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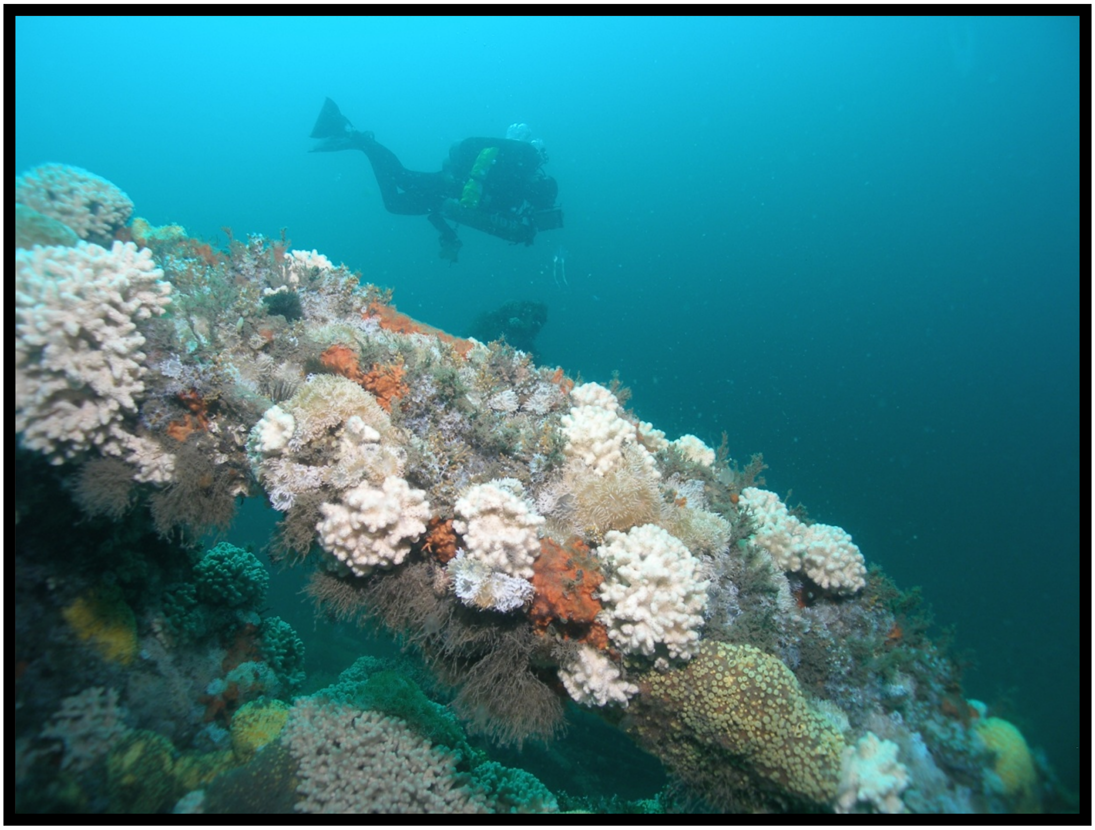

Fish and Habitat Community Assessments on North Carolina Shipwrecks: Potential sites for detecting climate change in the Graveyard of the Atlantic

U.S. Department of Commerce
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Fish and Habitat Community Assessments on North Carolina Shipwrecks: Potential sites for detecting climate change in the Graveyard of the Atlantic

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Cover

Cover photo by Doug Kesling Cooperative Institute for Ocean Exploration and Technology (CIOERT) shows the diverse benthic invertebrate community on the shipwreck, *City of Atlanta*, located north of Cape Hatteras, NC in the Graveyard of the Atlantic.

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Abstract

The *Monitor* National Marine Sanctuary (MNMS) was the nation's first sanctuary, originally established in 1975 to protect the famous civil war ironclad shipwreck, the USS *Monitor*. Since 2008, sanctuary sponsored archeological research has branched out to include historically significant U-boats and World War II shipwrecks within the larger Graveyard of the Atlantic off the coast of North Carolina. These shipwrecks are not only important for their cultural value, but also as habitat for a wide diversity of fishes, invertebrates and algal species. Additionally, due to their unique location within an important area for biological productivity, the sanctuary and other culturally valuable shipwrecks within the Graveyard of the Atlantic are potential sites for examining community change. For this reason, from June 8-30, 2010, biological and ecological investigations were conducted at four World War II shipwrecks (*Keshena, City of Atlanta*, *Dixie Arrow*, *EM Clark*), as part of the MNMS 2010 Battle of the Atlantic (BOTA) research project. At each shipwreck site, fish community surveys were conducted and benthic photo-quadrats were collected to characterize the mobile conspicuous fish, smaller prey fish, and sessile invertebrate and algal communities. In addition, temperature sensors were placed at all four shipwrecks previously mentioned, as well as an additional shipwreck, the *Manuela*. The data, which establishes a baseline condition to use in future assessments, suggest strong differences in both the fish and benthic communities among the surveyed shipwrecks based on the oceanographic zone (depth). In order to establish these shipwrecks as sites for detecting community change it is suggested that a subset of locations across the shelf be selected and repeatedly sampled over time. In order to reduce variability within sites for both the benthic and fish communities, a significant number of surveys should be conducted at each location. This sampling strategy will account for the natural differences in community structure that exist across the shelf due to the oceanographic regime, and allow robust statistical analyses of community differences over time.

Key Words

Shipwrecks, Fish Community, Habitat, North Carolina, Climate, Baseline Data, Graveyard of the Atlantic, Benthic

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Statement of Need

Background

The Monitor National Marine Sanctuary (MNMS) was the nation's first sanctuary, originally established in 1975 to protect and preserve the remains of the famed Civil War ironclad shipwreck, USS *Monitor*. Since 1977, research at the *Monitor* site has been directed toward documenting this important maritime heritage resource in detail and understanding how it has been affected by natural deterioration and human activities. More recently, the MNMS has conducted projects in and adjacent to the sanctuary in order to better understand and monitor the larger area's living and non-living resources, and to increase knowledge of the sanctuary's biological and cultural resources through research. The *Monitor* is located in an area known as the Graveyard of the Atlantic which also contains the final resting place of thousands of vessels lost to war, weather, or to the shallow sand shoals that extend off the North Carolina coast (Figure 1).

In 2008, the *Monitor* National Marine Sanctuary, in conjunction with the Office of National Marine Sanctuaries Maritime Heritage Program, initiated a multi-year study to examine the Battle of the Atlantic (BOTA) that took place during World War II. The fact that German U-boats and thus World War II came so close to the Eastern Seaboard is not commonly known by the general public. To better elucidate these historic events, determine the current state of these vessels, and monitor changes over time, archaeological surveys and documentation of shipwrecks lost during this event were initiated. To begin the project, the remains of three German U-boats (U-*85*, U-*701*, and U-*352*) were archaeologically surveyed in 2008. In 2009 and 2010 allied military and merchant vessel casualties were examined (see Hoyt 2010). It was during the 2010 mission that ecological and biological surveys were conducted in conjunction and secondary to these archeological investigations. The shipwrecks surveyed during the project were chosen based on their historical significance during the Battle of the Atlantic in World War II. The *Monitor* was not specifically surveyed during this mission.

Site Description

The shipwrecks surveyed during the 2011 BOTA mission (*Keshena*, *Dixie Arrow*, *EM Clark*, *City of Atlanta*) are positioned near Cape Hatteras, North Carolina, a natural zoogeographic break formed by the presence of the tropical Gulf Stream current flowing northward and the temperate Virginia and Labrador currents flowing southward (Briggs 1974). The area between Cape Hatteras, North Carolina and Cape Canaveral, Florida is commonly called the South Atlantic Bight (SAB) and contains three recognized oceanographic zones across the continental shelf. These zones are identified as the inner shelf (0-20m water depth), middle shelf (20-40m), and outer shelf (40-60m) (Atkinson et al. 1983, Yoder 1991). The inner shelf water temperatures are controlled by and similar to the ambient air temperature, and therefore, the biological community is influenced by bottom water temperatures that can be less than 10° C in the winter. While the middle shelf and outer shelf waters are often moderated by the Gulf Stream, bottom water temperatures, especially in water depths greater than 60m, can often be difficult to predict because of deep water upwelling that draws cooler, deeper waters onto the shelf.

The shipwrecks surveyed were all sunk in 1942, within six months of each other. At the time of the biological surveys, each vessel had been underwater for approximately 68 years (Figure 1):

City of Atlanta: 378 ft. in length, steam merchant vessel, sunk January 19, 1942 north of Diamond Shoals in 28 meters of water. Due to her location approximately 18 miles north of Diamond Shoals (middle shelf), the prevailing currents and bottom water temperatures are generally much more temperate and less tropical than locations south of the shoals. This is the northern most shipwreck surveyed during this study (Figure 1) (Gentile 1993).

Dixie Arrow: 485 ft. in length, tanker, sunk March 26, 1942 (Gentile 1992). Located approximately 23 miles southwest of Diamond Shoals in 28 meters of water (middle shelf). *Dixie Arrow* and the *Keshena* are within 5 miles of each other on the middle shelf in Raleigh Bay (Figure 1). The *Dixie Arrow* and the *Keshena* are likely to have warm conditions in the summer due to minimal upwelling effect that is present in deeper waters and to have cold conditions during the winter as there is less thermal influence of the Gulf Stream at both these sites (Yoder 1991, Atkinson et al. 1983).

EM Clark: 499 ft. in length, tanker, sunk March 18, 1942 (Gentile 1992). Located approximately 20 miles south of Diamond Shoals in 72 feet of water (deeper than outer shelf). Due to the depth, this site generally experiences variably colder water temperatures in the summer during cold water upwelling events (Yoder 1991, Atkinson et al. 1983) but remains thermally moderated due to Gulf Stream proximity during the winter.

Keshena: 142 ft. in length, tugboat, sunk July 19, 1942 (Gentile 1992). Located approximately 20 miles southwest of Diamond Shoals in 28 meters of water (middle shelf). *Dixie Arrow* and the *Keshena* are within 5 miles of each other on the middle shelf in Raleigh Bay (Figure 1).

Natural temperature fluctuations that occur across the shelf can strongly influence the types of marine communities (invertebrates, fishes, algae) that are found across the shelf (Wenner et al. 1983, Peckol and Searles 1984, Sedberry and Van Dolah 1984, Schobernd and Sedberry 2009). The vertical relief of the seafloor habitats has also been shown to influence fish community structure. Fish, sessile invertebrate, and algal abundance and diversity are found to be higher on elevated relief and structurally complex habitats (Hixon and Beets 1989, Lindquist et al. 1989, Kendall et al. 2007, Kendall et al. 2009, Schobernd and Sedberry 2009). It is thought that higher relief natural hardbottom habitat provides a more stable environment that is less susceptible to disturbance events such as sand abrasion, which can occur during large storms (Renaud et al. 1997).

Due to their high relief and structural complexity, shipwrecks, also called artificial reefs, provide habitat, for many species of mobile fish and invertebrates as well as hard substrate for a variety of attached benthic invertebrates and algal species. (Hixon and Beets 1989, Lindquist et al. 1989, Carr and Hixon 1997, Moura et al. 2007). For decades, artificial reefs have been used as a management tool to increase fisheries yield, restore degraded habitats, and meet conservation objectives (Christian et al. 1998, Seaman 2007). In coastal North Carolina, local economies have come to depend on the tourism income from divers and anglers who are attracted to the local shipwrecks as sources of recreation. Because shipwrecks function as important habitat, they can be studied along with natural reefs to better understand how climate change and other stressors (e.g., overfishing, invasive species) may impact marine communities. More importantly, the shipwrecks off North Carolina may be uniquely suited to this type of study due to their location within a natural zoogeographic transition zone. (Briggs 1974). Due to this transition zone, North Carolina waters are host to both temperate and tropical species of fishes and invertebrates (Whitfield et al. unpubl. data). However, in recent years, at a hardbottom site off North Carolina, Parker and Dixon (1998) found a community shift to a more tropical fauna. This study suggested that a 1° C increase in minimum winter bottom water temperatures may have caused the shift. In addition, during a five year study of the algal communities within natural temperate reefs off North Carolina, researchers found up to four tropical algae species never before documented in this area (Freshwater et al. unpubl. data). Combined, these data suggest that a transition to a more tropical community is already underway off North Carolina. While the shipwrecks within this study were chosen for their archaeological importance, they could also be used as sites for detecting community changes and could support existing data from natural hardbottom sites that have been collected for the past 5 years. Thus, the primary impetus for this work is to elucidate the ecological importance of these shipwrecks by collecting baseline community data and to use the initial data to improve future sampling designs that will increase the ability to detect future community shifts.

Goals and Objectives

Baseline biological and ecological assessments were conducted as part of the 2010 *Monitor* National Marine Sanctuary Battle of the Atlantic (BOTA) Research Project from June 8-30, 2010. Off the coast of Cape Hatteras, in 23 - 72 meters of water, researchers conducted the first biological surveys of several historic shipwrecks. The data collected included fish, invertebrate and algal surveys, and the deployment of temperature sensors. Researchers from the National Centers for Coastal Ocean Science (NCCOS) and National Marine Fisheries Service (NMFS) partnered with the MNMS to design sampling protocols for this mission. The information collected will not only establish a baseline, but will be used to support management documents such as future MNMS Condition Reports. Without this baseline data, determining changes and trends necessary for the Condition Report is impossible. In order to gain a better understanding of the biological community in and adjacent to the sanctuary and to begin to resolve unanswered questions from the 2008 MNMS Condition Report, the following goals were addressed:

- Establish and maintain a monitoring and research program of the MNMS's living resources and their habitats.
- Establish and promote specific sites within and adjacent to the sanctuary as locations for long-term monitoring.

The main objectives of this report are 1) to summarize the activities conducted and the biological communities present on the shipwrecks surveyed during the 2010 BOTA cruise, 2) present results of the surveys within the context of the oceanographic and climatic regime that prevailed during the mission, and 3) provide recommendations on the use of shipwrecks as potential sites for detecting community change.

Methods

Baseline community surveys were conducted at three historic shipwreck sites within two of the oceanographic zones south of Cape Hatteras: the middle shelf (20-40m (*Keshena* and *Dixie Arrow*) and outer shelf greater than 60m (*EM Clark*). North of Cape Hatteras, one site was surveyed on the middle shelf (*City of Atlanta*) (Figure 1, Table 1). At each site HOBO Pro v2® water temperature data loggers were deployed that were programmed to collect water temperature data once every 30 minutes. These temperature sensors will continue to log continuous measurements for up to 2 years. A temperature sensor was deployed at one additional site on the middle shelf south of Cape Hatteras (*Manuela*); however, no biological assessments were completed at this site due to inclement water conditions and time constraints.

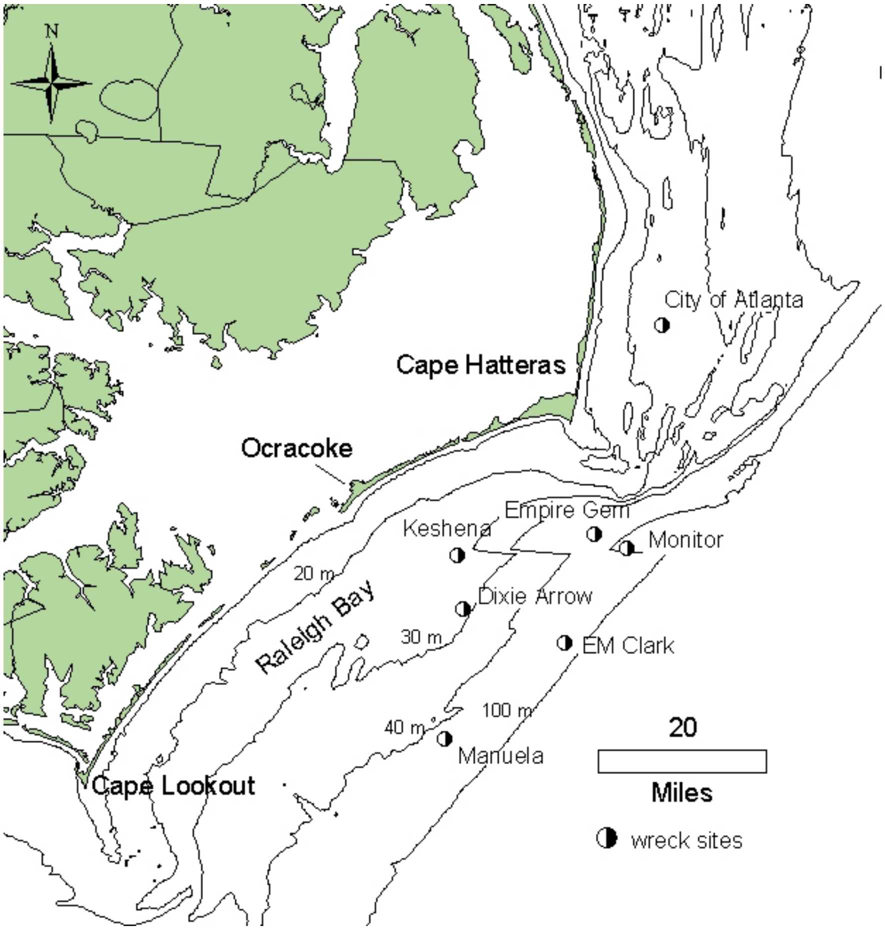


Figure 1. Map of shipwreck locations visited during BOTA 2010 expedition. (Map created by Paula Whitfield)

Table 1. Shipwrecks where biological surveys were conducted and/or where temperature sensors were placed during the 2010 Battle of the Atlantic expedition. This table does not include the *Empire Gem* or *Monitor* where only archaeological surveys were conducted. Vis. is abbreviated for visibility. n* = number of transect conducted at a site.

Sites	Dates surveyed (2010)	Depth (m)	Temp. Sensor (y/n)	Biological surveys (n*)	Bottom Water Temp. (F)	Year Sunk	Vis. (m)
City of Atlanta	June 11	23	y	Fish (1), Habitat (1)	53°	1942	10
Dixie Arrow	June 12, June 25	25	y	Fish (2), Habitat (1)	70° 75°	1942	10
EM Clark	June 15	72	y	Fish (1), Habitat (1)	70°	1942	8
Manuela	June 16	44	y	n/a	unk	1942	12
Keshena	June 22	25	y	Fish (2), Habitat (1)	72°	1942	8

Fish Community Assessments

All sampling protocols have inherent biases that can favor or exclude species based on factors such as behavior, habitat preference, or size (Allen et al. 1992, MacNeil et al. 2008). For example, traditional underwater visual census (UVC) transects geared towards conspicuous and highly mobile species may miss or underestimate smaller, benthic dwelling fishes. These smaller species are often cryptically colored and can either be the juvenile stage of conspicuous species or may remain cryptic and small throughout their life cycles, where they may function as important prey species within the fish community. For this reason, three different sampling approaches were combined in order to better capture the entire fish community within a given area. The first, a traditional UVC band transect method was used to enumerate all conspicuous fish species within 5m on either side of the transect (Sanderson and Solonsky 1986, Samoilys and Carlos 2000, Schmitt et al. 2002). The fish observer swam along the transect of each shipwreck, observing all mobile, conspicuous fishes within the transect band (10m total width, hereafter called “conspicuous fish transect”) were enumerated and lengths estimated (using 10cm size classes). The transect length was 50m but sometimes varied (30-50 m) due to dive time limitations. Once the diver swam 50m, or the temporal midpoint of the bottom time of the dive was reached (whichever came first), the diver began reeling in the meter tape and enumerating and estimating sizes (up to 10cm length) of the smaller, cryptic, prey fishes (hereafter called “prey fish transect”). The second sampling method targeting cryptic (or juvenile) prey fishes occurred when the survey was conducted in reverse along the same transect but with a narrower width (1m to each side). Due to time constraints, only one transect (conspicuous and prey) per shipwreck was conducted unless the site was revisited (e.g., *Dixie Arrow* and *Keshena*). Finally, one cryptic fish census was also conducted (limited by personnel availability) using a timed stationary quadrat method (at the *Keshena*). The purpose of the stationary quadrat technique was to sample smaller cryptic fishes that could be missed or underestimated on band transects (data in Appendix A).

Summary of fish community survey methods:

1. 50m x 10m (unless time limited) UVC band transects that targeted mobile conspicuous fishes (maximum area surveyed = 500m^2, variable depending on visibility and transect length).
2. 50m x 2m UVC band transects that targeted cryptic (or juvenile) prey fishes 10cm and less in length (maximum area surveyed = 100m^2).
3. Stationary UVC of 1m^2 quadrat (conducted only at the *Keshena*) placed on the benthos for a predetermined (7 min.) time period. This method favors the less mobile cryptic prey species less than 20cm but does not exclude conspicuous species (area surveyed = 1m^2).

For each site, the number of individuals and densities of fish were calculated. Densities were determined by dividing the number of fish observed by the area surveyed (reported in hectares). Species richness was also calculated using Pielou’s evenness and the Shannon diversity index to further compare the conspicuous fish communities at each site. The Shannon diversity index takes into account the number of species and the evenness of the species, the greater the index value the more diverse and even the species composition. Pielou's species evenness is an index from 0 to 1 where 1 represents an equal apportionment of individuals among species (Clark and Warwick 2001).

Similarity among the fish communities were examined by site using multi-dimensional scaling (MDS) analysis of fish densities with PRIMER v6 software. PRIMER allows multivariate analysis of community ecology variables without the need to satisfy many of the assumptions needed for parametric statistics (Clark and Warwick 2001). In the MDS plots, distance is a proxy for both similarity and dissimilarity (Clark and Gorley 2006), thus points that are farther from each other are the most dissimilar in their fish communities. A square root transformation was used to minimize the influence of extremely rare species relative to common ones.

MDS analyses on fish biomass was also determined for each fish species and site. Biomass was calculated from the length-weight relationship, $W = aL^b$, where w = weight in g and L = length in cm. The midpoint of the size categories was calculated for each 10cm category. For example, if the size category was 20-30cm, then the length was considered 25cm for the equation (Kendall et al. 2009). Values for the *a* and *b* parameters for each species were obtained from http://www.Fishbase.org (Froese and Pauly 2010). If the parameters for a particular species could not be found, then the parameters for a morphologically similar species within the same genus were used. Parameters for whitespotted soapfish (*Rypticus maculatus*) were not available in the literature or in the fishbase database, therefore, it was omitted from the biomass analysis.

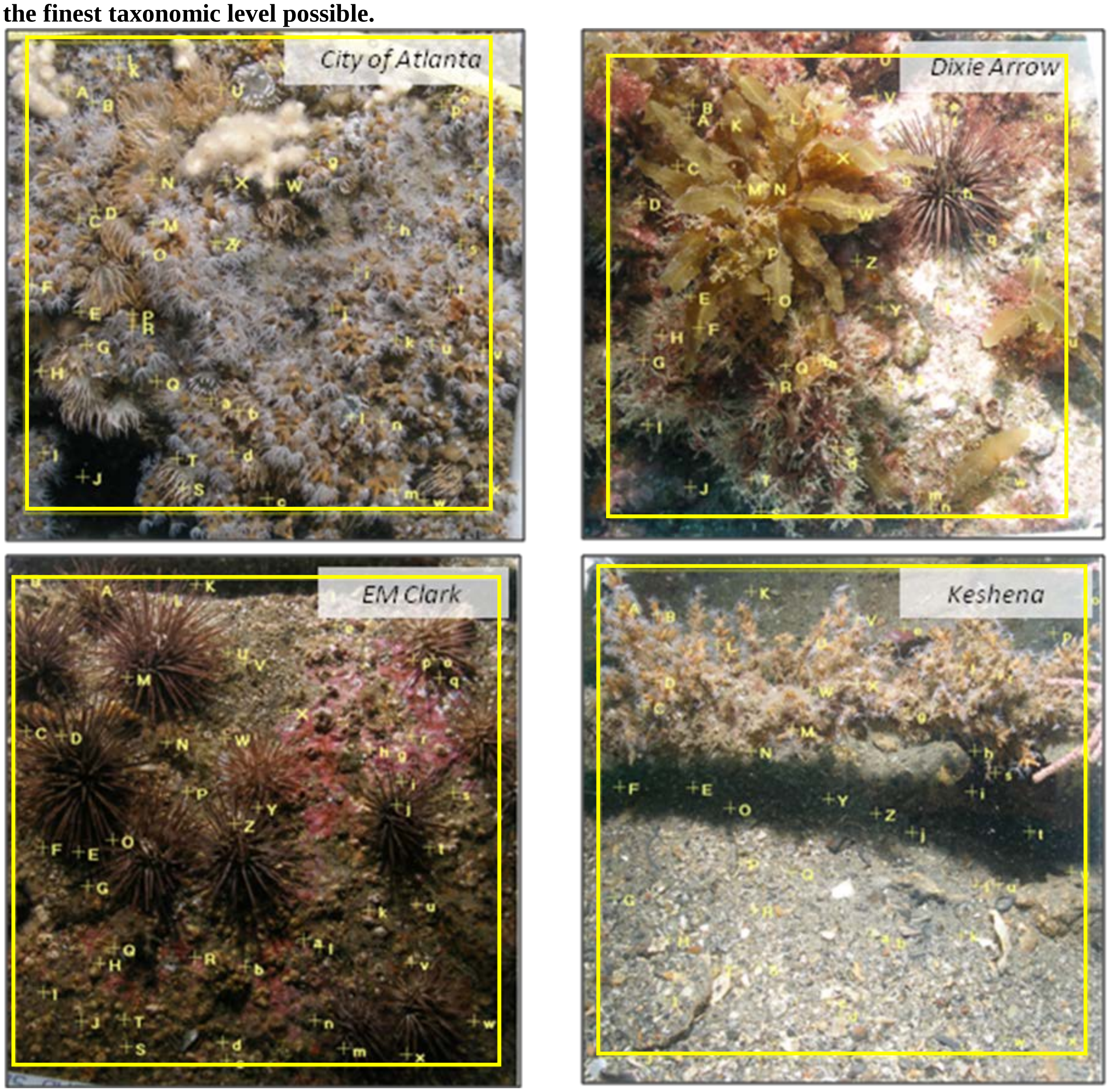
Benthic Habitat Assessments

Benthic habitat surveys were conducted concurrently with fish assessments. Using the fish transect as a guide, the benthic habitat surveyor took photographs (standardized with $0.25m^2$ area) every five meters, beginning at the zero meter. Due to varied transect length, the number of images per transect ranged from six to nine (see Table 3 for sample sizes). All photographs were taken at 7.0 mega pixel resolution by an experienced photographer. Percent cover of uncolonized substrate and epibiota was determined using Coral Point Count (CPCe) software (Kohler and Gill 2006). Fifty random points (asymptote of species accumulation curve conducted on images from North Carolina hardbottom reefs, data not shown) were overlaid on each photograph and the substrate type below each random point was classified to the finest taxonomic level possible (Figure 2). Only the top-most substrate type was classified and as a result, the amount of actual wreck underneath is under-represented at each site.

In instances where species or genus could not be identified, a classification based on morphology was made. For example, where species was unknown but phyla were identifiable, a point could be classified as 'rod shaped soft coral' or 'strap-like red algae.' Detailed description of species and morphological classes within each benthic habitat group is listed in Appendix B. Where phyla were unidentifiable (generally due to shadowing, image quality, or obstruction) the point was labeled as unknown and not included in analysis. For example, 50 points were overlaid on each image but the actual number of classifiable, and therefore analyzable, points is identified in Table 3. Percent cover was then calculated based on the number of classifiable points.

The null hypothesis of “no difference in benthic habitat by site” was tested using multi-dimensional scaling (MDS) analysis and the analysis of similarity (ANOSIM) test in PRIMER v6 software. The role of individual benthic components responsible for statistical differences was further examined with the similarity percentages (SIMPER) routine.

Figure 2. Examples of analyzed benthic habitat quadrats from each of the sites surveyed. Yellow box (25 x 25cm) delineates the analysis area of each image where 50 points are overlaid and classified to the finest taxonomic level possible.



Results

The shipwreck sites were located along a cross section of the shelf at water depths of 23 - 72m. Water temperatures during the sampling period in June ranged from 53 -78˚F. Overall, water conditions at depth were anomalous, especially for June, being much colder than expected throughout the time period of sampling (first author observation). Reports from fishermen in the area affirmed that the persistence of a cold water layer closer to shoreline (than usual) seemed to be influencing fish distributions in these areas. Many fishermen stated that they had to 'run' 40 miles or more offshore to locate the Gulf Stream, which was usually about 20 miles east from Hatteras or Ocracoke Inlet (Capt. Terry Leonard, pers. comm.) These observations are important because the surveyed abundance and diversity of fish species was lower than expected and the cold water layer was a likely cause (Sedberry and Van Dolah 1984). In some cases, poor water clarity also seriously hampered visibility needed to conduct surveys.

Fish Community Assessments

For all sites combined, 32 species of conspicuous fish and nine species of prey fish were observed (Appendix A). Eight conspicuous fish species made up 95% of the total number of fishes, including red barbier (*Hemanthias vivanus*), scad (*Decapturus spp*.), tomtate (*Haemulon aurolineatum*), longspine porgy (*Stenotomus caprinus*), vermilion snapper (*Rhomboplites aurorubens*), pinfish (*Lagodon rhomboids*), gray triggerfish (*Balistes capriscus*), and southern sennet (*Sphyraena picudilla*)(Figure 3A). For the fishes observed on the prey transects (fish up to 10cm in length), red barbier and longspine porgy represented over 95% of the total number of prey observed (Figure 3B). Ninety percent of the conspicuous fish biomass was comprised of 12 species including amberjack (*Seriola dumerili*), vermilion snapper, *Mycteroperca* spp., and gag grouper (*Mycteroperca microlepis*) (Figure 4A). Ninety-eight percent of the prey fish biomass was comprised of two species: red barbier and longspine porgy (Figure 4B).

For each site, the total number and densities of fishes were calculated. The sites that contained the highest number of conspicuous fishes were the *Keshena* (Figure 5A, 16 species censused over two days) and the *Dixie Arrow* (Figure 6C, 14 species censused over two days). The *EM Clark* had seven species (Figure 6A) and the *City of Atlanta* had the least, with only two species (Figure 5B). All of the sites that were surveyed had fewer species on the prey transects. The *Dixie Arrow* had the most, with seven prey species (Figure 6D). The *EM Clark* had three species (Figure 6B) and the *City of Atlanta* had only one species, black sea bass (*Centropristis striata*) (density = 822/hectare). There were no prey transects conducted at the *Keshena* due to time constraints. The highest density conspicuous fish species were red barbier at the *EM Clark* (67,000 /hectare) and scad (50,000/hectare), tomtate (14,666/hectare), longspine porgy (5371/hectare) and vermilion snapper (2583/hectare) at the *Dixie Arrow*.

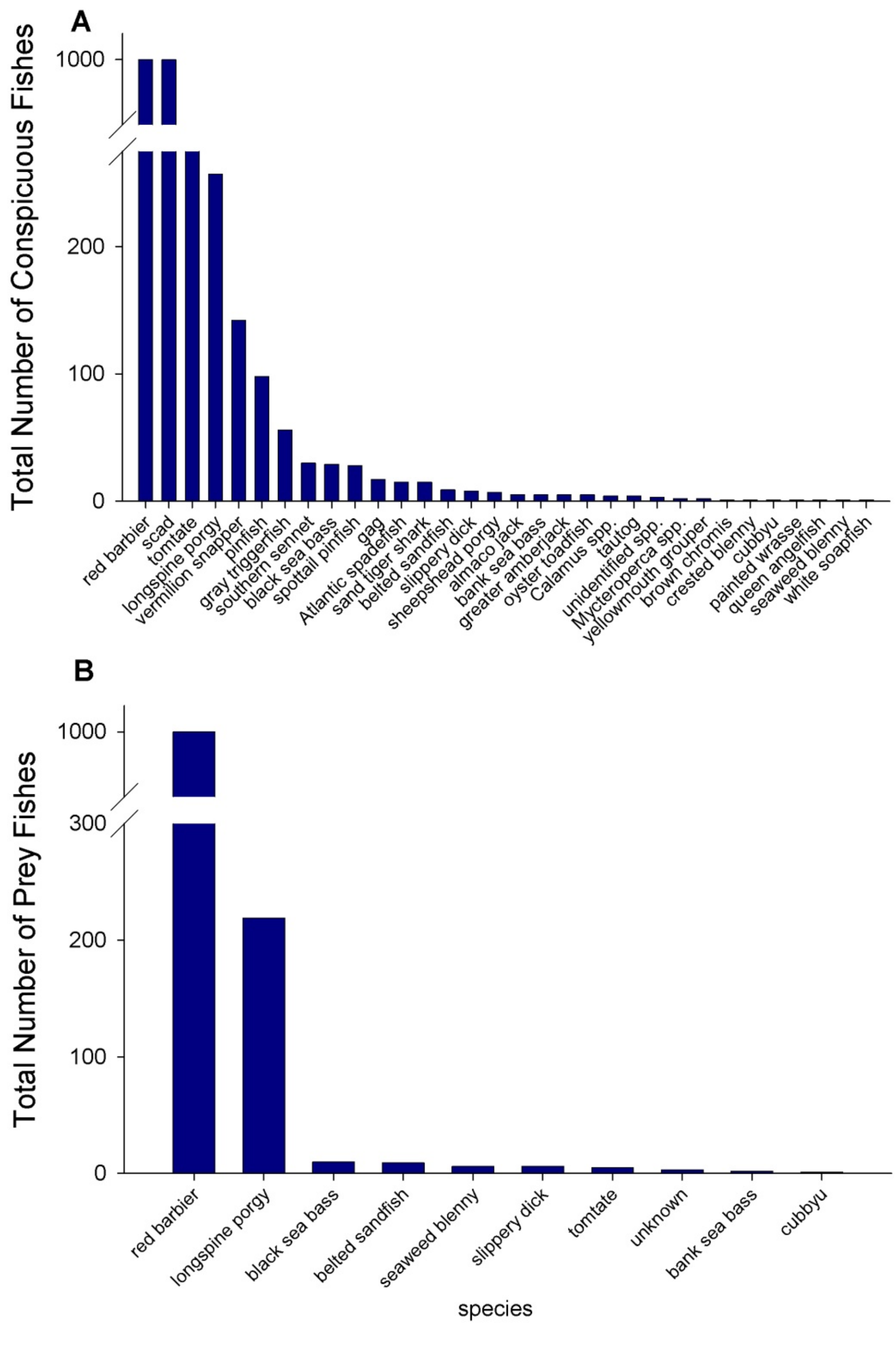


Figure 3. Total number of A) conspicuous fishes and B) prey fishes for all sites.

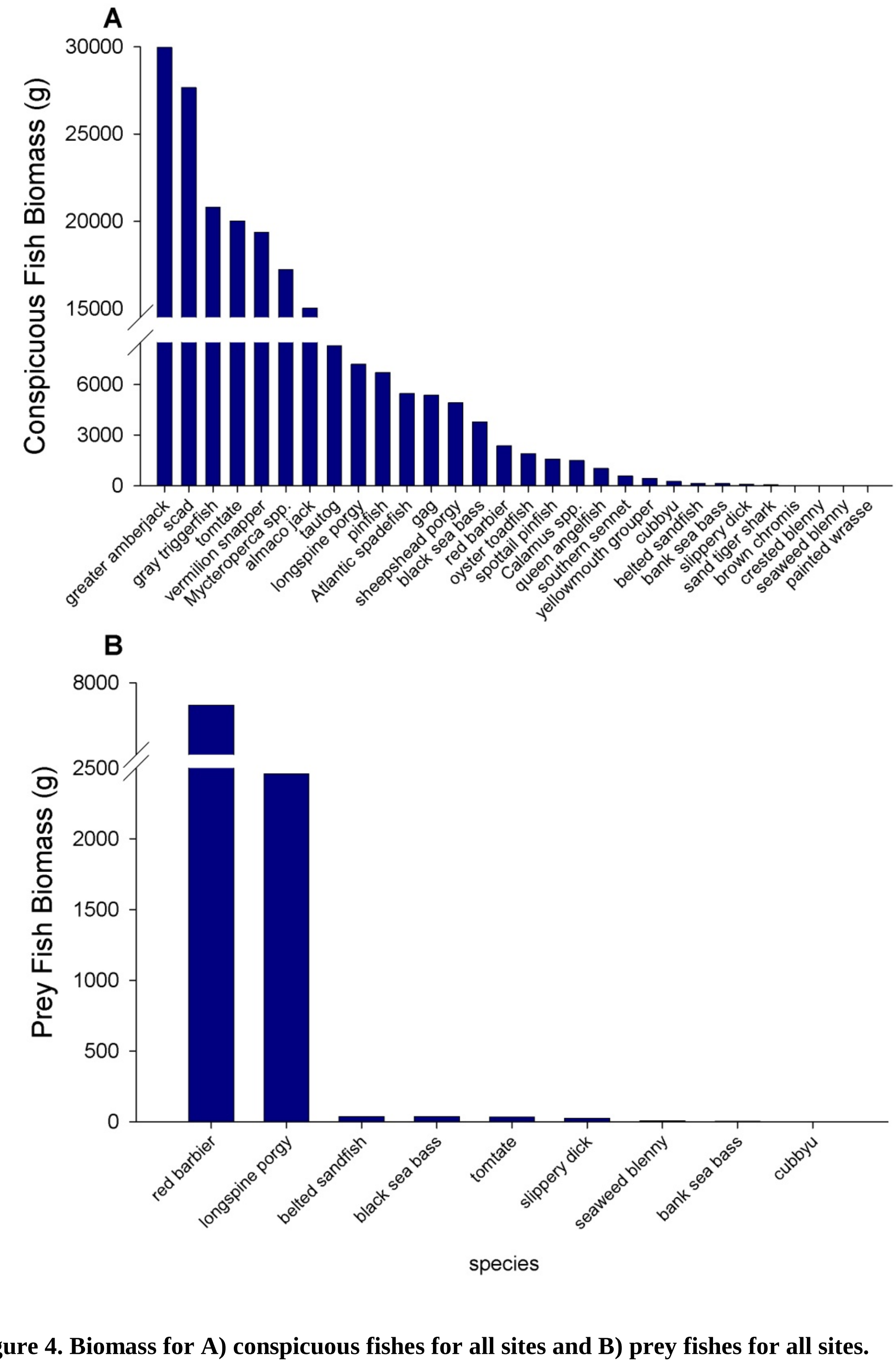


Figure 4. Biomass for A) conspicuous fishes for all sites and B) prey fishes for all sites.

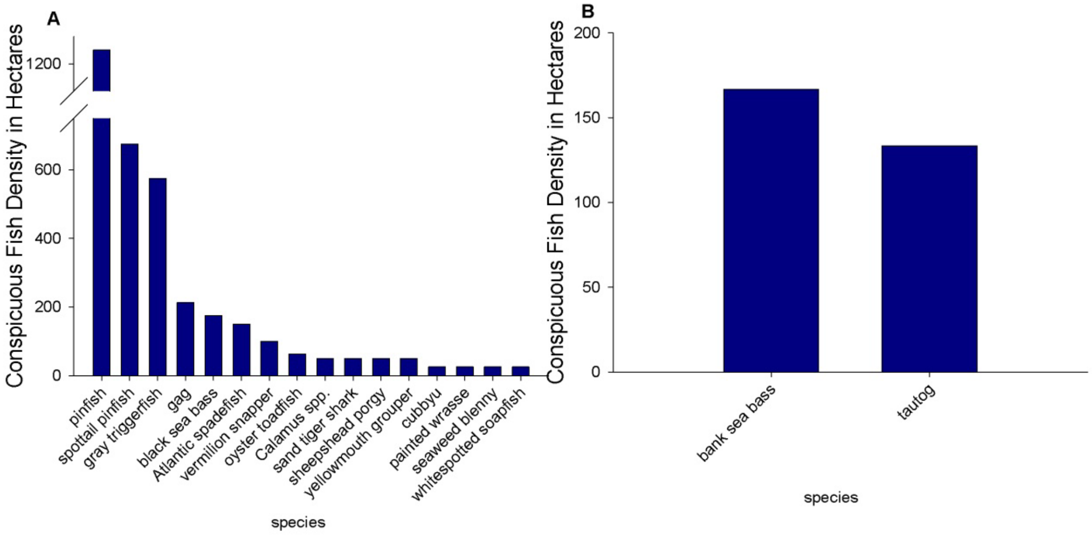


Figure 5. Densities of conspicuous fishes for the A) *Keshena* and B) the *City of Atlanta*.

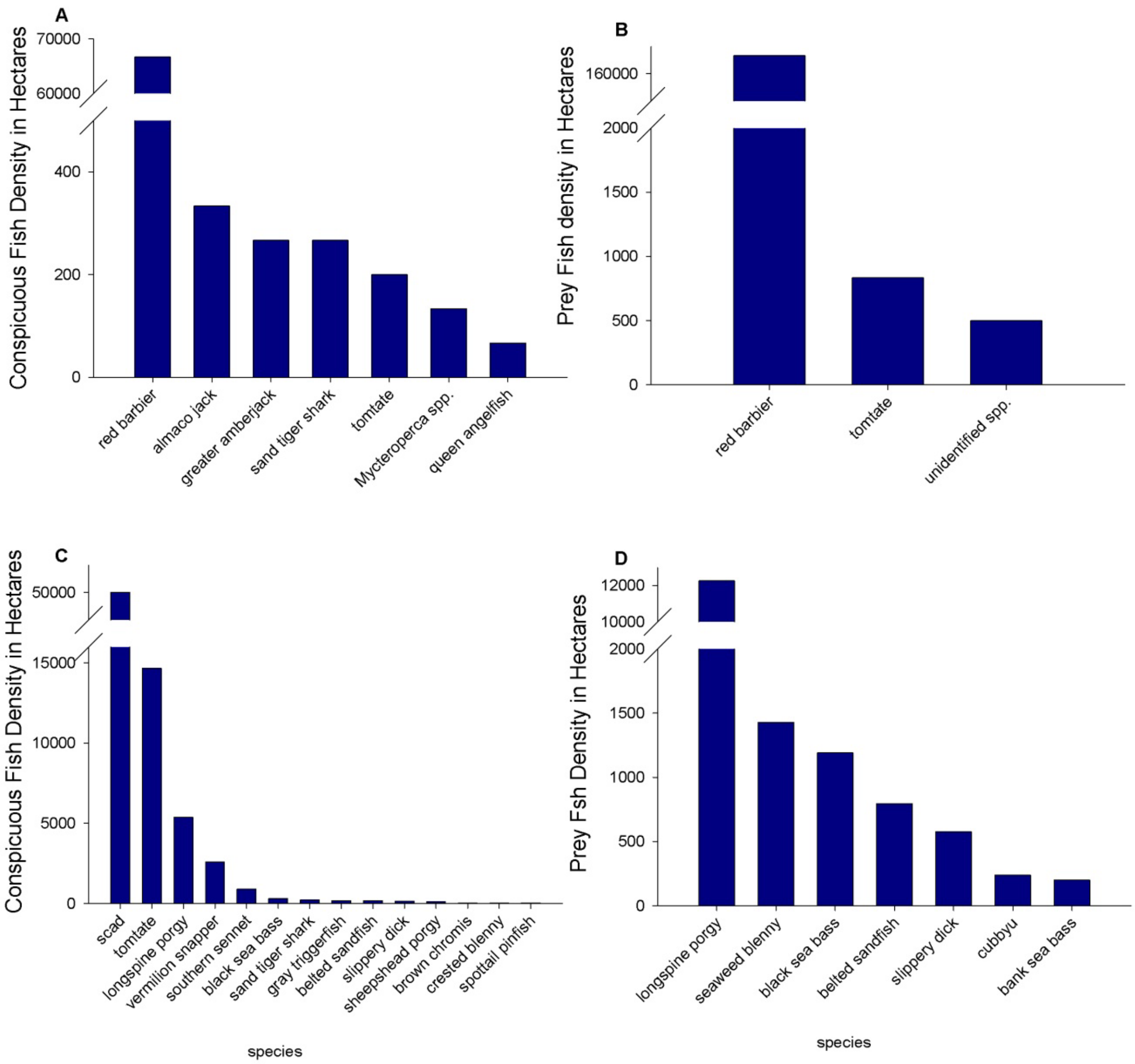


Figure 6. Densities of conspicuous and prey fishes for the A) B) *EM Clark* and the C) D) *Dixie Arrow*.

The results of the MDS analysis suggest that the conspicuous fish community among sites was different (Figure 7). Although insufficient replicates preclude a statistical analysis such as ANOSIM, the 10% similarity contours suggest that the fish communities at the *Dixie Arrow* and the *Keshena* were most similar to each other. This is not surprising because these two sites are geographically close to each other and are located at analogous depths and therefore, presumably share a similar oceanographic regime. The northernmost and most isolated of the sites, the *City of Atlanta*, was the most dissimilar in both species composition and density compared to the other sites. The *EM Clark* was the deepest site surveyed and was also shown to be dissimilar to the other sites. Results from the MDS analysis of the prey community yielded very similar results and are not presented here to avoid redundancy.

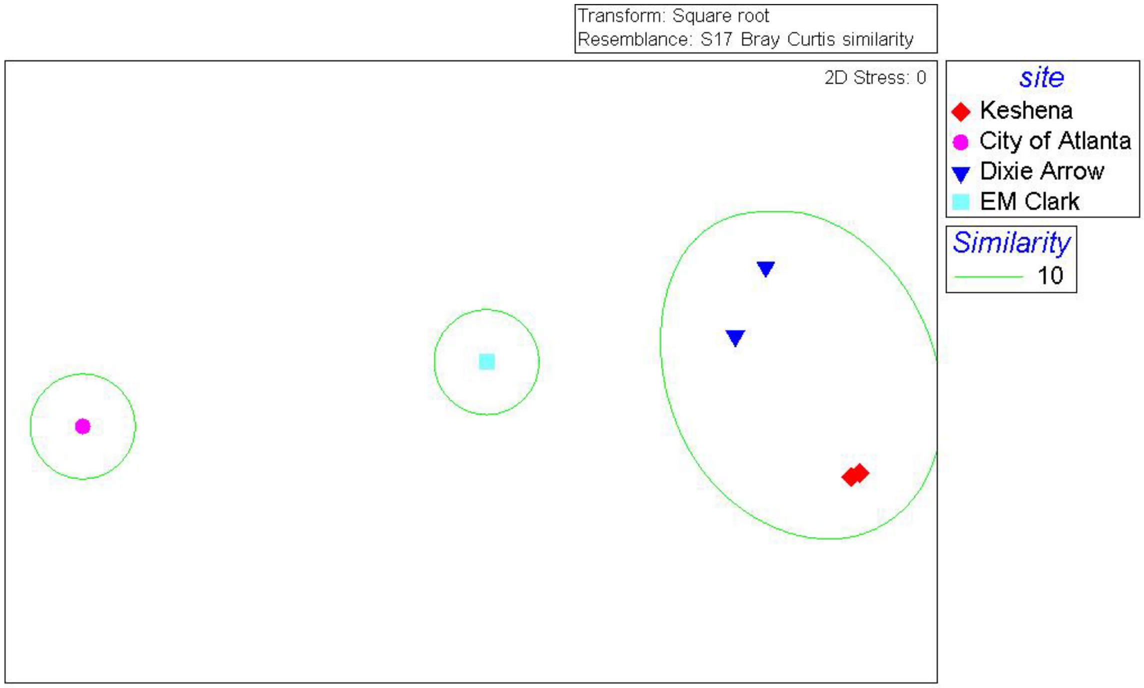


Figure 7. Multi-dimensional plot of the conspicuous fish community at all sites with 10% similarity contour overlaid.

The *Dixie Arrow* and the *Keshena* had the highest species richness and the highest Shannon diversity index (Table 2). The *City of Atlanta* had the lower diversity and a relatively high evenness index because there were only two species observed in relatively equal numbers, whereas the *EM Clark* has a low evenness index because the red barbier vastly outnumbered the other species at the site (Table 2, Figure 6A). These results also suggest that the middle shelf sites south of Cape Hatteras were more diverse than the outer shelf site, the *EM Clark*. Results of prey community diversity analyses were again similar and not presented here to avoid redundancy.

Size classes for the conspicuous (32 species, Figures 8 to 12) and prey fishes (nine species, Figures 13-14) are presented in order of descending biomass. For example, in Figure 4 whitespotted soapfish (*Rypticus maculatus*) was included last because there were no biomass parameter estimates available for this species.

Table 2. Diversity indices for conspicuous species by site.

Site	Date	Area surveyed (m^2)	Species richness	Evenness index (Peilou's)	Shannon diversity index	Oceano-graphic zone
City of Atlanta	06/11/2011	300	2	0.9911	0.687	middle shelf north of C. Hatteras
EM Clark	06/15/2011	150	7	.06922	0.144	outer shelf
Dixie Arrow	06/12/2011	200	10	0.4637	1.068	middle shelf
Dixie Arrow	06/25/2011	330	13	0.6422	1.647	middle shelf
Keshena	06/22/2011	400	13	0.7078	1.816	middle shelf
Keshena	06/23/2011	400	11	0.7087	1.699	middle shelf

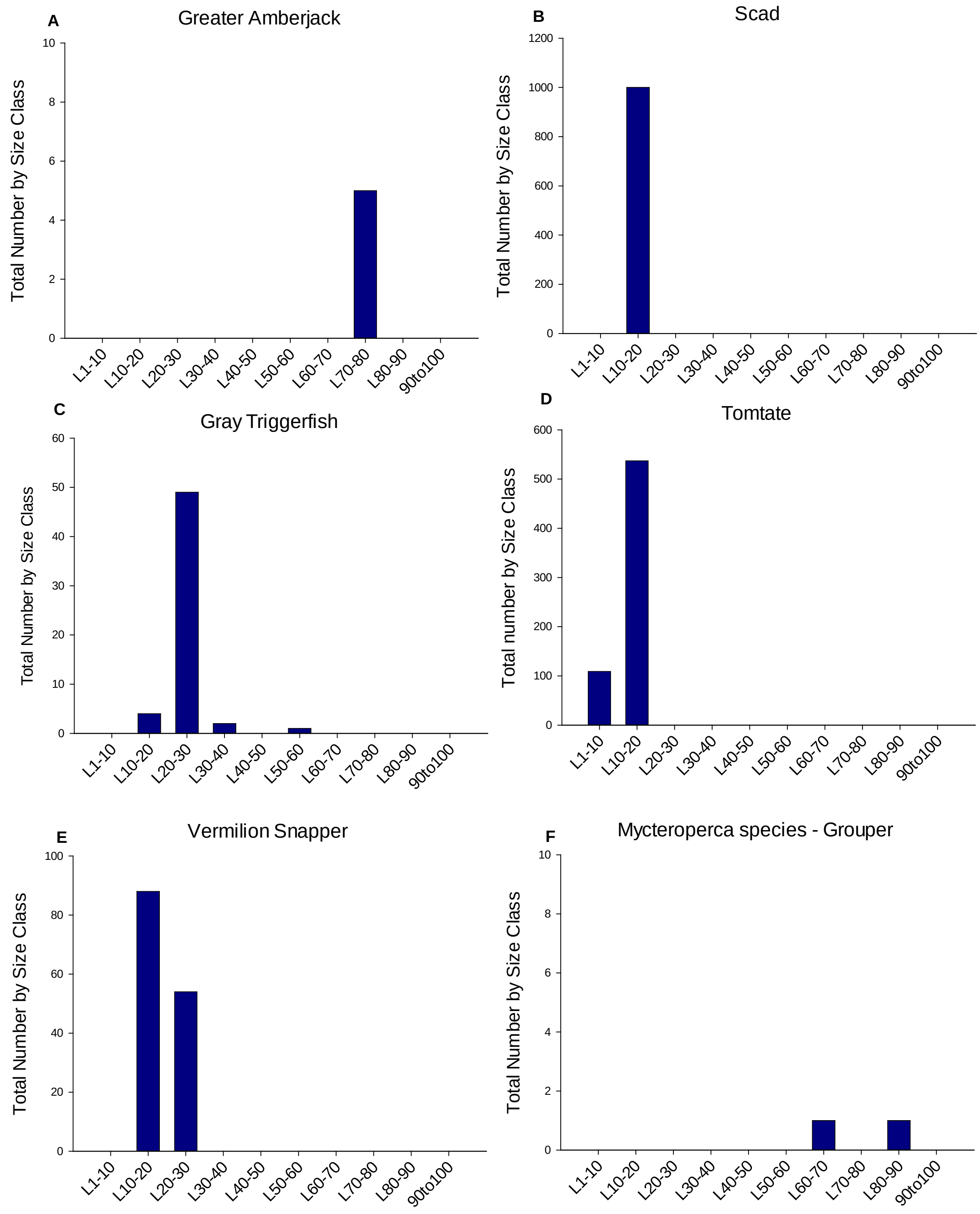


Figure 8. Size class graphs of conspicuous fishes representing the top six species in biomass.

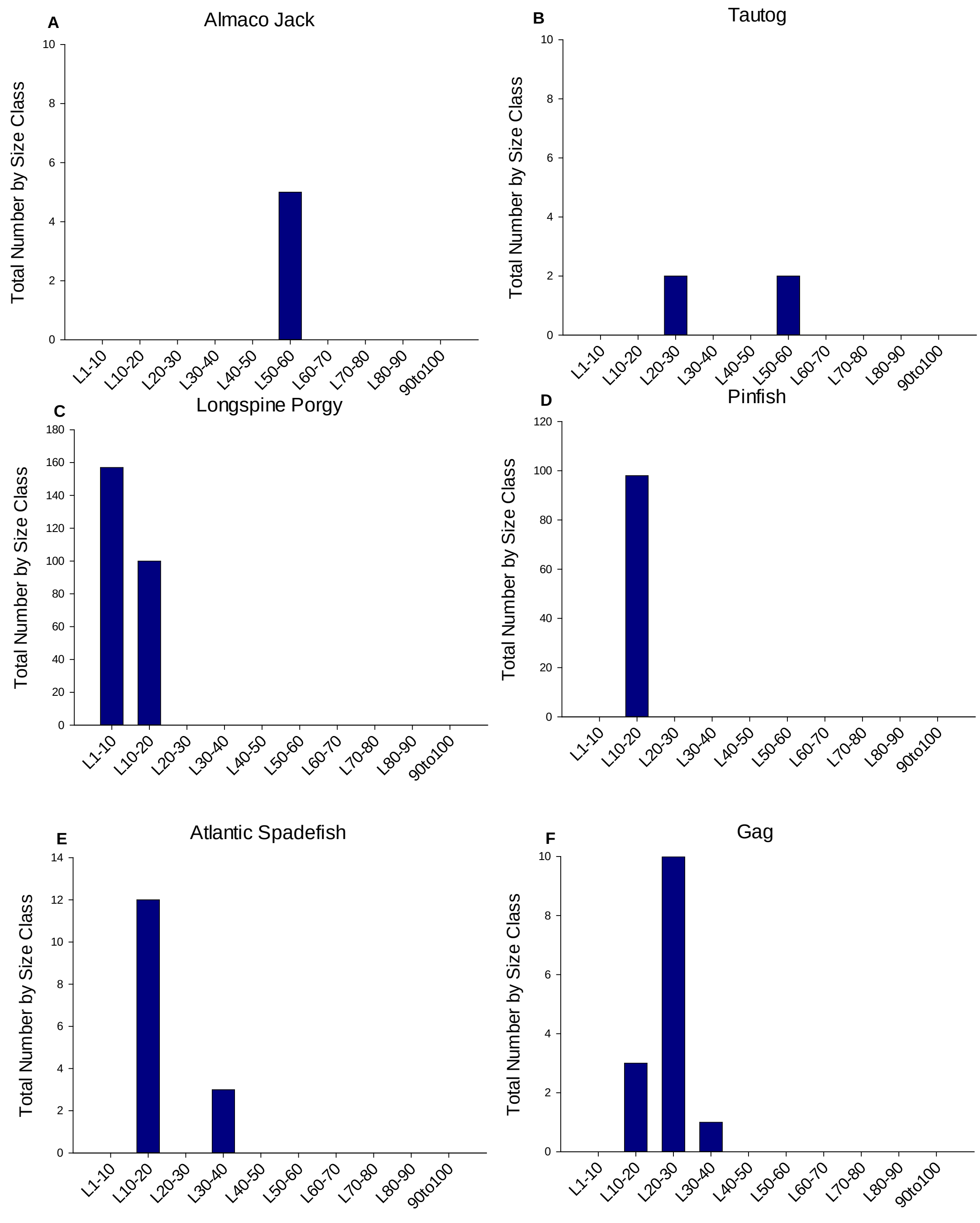


Figure 9. Size class graphs of conspicuous fishes representing the top seven to 12 species in biomass.

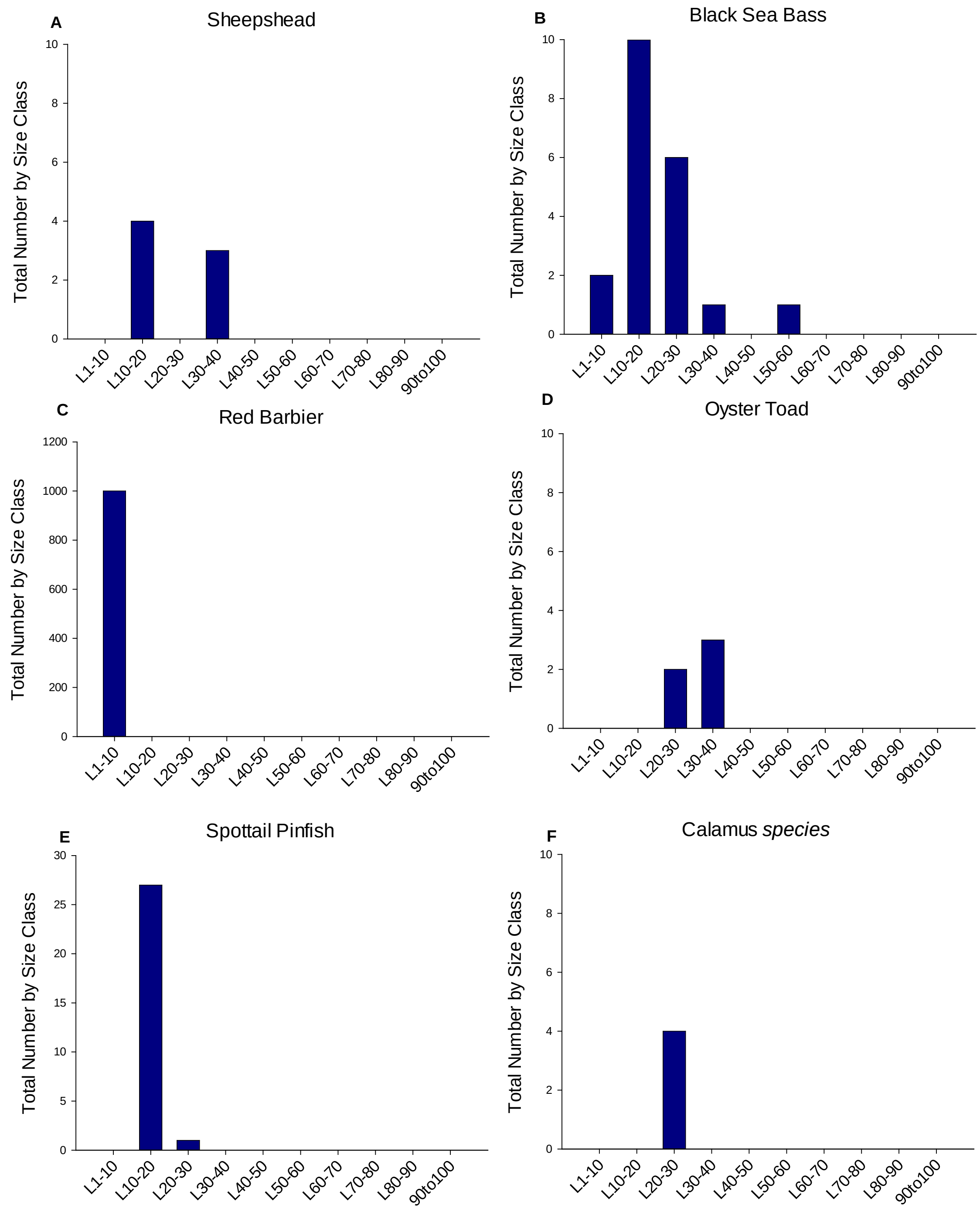


Figure 10. Size class graphs of conspicuous fishes representing the top 13 to 18 species in biomass.

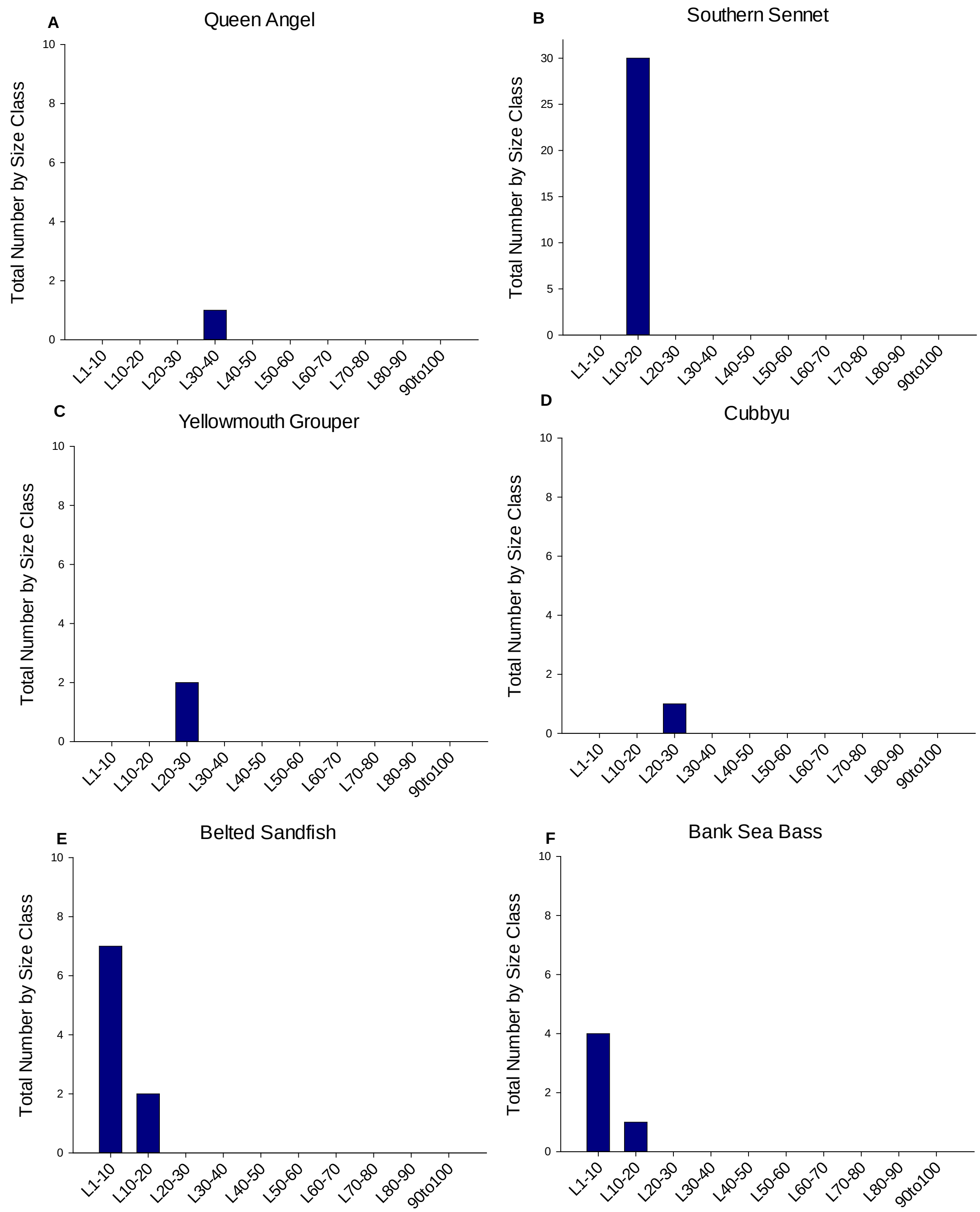


Figure 11. Size class graphs of conspicuous fish species representing the top 19 to 24 species in biomass

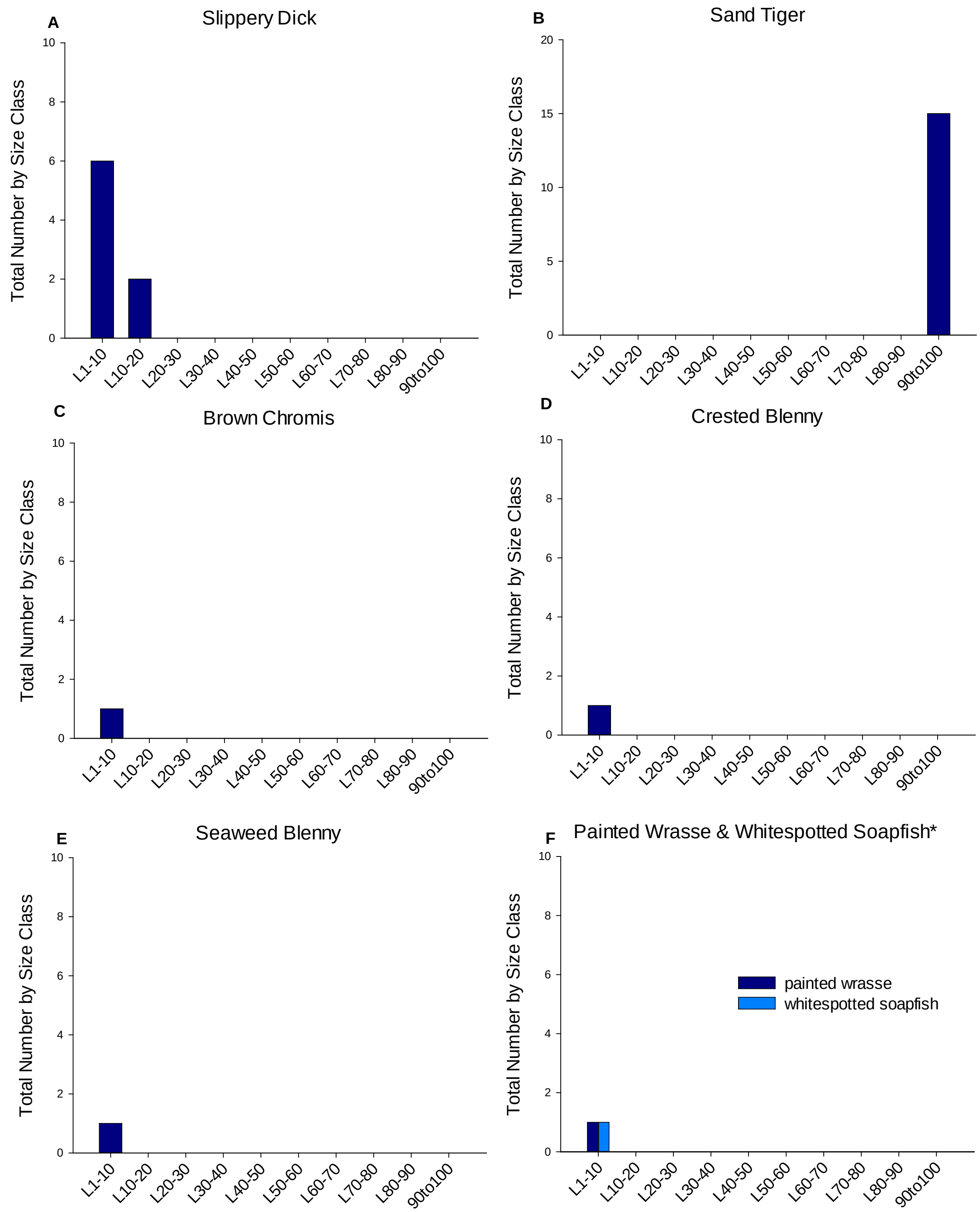


Figure 12. Size class graphs of conspicuous fishes representing the last 25 to 32 species in biomass. * Parameters to estimate biomass of whitespotted soapfish were not available.

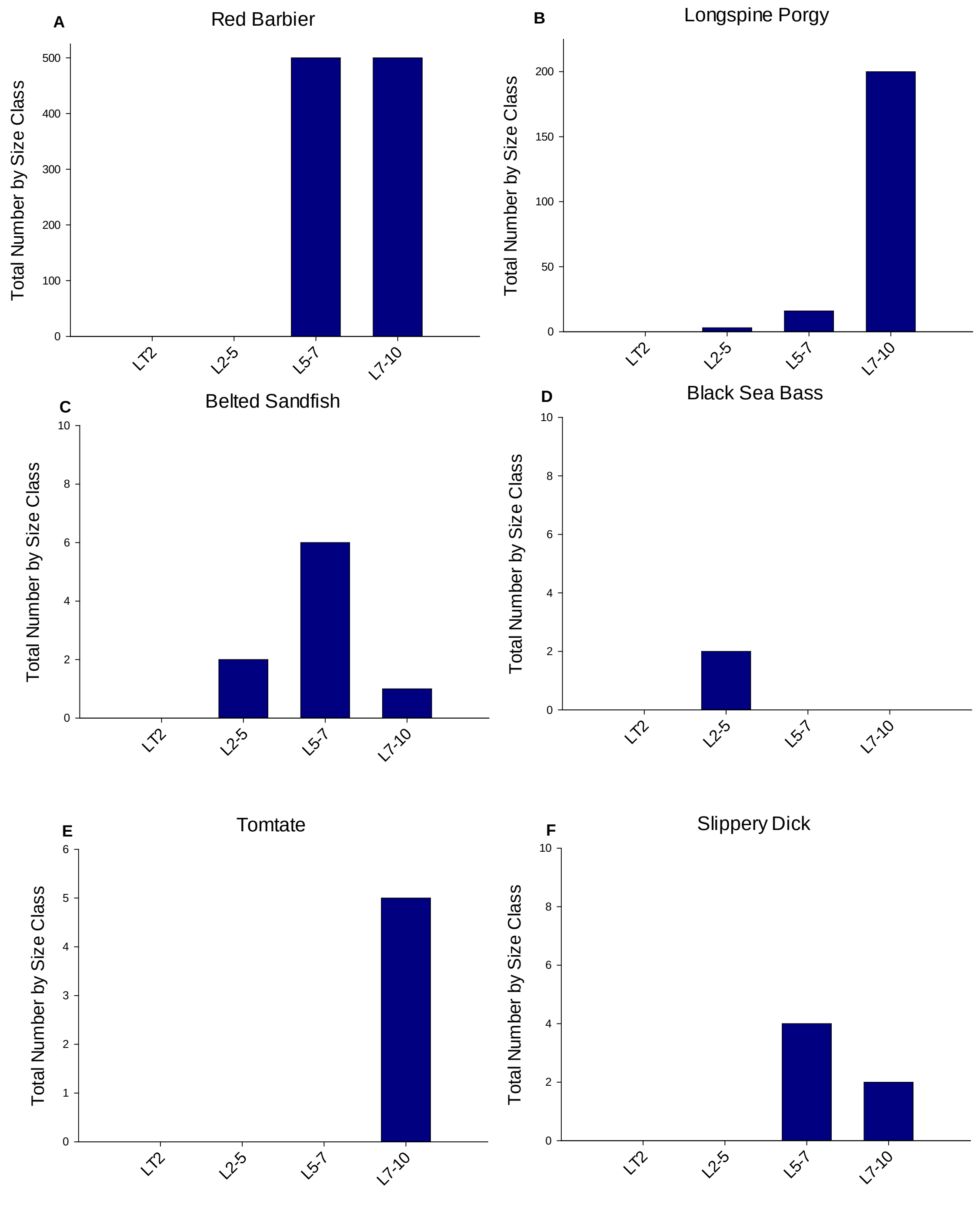


Figure 13. Size classes for prey fishes representing the top six species in prey fish biomass.

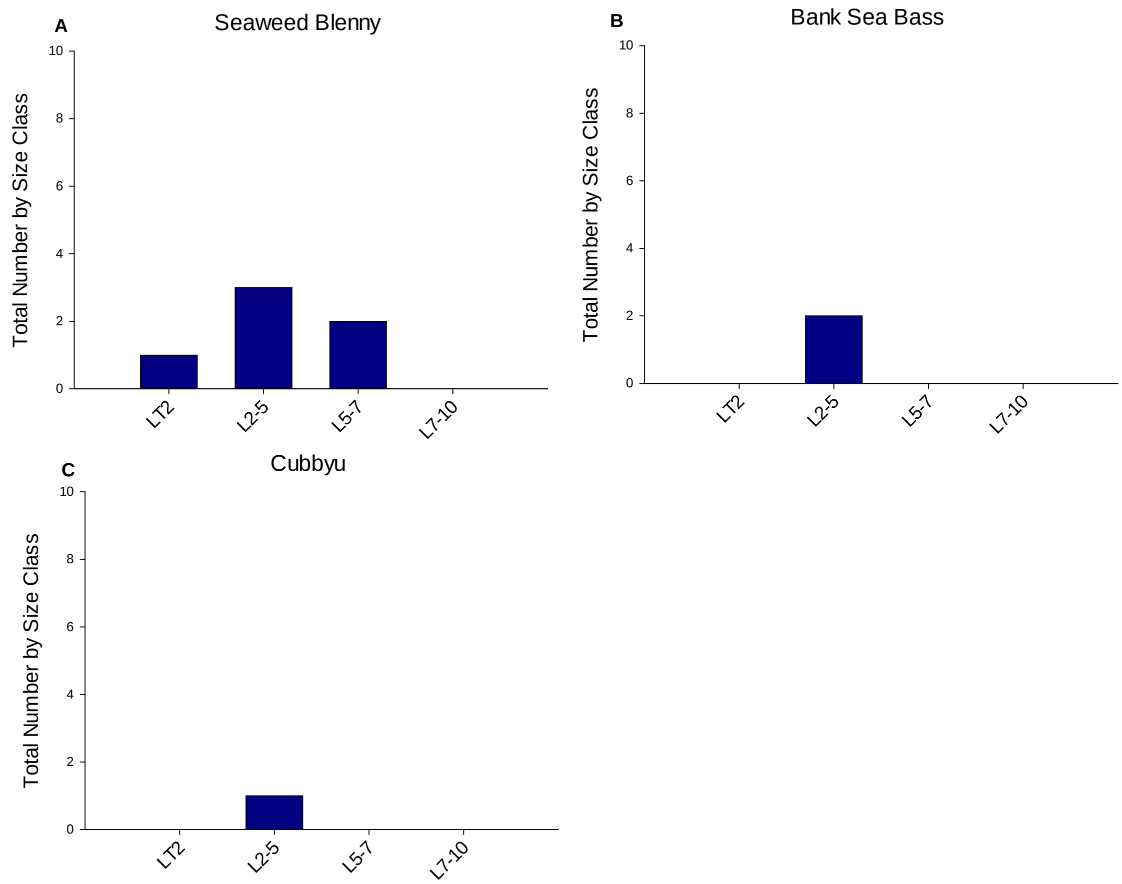


Figure 14. Size classes for prey fishes representing the last seven to nine species in prey fish biomass.

Benthic Habitat Assessments

The biotic and abiotic components of the surveyed wrecks were comprised of 33 different species and morphological groups, spanning 10 phyla (Appendix B, Figure 15). Images collected in June 2010 for benthic habitat analysis were of exceptional quality (Figure 2), with a mean of 91.25% (± 1.83 SE) of all points being identifiable at each site. The majority of unidentifiable points were due to shadowing (5.1% ± 1.49, mean ± SE), which is not unexpected given the complexity and rugose nature of the surveyed wrecks.

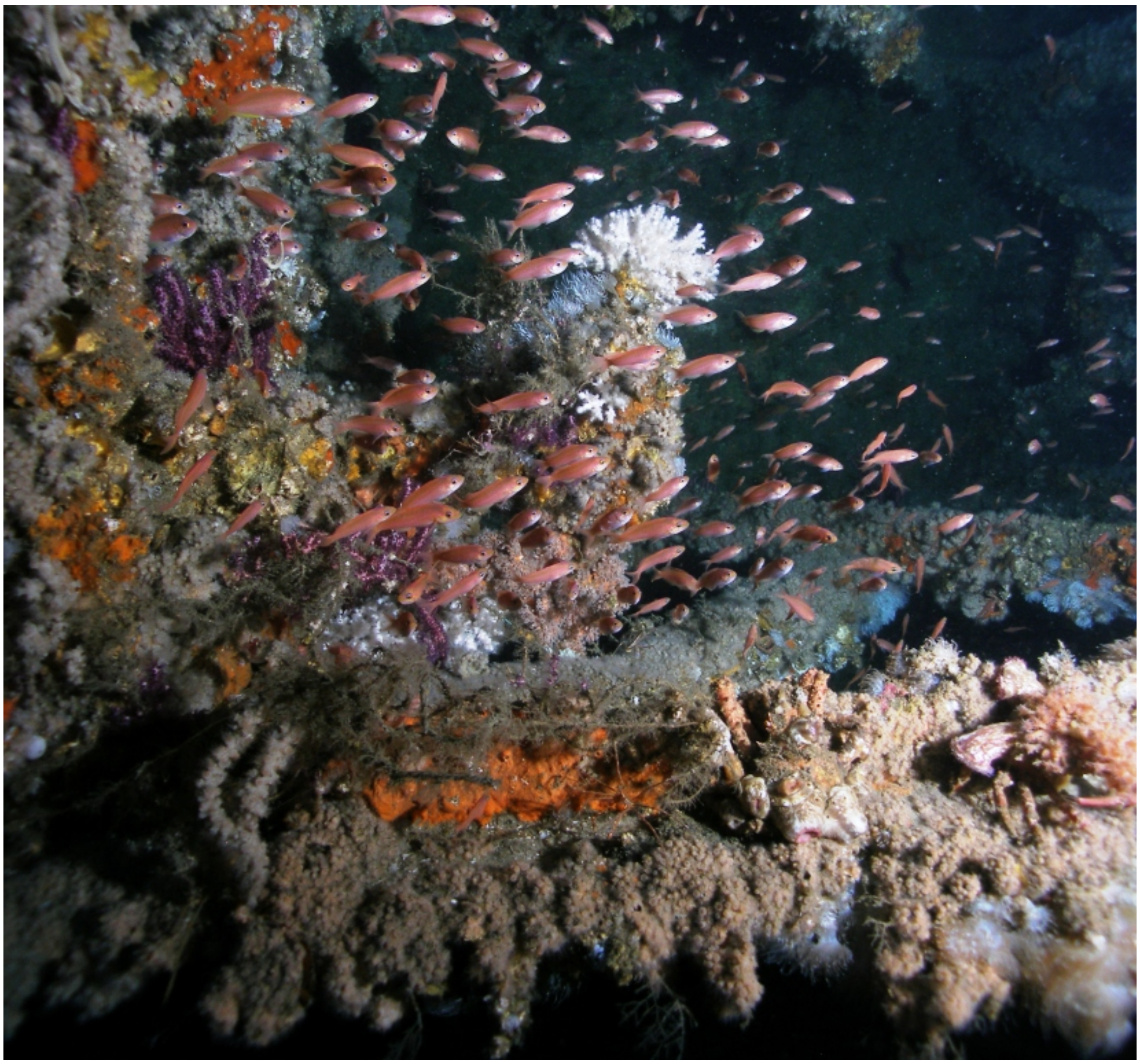


Figure 15. Photo of the diverse invertebrate community on the EM Clark (72m) with schooling red barbier (*Hemanthias vivanus*). Photo credit: Doug Kesling (CIOERT)

Results of MDS analysis and the ANOSIM test revealed significant differences in the benthic community among the four wrecks examined (Figure 16, Global R 0.45, $p < 0.0001$). The SIMPER routine provided a list of the community components that were responsible for the differences among the sites (Table 3.). For example, at the *EM Clark* the contributions of barnacles to the percent dissimilarity ranked high because barnacles were not found in high amounts on any other shipwreck (Figure 17). Likewise, the contribution of *Telesto* (octocoral) and anemones (cnidarian) to the percent dissimilarity of *City of Atlanta* versus other shipwrecks were relatively high due to the percent cover of these community components being greater than on any other shipwreck (Figure 17). Although the *Keshena* and *Dixie Arrow* share a similar oceanographic regime, the average dissimilarity among these two shipwrecks was 69%. Nearly 18% of this dissimilarity was due to the high amount of sand, shell and shell hash found at the *Keshena* (Table 3, Figure 17).

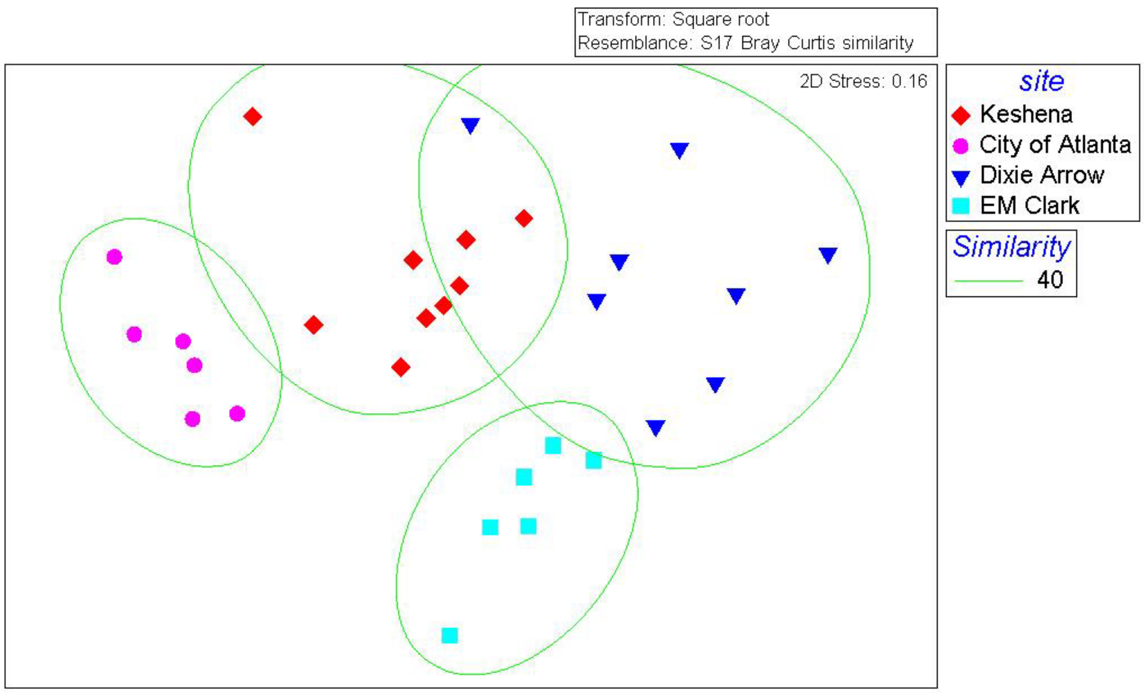


Figure 16. Multi-dimensional plot of benthic habitat percent cover data for each site with the 40% similarity contour overlaid to illustrate site differences.

Table 3. Average dissimilarities between sites and percent contributions to the average dissimilarities of individual benthic habitat components are reported. Results of SIMPER, listed are species composing top 70% dissimilarity.

Component	Percent	Component	Percent
Keshena vs. City of Atlanta		***City of Atlanta vs. EM Clark***	
Avg. DISSIMILARITY=66.75		Avg. DISSIMILARITY=79.49	
Crustose coralline	13.45	*Telesto sp.*	19.82
Anemone	13.21	*Barnacle*	13.13
Sediment – sand	12.54	*Anemone*	12.21
Telesto sp.	11.13	*Wreck*	10.68
Shell/shellhash	9.92	*Crustose coralline*	8.97
Oculina sp.	6.98	*Film*	7.26
Film	6.56		
Keshena vs. Dixie Arrow		***Dixie Arrow vs. EM Clark***	
Avg. DISSIMILARITY=69.04		Avg. DISSIMILARITY=68.99	
Telesto sp.	9.64	*Barnacle*	11.65
Sediment - sand	9.34	*Wreck*	10.58
Shell/shellhash	8.33	*Film*	10.45
Filamentous Red Algae	7.29	*Crustose coralline*	8.30
Sargassum filipendula	6.83	*Filamentous red algae*	7.75
Film	6.70	*Sargassum filipendula*	7.27
Crustose coralline	6.32	*Arbacia punctulata*	5.76
Bryozoans	5.70	*Bryozoans*	5.22
Euhermania gigantea	4.83	*Euhermania gigantea*	5.12
Hydroid	3.94		
Wreck	3.17		
City of Atlanta vs. Dixie Arrow		***Keshena vs. EM Clark***	
Avg. DISSIMILARITY=82.48		Avg. DISSIMILARITY=62.59	
Telesto sp.	16.30	*Barnacle*	13.98
Crustose coralline	14.68	*Sediment – sand*	12.69
Anemone .	9.35	*Telesto sp.*	12.43
Filamentous red algae	6.83	*Shell/shellhash*	10.03
Sargassum filipendula	6.41	*Wreck*	8.81
Film	5.56	*Crustose coralline*	7.19
Bryozoans	5.55	*Film*	7.05
Oculina sp.	5.17		
Euhermania gigantea	4.50		

Macroalgae Community

Macroalgae was the second most abundant biotic community, with an average cover of 23% per site. Predominant genera for all sites combined were crustose coralline/*Peyssonnelia* sp. (14% ± 6.3), *Sargassum* sp. (3% ± 3.2), filamentous red (2% ± 2.4), and fuzzy green algae (1.5% ± 1.5). *Sargassum* sp., a filamentous red, and a fuzzy green algae were found exclusively at the *Dixie Arrow*, which explained the higher standard error. Red algae (rhodophyta) was the most abundant (17% ± 8.9 per site) of the three macroalgal divisions (rhodophyta, phaeophyta, chlorophyta), and was largely found at the *Dixie Arrow* (Figure 17A). Macroalgae were not found at the *City of Atlanta*, differing greatly from the *Dixie Arrow*, where macroalgae comprised the dominant cover type (62%, Table 4). Greatest algal diversity was found at *Dixie Arrow* (nine species + morphological groups).

Invertebrate Community

Cnidarians were the most abundant biotic community type for all sites combined (26% ± 15.1). Type and cover of cnidarians differed among sites (Figure 17), with greatest cover at the *City of Atlanta* (Table 4). Predominant taxa/components at the *City of Atlanta* included *Telesto* sp. (44%), anemones (19%), and *Oculina* sp. (5%), and these species were among the most abundant species for all sites combined (15% ± 10.3, 5% ± 4.6, 1.5% ± 1.3 respectively) in addition to hydroids (1.7% ± 0.7). Coral cover consisted exclusively of *Oculina* sp. and was found at the *City of Atlanta* and the *Dixie Arrow*. Although absent from analyzed photos, cup coral (possibly *Phyllangia americana* or *Paracyathus pulchellus*) was also found in low densities in other descriptive photographs.

At the *EM Clark*, the large cover (19%) of crustaceans recorded consisted solely of barnacles. They were also found at the *Dixie Arrow* and the *Keshena* but in much lower cover (0.9%, 0.5% respectively). Additional noteworthy invertebrates found were the ascidian (tunicate), *Euhermania gigantea* (8% at *Dixie Arrow*) and echinoderm, *Arbacia punctulata* (purple-spined sea urchin) at the *Dixie Arrow* (3.4%) and the *EM Clark* (7.7%). No other echinoderms were recorded. *A. punctulata* is commonly found on live rock reefs off North Carolina. Barnacles and *E. gigantean* are less common on North Carolina temperate hardbottom reefs (Whitfield et al. unpub. data). Occasionally, a fish was photographed within the quadrat area. When a random point landed on a fish it was scored as a 'vertebrate' but species was not identified. Vertebrates (all fish) were recorded as a small percentage at the *Keshena* (1.2%) and the *EM Clark* (0.3%).

Abiotic Composition

The abiotic components or exposed substrate, was the most common cover type overall (35% ± 11.3 of total cover). Predominant abiotic cover types included exposed wreck (4% ± 3.3), inorganic-organic film (23% ± 6.1), sediment (4% ± 3.9), and shell / shell hash (3% ± 3.3). Inorganic-organic film is defined as a composite of benthic microalgae and inorganic silts, but microscopic observation would be required for absolute confirmation. Sediment was documented only at *Dixie Arrow* (1.4%) and *Keshena* (16%), shell/shell hash was found exclusively at *Keshena* (13%). The higher cover of sand and shell are not unexpected, as *Keshena* was more fragmented, in smaller parts, and had more sand encroachment than the other sites surveyed.

Table 4. Mean percent cover of major benthic habitat groupings from all sites surveyed.
*** Listed are classifiable points, all unclassified points were removed prior to cover calculations. Taxa within each group are listed in Appendix B.**

	City of Atlanta	*Dixie Arrow*	*EM Clark*	*Keshena*	Mean
Algae	0.00	62.07	10.45	18.52	22.76
Cnidarian	70.04	5.46	7.32	20.74	25.89
Porifera	7.22	0.57	0.00	2.22	2.50
Ascidian	0.00	10.06	0.00	0.25	2.58
Echinodermata	0.00	3.45	7.67	0.00	2.78
Crustacean	0.00	0.86	19.16	0.49	5.13
Mollusca	0.00	0.00	0.00	0.74	0.19
Other Invertebrates	1.44	6.61	1.39	0.25	2.42
Vertebrates	0.00	0.00	0.35	1.23	0.40
Exposed Substrate	21.30	10.92	53.66	55.31	35.30
Marine Debris	0.00	0.00	0.00	0.25	0.06
N frames (points*)	6 (277)	8 (348)	6 (287)	9 (405)	7.25 (329.25)

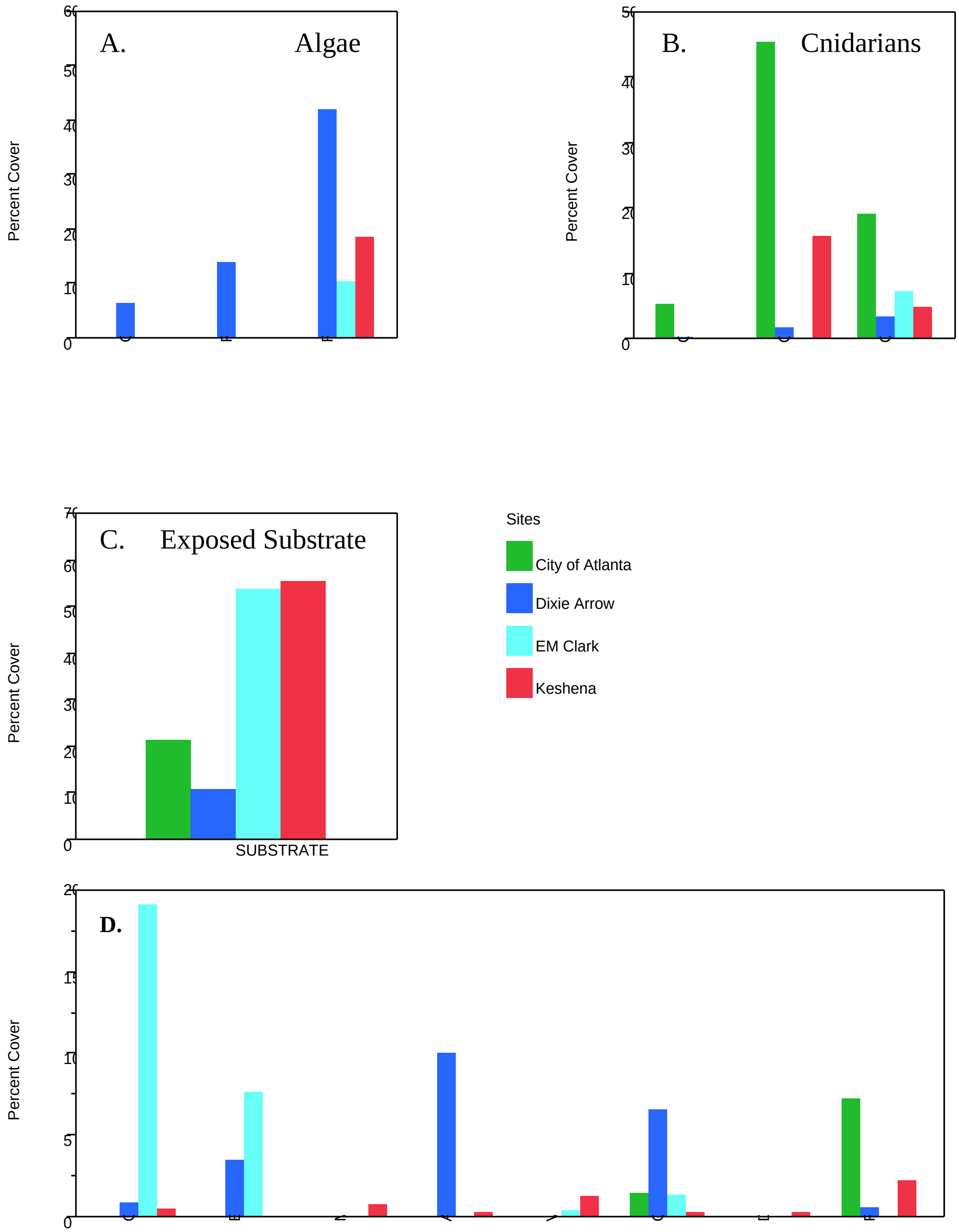


Figure 17. Percent cover by major benthic habitat category at all sites.

Discussion/Future Recommendations

Strong differences in both the fish and benthic habitat components were observed among most of the shipwrecks surveyed. These differences generally appeared to correlate with the oceanographic zone (depth), especially for the fish community surveys (Figure 7). These findings concur with the results of five years of fish surveys on temperate hardbottom reefs in North Carolina that found statistical differences among the fish communities based on the inner shelf (0-20m), middle shelf (20-40m) and outer shelf (40-60m) designations (Whitfield et al. unpub. data). Previous studies that extended into deeper water also found distinct faunal assemblages on the shelf (27-64m) and shelf edge (64-183m) (Grimes et al. 1982). In a trawl study, Sedberry and Van Dolah (1984) found fish abundance highest in the middle shelf locations (25-38m).

In general, the middle shelf region has been described as a thermally stable, transitional zone containing the highest diversity of organisms across the continental shelf (Wenner et al. 1983, Sedberry and Van Dolah 1984, Schobernd and Sedberry 2009). In this study, fish community diversity was the highest at the middle shelf locations (*Keshena* and *Dixie Arrow*) and the least diverse at the *City of Atlanta* (also middle shelf, but north of the zoogeographic break at Cape Hatteras). The low diversity at the *City of Atlanta* is likely attributed to the colder water temperatures that exist for much of the year compared to the other sites surveyed during this mission. Due to its proximity north of Cape Hatteras, it is influenced not by the Gulf Stream but by temperate and cold water currents such as the Virginia current and the Labrador current. At the time of the surveys, water temperatures on the *City of Atlanta* were 53° F. Although the *EM Clark* (72m) is located closest to the Gulf Stream, the fish community showed less diversity than expected (eight species), with few tropical species. This may have been due to the influence of cold water upwelling that most often occurs in deepwater shelf locations and results in greater thermal instability compared to middle shelf locations (Atkinson et al. 1983, Yoder 1991, Aretxabaleta et al. 2007). Cold water upwelling occurs intermittently along the North Carolina coast during the warm summer months (April-November) and can be responsible for fish kills or movement of fishes from an affected area (Huntsman 1976, Atkinson et al. 1983). However, Gulf Stream upwelling is also one of the main vectors for the influx of nutrients upon the shelf (Atkinson et al. 1983). It is possible that the anomalous cold water conditions that were experienced during this study may have been a result of Gulf Stream upwelling and the reason for the low diversity at the *EM Clark*. In this study, a total of 34 fish species from 18 different families was censused (Appendix A). In comparison, in a five year study on natural hardbottom reefs off North Carolina, a total of 157 species from 45 families was observed (Whitfield et al. unpubl. data). However, it is important to note that the present study was limited in time and geographic extent, and was conducted during adverse temperature conditions.

The results of the benthic habitat photo-quadrat analysis indicated statistically significant differences among all sites surveyed, even those closest to each other, the *Keshena* and *Dixie Arrow*. Although these two shipwrecks share a similar oceanographic regime, the

Dixie Arrow was characterized by a higher percent cover of algae (filamentous red and *Sargassum filipendula*), while the *Keshena* had a higher percent cover of sand, shell/shell hash and octocorals (*Telesto* sp.). However, this variation is not likely attributable to differences in oceanographic regime due to their close proximity to each other on the middle shelf (~6 miles)(Figure 1.). Instead, it is more likely that these striking differences in the benthic habitat community are due in part to localized variables such as the shipwreck relief, size and/or orientation as the *Dixie Arrow* is much larger, more intact, with less sand encroachment than the *Keshena*. The results from the *City of Atlanta* revealed higher percent cover of anemones and octocorals than the other sites. It is likely the temperate waters found north of Cape Hatteras which tend to be colder, darker and nutrient rich are driving the water column food chain with an abundance of plankton and zooplankton which in turn can limit light at depth. As filter feeders, anemones and octocorals would be able to feed on these resources and outcompete other organisms, such as algae that need more light, for space on the shipwreck. In the case of the *EM Clark*, it was characterized with the highest percent cover of barnacles. However, at this point, it is unclear why barnacles composed such a high percent cover on this shipwreck. It may simply be due to the sampling location, the starboard hull of the wreck, where there is very little micro-habitat complexity. This side was largely devoid of sessile invertebrates, with the exception of barnacles, while large areas of zooanthids, anemones and soft corals were observed intermittently on the superstructure (Figure 15). Perhaps the top of the shipwreck experiences more current shear and barnacles favor these areas.

In general, community composition also varies with age (Forteath et al. 1982); the shipwrecks surveyed in this study were all sunk in 1942 and had metal hulls. Spatial heterogeneity of the epibenthic community is well documented, where shipwreck orientation, surface composition, and hydrodynamic regime are considered the major factors capable of influencing community structure (Baynes and Szmant 1989, Lindquist and Pietrafesa 1989, Glasby 2000, Glasby and Connell 2001, Knott et al. 2004, Walker et al. 2007). Heterogeneity of the benthic habitat within the individual shipwrecks themselves was also observed, not only on the *EM Clark* but also on the *Keshena* where sand is encroaching the bottom of the shipwreck. To reduce the inherent variability in the benthic habitat within a site, it is imperative to use a sampling design that takes into account the within-site heterogeneity. For example, for a shipwreck like the *EM Clark,* consistently sampling different parts of the wreck to capture the natural variability at the site would reduce the potential for year-to-year variability caused by inconsistent sampling on one location only. Likewise, consistency in sampling methodology is important for surveying the fish community as well. To capture the fish community, sampling several times throughout the year or at least during the same season each year could aid in getting a better understanding of the fish community at a site. However, many fish will move in response to variable water conditions (i.e. current, temperature etc.) therefore, it is best to sample more than one time a year to fully characterize a location.

Based on these considerations, to utilize these shipwrecks as sites for detecting community shifts due to climate change or other stressors (e.g., overfishing), it is imperative to expand the scope of sampling both temporally and numerically. It is recommended that a subset of sites both within an oceanographic zone and across the shelf be repeatedly sampled over time. We also recommend increasing the sample size within each site to reduce the sampling variability within and among sites for the benthic and fish communities. These alterations will accommodate the natural differences in oceanographic regime that are known to exist across the shelf. Similarly, increased sample size on each wreck will reduce the within-site heterogeneity observed in the benthic community and provide the replication necessary for statistical analyses. Finally, incorporating bottom water temperature data (as sensors are retrieved) and other variables such as salinity, shipwreck area, and relief into future analyses will aid in relating fish and benthic community structure with local environmental variables.

In addition to their cultural significance, shipwrecks function as important habitat for a wide variety of fishes, invertebrates and algal species. In addition, due to their unique location off North Carolina at a natural zoogeographic transition zone, shipwrecks can also be important to understanding how our oceans and the communities within them are changing. The research presented in this study represents the first step in understanding how to implement a statistically valid sampling program that can utilize submerged cultural resources as sites for understanding community change.

Appendix

Appendix A. Comprehensive fish species list.

Families and species of all fishes found during the MNMS Battle of the Atlantic (BOTA) sampling from June 8-30, 2010. * indicates the type of survey in which the species was observed; c-conspicuous transect, p-prey transect, q-stationary quadrat, o-off- transect only. Whether the fish was observed (Y) or not (N) on NC temperate reefs during 2005-2010 sampling period in water depths from 75-150fsw, is also listed.

Family	Common Names	Genus	species	Sampling type*
Balistidae				
	gray triggerfish	*Balistes*	*capriscus*	c, y
Batrachoididae				
	oyster toad	*Opsanus*	*tau*	c, q, y
Blenniidae				
	crested blenny	*Hypleurochilus*	*geminatus*	c, n
	seaweed blenny	*Parablennius*	*marmoreus*	c, p, q, y
Carangidae				
	almaco jack	*Hypleurochilus*	*geminatus*	c, y
	greater amberjack	*Seriola*	*dumerili*	c, y
	scad	*Decapterus*	species	c, y
Coryphaenidae				
	dophinfish	*Coryphaena*	*hippurus*	o, n
Ephippidae				
	atlantic spadefish	*Chaetodipterus*	*faber*	c, q, y
Gymnuridae				
	smooth butterfly ray	*Gymnura*	*micrura*	o, n
Haemulidae				
	tomtate	*Haemulon*	*aurolineatum*	c, p, y
Labridae				
	painted wrasse	*Halichoeres*	*caudalis*	c, y
	slippery dick	*Halichoeres*	*bivittatus*	c, p, y
	tautog	*Tautoga*	*onitis*	c, y

Lutjanidae				
	vermilion snapper	*Rhomboplites*	*aurorubens*	c, y
Odontaspididae				
	sand tiger	*Odontaspis*	*taurus*	c, n
Pomacanthidae				
	queen angelfish	*Holacanthus*	*ciliaris*	c, y
Pomacentridae				
	brown chromis	*Chromis*	*multilineatus*	c, y
Sciaenidae				
	cubbyu	*Pareques*	*umbrosus*	c, p, y
Serranidae				
	bank sea bass	*Centropristis*	*ocyurus*	c, p, y
	black sea bass	*Centropristis*	*striata*	c, p, q, y
	belted sandfish	*Serranus*	*subligarius*	c, p, y
	gag	*Mycteroperca*	*microlepis*	c, y
	yellowmouth grouper	*Mycteroperca*	*interstitialis*	c, y
	mycteroperca species	*Mycteroperca*	species	c, y
	red barbier	*Hemanthias*	*vivanus*	c, p, y
	whitespotted soapfish	*Rypticus*	*maculatus*	c, q, y
Sparidae				
	longspine porgy	*Stenotomus*	*caprinus*	c, p, y
	porgy	*Calamus*	species	c, y
	pinfish	*Lagodon*	*rhomboides*	c, y
	sheepshead	*Archosargus*	*probatocephalus*	c, y
	spottail pinfish	*Diplodus*	*holbrookii*	c, y
Sphyraenidae				
	southern sennet	*Sphyraena*	picudilla	c, n
Sphyrnidae				
	hammerhead shark	*Sphyrna*	species	o, n

Appendix B. Comprehensive benthic habitat group and species list.
Benthic species and groups listed by major category found at four wrecks (*City of Atlanta, Dixie Arrow, EM Clark* and *Keshena*). * indicates species that were observed on North Carolina temperate reefs during 2007-2010 sampling period in water depths from 23-50m.

Major category	Common names or taxonomic group	Species or description of species group	Also on NC reefs*
Algae	Chlorophyta		
		Codium species	Y
		Fuzzy Green / Turf	Y
	Phaeophyta		
		Dictyota spp.	Y
		Sargassum filipendula	Y
		Turf / filamentous	Y
	Rhodophyta		
		Crustose coralline / *Peysonnelia* spp.	Y
		Rhodymenia pseudopalmata / Gracilaria mammalaris	Y
		Strap-like red	Y
		Filamentous red	Y
Cnidarian	Coral / Scleractinia		
		Oculina sp.	Y
	Octocoral		
		Leptogorgia virgulata	U
		Telesto sp.	N
		Sea Rod, unknown species	Y
	Other Cnidarians		
		Hydroid	Y
		Anemone	Y
		Zoanthids	Y
		Other / Unidentifiable	
Poriferans		*Cliona* spp.	N
		Encrusting sponge, unknown species	Y
Tunicates / Ascidians		*Euhermania gigantean*	N
		Tunicate, unknown spp.	Y
Echinoderms		*Arbacia punctulata*	Y
Crustaceans		Barnacle	U

Molluscs	Gastropod	Y
Other Invertebrates	Bryozoans	Y
	Worms	Y
	Unknown / Unidentifiable Invertebrate	Y
Vertebrates	Fish (unspecified species)	Y
Bottom Types	Exposed wreck	N
	Film (organic / inorganic deposit)	Y
	Sediment / sand	Y
	Shell or shellhash	Y
	Crack / crevice / hole	Y

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