South Atlantic marine protected areas: year three of a pre-closure evaluation of habitat and fish assemblages in five proposed reserves.

A report to the South Atlantic Fishery Management Council
February, 2008

Stacey Harter
Andrew David
Marta Ribera
NOAA Fisheries, Southeast Fisheries Science Center
Panama City Laboratory
3500 Delwood Beach Rd.
Panama City, Fl 32408 USA
Email: stacey.harter@noaa.gov, andy.david@noaa.gov

Abstract

The South Atlantic Fishery Management Council (SAFMC) has proposed implementation of eight marine protected areas (MPAs) between Cape Hatteras, NC and the Florida Keys to protect seven species of grouper and tilefish, all members of the deepwater snapper-grouper complex. During 2007, we completed the third annual survey of five of the proposed MPA sites with three main objectives: 1) establish pre-closure estimates of species composition and fish abundance, especially for species of grouper and tilefish; 2) describe habitat features; and 3) document the relationship between habitat and species assemblages. Gear employed during the surveys included a remotely operated vehicle (ROV) and a stationary video camera array. Four of the seven targeted reef fish (snowy grouper, speckled hind, warsaw grouper, and blueline tilefish) were observed in 2007. Relative fish abundances varied between proposed MPAs. None of the target species had the highest abundance of fishes observed; however other species of the snapper/grouper complex such as vermilion snapper (*Rhomboplites aurorubens*), tomtates (*Haemulon aurolineatum*), and red porgy (*Pagrus pagrus*) were among those most frequently observed. Lionfish (*Pterois volitans*) densities have exponentially increased since the 2004 and 2006 surveys and showed comparable densities to the most abundant grouper, scamp (*Mycteroperca phenax*). As expected, lionfish and grouper densities increased with increasing habitat complexity. This study presents a unique opportunity to examine proposed MPA sites before implementation of fishing restrictions, thus providing fishery managers with robust pre-closure data upon which efficacy evaluations of closures can be made.

Introduction

The South Atlantic Fishery Management Council (SAFMC) is considering the implementation of eight Type II MPAs between Cape Hatteras, NC and the Florida Keys to protect seven species of the deepwater snapper-grouper complex. These consist of five species of grouper; snowy grouper (*Epinephelus niveatus*), yellowedge grouper (*E. flavolimbatus*), warsaw grouper (*E. nigritus*), speckled hind (*E. drummondhayi*), and misty grouper (*E. mystacinus*) and two species of tilefish; tilefish (*Lopholatilus chamaeleonticeps*) and blueline tilefish (*Caulolatilus microps*). These species are considered to be at risk due to currently low stock densities and to life history characteristics which subject them to substantial fishing mortality. Based on recent stock assessments (SEDAR, 2004), four of these are considered to be overfished including snowy grouper (*Epinephelus niveatus*), warsaw grouper (*E. nigritus*), speckled hind (*E. drummondhayi*), and tilefish (*Lopholatilus chamaeleonticeps*). Yellowedge grouper (*E. flavolimbatus*) are not considered overfished, and the status of misty grouper (*E. mystacinus*) and blueline tilefish (*Caulolatilus microps*) is unknown at this time. Life history characteristics of several of the targeted species make them more vulnerable to overfishing. Many are protogynous hermaphrodites with highly female-skewed sex ratios, even in unfished populations. Aggregate spawning with strong interannual site fidelity is also common, offering knowledgeable fishermen the possibility to harvest large numbers of reproductively active fish in a short period of time. Dominant males aggressively defend these spawning aggregation sites and are more easily caught than during non-spawning periods, leading to further skewing of the sex ratios (Gilmore and Jones, 1992; Coleman et al., 1996). The proposed MPAs are known to contain habitat which supports populations of economically valuable reef fish including the seven target species and other reef-associated fishes. Our goal was to conduct preliminary examinations of five of the proposed MPAs including Snowy Grouper Wreck (hereafter denoted as NC), Northern South Carolina (SC), Edisto (ED), Georgia (GA), and North Florida (FL), each containing two or more alternatives (Figure 1). Three of the eight proposed MPA sites were not included in this survey, one artificial reef site off Charleston, SC and two sites off extreme southern Florida. The artificial reef site was excluded because the project focused on fish-habitat relationships in natural areas. The south Florida sites were excluded for logistical reasons related to their remoteness from the remaining five natural habitat sites in the South Atlantic Bight. Early in 2007, the SAFMC announced the preferred alternatives for closure (Figure 1). Within each proposed MPA, we characterized habitat and documented fish species composition and densities of all fish encountered with emphasis on economically important species. Our specific objectives were to: 1) establish pre-closure estimates of reef fish density and species composition associated with bottom features within and outside the preferred proposed MPAs; 2) describe habitat features within and outside the preferred proposed MPAs; and 3) document the relationship between habitat and species assemblages. This project supplements similar work conducted in 2004 and 2006 which also provided pre-closure information on fish communities and habitats in the proposed MPAs. This report is National Marine Fisheries Service Panama City Laboratory Contribution Number 08-06.

Methods

High resolution bathymetric maps exist only for a portion of the GA and SC proposed MPA sites. Sampling site selection for this cruise was based on these multibeam maps as well as results from the 2004 and 2006 cruises. The proposed MPAs were designed to protect deep reef grouper and tilefish, which are structure-oriented fish, thus suspected hardbottom and reef sites were the primary targets.

The principle gear used to characterize habitat and estimate fish densities was a remotely operated vehicle (ROV) owned and operated by the National Undersea Research Center (NURC) at the University of North Carolina at Wilmington (UNCW) and operated by the NURC at the University of Connecticut (UCONN). High currents required the use of a downweight to keep the ROV umbilical cable near the bottom throughout the dives. This downweight was tethered to the ROV umbilical and the ROV operated on a 30 m leash which provided sufficient freedom of movement to investigate habitat features within visual range of the transect line. The downweight configuration allowed the ROV to drift just above the bottom at a controlled over-the-ground speed of approximately 0.75 knot (range 0.5 to 1.5 knots). The geographic position of the ROV (± 3m) was constantly recorded throughout each dive with a tracking system linked to the ship's GPS system. The ROV was equipped with lights and a forward-looking color digital video camera which provided continuous imaging data. These dives resulted in approximately 22 hours of underwater video documentation. The video footage was used to delineate and quantify habitat type as well as fish species presence and density within each habitat type. Each dive was divided into 50 m transects within each habitat type. All fish within a 5 m radius on the video tapes were identified to the lowest discernable taxonomic level and counted (5 m was determined as the maximum distance that fish could reasonably be identified). Fish densities (# hectare^{-1}) were determined by estimating the area of view of the video camera during transects. The area of each transect was determined from transect length (L) and width (W). Transect length was calculated from latitude and longitude recorded by the ROV tracking system. The width of each transect was calculated using the following equation: W=2(tan (½A))(D) where A is the horizontal angle of view (78º, a constant property of the camera) and D is the distance from the camera at which fish could always be identified. The distance (D) was usually 4 m (range from 1.5 m to 4 m) and was determined by the clarity of the water. Transect area (TA) was then calculated as: TA= (LxW) - ½ (WxD). Density of each fish species was calculated by dividing the number of each species by the TA. Average densities were calculated for all observed fish species. Grouper and lionfish (*Pterois volitans*) densities were compared by species and among habitats inside and outside each preferred MPA alternative. The percentage of each habitat covered by the ROV inside and outside each preferred MPA alternative was also calculated.

We also used a stationary video camera array to determine relative abundance of fish and percent cover of habitat within and outside each preferred proposed MPA. The array was comprised of four Sony VX-2000 digital camcorders in Gates Diego underwater housings mounted at 90º angles to each other in the horizontal plane at a height of 30 cm above the bottom of the array. The camera array was allowed to soak on the bottom for at least thirty minutes during each deployment. This allowed sufficient time for sediment stirred up during camera deployment to dissipate and ensured tapes with an unoccluded view of at least twenty minutes duration. All fish captured on videotape were identified to the lowest discernable taxonomic level. Abundance values were calculated from the maximum number of fish of a given species in the field of view at any time during the twenty minute videotape. This is a more conservative abundance estimate than one derived from the total number of individuals observed, but it avoids multiple counts of the same individual and produces more reproducible estimates. The maximum number of each species as well as the percent coverage of each habitat type inside and outside each preferred MPA alternative were determined.

A similar project examining shelf edge MPAs in the Gulf of Mexico has revealed modified fish behavior in the presence of ROVs. The lights, sounds, and motion of the vehicle attract some species and scare others whereas the stationary array has minimal impact upon fish behavior. However the array provides data on only a single spot with each deployment whereas the ROV can cover more than a kilometer with each dive. We have used both types of gear in an effort to maximize the area surveyed (ROV) and minimize fish behavior modification (array).

Results

The cruise took place between 17 and 23 August 2007. Maps displaying locations and types of gear deployed at each proposed MPA alternative are shown in Figure 2. At each MPA, we conducted two ROV dives and one camera array drop both inside and outside the preferred alternative with the exception of SC where we had more time and were able to complete three ROV dives and 2 camera array drops and GA where we had less time and were only able to conduct one ROV dive and no camera array drops. Sites outside the preferred alternatives were either from the other (non-preferred) MPA alternatives or outside all alternatives completely but in the immediate surrounding area.

A total of 20 ROV dives were made. Five major habitats were identified from the dives: 1) soft substrate/sand (hereafter denoted as SA), 2) pavement (PAV), 3) low relief outcrops (LRO), 4) moderate relief outcrops (MRO), and 5) high relief ledge (HRL). SA habitats exhibited no relief and were composed of fine to coarse sand, sometimes with a shell hash. PAV habitats were composed of hardbottom with no relief and usually had some degree of coverage with sessile and encrusting invertebrates and a presence of cracks/crevices up to 2 m deep. LRO consisted of rock outcrops with < 1 m relief. MRO habitat was made up of rock outcrops with 1-3 m relief and HRL exhibited > 3 m relief often with large boulders and overhangs. Not all habitats were observed in each proposed MPA; however some quantity of hardbottom was seen on each dive except for one dive in FL (outside the preferred alternative). SA, PAV, and LRO were the most common habitats, while the higher relief areas (MRO and HRL) were only observed in FL, ED, and SC (Table 1).

A total of 76 fish species were identified from the ROV dives, including three of the seven targeted reef fish; snowy grouper, speckled hind, and blueline tilefish. To compare fish community structure inside and outside of each preferred proposed MPA alternative, relative abundances (%) of fishes were calculated (# individuals/total # individuals * 100) (Table 2). The most abundant taxa differed between proposed MPAs, however none of the target species were among the three most frequently observed. Nonetheless, other members of the snapper/grouper complex were often among the top three most abundant species. Both inside and outside the preferred FL alternative, vermilion snapper (*Rhomboplites aurorubens*) was the dominant species. Inside the GA preferred alternative, saddle bass (*Serranus notospilus*), blackbar drum (*Pareques iwamotoi*), and short bigeye (*Pristigenys alta*) were most frequently observed. Outside the preferred GA alternative, cubbyu (*Equetus umbrosus*), red porgy (*Pagrus pagrus*), and scamp (*Mycteroperca phenax*) were most abundant. Wrasses (*Halichoeres* spp.) dominated inside the preferred ED alternative while grunts (*Haemulon* spp.) dominated outside the ED preferred alternative. Grunts were also the most frequently observed species both inside and outside the SC preferred alternative. Inside and outside the preferred NC alternative was dominated by anthiids comprised of roughtongue bass (*Pronotogrammus martinicensis*) and red barbier (*Hemanthias vivanus*).

As expected, grouper and lionfish were only found on hardbottom habitats (PAV, LRO, MRO, and HRL) and never on SA habitat (Table 3). Total grouper densities ranged from 0.0 hectare^{-1} to 327.9 hectare^{-1}. Lionfish densities ranged from 0.0 hectare^{-1} to 806.2 hectare^{-1}. The latter density came from a dive outside the SC preferred alternative with 1-2 m relief. We were able to capture a still image during the dive that showed at least 7 lionfish within a single field of view. Lionfish densities increased exponentially in 2007 compared to the 2004 and 2006 surveys. The highest density in previous years was approximately 22 hectare^{-1}. Lionfish and grouper densities progressively increased as habitat complexity increased. Grouper densities were primarily greater outside the preferred alternatives (Figure 3). Scamp was the most abundant grouper species with a max density of 517.3 hectare^{-1}. Lionfish displayed comparable densities to scamp and higher densities than all other grouper species in ED and NC and higher densities than all grouper species including scamp in SC.

Ten camera array drops were made. Rock was the dominant habitat with 1 m or less relief except outside the preferred FL alternative where only sand was observed (Table 4). A total of 42 fish species were observed on the videotapes, three of which were target species (warsaw grouper, snowy grouper, and speckled hind). Only greater amberjack (*Seriola dumerili*) and a snake eel (Ophichthidae) were observed outside the FL preferred alternative, but this can be explained by the SA habitat with no relief (Figure 4). The dominant species for each MPA somewhat mirrored those from the ROV dives. Vermilion snapper were the most abundant species inside the FL preferred alternative (Figure 4). Grunts were the most frequently observed species outside the ED preferred alternative, while porgies dominated inside. SC (both inside and outside the preferred alternative) had the highest diversity of fish species of all the MPAs. Gray triggerfish (*Balistes capriscus*), wrasses, and porgies dominated outside the SC preferred alternative, while grunts were most abundant inside. Both inside and outside the NC preferred alternative, anthiids were most common.

Discussion

Ideally, assessment of the efficacy of MPAs for increasing populations of economically valuable reef fish would require a sequential approach of mapping, habitat delineation, and fishery surveys. High resolution maps are extremely crucial in site selection for this type of study. However, since a limited amount of mapping has been done in the proposed areas, site selection was primarily based on results from the 2004 and 2006 cruises. Site selection for the earlier cruises was based upon published data and personal communications with other researchers familiar with the areas.

Four of the target species (snowy grouper, speckled hind, warsaw grouper, and blueline tilefish) were observed during this study. Yellowedge grouper, misty grouper, and tilefish were not seen. Tilefish prefer muddy habitat offshore from the shelf/slope break and as we targeted reef habitat, it is not surprising tilefish were not observed. Depth probably explains why yellowedge and misty grouper were not found. Of the targeted grouper, these two are found in the deepest waters and the majority of our ROV dives targeted shallower hardbottom areas (< 100 m). Landings data from the South Atlantic region demonstrate that yellowedge grouper and tilefish are caught all year round with the highest landings between April and September (during the time of the cruise). Therefore, seasonality does not explain why these species were not observed.

Usually, examination of marine reserves does not begin until after the closures have been implemented. This study presented a unique opportunity to examine these areas before fishing restrictions have been implemented allowing pre-closure data to be collected. These MPAs may be put into effect later this year, thus three years of data (2004, 2006 and 2007) have been acquired and will be available to compare the population levels of these sites under reduced fishing pressure. Location of the reserves is critical if enhancement of fishery yields is to occur (Stockhausen et al., 2000). It is hoped that results from these three years of research will aid the SAFMC in making final decisions on MPA placement. Since grouper and tilefish occupy slightly different habitat types, separate sites may have to be chosen for each group of species.

An on-going problem for marine reserves is enforcement of fishing restrictions. In order to evaluate the efficacy of MPAs, fishing must cease in those designated areas. In lieu of cessation of fishing, the level of fishing effort should be determined. A monitoring program written into the FMP amendment incorporating an effort survey and annual fish assessments would be beneficial to future evaluations. Any fishing activity will make it difficult to evaluate the impact of closure on fishery productivity. Even relatively moderate levels of poaching can quickly deplete gains achieved by closure (Roberts and Polunin, 1991).

Acknowledgements

We would like to thank the crew of NASA's M/V Freedom Star and NOAA's Teacher-at-Sea program participants. We also thank NURC/UCONN and NURC/UNCW for providing ROV services. This project was supported by a grant from NOAA's Coral Reef Conservation Program.

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Table 1. Percentage of each habitat covered by the ROV inside and outside each preferred MPA alternative. SA=sand, PAV=pavement, LRO=low relief outcrops, MRO=moderate relief outcrops, and HRL=high relief ledge.

MPA	% SA	% PAV	% LRO	% MRO	% HRL
FL-IN	46.3	29.0	12.5		12.1
FL-OUT	66.1		25.2	8.7	
GA-IN	85.2		14.8		
GA-OUT	45.7	54.3			
ED-IN	18.7	6.2	75.1		
ED-OUT	4.8	19.4	33.6	42.2	
SC-IN	36.5	10.1	39.0		7.1
SC-OUT	50.5	39.0	6.5	4.1	
NC-IN		6.4	93.6		
NC-OUT	80.0		20.0		

Table 2. Relative abundances (%) of all fish species observed with the ROV inside and outside each preferred MPA alternative. X indicates a member of the grouper/snapper complex.

	FL		GA		ED		SC		NC	
Taxa	IN	OUT	IN	OUT	IN	OUT	IN	OUT	IN	OUT
Carcharhinidae										
Undetermined			1.1							
Muraenidae										
Undetermined								0.2		
Gymnothorax moringa	0.2			1.8				0.1		0.2
Gymnothorax spp.		0.5								
Ophichthidae										
Undetermined					0.2					
Synodontidae										
Synodus intermedius					0.2			0.1	0.1	
Synodus spp.	0.2	0.9	4.5		0.6	0.2		0.1	0.1	
Ogcocephalidae										
Ogcocephalus spp.			2.2							
Batrachoididae										
Opsanus spp.				0.9						
Caproidae										
Antigonia spp.							2.0			
Holocentridae										
Undetermined	0.2					0.3			0.1	
Holocentrus rufus										
Holocentrus spp.	0.8				0.8	0.4	0.7	2.0	0.1	
Ostichthys trachypoma							0.1			
Scorpaenidae										
Undetermined							0.5		0.1	
Pterois volitans					1.0	1.7	0.7	3.9	0.1	0.3

	FL		GA		ED		SC		NC	
Taxa	IN	OUT	IN	OUT	IN	OUT	IN	OUT	IN	OUT
Triglidae										
Undetermined		0.5	2.2							
Serranidae										
Undetermined			2.2	8.0		0.1		0.1	0.1	0.2
Anthiinae			2.2				0.1		46.1	60.3
Centropristis ocyurus (X)	1.4		2.2	2.7		0.1	0.03			
Centropristis spp. (X)				7.1						
Epinephelus adscensionis (X)							0.03	0.5		
Epinephelus cruentatus (X)					0.4	0.3	0.1	0.2		
Epinephelus drummondhayi (X)								0.3	0.1	
Epinephelus fulvus (X)					0.2		0.03	0.1		
Epinephelus niveatus (X)			2.2				0.1		0.3	
Hemanthias vivanus									0.2	23.9
Liopropoma eukrines	0.4	0.5	1.1			0.1	0.1	0.7	0.1	0.9
Mycteroperca microlepis (X)						0.1	0.03			
Mycteroperca phenax (X)		1.4	4.5	11.6	0.6	1.1	0.4	0.7	0.1	0.3
Mycteroperca spp. (X)										0.2
Paranthias furcifer						0.1	0.3	0.4	0.1	
Pronotogrammus martinicensis								7.8	30.6	7.9
Rypticus saponaceus							0.1	0.3		1.2
Serranus annularis					1.0		0.03		0.1	
Serranus notospilus			20.2	0.9			0.1			
Serranus phoebe	10.7	1.9		10.7	8.4	0.4	0.7	5.4	1.1	1.4
Serranus spp.							0.03			
Priacanthidae										
Undetermined										0.2

	FL		GA		ED		SC		NC	
Taxa	IN	OUT	IN	OUT	IN	OUT	IN	OUT	IN	OUT
Priacanthus arenatus							0.1	0.3	0.3	0.2
Priacanthus cruentatus		1.4								
Pristigenys alta		0.5	9.0	5.4	1.8	0.7	0.1	8.5	1.1	
Malacanthidae										
Caulolatilus microps (X)							0.1			
Malacanthus plumieri								0.2		
Carangidae										
Undetermined							0.1		0.2	
Caranx crysos									0.1	
Seriola dumerili (X)	1.2				3.9	0.4		0.6		
Seriola rivoliana (X)	1.2				0.2	0.2				
Seriola spp. (X)	0.6				1.0	2.1	0.1		1.4	
Lutjanidae										
Lutjanus campechanus (X)	0.2			0.9						
Pristipomoides aquilonaris			1.1							
Rhomboplites aurorubens (X)	49.6	79.9					1.3			
Haemulidae										
Anisotremus surinamensis (X)						0.1				
Haemulon aurolineatum (X)	11.7	1.9				46.2	17.4			
Haemulon plumieri (X)						0.1	0.1	0.3		
Haemulon spp. (X)		2.8					52.9	20.9		
Haemulon striatum (X)		1.4								
Sparidae										
Undetermined	0.2	0.5		0.9	0.2	0.3		0.3		
Calamus spp. (X)				0.9	1.2	0.3	0.2	2.8		0.2
Pagrus pagrus (X)	2.4			18.8	0.4	0.2				
Sciaenidae										

	FL		GA		ED		SC		NC	
Taxa	IN	OUT	IN	OUT	IN	OUT	IN	OUT	IN	OUT
Equetus lanceolatus					1.0	0.1	0.1	0.2		
Equetus umbrosus	0.8			26.8		0.4	2.3	0.6		
Pareques iwamotoi	0.2		12.4				0.1			
Mullidae										
Pseudupeneus maculatus							0.3			
Ephippidae										
Chaetodipterus faber (X)						2.1				
Chaetodontidae										
Chaetodon aya	0.2				2.1	0.4	0.3	0.1	0.5	0.3
Chaetodon ocellatus					0.4	0.7	0.5	0.3		
Chaetodon sedentarius	2.4	0.9			6.0	2.9	0.9	1.5	0.3	0.5
Chaetodon spp.						0.1	0.1			
Pomacanthidae										
Holacanthus bermudensis	2.2				1.9	1.9	0.8	0.4	0.1	
Holacanthus tricolor							0.2			
Pomacanthus arcuatus	0.6					0.1				
Pomacanthus paru						0.1	0.1			
Pomacanthus spp.							0.1			
Pomacentridae										
Chromis enchrysurus	2.6	0.9			4.3	8.5	1.0	7.2	0.1	
Chromis insolatus					0.6	0.6				
Chromis scotti	0.6				2.7	3.6	1.0			
Chromis spp.	0.2				4.3	1.5	1.7	0.2		
Pomacentrus partitus						0.2	0.03			
Labridae										
Bodianus pulchellus					1.2	1.5	0.9	1.3	0.1	
Decadon puelleris							0.1			

	FL		GA		ED		SC		NC	
Taxa	IN	OUT	IN	OUT	IN	OUT	IN	OUT	IN	OUT
Halichoeres bathyphilus							0.3			
Halichoeres garnoti							0.2			
Halichoeres spp.	2.8			0.9	43.5	4.4		24.6	0.3	0.9
Hemipteronotus spp.							1.7	0.3		
Lachnolaimus maximus (X)					0.8	0.2	0.2	0.8		0.2
Sphyraenidae										
Sphyraena barracuda							0.03			
Acanthuridae										
Acanthurus chirurgus					0.4	0.1	0.5	0.7		
Bothidae										
Undetermined		0.9	1.1				0.03			
Balistidae										
Balistes capriscus (X)					0.4	0.4	0.03	0.5		
Ostraciidae										
Lactophrys quadricornis						0.2	0.03	0.1		
Lactophrys spp.						0.1			0.1	
Tetraodontidae										
Canthigaster rostrata	0.2				0.6	0.5	0.2	0.6		0.2
Sphoeroides spengleri						0.1	0.03	0.4		
Diodontidae										
Chilomycterus spp.						0.1				
Diodon hystrix						0.1				
Undetermined	5.9	3.3	31.5	1.8	8.0	14.3	8.2	3.0	16.4	0.7

Table 3. Total grouper and lionfish densities (# hectare^{-1}) by habitat type inside and outside each preferred MPA alternative from ROV dives. SA= sand, PAV= pavement, LRO= low relief outcrops, MRO= moderate relief outcrops, and HRL= high relief ledge. Numbers in () represent standard errors. A dash denotes that particular habitat was not present in that MPA alternative.

	Grouper					**Lionfish**				
MPA	SA	PAV	LRO	MRO	HRL	SA	PAV	LRO	MRO	HRL
FL-IN	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	-	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	-	0.0 (0.0)
FL-OUT	0.0 (0.0)	-	45.9 (45.9)	67.8 (0.0)	-	0.0 (0.0)	-	0.0 (0.0)	0.0 (0.0)	-
GA-IN	0.0 (0.0)	-	327.9 (0.0)	-	-	0.0 (0.0)	-	0.0 (0.0)	-	-
GA-OUT	0.0 (0.0)	258.6 (258.6)	-	-	-	0.0 (0.0)	0.0 (0.0)	-	-	-
ED-IN	0.0 (0.0)	0.0 (0.0)	15.7 (7.2)	-	-	0.0 (0.0)	0.0 (0.0)	13.1 (6.0)	-	-
ED-OUT	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	98.3 (27.4)	-	0.0 (0.0)	0.0 (0.0)	23.4 (11.9)	103.2 (59.8)	-
SC-IN	0.0 (0.0)	0.0 (0.0)	30.1 (13.2)	66.4 (47.8)	98.8 (57.6)	0.0 (0.0)	0.0 (0.0)	27.4 (8.9)	53.2 (26.6)	141.0 (80.1)
SC-OUT	0.0 (0.0)	6.9 (4.7)	169.0 (82.5)	268.7 (0.0)	-	0.0 (0.0)	19.9 (9.5)	146.7 (146.7)	806.2 (0.0)	-
NC-IN	-	0.0 (0.0)	22.7 (10.3)	-	-	-	0.0 (0.0)	0.0005 (0.0005)	-	-
NC-OUT	0.0 (0.0)	-	47.3 (47.3)	-	-	0.0 (0.0)	-	31.5 (31.5)	-	-

Table 4. Occurrence (%) of sand and rock observed from camera array drops inside and outside each preferred MPA alternative. Relief (m) is also noted.

MPA	% Sand	% Rock	Relief (m)
FL-IN	50	50	<1
FL-OUT	100	0	0
ED-IN	20	80	<1
ED-OUT	0	100	1
SC-IN	10	90	1
SC-OUT	47.5	52.5	<1
NC-IN	30	70	<1
NC-OUT	25	75	1

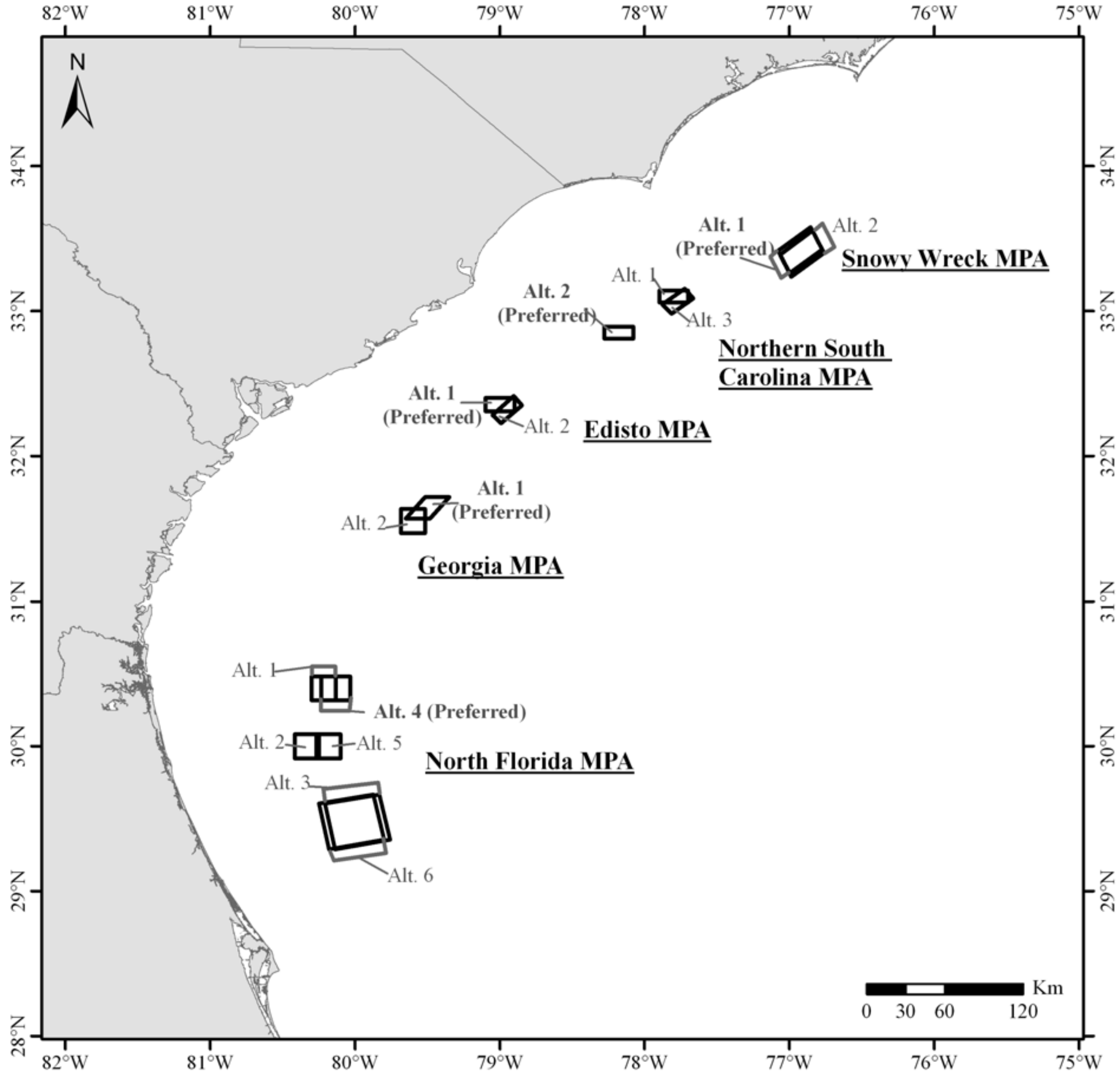


Figure 1. Locations of five proposed, natural bottom, MPA sites in the South Atlantic. The SAFMC preferred alternatives are noted.

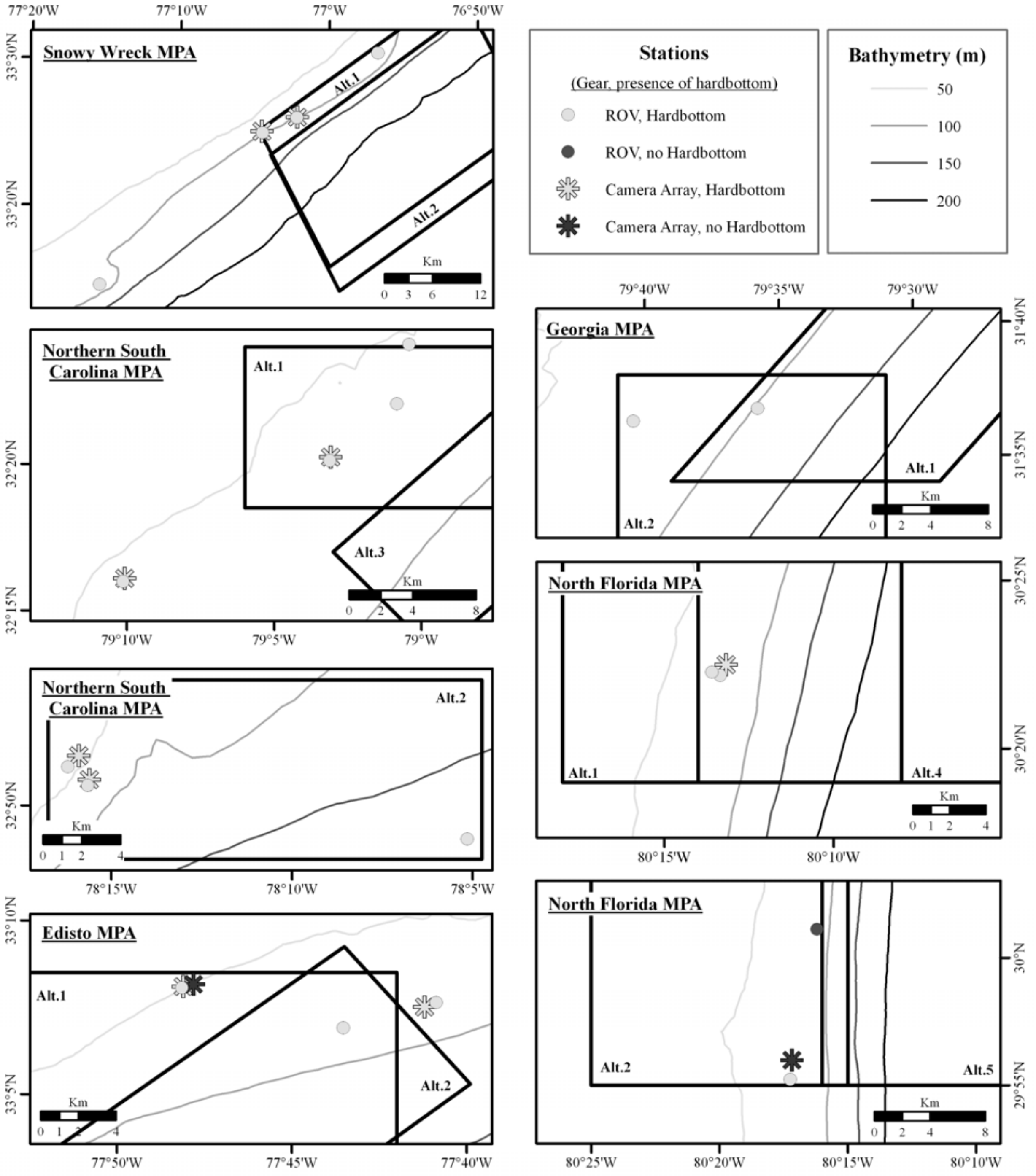


Figure 2. Maps of each proposed MPA examined and the locations and types of gear that were deployed in each. Circles display locations of ROV dives; gray circles represent dives where hardbottom was found and black circles indicate no hardbottom was observed. Asterisks represent locations where camera drops were made; gray asterisks indicated that hardbottom was found and black asterisks where no hardbottom was observed.

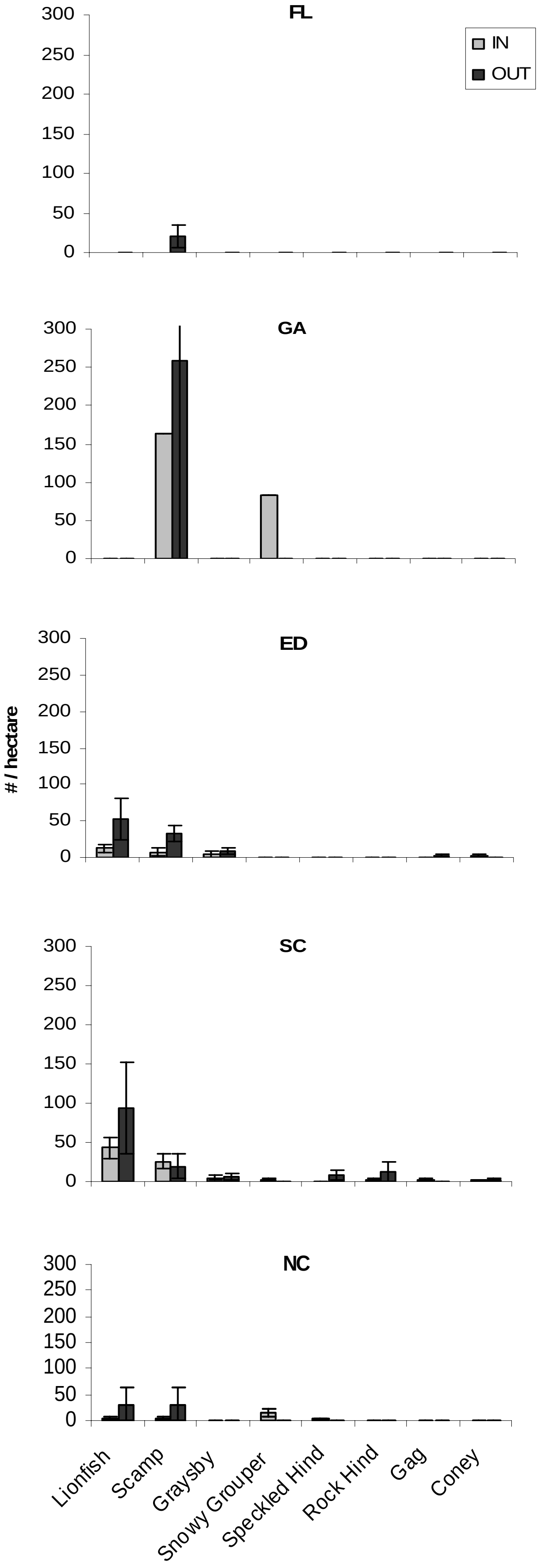
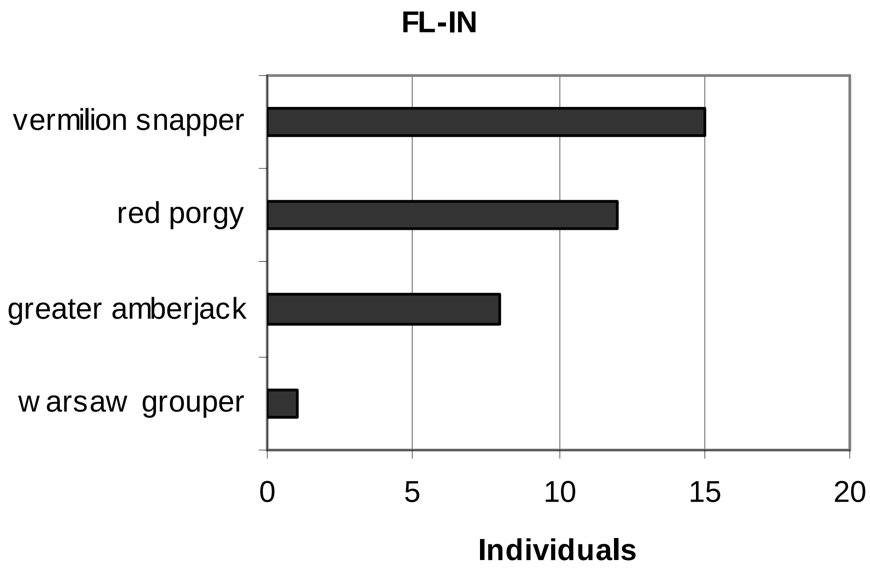


Figure 3. Average grouper and lionfish densities by species for each MPA (inside and outside the preferred alternative) ± S.E from ROV dives.



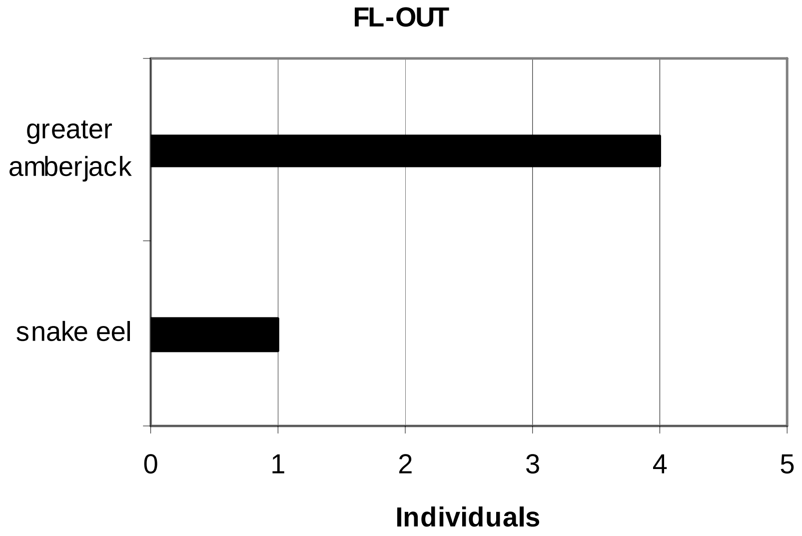


Figure 4. Maximum number of individuals by species observed inside and outside the FL preferred alternative from the camera array.

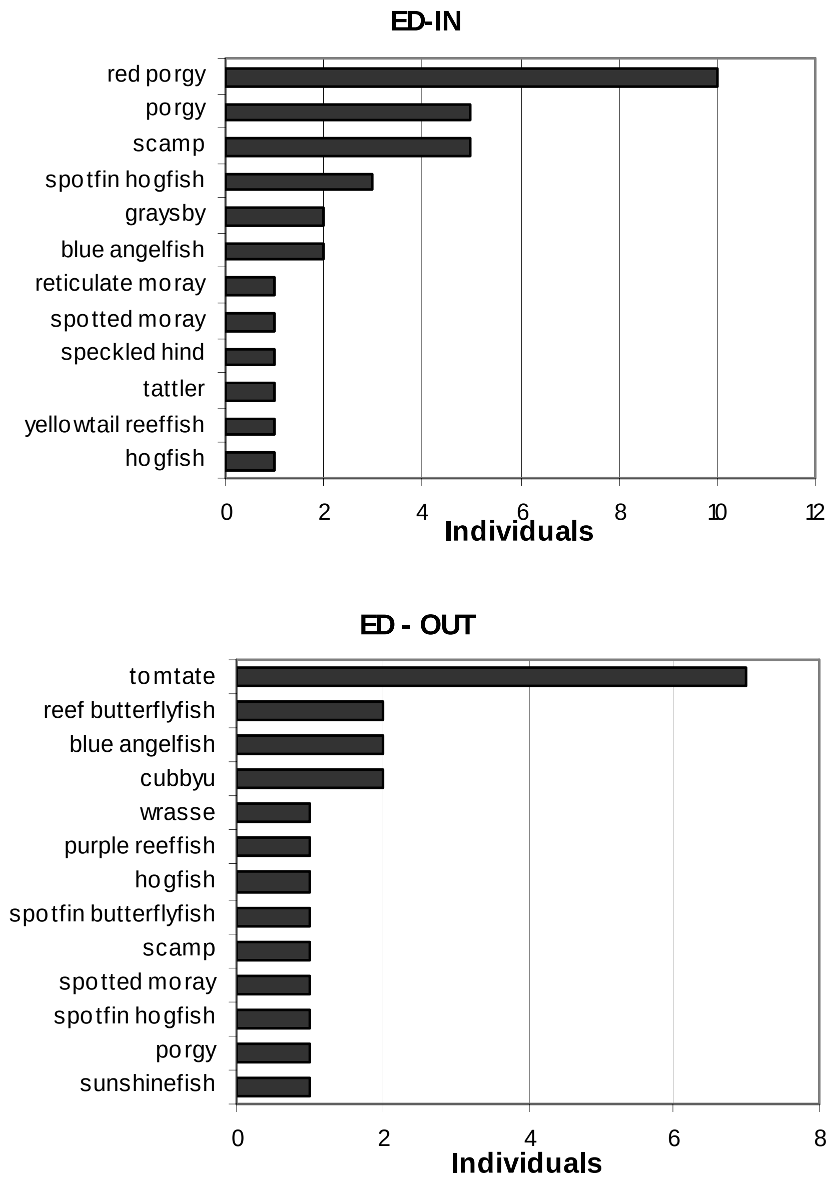
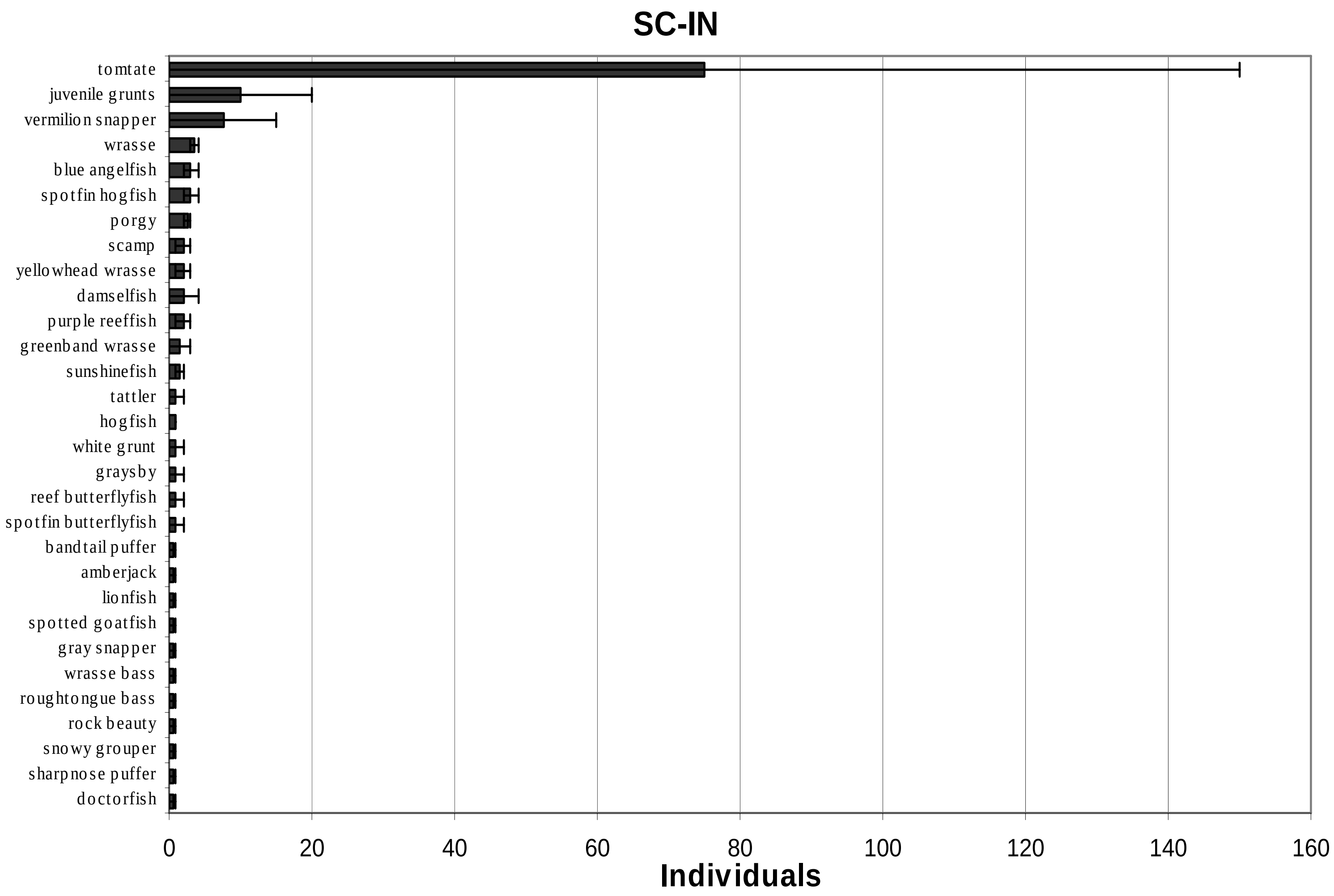


Figure 5. Maximum number of individuals by species observed inside and outside the ED preferred alternative from the camera array.


SC-IN
tomtate
juvenile grunts
vermilion snapper
wrasse
blue angelfish
spotfin hogfish
porgy
scamp
yellowhead wrasse
damselfish
purple reeffish
greenband wrasse
sunshinefish
tattler
hogfish
white grunt
graysby
reef butterflyfish
spotfin butterflyfish
bandtail puffer
amberjack
lionfish
spotted goatfish
gray snapper
wrasse bass
roughtongue bass
rock beauty
snowy grouper
sharpnose puffer
doctorfish
0
20
40
60
80
100
120
140
160
Individuals

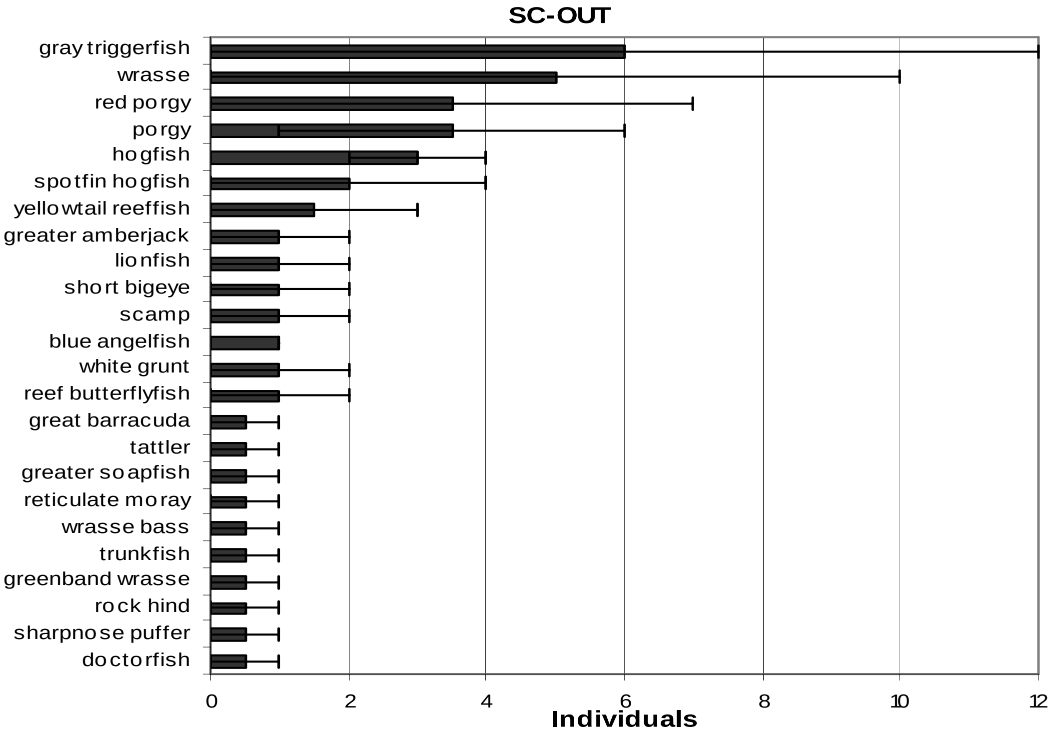


Figure 6. Maximum number of individuals (± S.E.) by species observed inside and outside the SC preferred alternative from the camera array.

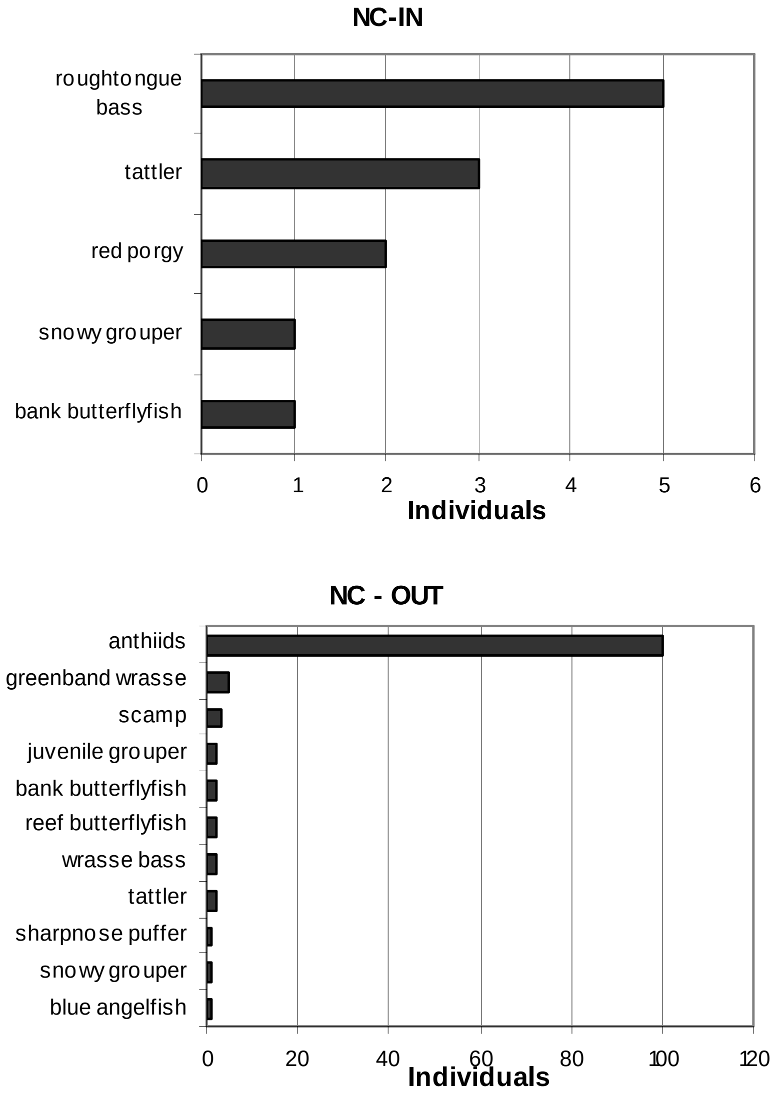


Figure 7. Maximum number of individuals by species observed inside and outside the NC preferred alternative from the camera array.