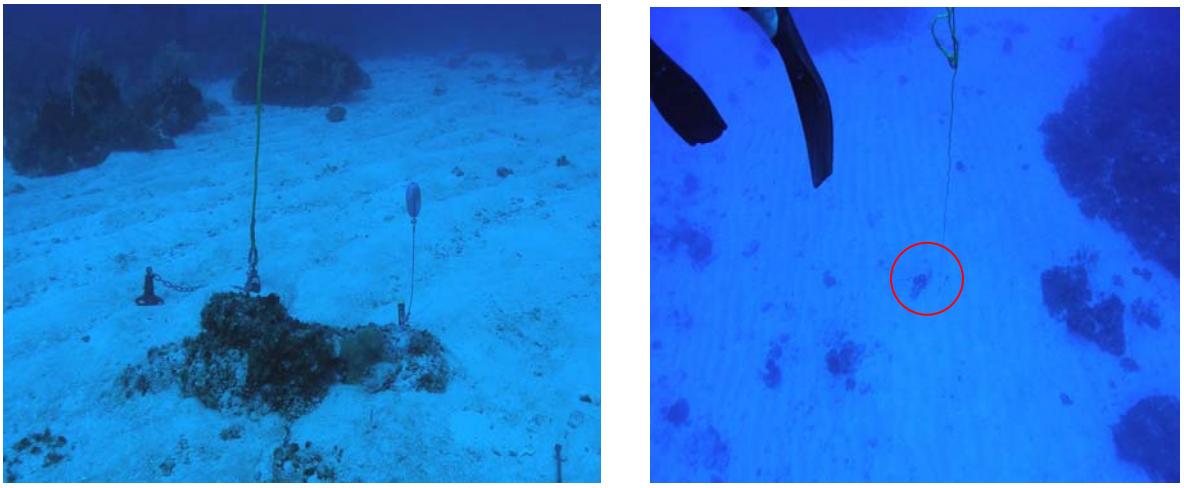

Figure 12. Images of the installed temperature logger viewed from side (left) and from mid water column (right). The logger location in the right image is noted with a red circle.

Loggers 6 (serial # 967886) and 7 (serial # 967889): Lulu Bay (18° 23.800' N, 75° 01.211' W). The coordinates mark the location of logger 6, which was installed at 84 ft on the south side of a small coral reef mound (~3 ft diameter) located on a sandy bottom between two

much larger coral reefs (Figure 13). Logger 7 is located shoreward and to the right of logger 6, in 50 ft of water against the wall at Lulu Bay just to the left of the usual fishing boat anchorage where the left side of a small cavern begins.

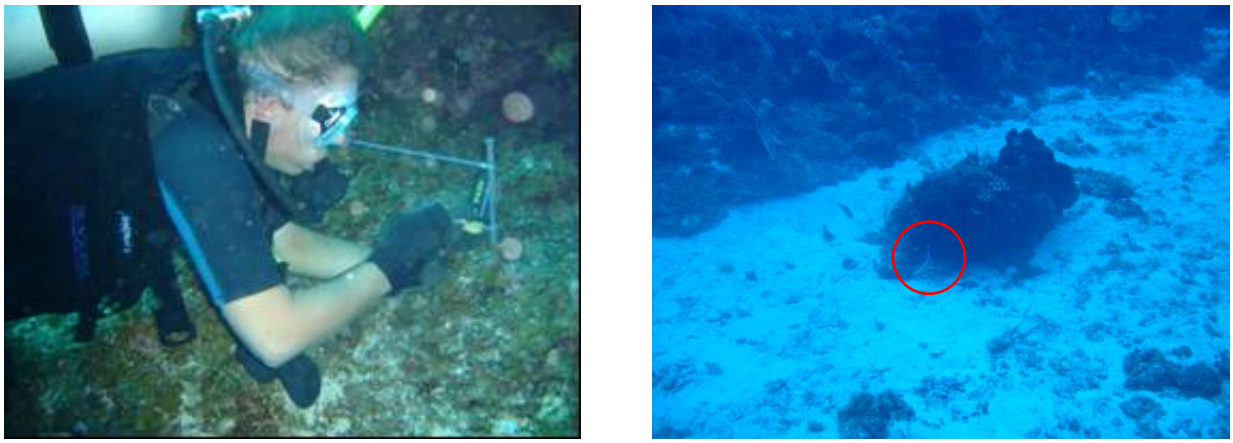

Figure 13. Diver installing logger 7 at the base of the wall (left). Location of logger 6 underneath a small reef patch (right), noted with a red circle. (*Photos by Jean Wiener*)

Specimen Collections

The USFWS Special Use permit conditions (Appendix 1) allowed for the collection of biological samples for laboratory assays. Fish were collected by divers with pole spears, or by hook and line fishing from a surface vessel; divers also collected corals and macroalgae by hand. The samples will be used for trophic analyses via stable isotopes ($\delta^{15}N$ and $\delta^{13}C$); in addition, apex predators (e.g., barracuda) will be sampled for ciguatera. Appendix 8 provides a complete list of specimens collected.

Drop Camera Surveys

On a previous research cruise to Navassa, Art Gleason (University of Miami) created a bathymetry grid and habitat map from QTC VIEW™ survey equipment and a 50 kHz single-beam fathometer. As previously stated, this existing bathymetry data assisted with site selection for this research cruise. In addition, drop camera surveys were conducted on this cruise (Table 8) for use as additional ground-truthing points for habitat mapping. A survey launch navigated

to the site using a Trimble GPS system. After determining the direction and speed of the current, the launch maneuvered upstream of the site and a SeaViewer® Sea-Drop™ color video camera (650 series) mounted in a custom frame was lowered on an outrigger boom until the sea floor came into view. As the survey launch drifted over the site, video footage was recorded on a Sony DV Walkman and stamped with Trimble GPS coordinate data using a Horita GPT-50 video tilter.

Table 8 Drop camera survey sites. Hard bottom is defined as colonized by sponges, soft corals, and/or scleractinian corals.

Site	Latitude	Longitude	Habitat	Personnel
DEL5	18º 23.191' N	75º 00.869' W	colonized hard bottom	Uhrin, Hilmer, Wiener
DEL7	18º 23.201' N	75º 00.500' W	colonized hard bottom	Uhrin, Hilmer, Wiener
DEL8	18º 23.312' N	75º 00.376' W	sparse hard bottom	Uhrin, Hilmer, Wiener
DEL10	18º 23.362' N	75º 00.221' W	moderate hard bottom	Uhrin, Hilmer, Wiener
DEL14	18º 23.200' N	75º 00.454' W	colonized hard bottom	Uhrin, Hilmer, Wiener
DED7	18º 23.269' N	75º 59.538' W	pavement/sponges	Uhrin, Hilmer, Wiener
DED9	18º 23.070' N	75º 00.253' W	rubble/algae	Uhrin, Hilmer, Wiener
DED10	18º 23.381' N	75º 00.021' W	rubble/pavement	Uhrin, Hilmer, Wiener
DED14	18º 23.184' N	75º 00.013' W	rubble/algae	Uhrin, Hilmer, Wiener
DED16	18º 23.038' N	75º 00.191' W	rubble/algae	Uhrin, Hilmer, Wiener
NDB1	18º 25.148' N	75º 01.634' W	colonized hard bottom	Piniak, Whitfield
NDB2	18º 25.145' N	75º 01.553' W	rubble, patchy hard bottom	Piniak, Whitfield
NDB3	18º 25.150' N	75º 01.587' W	mostly rubble	Piniak, Whitfield
WD1	18º 24.689' N	75º 02.144' W	colonized hard bottom	Uhrin, Piniak, Poray
WD2	18º 24.584' N	75º 02.238' W	colonized hard bottom	Uhrin, Piniak, Poray
WD3	18º 24.797' N	75º 02.222' W	moderate hard bottom	Uhrin, Piniak, Poray
NDA2	18º 24.860' N	75º 00.390' W	sand and sparse algae	Piniak, Whitfield
NDA4	18º 24.836' N	75º 00.259' W	sand	Piniak, Whitfield
NDA5	18º 24.933' N	75º 00.519' W	sand	Piniak, Whitfield
WL1	18º 24.825' N	75º 02.066' W	rubble/sparse soft coral	Uhrin, Piniak, Poray
WL5	18º 24.982' N	75º 01.939' W	sparse hard bottom	Uhrin, Piniak, Poray
WL8	18º 24.916' N	75º 01.984' W	rubble and hard bottom	Uhrin, Piniak, Poray

Submerged Cultural Resources

NOAA chart 26194 provides bathymetry information for the area around Navassa and lists a shipwreck off the southeast side of the island, noted as PD (position doubtful). The

NOAA Office of Coast Survey Automated Wreck and Obstruction Information System (AWOIS) report indicates the British steamer *Ferngarth* was reported sunk in 26 fathoms of water on August 13, 1921. A 1981 echo sounder survey of the site did not locate the wreck, and deletion from the database was proposed.

The multibeam sonar survey on this cruise pinpointed the location of a large wreck. Coordinates are not provided here although the U.S. Fish and Wildlife Service may obtain them upon request. The wreck is approximately 300 ft long; the top of the wreck lies in approximately 140 ft of water and the surrounding seafloor is at approximately 160 ft. Video images of the site were obtained by drifting drop camera surveys from a launch on April 24, 2006 and from the *Nancy Foster* on April 26, 2006. The wreck appeared broken up, free of entanglements from fishing gear or other obstructions, and had a large fish community. As the last dive of the cruise (see Appendix 5), two divers from the scientific party with technical diving experience conducted a controlled above-bottom dive to 130 ft to video the wreck, supervised by safety divers from the *Nancy Foster*. The divers did not physically interact with the wreck in any way, and the identity of the wreck could not be confirmed.

Acknowledgments

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such a safe and enjoyable cruise. Thanks to the scientific party for their enthusiasm and hard work; in addition, Vanessa Nero made substantial contributions to the planning and successful execution of the cruise. Invaluable planning information and assistance was provided by Margaret Miller, Art Gleason, and Tim Battista. This manuscript was improved by comments from Mark Fonseca, Patricia Hay, Patti Marraro, Vanessa Nero, Jenny Vander Pluym, and Paula Whitfield.

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Appendix 1. Special access permit for cruise, issued by U.S. Fish and Wildlife Service.

UNITED STATES DEPARTMENT OF THE INTERIOR
FISH AND WILDLIFE SERVICE

NAVASSA NATIONAL WILDLIFE REFUGE

SPECIAL USE PERMIT

Station No. to be Credited Permit No.
41529 - 01

Date February 9, 2006

Period of Use (inclusive)
From April 19, 2006
To May 8, 2006

Permittee Name
NOAA - Center for coastal Fisheries and Habitat Research
Principle Investigator
Dr. Greg Piniak

Permittee Address
NOAA
101 pivers Island Road
Beaufort, NC 28516

Purpose (specify in detail privilege requested, or units of products involved)
Access Navassa NWR for research purposes including; scuba surveys and temporary establishment of transect/quadrats and photography. Ship based surveys; sidescan/multibeam sonar/towed video/Acoustic doppler current profilers/water samples. Installation of ten (10) temperature loggers in non-living reef framework. Collection of marine plants for herbivory assays, by Collection of biological samples for stable isotope analysis.

Description (specify unit numbers: metes and bounds, or other recognizable designations)
Navassa Natioanl Wildlife Refuge

Amount of fee if not a fixed payment, specify rate and unit of charge:

☒ Payment Exempt - Justification: compatible with refuge management objectives
☐ Full Payment
☐ Partial Payment - Balance of payments to be made as follows:

Record of Payments
N/A

Special Conditions
1. Permittee will provide FWS with a complete list of expedition participants, including affiliation and expertise.
2. Permitte will provide complete list of all biological specimens collected, family, genus, species and their locations.
3. Permittee will provide FWS with a copy of the protocol foa all surveys conducted and the data collected from each.
4. Permittee will provide FWS with a copy of a field trip report (intro, methods, results,and discussion) and all published reports resulting from expedition.
5. Noaa Research ship Nancy Forster is encouraged to setup a temporary mooring stationn while on site.
6. Permittee is requested to record all other watercraft and crews observed visiting refuge while on site.
7. Access to island is harzardous. No Ham radio operation is permitted from island.
8. No access to the island will occur unless accompanied by FWS personnel,except in an emergency.

This permit is issued by the U.S. Fish and Wildlife Service and accepted by the undersigned, subject to the terms, covenants, obligations, and reservations, expressed or implied herein, and to the conditions and requirements appearing on the reverse side.

Permittee Signature

Issuing Officer Signature and Title

Form 3-1383 (Rev. 5/97)

Appendix 2. Sample data sheet for fish surveys.

Site 205 Date 4/22/06 Observer A

Transect bearings 1st 342 2nd 313 3rd 229 Fin Kicks 0

Depth (ft) 95 Visibility 30+ m

Site Category: Continuous Reef Patchy Reef Pavement Sand

Elevation: Low (<1m) Med. (1-3m) High (3+m)

Substrate type			Benthic cover		
1°	spur (reef)	70 %	1°	Sponge	50 %
2°	groove (sand)	30 %	2°	coral	30 %
3°		%	3°	sand	20 %

Seabass/Grouper:
graysby IIII I

Grunts:

Snappers:

Jacks:

Parrotfish:
SL III
redband IIII I
princess IIII II

Squirrelfish:
longspine IIII III
silver IIII III

Angels/Wrasse:
rock beauty II
spanish hog I
HOGFISH I

Triggerfish:
Sargassum IIII IIII IIII
ocean (24)
black durgeon IIII I
queen

Pelagics (tuna, mackerel, barracuda):
cuda I

Surgeonfish:
blue tang IIII
ocean surgeon IIII I

Non-fish (turtle, shark, ray, conch, & lobster):

Other:
spotted goat I
y goat IIII

Comments:
Sponge heaven
BEAUTIFUL

Appendix 3. Fish species of interest (species in bold were counted to limit of visibility **–** others enumerated within 4 m belt):

All sharks, turtles, & rays

Squirrelfishes – squirrelfish, longspine squirrelfish, blackbar squirrelfish, longjaw squirrelfish, cardinal soldierfish, reef squirrelfish, dusky squirrelfish

Sea basses –goliath grouper, Nassau grouper, comb grouper, yellowmouth grouper, tiger grouper, yellowfin grouper, marbled grouper

Other seabasses - soapfish, graysby, red hind, rock hind, coney

Bigeyes – glasseye snapper

Jacks – yellow jack, horse-eye jack, black jack, bar jack, rainbow runner, almaco jack, amber jack, blue runner

Snappers – schoolmaster, blackfin snapper, grey snapper, dog snapper, silk snapper, yellowtail snapper, cubera, mutton

Grunts – white & black margate, Caesar grunt, French grunt, Spanish grunt, bluestriped grunt, white grunt

Goatfishes – yellow goatfish, spotted goatfish

Angelfishes: queen angel, French, grey, rock beauty

Spadefishes – spadefish

Wrasses – Spanish hogfish, puddingwife**, hogfish**

Parrotfishes – *Scarus, Sparisoma* – primary parrots caught are queen & blue

Barracudas – great barracuda

Pelagic fishes – wahoo, skipjack tuna, blackfin tuna, false albacore, mackerel (cero, Spanish, king), dolphinfish

Lefteye flounders – peacock flounder, eyed flounder

Triggerfishes – queen triggerfish, ocean triggerfish, black durgon, Sargassum triggerfish

Surgeonfishes – blue tang, doctorfish, surgeonfish
Boxfish – cow & trunk fish

Additional species to be censured: lobster (spiny & slipper), conch (noting juvenile & adult), moray

Appendix 4. Settings for benthic photo surveys.

All photos were taken using 7.1 megapixel Olympus C-7070 Wide Zoom cameras (settings: autofocus, scene = underwater wide, resolution = TIFF 3072x2304, ISO = auto, white balance = cloudy) with wide-angle lenses and Halcyon dual 24 watt High Intensity Discharge (HID) lights. The camera housings (Light and Motion Tetra or Olympus PT-027) were fitted with stainless steel marker sticks so that images were taken at a fixed distance from the bottom. The actual length of the stick varied with housing type as the mounting position differed, but was calibrated so that a perpendicular image on a flat sandy surface underwater was 80 cm wide x 60 cm long.

Appendix 5. Dive statistics for scientists and *Nancy Foster* crew.

Date	Site	Divers	PSI in	PSI out	Time in	Time out	Depth (ft)	Bottom time	Gas mix	Task
4/20/06	n/a	Wiener	3000	500	1413	1453	74	33	air	checkout
		Score	2900	1200	1413	1453	74	33	32	
		Hamburger	3000	800	1413	1453	74	33	32	
	n/a	Poray	3000	1700	1420	1502	74	30	32	camera training
		Uhrin	3000	1250	1420	1502	74	30	32	
		Hilmer	3500	989	1420	1502	74	30	32	
	n/a	Whitfield	4000	2300	1432	1505	70	30	32	fish training
		Kelty	3100	1900	1432	1505	69	29	32	
		Foust	2800	750	1432	1505	72	30	32	
	n/a	Piniak	3100	1800	1540	1617	69	29	32	camera training
		Marr	3600	1500	1540	1617	77	30	32	
		Moneysmith	3800	1000	1540	1617	69	30	32	
	n/a	Degan	3000	1500	1556	1633	73	29	32	fish training
		Addison	2900	1500	1556	1633	68	29	32	
		Vander Pluym	3500	1800	1556	1633	73	29	32	
4/21/06	102	Whitfield	3200	700	0802	0846	99	27	32	site survey
		Uhrin	3200	1000	0802	0846	99	27	32	
		Hilmer	3200	1000	0802	0846	99	27	32	
	102	Addison	3100	1500	0817	0852	108	22	32	site survey
		Moneysmith	3100	1400	0817	0852	108	22	32	
		Vander Pluym	3100	700	0817	0852	108	22	32	
	102	Degan	2800	700	0905	0942	110	26	32	site survey
		Poray	3100	1200	0905	0942	110	26	32	
	108	Kelty	3100	1500	1749	1823	105	23	32	site survey
		Marr	2800	800	1749	1823	101	23	32	
		Moneysmith	3200	1000	1749	1823	101	23	32	
	108	Whitfield	3000	1200	1801	1839	100	25	32	site survey
		Uhrin	3100	1350	1801	1839	100	25	32	
		Hilmer	2980	700	1801	1839	100	25	32	

Date	Site	Divers	PSI in	PSI out	Time in	Time out	Depth (ft)	Bottom time	Gas mix	Task
	108	Degan Poray			1856 1856	1929 1929	110 110	26 26	32 32	site survey
4/22/06	305	Addison Moneysmith	3000 3100	1300 700	0843 0843	0922 0922	106 106	25 25	32 32	site survey
	305	Kelty Piniak Marr	3100 3100 3100	1700 700 700	0929 0929 0929	0954 0954 0954	110 107 110	23 23 23	32 32 32	site survey
	305	Whitfield Uhrin	3100 3100		0939 0939	1011 1011	110 110	26 26	32 32	site survey
	18° 24.173’ N 75° 01.432’ W	Addison Hilmer			1421 1421	1504 1504	80 80		32 32	conch
	205	Degan Poray	3000 3200	1100 1500	1736 1736	1812 1812	96 96	23 23	32 32	site survey
	205	Kelty Marr Piniak	3100 3100 3100	1700 1400 1000	1808 1808 1808	1848 1848 1848	105 105 105	26 26 26	32 32 32	site survey
	205	Moneysmith Vander Pluym Foust	3000 3200 3000	1000 1400 1000	1818 1818 1818	1858 1858 1858	102 105 105	23 23 23	32 32 32	site survey
4/23/06	203	Moneysmith Vander Pluym Addison	3000 3000 3000	600 600 1200	0805 0805 0805	0853 0853 0853	97 104 98	30 30 30	32 32 32	site survey
	203	Whitfield Uhrin Hilmer	2900 3000 3000	700 1100 600	0817 0817 0817	0900 0900 0900	98 98 98	26 26 26	32 32 32	site survey
	203	Kelty Piniak	3100 3000	1400 800	0903 0903	0939 0939	101 101	25 25	32 32	site survey
	Northwest Point	Hilmer Whitfield	3000 3100	2000 2000	1441 1441	1517 1517	71 66	30 30	32 32	stable isotopes, temp logger
	West Pinnacles	Degan Poray	3300 3100	500 1000	1547 1547	1636 1636	83 83	40 40	32 32	stable isotopes, temp logger

Date	Site	Divers	PSI in	PSI out	Time in	Time out	Depth (ft)	Bottom time	Gas mix	Task
	18° 24.820’ N 75° 00.805’ W	Addison Marr	3100 3100	1800 1400	1557 1557	1633 1633	91 91	23 23	32 32	conch, temp logger
	Lulu Bay	Hamburger Wiener	2800 3000	1250 1000	1705 1705	1735 1735	84 84	25 25	32 air	temp loggers
4/24/06	201	Whitfield Uhrin Hilmer	3100 3100 3100	1200 1000 1000	0801 0801 0801	0845 0845 0845	110 110 110	23 23 23	32 32 32	site survey
	201	Degan Poray	3100 3100	600 1000	0815 0815	0850 0850	108 108	26 26	32 32	site survey
	201	Moneysmith Vander Pluym	3000 3000	500 550	0850 0850	0936 0936	104 104	30 30	32 32	site survey
	18° 24.265’ N 75° 00.517’ W	Uhrin Poray Salerno	3000 3200 2800	1500 1500 800	1400 1400 1400	1435 1435 1435	80 80 80	26 26 26	32 32 32	gear impact
	18° 24.083’ N 75° 00.114’ W	Addison Degan	3000 3000	1800 1400	1407 1407	1449 1449	92 92	23 23	32 32	conch
	202	Kelty Marr	3000 3000	1200 600	1737 1737	1813 1813	107 107	25 25	32 32	site survey
	202	Whitfield Piniak	3000 3100	1000 1000	1805 1805	1841 1841	110 110	24 24	32 32	site survey
	202	Foust Wiener	3100 2900	1200 1000	1818 1818	1847 1847	104 104	20 20	32 air	observation
	202	Moneysmith Vander Pluym	3000 3000		1830 1830	1908 1908			32 32	site survey
4/25/06	301	Moneysmith Addison Vander Pluym	3000 3000 3000		0813 0813 0813	0902 0902 0902	105 105 105	30 30 30	32 32 32	site survey
	301	Kelty Piniak Hilmer	3000 3000 3100		0821 0821 0821	0858 0858 0858	106 106 106	27 27 27	32 32 32	site survey

Date	Site	Divers	PSI in	PSI out	Time in	Time out	Depth (ft)	Bottom time	Gas mix	Task
	301	Marr Whitfield	3000 3000		0857 0857	0935 0935	105 105	23 23	32 32	site survey
	18° 24.753’ N 75° 00.222’ W	Addison Kelty Moneysmith	3000 2800 3000		1403 1403 1403		99 99 99		32 32 32	conch
	Lulu Bay	Wiener Salerno	3000 2800		1424 1424	1458 1458	76 76	28 28	air 32	observation
	302	Degan Poray	3000 3100	1200 1500	1750 1750	1820 1820	106 106	18 18	32 32	site survey
	302	Marr Vander Pluym	3100 3100	500 900	1800 1800	1833 1833	105 105	25 25	32 32	site survey
	302	Uhrin Whitfield Hilmer	3000 3400 3100	1000 1100 900	1810 1810 1810	1837 1837 1837	106 106 106	24 24 24	32 32 32	site survey
4/26/06	101	Degan Poray			0800 0800		110 110		32 32	site survey
	101	Whitfield Uhrin Hilmer			0815 0815 0815		107 107 107		32 32 32	site survey
	101	Kelty Piniak Marr			0850 0850 0850		110 110 60	27 27	32 32 32	site survey
	18° 24.897’ N 75° 01.846’ W	Addison Vander Pluym					102 102		32 32	conch
	18° 24.836’ N 75° 01.451’ W	Piniak Delinski Salerno					75	20	32 32 32	stable isotopes
4/27/06	104	Degan Poray Hilmer	3100 3100 3100	500 1100 1000	0805 0805 0805	0843 0843 0843	103 103 103	25 25 25	32 32 32	site survey

Date	Site	Divers	PSI in	PSI out	Time in	Time out	Depth (ft)	Bottom time	Gas mix	Task
	104	Addison	3100	1000	0814	0901	104	30	32	site survey
		Moneysmith	3100	500	0814	0901	104	30	32	
		Vander Pluym	3100	500	0814	0901	104	30	32	
	104	Uhrin	3200		0850				32	site survey
		Kelty	3300		0850				32	
		Marr	3100		0850				32	
	Lulu Bay	Addison	3200	1500	1420		72	39	32	conch
		Vander Pluym	3200	1000	1420		73	41	32	
		Moneysmith	3400	1000	1420		73	41	32	
	115	Whitfield	3200	700	1805	1843	109	24	32	site survey
		Hilmer	3000	1000	1805	1843	109	24	32	
		Piniak	3200	750	1805	1843	109	24	32	
	115	Degan	3200	500	1810	1853	104	27	32	site survey
		Poray	3500	1200	1810	1853	102	27	32	
	115	Marr	3000	600	1823	1858	104	27	32	site survey
		Kelty	3300	1400	1823	1858	104	27	32	
	115	Uhrin	3200	1750	1823	1855	100	25	32	observation
		Wiener	3000	500	1823	1855	100	25	air	
4/28/06	112	Degan	3400	1100	0804	0845	104	30	32	site survey
		Poray	3000	500	0804	0845	104	30	32	
		Vander Pluym	3100	900	0804	0845	104	30	32	
	112	Whitfield	3200	1100	0812	0849	96	30	32	site survey
		Uhrin	3100	1000	0812	0849	96	30	32	
		Hilmer	3200	900	0812	0849	96	30	32	
	112	Kelty	3000	1600	0840	0915	96	23	32	site survey
		Marr	3000	600	0840	0915	96	23	32	
		Moneysmith	3000	1400	0840	0915	96	23	32	
	210	Addison	3200	1800	1732	1810	105	27	32	site survey
		Piniak	3200	1100	1732	1810	105	27	32	
		Vander Pluym	3100	800	1732	1810	105	27	32	

Date	Site	Divers	PSI in	PSI out	Time in	Time out	Depth (ft)	Bottom time	Gas mix	Task
	210	Poray Degan	3500 3000	1200 700	1744 1744	1822 1822	105 105	27 27	32 32	site survey
	210	Uhrin Whitfield	3200 3400	1000 1100	1754 1754	1831 1831	99 105	26 26	32 32	site survey
	210	Foust Marr	3000 3000	600 600	1754 1754	1831 1831	105 105	26 26	32 32	observation
4/29/06	109	Kelty Piniak	3200 3200	1400 1000	0753 0753	0834 0834	104 104	28 28	32 32	site survey
	109	Degan Poray	3200 3200	700 1300	0803 0803	0942 0942	104 104	30 30	32 32	site survey
	109	Wiener Hilmer	3100 3200	1100 1600	0807 0807	0939 0939	90 98	20 20	air 32	observation
	109	Moneysmith Vander Pluym Uhrin	3300 3100 3200	800 900 1250	0823 0823 0823	0905 0905 0905	105 105 105	30 30 30	32 32 32	site survey
	Ferngarth	Whitfield Addison	3400 3200	800 1100	0949 0949	1037 1037	130 130	20 20	32 32	observation
	Ferngarth	Score Delinski	2900 3300	1200 1000	1008 1008	1037 1037	118 119	14 14	32 32	safety divers

Appendix 6. Conch survey datasheet, adapted from Glazer, 1999. Coordinates for sample locations may be found in Table 7.

SITE: East 1 DATE: 4/24/06 TRANSECT L (M): 30 VIZ(M) BEARING 313 R

Trans 2 R

DPTH(FT)	81	81											
HABITAT	3432	3432											
METERS	0	17											
AGE													
SIZE													
MICROHAB													
NOTES													

TOTAL CONCH: A: 0 J: 0 TL: 0 TOT: 0

EGGS: M: F: F/E:

Notes:

Area Surveyed: 30m x 2m

SITE: East 1 DATE: 4/24 TRANSECT L (M): 30 VIZ(M) BEARING 313 L

Trans 2 L

DPTH(FT)	81	81											
HABITAT	2	3432											
METERS	30	15											
AGE													
SIZE													
MICROHAB													
NOTES													

TOTAL CONCH: A: 0 J: 0 TL: 0 TOT: 0

EGGS: M: F: F/E:

Notes:

Area Surveyed: 30m x 2m

SITE: East 1 DATE: 4/24 TRANSECT L (M): 30 VIZ(M) BEARING 109

Trans 3 L

DPTH(FT)	82	84	90										
HABITAT	3432	34	3432										
METERS	0	6	22										
AGE													
SIZE													
MICROHAB													
NOTES													

TOTAL CONCH: A: J: TL: TOT:

EGGS: M: F: F/E:

Notes:

Area Surveyed: 30m x 2m

(garmin coord) East 1: 18° 24 05.0 75° 00 06.8

Appendix 7. Conch habitat codes used to classify available and utilized habitat. Adapted from Glazer, 1999.

REEF		1
HARDBOTTOM		2
	Sponges/soft corals/red algae (colonized pavement)	21
	Soft bottom (*Halimeda/Penicillus*)	22
	Soft hard bottom (*Lobophora*/soft algae covered rock)	23
SEDIMENT		3
	Silt	31
	Sand	32
	Coarse sand	33
	Rubble	34
SEAGRASS		4
	Thalassia	41
	Syringodium	42
	Mixed	43
	Density	Thick --1
		Thin --2
Examples	Coarse sand plain with rubble	3334
	Reef with rubble	134
	Coarse sand w/rubble with soft corals/sponge	333421

Appendix 8. Specimen collection log. Coordinates for numbered sites may be found in Table 2; the coordinates for NW Point and West Pinnacles are the same as those for the temperature loggers (see text). Site E of NW Point is located at 18° 24.836' N, 75° 01.451' W. No size was recorded for algal collections.

Species	Type	Size (mm)	Date collected	Location	Depth (ft)	Method	Collector
Graysby	fish	210	4/23/06	West Pinnacles	83	spear	Degan
Graysby	fish	210	4/23/06	West Pinnacles	83	spear	Degan
Graysby	fish	220	4/27/06	104	104	spear	Addison
Blue tang	fish	105	4/27/06	104	104	spear	Addison
Blue tang	fish	85	4/27/06	104	103	spear	Degan
Ocean surgeon	fish	170	4/27/06	104	103	spear	Degan
Graysby	fish	200	4/27/06	Lulu Bay	n/a	spear	Degan
Blue tang	fish	180	4/27/06	Lulu Bay	n/a	spear	Degan
Silky snapper	fish	830	4/27/06	S of Lulu Bay	350	hook/line	Degan
Longspine squirrelfish	fish	310	4/27/06	S of Lulu Bay	350	hook/line	Degan
Graysby	fish	240	4/28/06	112	104	spear	Degan
Graysby	fish	230	4/28/06	112	104	spear	Degan
Blue tang	fish	125	4/28/06	112	104	spear	Degan
Longspine squirrelfish	fish	240	4/28/06	112	104	spear	Degan
Longspine squirrelfish	fish	225	4/28/06	210	105	spear	Degan
Longspine squirrelfish	fish	205	4/28/06	210	105	spear	Degan
Longspine squirrelfish	fish	235	4/28/06	210	105	spear	Degan
Longspine squirrelfish	fish	215	4/28/06	210	105	spear	Vander Pluym
Longspine squirrelfish	fish	225	4/28/06	210	105	spear	Degan
Redband parrotfish	fish	130	4/28/06	210	105	spear	Vander Pluym
Princess parrotfish	fish	180	4/28/06	210	105	spear	Vander Pluym
Black snapper	fish	330	4/28/06	S of Lulu Bay	350	hook/line	Degan
Redband parrotfish	fish	210	4/29/06	109	104	spear	Degan
Princess parrotfish	fish	175	4/29/06	109	105	spear	Vander Pluym

Species	**Type**	**Size (mm)**	**Date collected**	**Location**	**Depth (ft)**	**Method**	**Collector**
Redband parrotfish	fish	180	4/29/06	109	104	spear	Degan
Redband parrotfish	fish	160	4/29/06	109	104	spear	Degan
Redband parrotfish	fish	125	4/29/06	109	104	spear	Degan
Great barracuda	fish	750		south coast (trolling)	n/a	hook/line	Degan
Great barracuda	fish	840		south coast (trolling)	n/a	hook/line	Degan
Great barracuda	fish	1050		south coast (trolling)	n/a	hook/line	Degan
Montastraea cavernosa	coral	58 x 65	4/23/06	NW Point	36-66	hand	Whitfield/Hilmer
Montastraea annularis	coral	33 x 49	4/23/06	NW Point	36-66	hand	Whitfield/Hilmer
Porites astreoides	coral	65 x 88	4/23/06	NW Point	36-66	hand	Whitfield/Hilmer
Porites porites	coral	25 x 12	4/23/06	NW Point	36-66	hand	Whitfield/Hilmer
Porites porites	coral	16 x 48	4/23/06	NW Point	36-66	hand	Whitfield/Hilmer
Siderastrea siderea	coral	35 x 36	4/23/06	NW Point	36-66	hand	Whitfield/Hilmer
Siderastrea radians	coral	20 x 25	4/23/06	NW Point	36-66	hand	Whitfield/Hilmer
Stephanocoenia intersepts	coral	24 x 30	4/23/06	NW Point	36-66	hand	Whitfield/Hilmer
Montastraea annularis	coral	45 x 16	4/23/06	West Pinnacles	83	hand	Poray
Siderastrea siderea	coral	22 x 21	4/23/06	West Pinnacles	83	hand	Poray
Porites astreoides	coral	21 x 45	4/23/06	West Pinnacles	83	hand	Poray
Agaricia agaricites	coral	46 x 67	4/23/06	West Pinnacles	83	hand	Poray
Montastraea annularis	coral	60 x 81	4/23/06	West Pinnacles	83	hand	Poray
Montastraea franksi	coral	34 x 20	4/26/06	E of NW Point	55	hand	Piniak
Montastraea franksi	coral	16 x 17	4/26/06	E of NW Point	55	hand	Piniak
Porites astreoides	coral	38 x 25	4/26/06	E of NW Point	20	hand	Piniak
Porites astreoides	coral	17 x 10	4/26/06	E of NW Point	20	hand	Piniak
Siderastrea radians	coral	45 x 25	4/26/06	E of NW Point	20	hand	Piniak
Dictyota	algae		4/23/06	NW Point	36-66	hand	Whitfield/Hilmer
Halimeda	algae		4/23/06	NW Point	36-66	hand	Whitfield/Hilmer
Stypopodium	algae		4/23/06	NW Point	36-66	hand	Whitfield/Hilmer
Dictyota	algae		4/23/06	West Pinnacles	83	hand	Poray

Species	Type	Size (mm)	Date collected	Location	Depth (ft)	Method	Collector
Lobophora	algae		4/23/06	West Pinnacles	83	hand	Poray
Rhipocephalus	algae		4/25/06	Conch East2	99	hand	Poray
Sargassum	algae		4/25/06	Conch East2	99	hand	Poray
Stypopodium	algae		4/25/06	Conch East2	99	hand	Poray
Avrainvillea	algae		4/26/06	101	110	hand	Poray
Ventricaria	algae		4/26/06	101	110	hand	Poray
Halimeda	algae		4/26/06	E of NW Point	55	hand	Piniak
Lobophora	algae		4/26/06	E of NW Point	55	hand	Piniak
Dictyota	algae		4/26/06	E of NW Point	55	hand	Piniak
Rosinvingea	algae		4/26/06	E of NW Point	55	hand	Piniak
Padina	algae		4/26/06	E of NW Point	55	hand	Piniak
Ulva	algae		4/26/06	E of NW Point	55	hand	Piniak

United States Department of Commerce

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