MARMAP/SEAMAP-SA/SEFIS Reef Fish Survey sampling protocol
Updated: April 2013

Background and history

Prior to 2010, and dating to the 1970s, the *MA*rine *R*esources *M*onitoring *A*ssessment and *P*rediction (MARMAP) program was the sole fishery-independent data collection program providing data on federally managed reef fish species in southeastern US Atlantic Ocean waters (continental shelf and shelf-break waters ranging from Cape Hatteras, NC to Port St. Lucie, FL; hereafter "SEUS"). Based out of the South Carolina Department of Natural Resources Marine Resources Research Institute, MARMAP continues to perform National Marine Fisheries Service Southeast Fisheries Science Center (NMFS SEFSC)-funded fishery-independent sampling to generate life-history information and abundance indices to inform stock assessments for multiple federally managed species. MARMAP has used standardized trap deployments to annually sample and monitor hardbottom-associated reef fish species in SEUS waters since 1978, and chevron traps since 1990. In 2009, the SouthEast Area Monitoring, Assessment, and Prediction program, South Atlantic (SEAMAP-SA), began cooperating with MARMAP to form the MARMAP/SEAMAP-SA Reef Fish Survey to increase fishery independent sampling efforts including increasing regional coverage and the potential addition of sampling gears. In 2010, based on recommendations generated during a South Atlantic Fishery Independent Monitoring Program Workshop (Williams and Carmichael 2009), the NMFS SEFSC SouthEast Fishery-Independent Survey (SEFIS) was established to work cooperatively with MARMAP/SEAMAP-SA to:

(1) Expand the sample size and spatial distribution of the ongoing trap survey;
(2) Add video cameras as a region-wide survey gear;
(3) Initiate extensive, annual multibeam mapping efforts to improve knowledge of hardbottom habitat distribution within the survey area, with ramifications for improving survey design; and
(4) Perform directed research to assess and compare survey methods and to address critical management issues.

As a result, beginning in 2010, MARMAP/SEAMAP-SA and SEFIS have worked cooperatively to perform an annual, region-wide chevron trap survey targeting reef-associated species in SEUS waters. Additionally, SEFIS initiated a video survey (with video cameras attached to the chevron traps, hereafter referred to as "camera-traps") in GA and FL waters in 2010. This methodology enabled continued collection of biological samples [otoliths and gonads] within the traps and paired comparisons of trap and video gears. Beginning in 2011, MARMAP/SEAMAP-SA and SEFIS have worked cooperatively to perform the video survey at the same region-wide scale as the trap survey, thus creating one regional Reef Fish Survey. Within the Reef Fish Survey, MARMAP/SEAMAP-SA programs sample all random stations off North and South Carolina, and the SEFIS program samples all the random stations in waters off Georgia and Florida. This approach optimizes the use of sea days by eliminating unnecessary steam time between sampling areas. Identical sampling procedures are used by both programs.

Study area

Trap sampling by the Reef Fish Survey (RFS) targets reef fish species associated with hard substrates on the continental shelf and continental shelf-break in the SEUS (Figure 1). The continental shelf and shelf-break in the SEUS are dominated by sand and mud substrates, within which areas of hard, rocky substrates ("hardbottom") occur with a highly diverse associated reef fish assemblage. Hardbottom habitats range in complexity from flat limestone pavement, sometimes covered with a sand or gravel veneer, to high-relief rocky ledges (Schobernd and Sedberry, 2009; Glasgow, 2010). Hardbottom often hosts diverse epifauna that can provide food and shelter for reef fish. The major oceanographic feature of the SEUS is the Gulf Stream, which influences outer sections of the continental shelf as it flows northward. Consistently warm Gulf Stream waters along the outer SEUS shelf allow tropical and subtropical species to inhabit areas at least as far north as North Carolina (Miller and Richards, 1980). Historically, MARMAP sampling occurred predominantly from approximately Cape Lookout, North Carolina, to St. Lucie Inlet, Florida. Beginning in 2011, SEFIS sampled Georgia and Florida waters and MARMAP/SEAMAP-SA sampled North and South Carolina waters.

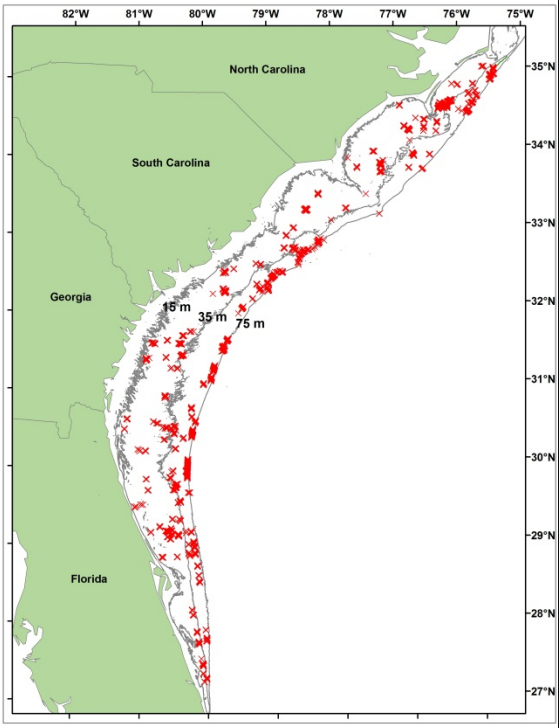

Figure 1. Reef Fish Survey sampling frame.

Sampling frame

Before SEFIS and SEAMAP-SA joined the Reef Fish Survey, MARMAP had developed a sampling frame consisting of approximately 1,500 stations between North Carolina and Florida where hardbottom was present, based on information derived from commercial fishermen, recreational anglers, MARMAP underwater television surveys, reconnaissance sampling (e.g. trap deployments), and cameras mounted on traps in the early 1990s, and other scientific surveys. In 2009, SEAMAP-SA funding allowed expansion of the sampling frame via reconnaissance surveys, and stations were added in particular off North Carolina and Florida. SEFIS then expanded the sampling frame in the southern (Florida; 2010–2011) and northern (northern North Carolina; 2012) portions of the study area, where points in the sampling frame were much less dense. SEFIS first accumulated information from fishermen, fishing charts, scientific studies (including MARMAP and SEAMAP-SA surveys), and historical survey information where hardbottom was suspected to be present. Hardbottom was then identified either by multibeam sonar mapping or by simply using the ship's echosounder. New stations were added to the sampling frame only after hardbottom or at least one reef indicator species was seen on video from that station, or at least one reef indicator species was caught in the sampling gear (see Appendix A for protocol). If any of these conditions were met, that station was added to the pool of sampling frame stations available to be sampled the following year. As of 2013, the number of stations has increased to 2,685.

In any given year, three types of trap deployments occur: (1) RANDOM, which are truly randomly selected stations from the sampling frame (see below), (2) OPPORTUNISTIC, which are stations sampled opportunistically from the sampling frame even though they were not randomly selected for sampling in a given year, and (3) RECON, which are deployments made because hardbottom was suspected to be present.

Annual sample station random selection

Before each year's cruise season, MARMAP randomly selects a number of stations from the Reef Fish Survey sampling frame. First, all stations are arranged in random order. The randomized list is entered in GPS Babel, which iteratively checks stations in order for proximity less than 400 m. Starting with the first station in the randomized list, all subsequent stations that are closer than 400 m are removed. In a given year, this generates a list of randomly selected stations with 400 m buffers around them that generally contains ~60% of the full sampling frame. Although the MARMAP sampling protocol initially stated that a 200 m buffer was sufficient to minimize interactions among traps, historically, 400 m was used to ensure the 200 m minimum distance was maintained at sea where variability in placement of traps can occur. At sea, the chief scientist has the choice to sample "opportunistic" stations, which are those that were eliminated by the 400 m buffer but are more than 200 m from other gear deployments.

Sample station selection during cruises

SEFIS typically schedules 5–7 research cruises per year totaling between 50–80 daysat-sea (Table 1). Approximately 2/3 of the days at-sea occur on a contract vessel and are dedicated to sampling randomly selected stations with camera-trap gear, and the remaining 1/3 of the days at-sea occur on a NOAA ship and are jointly dedicated to (1) finding new hardbottom habitat (predominantly via multibeam mapping) and (2) sampling opportunistic or recon stations with camera-trap gear. Effort is spread out over the SEFIS sampling area (GA/FL) on each contract vessel cruise. Sampling is also highly weather-dependent, and reduced spatial coverage has occurred for some cruises when weather has been limiting.

Table 1. SEFIS sampling effort in 2010–2012.

	2010	2011	2012
Total monitoring cruises	7	5	7
Total days at-sea	63	54	78
Contract vessel	29	42	49
NOAA ship	34	12	29
Camera-trap deployments	480	546	945
Months sampled	Jul - Oct	May - Sep	Apr - Sep
States sampled	GA, FL	GA, FL	GA, FL, NC

MARMAP/SEAMAP-SA typically has 10-14 cruises per year on SC-DNR owned vessels (R/V *Palmetto* and R/V *Lady Lisa*) totaling ~ 80-100 planned and 40-70 realized days at-sea (see Table 2 for overview for three most recent years). A majority of these days are dedicated to trap gear (with cameras in recent years), but also include hook and line efforts for companion projects and two longline surveys. All camera-trap sampling takes place on the R/V *Palmetto*. Days at-sea funded by SEAMAP-SA generally are dedicated to the deployment of RECON gear in areas of suspected hardbottom, and hook and line efforts. However, increasingly SEAMAP-SA efforts have concentrated on monitoring efforts as MARMAP funding has stagnated or declined. A long

bottom long line survey targeting golden tilefish, which occurred using the RV *Lady Lisa*,was halted or severely reduced as a result of a significant funding reduction for MARMAP in 2012.

Table 2. MARMAP/SEAMAP-SA sampling effort in 2010-2012.
[*1]: no sea days as long bottom long-line survey was halted.
[*2]: during 2010, not all deployed traps had video cameras mounted.

	2010	2011	2012
Total monitoring cruises	15	16	9
Total days at-sea	75	62	40
R/V Palmetto	59	53	40
R/V Lady Lisa	16	9	0[*1]
Camera-trap deployments	758[*2]	610	448
Months sampled	May – Oct.	May – Oct.	Apr – Oct.
States sampled	NC, SC	NC, SC	NC, SC

Sampling a station

A random or opportunistic station typically is sampled by driving the vessel directly over the station at approximately 5 $km \cdot hr^{-1}$, and the camera-trap array is deployed off the stern when the sampling location is reached and hardbottom is observed on the vessel's echosounder. Hardbottom typically is identified on the echosounder as an uneven surface (if relief is present) and/or a thickening of the bottom that results from a stronger acoustic return of rock compared to sand and mud. If hardbottom is not observed directly on the station point, the chief scientist and captain will search for hardbottom within a radius of 100 meters of the point since there is some inherent error associated with GPS points while at sea (e.g., GPS antenna is approximately midship when a trap is deployed off the stern, a distance of up to 50 meters on NOAA ships). If no hardbottom is found at a sampling station after a considerable search, the trap is deployed on the station's GPS coordinates. If catches and information from video examination indicate that hard bottom is not (or no longer) present, the station may be considered for removing from the sampling frame.

Typically, six camera-traps are deployed sequentially at random and opportunistic stations within a relatively small area (but no closer than 200 meters from one another) and soaked simultaneously (for approximately 90 minutes). MARMAP found that soaking six traps simultaneously was the most efficient method of sampling, because by the time six traps are deployed sequentially and a CTD cast is made, it is often time for the first trap to be retrieved.

A variety of water quality parameters are measured for the simultaneously deployed group of camera-trap arrays using a CTD. CTD casts are conducted during each camera-trap soak period, with the instrument recording depth-specific water quality parameters from the surface to within 2 meters of the bottom.

Gear justification, specifications, deployment, and retrieval

Fish traps are used to index the abundance of reef fish and invertebrate species around the world, and are particularly useful in areas with sensitive habitats such as coral reefs (Recksiek et al. 1991; Evans and Evans 1996; Rudershausen et al. 2010). Chevron fish traps were recommended specifically in the South Atlantic Fishery Independent Monitoring Program Workshop (Williams and Carmichael 2009). MARMAP has used chevron traps since 1988 and

in a consistent, standardized manner since 1990, to collect information for relative abundance (index), length compositions, and life history (age, reproduction, diet, etc.) for a variety of reef fish species in the SEUS. The time series of chevron trap catches has been useful in a variety of (SEDAR) stock assessments (e.g., black sea bass, red porgy, vermilion snapper, red grouper, gray triggerfish).

Chevron traps are constructed from plastic-coated galvanized 12.5 ga wire (mesh size = 3.4 cm^2), and are shaped like an arrowhead that measures 1.7 m × 1.5 m × 0.6 m, with a total volume of 0.91 m^3. The trap mouth openings are shaped like a teardrop and are approximately 18 cm wide and 45 cm high. Each trap is baited with 24 menhaden (*Brevoortia* spp.), 16 of which are suspended on freely-accessible stringers and the other 8 are placed loosely inside the trap. The traps are buoyed to the surface using 8 mm (5/16 inch) polypropylene line with a polyball buoy attached to a hi-flyer buoy or a second polyball buoy by a 10 m trailer line, depending on location and conditions.

In 2008, MARMAP started deploying all chevron traps with still cameras mounted above the mouth (same location the Cannon cameras are currently mounted, Figure 2) that took a picture every 5 minutes. This was done to assist with verifying bottom habitat, observe trap movement, and develop additional indices of relative abundance (e.g. for lionfish and other species). These still cameras were replaced by GoPro cameras in 2013 (see details below).

The addition of video cameras by SEFIS in 2010, and the initiation of the region-wide (MARMAP/SEAMAP-SA/SEFIS) video survey in 2011, was driven primarily by the perception of fishermen and scientists that red snapper and some other reef fish species may not be effectively surveyed with traps (Conn 2011). It is expected that video will be used to generate a separate index of abundance for many reef fish species, or perhaps a combined camera-trap index using occupancy or *N*-mixture modeling approaches (McKenzie et al. 2002; Royal 2004).

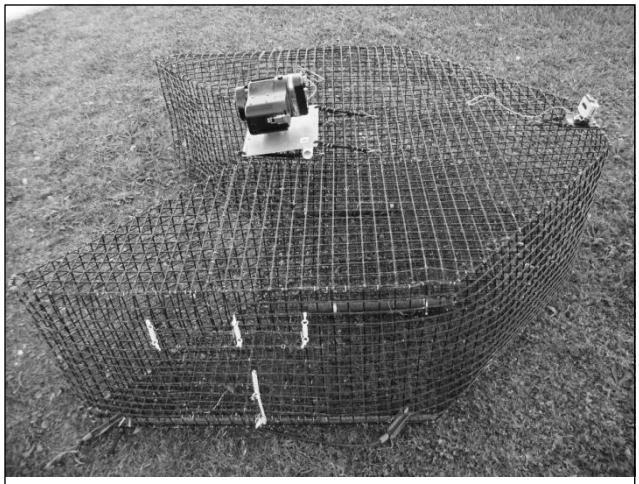

Figure 2. Camera-trap array used by the Reef Fish Survey.

High-definition video cameras (n=2) are mounted directly on each chevron trap (Figure 2). A Canon Vixia HFS200 is attached over the mouth and a GoPro Hero® attached over the nose of each trap, both looking away from the trap. Canon cameras over the mouth are used for counting fish and quantifying habitat, whereas GoPro cameras are used only for quantifying habitat. Both cameras are turned on and set to record as the vessel approaches a sampling station. Both cameras record high-definition video for most or all of the time the camera-trap array soaks (approximately 90 minutes). After a trap is retrieved, memory cards are removed from video cameras and downloaded onto external hard drives for transport to the laboratory for processing.

The camera-trap array is deployed off the back deck when the vessel arrives at a sampling station. Camera-trap arrays are retrieved using a hydraulic pot hauler. Traps are deployed no earlier than 30 minutes after sunrise and retrieved no later than 30 minutes before sunset.

Processing of the catch

All fish caught in the chevron trap are sorted by species and a total species wet weight is recorded for all species. Individuals of each species are then enumerated, measured for total length, and either released or retained for biological sample extraction. All individuals of priority species in the "snapper-grouper" complex are retained, but black sea bass, vermilion snapper, red porgy, and gray triggerfish are sub-sampled randomly due to the high volume of these species. From 2009 to 2012 33% of black sea bass, 50% of vermilion snapper, 75% of red porgy, and 80% of gray triggerfish were retained for further processing. Unusually large or small individuals (pre-defined for each species) of these four species are retained for further processing if not randomly selected. In 2013, these sub-samples were modified based on abundances in 2011 and 2012 to 20% black sea bass, 75% red porgy, 50% vermilion snapper, and 100% gray triggerfish. Fish retained for further processing are measured for standard, fork, and total length (to nearest millimeter) and weighed to the nearest gram. Sagittal otoliths are extracted for age estimation, as are samples of reproductive tissues for determination of sex, spawning seasonality, maturity stage, and fecundity. Other biological samples (e.g., fin clips for DNA, stomachs for diet analysis) are removed when there is a specific need or request.

Trap data analysis

Reef Fish Survey scientists work together to provide trap survey indices of abundance for relevant reef species as part of the Southeast Data, Assessment, and Review process. In recent years, catch rates have been standardized using a delta-GLM modeling approach to control for annual variation in the spatial or temporal aspects of the survey or for variability in environmental conditions (e.g., bottom temperature) over the study area (Dick 2004; Maunder and Punt 2004). Typical predictor variables included in delta-GLM models are season, latitude, depth, and water temperature.

Video data

Each underwater video is "read" during the offseason. Only trained video readers read videos, and all videos from new video readers are re-read by another video reader until no systematic errors are evident, at which point normal QAQC procedures apply (see below). Because of the time constraints associated with reading videos for all video species, videos are read for a subset of species (n = 107): (1) all snapper, grouper, and amberjack species, (2) all species included in the Fish Sustainability Index, (3) all large pelagic species, and (4) lionfish. Some common and presumably ecologically important species such as tomtate and *Stenotomus* spp. are excluded because of the significant extra effort that would be required to read videos for these species.

Videos are read beginning 10 minutes after the trap lands on the bottom, to allow time for fish to acclimate to the presence of the trap, and ending 30 minutes after the trap lands on the bottom. Within that 20-minute window, we read videos using the MeanCount approach (Conn 2011; Schobernd et al. in review). Specifically, we examine 1-second "snapshots" every 30 seconds, for a total of 41 1-second snapshots. Within each 1-second interval, we record the maximum number of individuals of a particular species in a single frame. The overall MeanCount for each video is the mean number of individuals of each species seen in each of the 41 intervals. SEFIS not only reads videos collected on SEFIS research cruises, but also videos collected during MARMAP research cruises (totaling 1,393 videos in 2012). Since the video survey was initiated in 2010, the video index time series is still quite short.

QAQC

Nearly all Reef Fish Survey data is checked for quality assurance and quality control multiple times (Table 2). All (100%) of the station-level, fish catch and workup, and video entry data is QAQCed by two or, more often, three people. In addition, a minimum of 10% or $N = 15$ (whichever is more) underwater videos from each reader are re-read by other video readers to corroborate fish identifications and the number of fish counted at each interval. Fish ID experts then meet with video readers to discuss identification or counting errors, and if any systematic errors occurred, all of that reader's videos are re-read. Note that through 2011, no systematic video reading errors have occurred, and error rates for all other data types have been well below 1%.

Table 2. Overview of QAQC protocol for various Reef Fish Survey data types.

Data type	# checks	% reviewed	Responsible parties
1. Station data	3	100	1. Chief scientist, 2. Database manager, 3. Progr. coordinators
2. Length-frequency data	3	100	1. Watch chief, 2. Database manager, 3. Progr. coordinators
3. Age-reproduction data	3	100	1. Watch chief, 2.Age growth and reproduction Scientist and species leaders, 3. Database manager, 4. MARMAP coordinator
4. Video log data	3	100	1. Video watch chief, 2. Data manager, 3. SEFIS coordinator
5. Video to paper data	2	≥10	1. Video reader asking for local help, 2. Fish ID experts
6. Video mean count data	2	100	1. Video reader, 2. SEFIS coordinator
7. Video data to Access	2	100	1. Video reader, 2. SEFIS coordinator

References

Conn, P.B. 2011. An evaluation and power analysis of fishery independent reef fish sampling in the Gulf of Mexico and U.S. South Atlantic. NOAA Technical Memorandum NMFS-SEFSC-610.

Dick, E.J. 2004. Beyond 'lognormal versus gamma': discrimination among error distributions for generalized linear models. Fisheries Research 70:351–366.

Evans, C.R., and A.J. Evans. 1996. A practical field technique for the assessment of spiny lobster resources of tropical islands. Fisheries Research 26:149–169.

Glasgow, D.M. 2010. Photographic evidence of temporal and spatial variation in hardbottom habitat and associated biota of southeastern U.S. Atlantic continental shelf. Master's thesis. College of Charleston, Charleston, SC.

MacKenzie D.I., J.D. Nichols, G.B. Lachman, S. Droege, J.A. Royle, and C.A. Langtimm. 2002. Estimating site occupancy rates when detection probabilities are less than one. Ecology 83:2248–2255

Maunder, M.N., and A.E. Punt. 2004. Standardizing catch and effort data: a review of recent approaches. Fisheries Research 70:141–159.

Miller, G.C., and W.J. Richards. 1980. Reef fish habitat, faunal assemblages, and factors determining distributions in the South Atlantic Bight. Proceedings of the Gulf and Caribbean Fisheries Institute 32:114–130.

Recksiek, C.W., R.S. Appeldoorn RS, and R.G. Turingan. 1991. Studies of fish traps as stock

assessment devices on a shallow reef in southwestern Puerto Rico. Fisheries Research 10:177–197.
Royal, J.A. 2004. *N*-mixture models for estimating population size from spatially replicated counts. Biometrics 60:108–115.
Rudershausen, P.J., W.A. Mitchell, J.A. Buckel, E.H. Williams, and E. Hazen. 2010. Developing a two-step fishery-independent design to estimate the relative abundance of deepwater reef fish: application to a marine protected area off the southeastern United States coast. Fisheries Research105:254–260.
Schobernd, C.M., and G.R. Sedberry. 2009. Shelf-edge and upper-slope reef fish assemblages in the South Atlantic Bight: habitat characteristics, spatial variation, and reproductive behavior. Bulletin of Marine Science 84:67–92.
Schobernd, Z.H., N.M. Bacheler, and P.B. Conn. In review. Examining the utility of alternative video monitoring metrics for indexing reef fish abundance. Canadian Journal of Fisheries and Aquatic Science
Williams, E.H., and J. Carmichael. 2009. South Atlantic fishery independent monitoring program workshop final report. National Marine Fisheries Service and South Atlantic Fishery Management Council, Beaufort, NC.

Appendix A. Methodological approach used to determine if station should be included in the sampling frame.

Is video/still image of bottom available and readable?

Yes

- Is hardbottom habitat present on video/still image (see hard bottom description below)?
  - Yes - include station in sampling frame.
  - No
    - Did you catch or see at least one reef-indicator species (see list below) in the sampling gear or on the video/still image?
      - Yes - include station in sampling frame.
      - No - do not include station in sampling frame.

No

- Did you catch at least one reef-indicator species in sampling gear?
  - Yes - include station in sampling frame.
  - No - do not include station in sampling frame.

Hard bottom is defined as exposed rock or consolidated sediments that are easily distinguishable from surrounding unconsolidated sediments. In locations with both consolidated and unconsolidated sediments (mixed habitat), hard bottom will be identified if rocks/boulders are the size of a fist or larger, and/or hard pavement is suspected under a sand veneer from the presence of obvious and numerous attached biota.

Reef-Indicator Species:

Acanthuridae (Sugeonfishes)
Apogonidae (Cardinalfishes)
Balistidae (Triggerfishes)
Chaetodontidae (Butterflyfishes)
Diodon spp. (Balloon/Porcupinfishes)
Aulostomidae (Trumpetfishes)
Fistulariidae (Cornetfishes)
Haemulon spp. (Grunts)
Anisotremus spp. (Margate/Porkfish)
Holocentridae (Squirrelfishes)
Bodianus spp. (Hogfishes)
Halichoeres spp. (Wrasses)
Lachnolaimus maximus (hogfish)
Thalasosoma bifasciatum (bl. hd. wrasse)
Lutjanus spp. (Snappers)
Ocyurus chysurus (yellowtail snapper)
Rhomboplites aurorubens (vermilion snapper)
Cantherhines spp. (Filefishes)
Ostraciidae (Boxfishes)
Pomacanthidae (Angelfishes)
Pomacentridae (Damselfishes)
Priacanthidae (Bigeyes)
Scaridae (Parrotfishes)
Pterois spp. (Lionfishes)
Anthiinae (Basses)
Epinephelinae (Groupers/Hinds/Hamlets)
Grammistinae (Soapfishes)
Liopropomatinae (Basslets)
Calamus nodosus (knobbed porgy)
Calamus proridens (littlehead porgy)
Pagrus pagrus (red porgy)
Canthigaster rostrata (sharpnose puffer)
**Centropristis striata* (black sea bass)