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Fish Census of Selected Artificial Reefs in Broward County

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INTRODUCTION

Derelict ships have been used to aggregate fish assemblages since before their first recorded deployment off the coast of New Jersey in 1935 (Stone 1985). There are well over 400 such reefs in Florida, with 40+ in Broward County alone. Deployed mainly for fishers and divers, in Broward County most ships have been sunk in shallow coastal waters, at less than 150', since 1980. Despite the popularity of these reefs, there have been a surprisingly small number of studies on the fish assemblages associated with sunken ships and few of these have been rigorous. (Tsuda et al., 1975; Higo et al., 1978, 1979, 1983; Jones and Thompson, 1978; Chandler et al., 1985; Baynes and Szmant, 1989; Lindquist and Pietrafesa, 1989; Okamoto, 1989; Shinn and Wicklund, 1989; Stephan and Lindquist, 1989; Brock 1994; Markevich 1994; Eggin 1997). This study is one of few to statistically compare the fish assemblages on shipwrecks to adjacent natural reefs (Jones and Thompson, 1978; Markevich 1994).

The objectives for this study are to 1) acquire a multi-seasonal portrait of the fish assemblages associated with six ships used as artificial reefs in Broward County 2) compare the fish assemblages among the six ships 3) compare the fish assemblages between the ships and the adjacent natural reefs. The study is planned for two years; this report covers the first year.

MATERIALS and METHODS

Site

The inshore environment of Broward generally consists of three reef-tracts (inshore, middle, and offshore; locally labeled first, second and third reef) each separated by sand substrate, running parallel to the coast in sequentially deeper water. The six shipwrecks were deployed as artificial reefs at various times between the early 1970's and 1999 (Table 1). All vessels lie on the sandy substrate separating the middle and offshore reef tracts in approximately 20-25m of water (Figure 1).

Data Collection

During the 13-month period (March 2000 through March 2001) SCUBA divers used a non-destructive, visual census method, commonly called a point-count, (Bohnsack and Bannerot 1986) to determine species richness and abundance at the shipwrecks and the adjacent natural reef sites. Each ship was censused at least four times during the year, two ships per month (Table 2). The censuses of the adjacent natural reefs occurred at irregular intervals throughout the study period. In brief, the visual census consisted of counting the fishes in a 15m diameter cylinder, which extends from the substrate to the surface. Each diver was equipped with a 7.5m line and anchor weight, a slate with a waterproof data sheet and pencil, an underwater watch, and a one meter fish-stick as an aid in measuring fish lengths. The 7.5m line was used as a reference radius for the sample area. Safety divers would remain well outside of the 15m cylinder, within visual contact, while the trained fish counter completed the sample.

First the diver recorded all the species seen during a 5 min period. After the 5 min species count was completed, the number of fish per species and the minimum, maximum and mean total length was recorded. Total length estimates allow for post-census calculation of biomass using length-weight equations published by Bohnsack and Harper (1988). When a length-weight equation for an identified species was not available, the equation for a congeneric was used. Sample times outside of the five-minute initial count were kept to no more than 20 min. The 20 min time limit was sufficient to complete abundance and size data collection and allowed divers to complete repetitive dives without need for lengthy decompression.

The bow, stern, port and starboard sides were censused on 5 of the 6 ships to obtain a reliable estimate of the ship's fish assemblage. Due to its high complexity and extensive footprint, the sixth ship (Edmister) required two additional mid-ship sites to get an accurate estimate of its fish assemblage. A total of 114 point-counts were made on the ships over the 13-month period of this report.

A concurrent study, funded by the National Marine Fisheries Service (NMFS) and also using the point-count method, counted fishes on the natural reefs of Broward County. This NMFS study is inventorying the fishes on east-west transects every quarter nautical mile along the coastline of Broward County. On each transect a point count is made at the eastern and western edges of each reef-tract as well as the center or crest of each tract (for details on methodology see Ettinger et al., in press). Sixteen transects were made in the vicinity of the permitted artificial reef site containing the ships used in this study. Therefore, we have also included data from the reef-tract edges that border the ships. Specifically 15 point counts on the eastern edge of the second reef-tract and 16 counts from the western edge of the third reef-tract are included. Only edge data nearest the ships is included because of their close proximity and the fact that the edges have the most complex habitat and hold the most species and total fish of reef tract sites (Ettinger et al., in press). The assumption is that if fishes are moving between natural and artificial reef, or being aggregated from natural to artificial reef, they will most likely come from neighboring sites. Also, comparing neighboring reef areas of high topographical relief and large numbers of fishes, to ships, which also show these characteristics, is probably a more realistic comparison than one incorporating low relief hardbottom.

Statistical Analysis

Fish abundance, fish richness, and fish biomass were entered into the SAS® program and analyzed by several analysis of variance (ANOVA) techniques with PROC GLM procedures [ANOVA] and Student-Newman-Keuls (SNK) comparison of means (SAS Institute Inc., Cary, N.C., USA). A probability value of less than 0.05 in both ANOVA and SNK were accepted as a significant difference. The data was not normally distributed and were heteroscedastic with highly differing variances. The most appropriate analysis of such data is open to question. According to some statisticians, although the data does not meet basic assumptions of a parametric ANOVA the equal cell numbers and high sample numbers make rigorous analysis of the data by parametric tests possible (Zar

1999). Other statisticians counsel the use of non-parametric techniques in such a situation (Krauth, 1988). Therefore, to be assured of optimum statistical interpretation, the data were subjected to multiple analysis of variance techniques. Specifically a 2-way ANOVA; a ranked (non-parametric) ANOVA (PROC RANK in SAS ≅ Kruskal-Wallis test); and, due to extreme heteroscedasticity, the log transformation $Y = \log(X+1)$ was employed (Zar, 1999) for abundance data and the transformed data analyzed with a parametric ANOVA. The parametric and non-parametric tests yielded similar results. Therefore, parametric analysis of richness and parametric analysis of transformed abundance data is used in the rest of this paper.

RESULTS

Abundance

A total of 59467 fish were counted on ships and natural reef combined. Excluding the natural sites but with all ships combined there was no statistical difference ($p>0.05$, ANOVA) (Figure 2) amongst months. There was also no difference in fish abundance between individual ships ($p>0.05$, ANOVA)(Figure 3). However, there was a significantly greater abundance of fish on ships than either reef edge ($p<0.05$, ANOVA) but not between edges ($p>0.05$, ANOVA)(Figure 4).

Richness

A total of 191 species were counted on ships and natural reef combined, of these 59 were only found on natural reef and 20 only on ships (Table 3, 4). Excluding the natural sites but with all ships combined there was a difference amongst months with December having more species present than May ($p<0.05$, ANOVA; SNK)(Figure 5). There was also a difference in richness between individual ships with the "unnamed barge" having more species than the Tracy ($p<0.05$, ANOVA; SNK)(Figure 6). There were significantly more species on the ships than the edge of the third reef ($p<0.05$, ANOVA) but not the eastern edge of the second reef ($p>0.05$, ANOVA)(Figure 7).

Biomass

Excluding the natural sites but with all ships combined there was a difference amongst months with January having a higher biomass present than July ($p<0.05$, ANOVA; SNK)(Figure 8). There was no statistical difference in biomass between individual ships ($p>0.05$, ANOVA)(Figure 9). The ships had a higher amount of biomass than either reef edge ($p<0.05$, ANOVA); edges did not differ from each other ($p>0.05$, ANOVA)(Figure 10).

DISCUSSION

Abundance

The one thing that stands out concerning fish abundance is the greater number of fishes noted on the ships than on surrounding reef. Similar differences have been reported previously (for references see Bohnsack et al., 1991). In this study there was a mean of 146 ± 41 individuals on the eastern edge of the middle reef and 79 ± 9 on the western edge of the offshore reef and 491 ± 56 on the ships. The lower number on the natural reefs is apparently not a function of a lower sampling frequency missing a period of increased abundance. A previous study in Broward County, also using point counts, reported abundance means of 108 ± 49 and 75 ± 16 on the second reef eastern and third reef western edges respectively (Ettinger et al., in press). The reason for greater abundance on artificial reefs is not clear but may be due to either the ships providing greater vertical relief or void space than surrounding reef or access to increased food resources in soft sediment or plankton (Lindquist et al., 1994; Lindquist and Pietrafesa, 1989).

Richness

The increased numbers of fishes in December versus May is unexpected but not unique. Other studies in Broward County, on artificial as well as natural reefs, have repeatedly indicated a decline in species numbers during winter months. However, several of these same studies highlighted exceptions when winter months had higher species numbers (Spieler 1998 a, b, c, 2000; Ettinger et al., in press).

The difference in richness between individual ships, with the "unnamed barge" having more species than the Tracy, may to some extent be a measure of the deployment date. The "unnamed barge" was sunk in the late 1970's whereas the Tracy was deployed in 1999. Although the "unnamed barge" has less vertical relief than the Tracy, it carries a much richer fouling community. Thus, it appears that the "unnamed barge" would offer more diverse food and refuge resources than the Tracy.

The increased species numbers on the ships in comparison to the edge of the third reef is also not surprising as previous reports on other artificial reefs have reported increased, as well as decreased, species on artificial reefs in comparison to adjacent natural reef (Rilov and Benayahu, 2000).

It is noteworthy that of the total 191 species recorded in this study 59 were only found on natural reef and 20 exclusively only on ships. Some of the latter fish are soft sediment species that would be expected to be on the bottom area surrounding the ships while others are relatively rare and it is unclear if their presence represents a preference (Table 2, 3). However, some of the species found only on the ships have rarely or never been previously recorded in natural reef surveys in Broward County i.e. yellow goatfish *Mulloidichthys martinicus*, and blackfin snapper, *Lutjanus buccanella*. The blackfin snapper presence is particularly interesting, as this is a deep-water species of recreational and commercial value. Only juveniles, ranging in size from 10-26 cm total length, were recorded. Interestingly, another deep-water species, the snowy grouper, *Epinephelus niveatus*, has also only been recorded in shallow water from artificial reef surveys in Broward County and only as a juvenile. It has previously been hypothesized that Broward County reef tracts may be refuge limited (Spieler, 1998c). Further, the deep-reef environment (>70m) appears to be mainly low-relief with abundant fine-grained sediment (Ken Banks, personal communication). Thus, although other hypotheses can be forwarded, it appears the ships are supplying ancillary nursery/juvenile habitat for these animals that later migrate to deep water.

Biomass

Biomass has also repeatedly been reported to be higher on artificial than natural reefs (for references see Bohnsack et al., 1991). In this study, the differences in biomass parallel the differences noted in abundance. This indicates the increased fish abundance noted on the ships is not due simply to large numbers of juveniles as juvenile fishes normally weigh dramatically less than adults.

Conclusion

This report analyzes the data of a planned two-year study. The second year's data should clarify whether or not the seasonal and site associated distributions of specific species noted here represent true distributional patterns or simply chance occurrences. Nonetheless, it is clear from this study that the fish assemblages on derelict ships and neighboring reef differ in species composition as well as numbers of fish and biomass per unit volume.

The fact that some species appear to be restricted to, or at least predominate at, the sunken vessels implies that these structures offer some unique resource(s) either not available or limited on neighboring reef. It would be premature to conclude that increasing both diversity and biomass of fishes in Broward County by deploying derelict vessels is desirable. However, certainly the data in this report indicate a more detailed examination of deploying ships as artificial reefs is warranted.

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Table 1. Artificial reefs (derelict vessels), date of deployment, water depth of deployment site substrate, and site coordinates.

Tracy	133' supply boat	1999	64'	N 26 09.578' W 80 04.754'
Merci Jesus	90' freighter	1998	64'	N 26 09.635'W 80 04.747'
Jay Scutti	97' tug	1986	64'	N 26 09.520'W 80 04.760'
Peter B. McAllister	85' tug	1998	69'	N 26 10.149'W 80 04.718'
Robert Edmister	95' USCG cutter	1989	70'	N 26 09.193'W 80 04.837'
"Unnamed Barge"	80' barge	1970's	70'	N 26 08.520'W 80 04.886'

Table 2. Sampling schedule

	Unnamed	Edmister	Scutti	Tracy	Merci Jesus	Mcallister
Mar '00	X	X				
Apr '00			X	X		
May '00					X	X
June '00	X	X				
July '00			X	X		
Aug '00					X	X
Sep '00	X	X				
Oct '00			X	X		
Nov '00					X	X
Dec '00	X	X				
Jan '01			X	X		
Feb '01					X	X
Mar '01	X	X				

Table 3. Species exclusive to ships, number of times observed / total abundance

	Edmister	McAllister	Merci Jesus	Scutti	Tracy	Unnamed
Aluterus schoepfi	-	-	-		-	1/3
Amblycirrhitus pinos	-	-	-	1/1	1/1	-
Apogon affinis	-	-	-	1/6	-	1/25
Apogon townsendi	-	-	-	1/1	-	-
Clupeus sp.	-	1/500	-	-	-	-
Decapterus punctatus	-	4/2517	-	2/180	-	-
Elagatis bipinnulata	-	-	-	-	1/1	-
Emmelichthyops atlanticus	-	1/500	-	1/25	-	-
Epinephelus adscensionis	-	-	1/1	-	-	-
Epinephelus fulvus	-	-	2/2	-	-	-
Epinephelus niveatus	-	-	-	-	2/2	-
Euthynnus alletteratus	-	-	1/6	-	-	-
Haemulon album	2/2	1/2	1/6	-	1/4	-
Lutjanus buccanella	5/12	8/32	2/2	1/1	11/94	10/360
Mulloidichthys martinicus	15/127	8/95	11/81	10/72	4/41	-
Ogcocephalus nasutus	-	-	1/1	-	-	-
Ogcocephalus radiatus	-	2/2	-	-	-	-
Rachycentron canadum	-	1/1	-	-	-	2/2
Rhomboplites aurorubens	-	-	-	1/2	-	-
Seriola dumerili	5/35	6/20	-	-	-	1/1
Total Ship Exclusive Species	4	9	7	8	6	5

Table 4. List of fishes and site where recorded. Inshore, middle, and offshore refer to reef tract.

Common Name	Scientific Name	Inshore	Middle	Offshore	Ships
ANGELFISHES	**POMACANTHIDAE**				
Queen Angelfish	*Holocanthus cilaris*	X	X	X	X
Blue Angelfish	*Holocanthus bermudensis*	X	X	X	X
Rock Beauty	*Holcanthus tricolor*		X	X	X
French Angelfish	*Pomacanthus paru*	X	X	X	X
Cherubfish	*Centropyge argi*			X	
Gray Angelfish	*Pomacanthus arcuatus*	X	X	X	X
BARRACUDAS	**SPHYRAENIDAE**				
Great Barracuda	*Sphyraena barracuda*	X	X	X	X
BATFISH	**OGCOCEPHALIDAE**				
Polka-Dot Batfish	Ogcocephalus radiatus				X
Shortnose Batfish	*Ogcocephalus nasutus*				X
BIGEYES	**PRICANTHIDAE**				
Glasseye Snapper	*Priacanthus cruentatus*		X	X	
BONNETMOUTHS	**INERMIIDAE**				
Bonnetmouth	*Emmelichthyops atlanticus*				X
Boga	*Inermia vittata*			X	X
BOXFISHES	**OSTRACIIDAE**				
Scrawled cowfish	*Lactophrys quadricornis*	X	X	X	X
Honeycomb cowfish	*Lactophrys polygonia*			X	X
Smooth trunkfish	*Lactrophrys triqueter*	X	X	X	X
BUTTERFLYFISHES	**CHAETODONTIDAE**				
Spotfin Butterflyfish	*Chaetodon ocellatus*	X	X	X	X
Banded Butterflyfish	*Chaetodon striatus*		X		
Foureye Butterflyfish	*Chaetodon capistratus*	X	X	X	X
Longsnout Butterflyfish	*Chaetodon aculeatus*			X	
Reef Butterflyfish	*Chaetodon sedentarius*	X	X	X	X
CARDINALFISHES	**APOGONIDAE**				
Twospot Cardinalfish	*Apogon pseudomaculatus*	X			X
Belted Cardinalfish	*Apogon townsendi*				X
Barred Cardinal Fish	*Apogon binotatus*			X	X
Bigtooth Cardinalfish	*Apogon affinis*				X
Flamefish	*Apogon maculatus*	X	X		X
CLINIDS	**CLINIDAE**				
Rosy Blenny	*Malacoctenus macropus*	X	X		X
Saddled Blenny	*Malacoctenus triangulatus*	X	X		X
Downy Blenny	*Labrisomus kalisherae*	X			
Sailfin Blenny	*Emblemaria pandionis*	X	X	X	X

Roughhead Blenny	*Acanthemblemaria aspera*		X		
COBIA	**RACHYCENTRIDAE**				
Cobia	*Rachycentron canadum*				X
COMBTOOTH BLENNIES	**BLENNIDAE**				
Barred Blenny	*Hypleurochilus bermudensis*		X		X
Seaweed Blenny	*Parablennius marmoreus*	X	X		X
CONGER EELS	**CONGRIDAE**				
Garden Eel	*Heteroconger halis*			X	X
CORNETFISHES	***FISTULARIIDAE***				
Bluespotted Cornetfish	*Fistularia tabacaria*	X			
DAMSELFISHES	**POMACENTRIDAE**				
Beaugregory	*Stegastes leucostictus*	X	X	X	X
Longfin Damselfish	*Stegastes diencaeus*	X	X		X
Dusky Damselfish	*Stegastes fuscus*	X	X		X
Threespot Damselfish	*Stegastes planifrons*	X	X		X
Bicolor Damselfish	*Stegastes partitus*	X	X	X	X
Cocoa Damslefish	*Stegastes variabilis*	X	X	X	X
Yellowtail Damselfish	*Microspathadon chrysurus*	X	X		
Sunshinefish	*Chromis insolatus*		X	X	X
Yellowtail Reeffish	*Chromis enchrysurus*		X	X	X
Brown Chromis	*Chromis multilineatus*	X		X	X
Purple Reeffish	*Chromis scotti*		X	X	X
Sergeant Major	*Abudefduf saxatilis*	X	X	X	X
Blue Chromis	*Chromis cyanis*		X	X	X
DRUMS	**SCIAENIDAE**				
Spotted Drum	*Equetus punctatus*			X	
Jacknife Fish	*Equetus lanceolatus*		X	X	
Highhat	*Equetus acuminatus*	X	X	X	
FLYINGFISH	**EXOCOETIDAE**				
Ballyhoo	*Hemiramphus brasiliensis*		X		
GOATFISHES	**MULLIDAE**				
Yellow Goatfish	*Mulloidichthys martinicus*				X
Spotted Goatfish	*Pseudupeneus maculatus*	X	X	X	X
GOBIES	**GOBIIDAE**				
Seminole Goby	*Microgobius carri*	X			
Colon Goby	*Coryphopterus dicrus*	X			
Dash Goby	*Gobiosoma saepepallens*		X	X	X
Neon Goby	*Gobiosoma oceanops*	X	X	X	X
Tiger Goby	*Gobiosoma macrodon*	X			
Bridled Goby	*Coryphopterus glaucofraenum*	X	X	X	X
Blue Goby	*Ioglossus calliurus*	X	X	X	X
Hovering Goby	*Ioglossus helenae*			X	
Masked/Glass Goby	*Coryphopterus hyalinus/personatus*	X	X	X	X

Goldspot Goby	*Gnatholepis thompsoni*	X	X	X	X
GRUNTS	**HAEMULIDAE**				
Porkfish	*Anisotremus virginicus*	X	X	X	X
Juvenile Grunts	*Haemulon sp.*	X	X		X
Spanish Grunt	*Haemulon macrostomum*	X			
Caesar Grunt	*Haemulon carbonarium*	X			X
Striped Grunt	*Haemulon striatum*		X	X	X
Smallmouth Grunt	*Haemulon chrysargyreum*	X			X
Cottonwick	*Haemulon melanurum*			X	X
White Grunt	*Haemulon plumieri*	X	X	X	X
Margate	*Haemulon album*				X
Black Margate	*Anisotremus surinamensis*	X		X	X
Tomtates	*Haemulon aurolineatum*	X	X	X	X
French Grunt	*Haemulon flavolineatum*	X	X	X	X
Bluestripe Grunt	*Haemulon sciurus*	X	X	X	X
Sailors Choice	*Haemulon parrai*	X			X
GUITARFISH	**RHINOBATIDAE**				
Atlantic Guitarfish	*Rhinobatos lentiginosus*		X	X	
HAWKFISHES	**CIRRHITIDAE**				
Redspotted Hawkfish	*Amblycirrhitus pinos*				X
HERRINGS	**CLUPEIDAE**				
Unidentified Clupeid	*Clupeus sp.*				X
JACKS	**CARANGIDAE**				
Almaco Jack	*Seriola rivoliana*		X		X
Greater Amberjack	*Seriola dumerili*				X
Bigeye Scad	*Selar crumenophthalmus*	X	X		
Round Scad	*Decapterus punctatus*				X
Mackerel Scad	*Decapterus macarellus*		X	X	X
Rainbow Runner	*Elagatis bipinnulata*				X
Yellow Jack	*Caranx bartholomaei*	X	X	X	X
Leatherjacket	*Oligoplites saurus*		X		
Blue Runner	*Caranx crysos*	X	X		X
Bar Jack	*Caranx ruber*	X	X	X	X
JAWFISH	**OPISTOGNATHIDAE**				
Yellowhead Jawfish	*Opistognathus aurifrons*		X	X	X
Banded Jawfish	*Opistognathus macrognathus*	X			
Dusky Jawfish	*Opistognathus whitehursti*	X	X		
LEATHERJACKETS	**BALISTIDAE**				
Scrawled Filefish	*Aluterus scriptus*		X	X	X
Orange Filefish	*Aluterus schoepfi*				X
Slender Filefish	*Monacanthus tuckeri*		X	X	X
Orangespotted Filefish	*Cantherhines pullus*	X	X	X	X
Planehead Filefish	*Monocanthus hispidus*		X	X	X
Queen Trigger	*Balistes vetula*			X	
Ocean Trigger	*Canthidermis sufflamen*			X	
Gray Trigger	*Balistes capriscus*	X	X	X	X

LIZARDFISHES	**SYNODONTIDAE**				
Sand Diver	*Synodus intermedius*			X	X
MACKERELS	**SCOMBRIDAE**				
Little Tunny	*Euthynnus alletteratus*				X
Cero	*Scomberomorous regalis*	X	X	X	X
MOJARRAS	**GERREIDAE**				
Yellowfin Mojarra	*Gerres cinereus*	X			
MORAY EELS	**MURAENIDAE**				
Spotted Moray	*Gymnothorax moringa*		X	X	X
Goldentail Moray	*Gymnothorax miliaris*			X	
Green Moray	*Gymnothorax funebris*			X	X
Purplemouth Moray	*Gymnothorax vicinus*	X	X		
NURSE SHARKS	**ORECTOLOBIDAE**				
Nurse Shark	*Ginglymostoma cirratum*	X		X	X
PARROTFISHES	**SCARIDAE**				
Parrotfish	*Scaridae spp.*		X	X	X
Striped Parrot	*Scarus croicensis*	X	X	X	X
Queen Parrot	*Scarus vetula*	X	X		X
Princess Parrot	*Scarus taeniopterus*	X	X	X	X
Midnight Parrot	*Scarus coelestinus*	X			X
Blue Parrot	*Scarus coeruleus*		X		
Bucktooth Parrot	*Sparisoma radians*	X	X	X	
Rainbow Parrot	*Scarus guacamaia*	X	X	X	
Redtail Parrot	*Sparisoma chrysopterum*	X	X	X	X
Redfin Parrot	*Sparisoma rubripinne*	X	X	X	X
Redband Parrot	*Sparisoma aurofrenatum*	X	X	X	X
Stoplight Parrot	*Sparisoma virride*	X	X	X	X
Greenblotch Parrot	*Sparisoma atomarium*	X	X	X	X
Bluelip Parrot	*Cryptotomus roseus*	X	X	X	
PORGIES	**SPARIDAE**				
Jolthead Porgy	*Calamus bajonado*			X	
Spottail Pinfish	*Diplodus holbrooki*	X	X		X
Sheepshead Porgy	*Calamus penna*	X	X		
Silver Porgy	*Diplodus argenteus*		X		
Knobbed Porgy	*Calamus nodosus*			X	
Littlehead Porgy	*Calamus proridens*		X	X	X
Saucereye Porgy	*Calamus calamus*	X	X	X	X
PUFFERS	**TETRAODONTIDAE**				
Sharpnose Puffer	*Canthigaster rostrata*	X	X	X	X
Bandtail Puffer	*Sphoeroides spengleri*		X	X	
REMORAS	**ECHENEIDIDAE**				
Sharksucker	*Echeneis naucrates*			X	
SEA BASSES	**SERRANIDAE**				
Scamp	*Mycteroperca phenax*	X	X		X
Snowy Grouper	*Epinephelus niveatus*				X
Yellowfin Grouper	*Mycteroperca venenosa*	X			

Coney	*Epinephelus fulvus*				X
Rock Hind	*Epinephelus adscensionis*				X
Red Grouper	*Epinephelus morio*	X	X	X	
Graysby	*Epinephelus cruentatus*	X	X	X	X
Sand Perch	*Diplectum formosum*	X	X	X	X
Hamlet Juvenile	*Hypoplectrus sp.*	X		X	X
Barred Hamlet	*Hypoplectrus puella*	X	X	X	X
Black Hamlet	*Hypoplectrus nigricans*			X	
Blue Hamlet	*Hypoplectrus gemma*	X	X	X	X
Shy Hamlet	*Hypoplectrus guttavarius*		X	X	
Butter Hamlet	*Hypoplectrus unicolor*	X	X	X	X
Orangeback Bass	*Serranus annularis*		X	X	
Lantern Bass	*Serranus baldwini*	X	X	X	X
Tobaccofish	*Serranus tabacarius*		X	X	X
Harlequin Bass	*Serranus tigrinus*	X	X	X	X
Chalk Bass	*Serranus tortugarum*		X	X	X
Tattler Bass	*Serranus phoebe*			X	
SEA CHUBS	**KYPHOSIDAE**				
Bermuda Chub	*Kyphosus sectatrix*	X	X		
SCORPIONFISH	**SCORPAENIDAE**				
Spotted Scorpionfish	*Scorpaena plumieri*	X	X	X	
SNAKE EELS	**OPHICHTHIDAE**				
Sharptail Eel	*Myrichthys breviceps*	X			
SNAPPERS	**LUTJANIDAE**				
Blackfin Snapper	*Lutjanus buccanella*				X
Gray Snapper	*Lutjanus griseus*	X	X	X	X
Dog Snapper	*Lutjanus jocu*		X		
Lane Snapper	*Lutjanus synagris*	X			X
Vermilion Snapper	*Rhomboplites aurorubens*				X
Mutton Snapper	*Lutjanus analis*	X	X	X	X
Yellowtail Snapper	*Ocyurus chrysurus*	X	X	X	X
Schoolmaster	*Lutjanus apodus*	X			
SPADEFISHES	**EPHIPPIDAE**				
Spadefish	*Chaetodipterus faber*	X	X	X	
SPINY PUFFERS	**DIODONTIDAE**				
PorcupineFish	*Diodon hystrix*	X			X
Striped Burrfish	*Chilomycterus schoepfi*			X	
Balloonfish	*Diodon holocanthus*	X	X	X	
SQUIRRELFISH	**HOLOCENTRIDAE**				
Blackbar Soldierfish	*Myripristis jacobus*	X		X	
Squirrelfish	*Holocentrus adscensionis*	X	X	X	X
STINGRAY	**DASYATIDAE**				
Yellow Stingray	*Urolophus jamaicensis*	X	X	X	
Southern stingray	*Dasyatis americana*			X	X
SURGEONFISHES	**ACANTHURIDAE**				
Ocean Surgeon	*Acanthurus bahianus*	X	X	X	X

Doctorfish	*Acanthurus chirurgus*	X	X	X	X
Blue tang	*Acanthurus coeruleus*	X	X	X	X
SWEEPERS	**PEMPHERIDAE**				
Glassy Sweeper	*Pempheris schomburgki*	X			
TARPON	**ELOPIDAE**				
Tarpon	*Megalops atlanticus*	X	X		
TILEFISHES	**MALACANTHIDAE**				
Sand Tilefish	*Malacanthus plumieri*		X	X	X
TRUMPETFISH	**AULOSTOMIDAE**				
Trumpetfish	*Aulostomus maculatus*		X	X	X
WRASSES	**LABRIDAE**				
Hogfish	*Lachnolaimus maximus*	X	X	X	X
Spotfin Hogfish	*Bodianus pulchellus*			X	X
Spanish Hogfish	*Bodianus rufus*	X	X	X	X
Creole Wrasse	*Clepticus parrai*	X	X	X	X
Clown Wrasse	*Halichores maculipinna*	X	X	X	X
Slippery Dick	*Halichores bivittatus*	X	X	X	X
Puddingwife	*Halichores radiatus*	X	X	X	
Yellowcheek Wrasse	*Halichoeres cyanocephalus*		X	X	
Rainbow Wrasse	*Halichoeres pictus*		X	X	
Blackear Wrasse	*Halichoeres poeyi*	X	X		
Green Razorfish	*Hemipteronotus splendens*	X	X		X
Yellowhead Wrasse	*Halichores garnoti*	X	X	X	X
Bluehead Wrasse	*Thalassoma bifasciatum*	X	X	X	X
	Species per site	117	129	124	133
	Reef Exclusive Species	12	7	13	20
	Species only on ships	20			
	Species Found on all 3 reefs	10			
	Species only on nat. reefs	59			
	Total Species	191			
	Total Abundance on Ships		56007		
	Total Abundance on Edges		3460		
	Mean Abundance per count on ships		491.2		
	Mean Abundance per count on reefs		111.6		
	Total Abundance on ME		2189		
	Total Abundance on OW		1271		
	Mean Abundance per count on ME		145.9		
	Mean Abundance per count on OW		79.4		
	# of counts on ships		114		
	# of counts on ME		15		
	# of counts on OW		16		

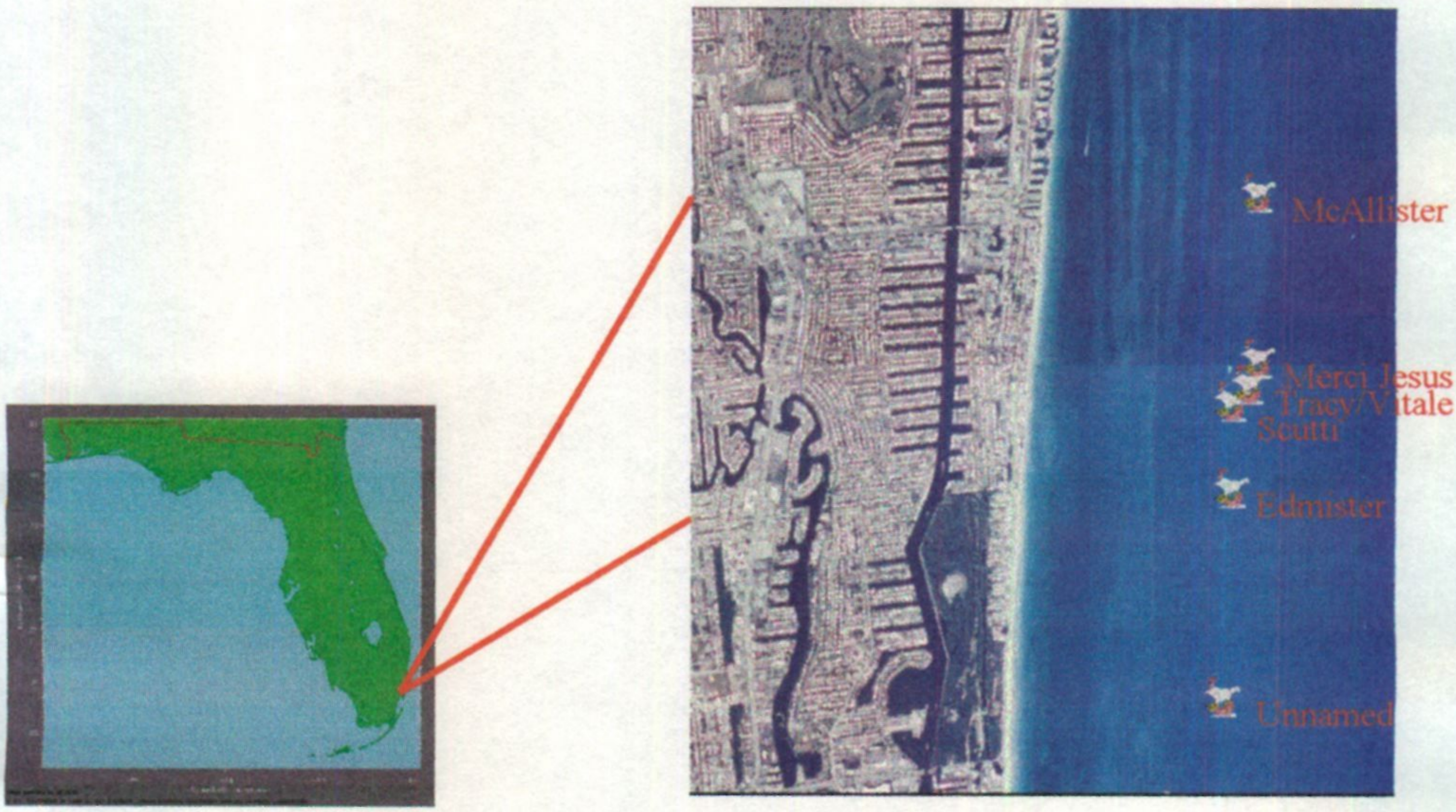


Figure 1. Geographical location of the six ships located in the sandy substrate between the middle and offshore reefs.

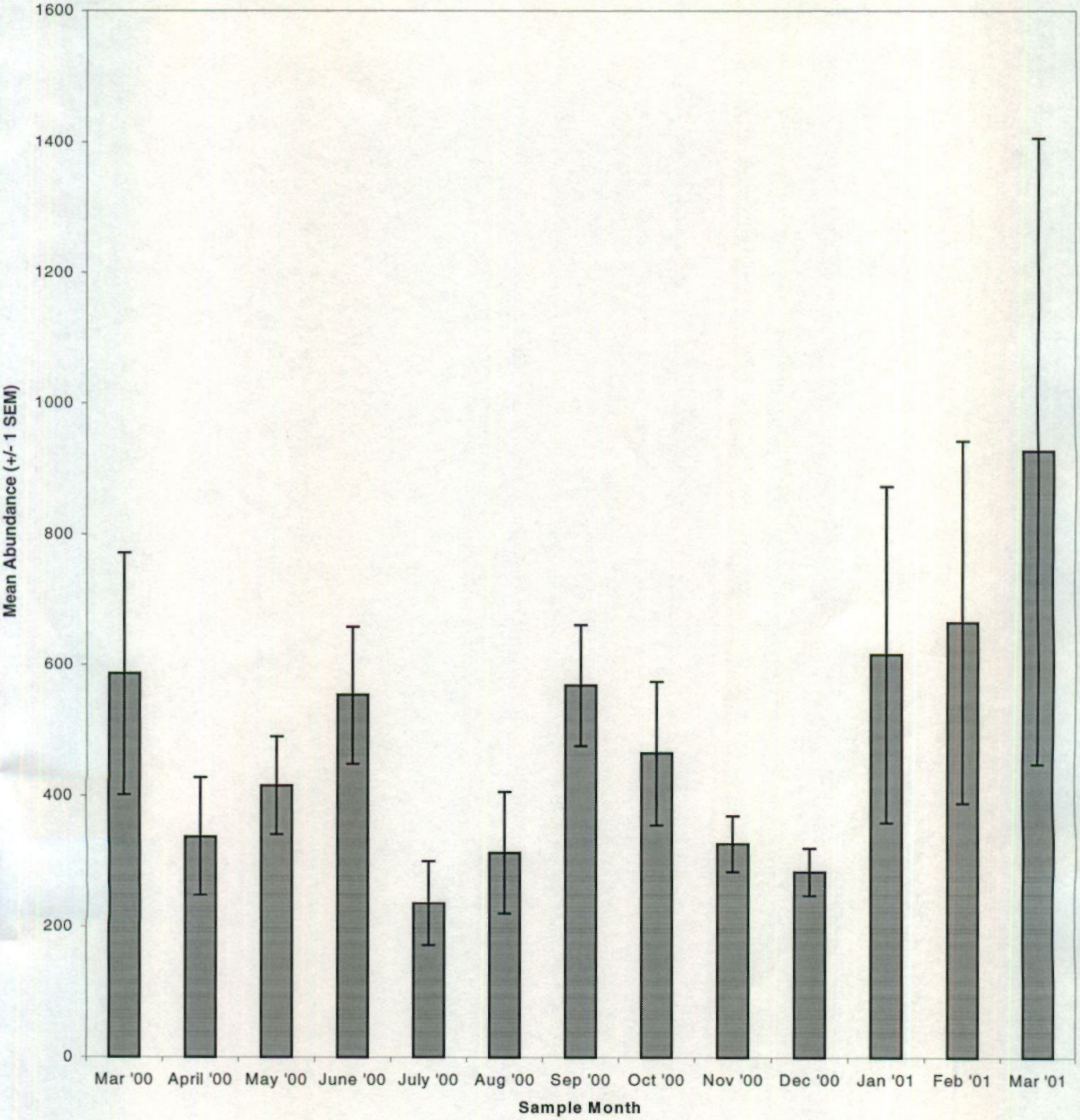


Figure 2. Mean fish abundance on ships. Vertical lines represent standard error of the mean.

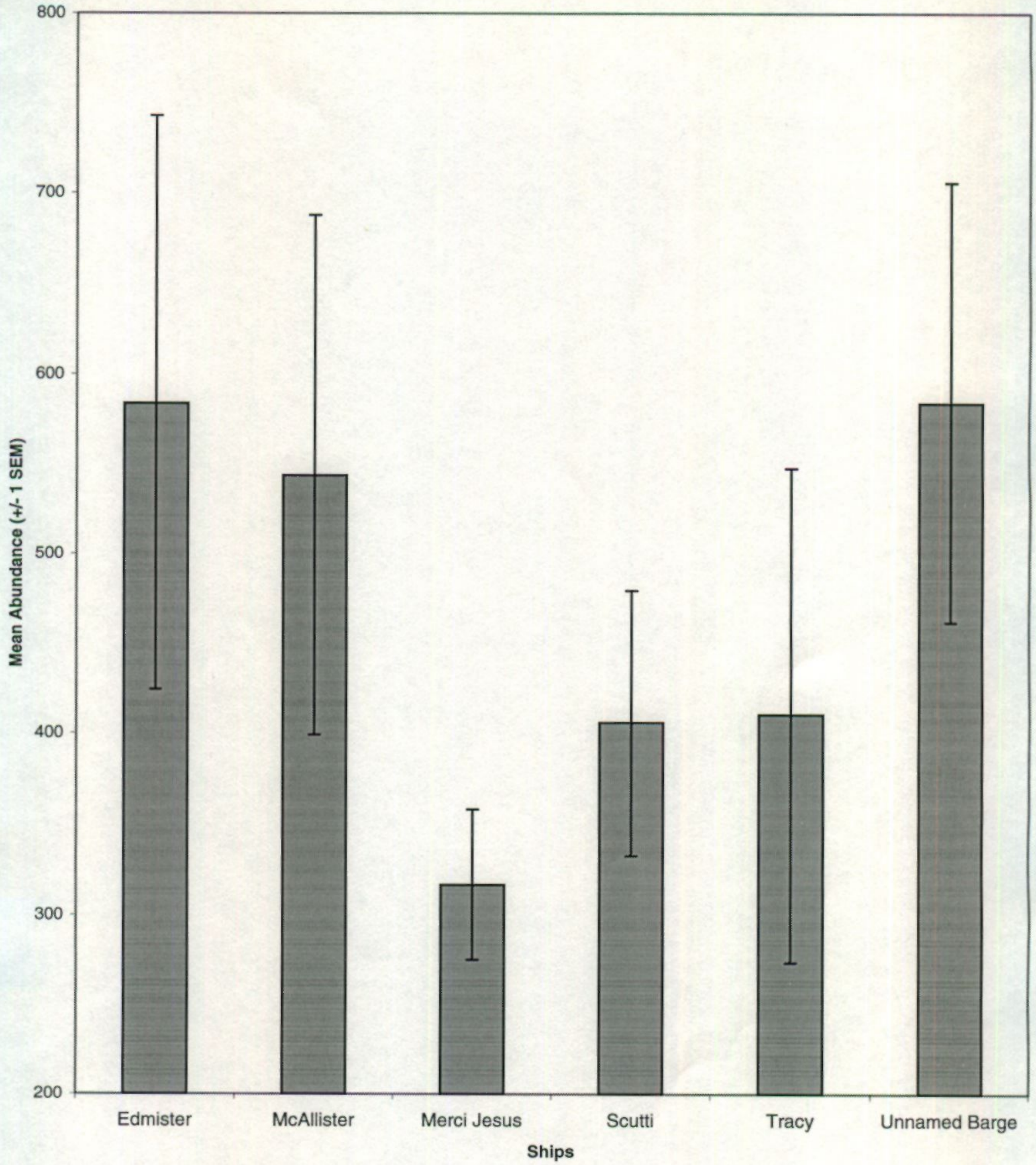


Figure 3. Mean abundance of fish on ships. Vertical lines represent standard error of the mean.

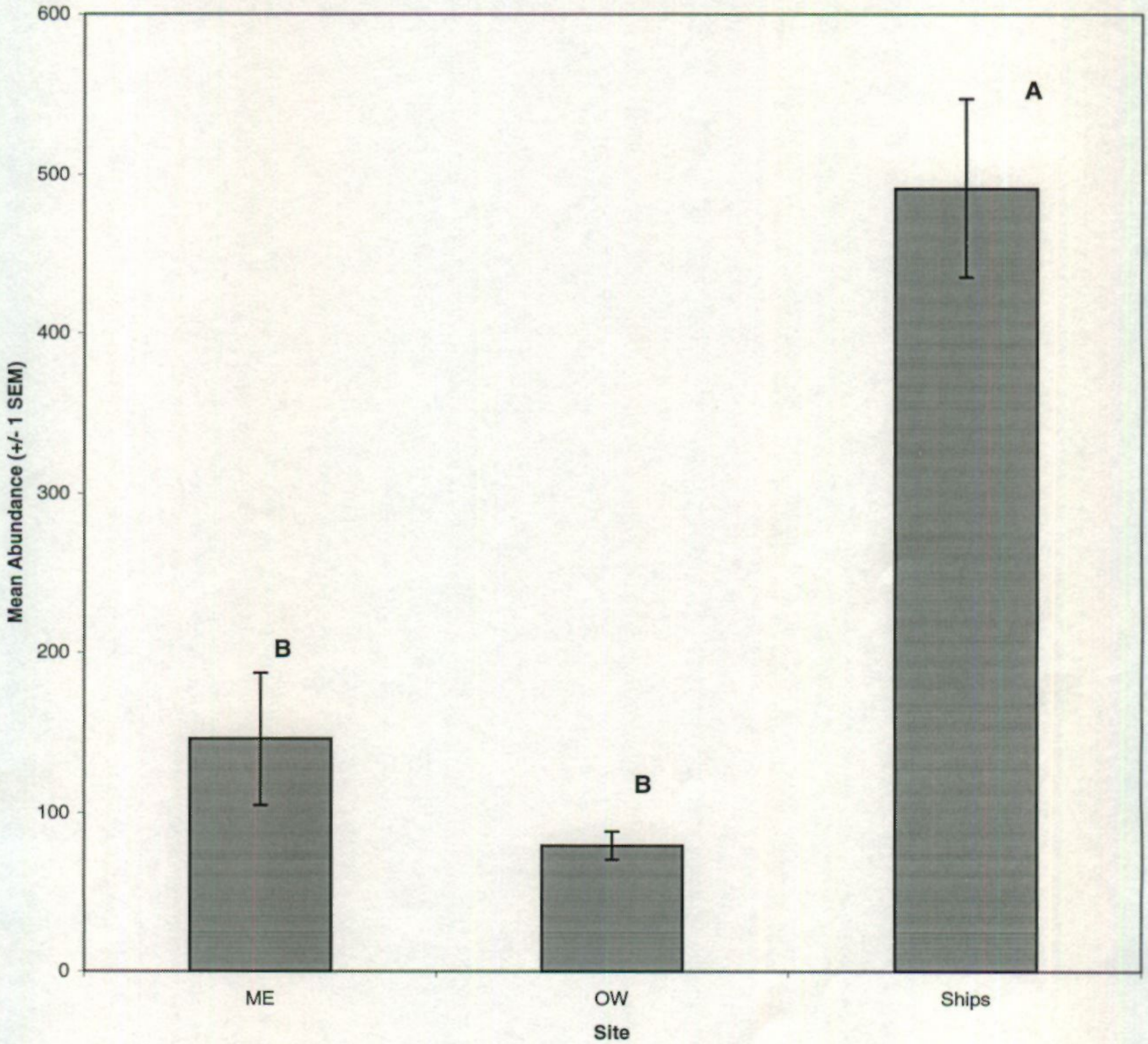


Figure 4. Mean fish abundance on natural and artificial reef sites, second reef eastern edge = ME, third reef western edge = OW. Vertical lines represent standard error of the mean. Means with differing letters are statistically different ($p<0.05$; ANOVA,SNK).

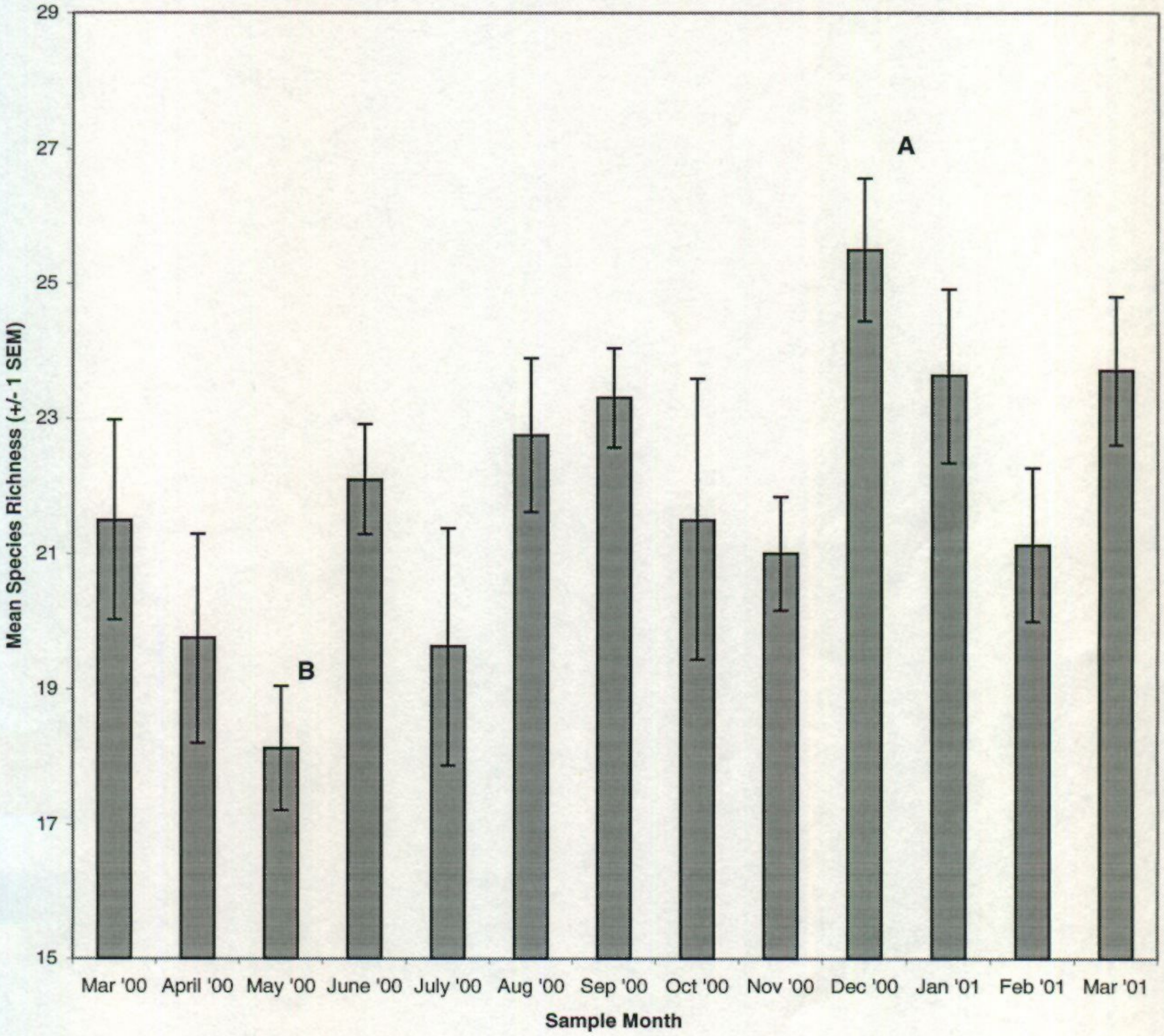


Figure 5. Mean monthly species number on ships. Vertical lines represent standard error of the mean. Means with differing letters are statistically different ($p<0.05$; ANOVA, SNK).

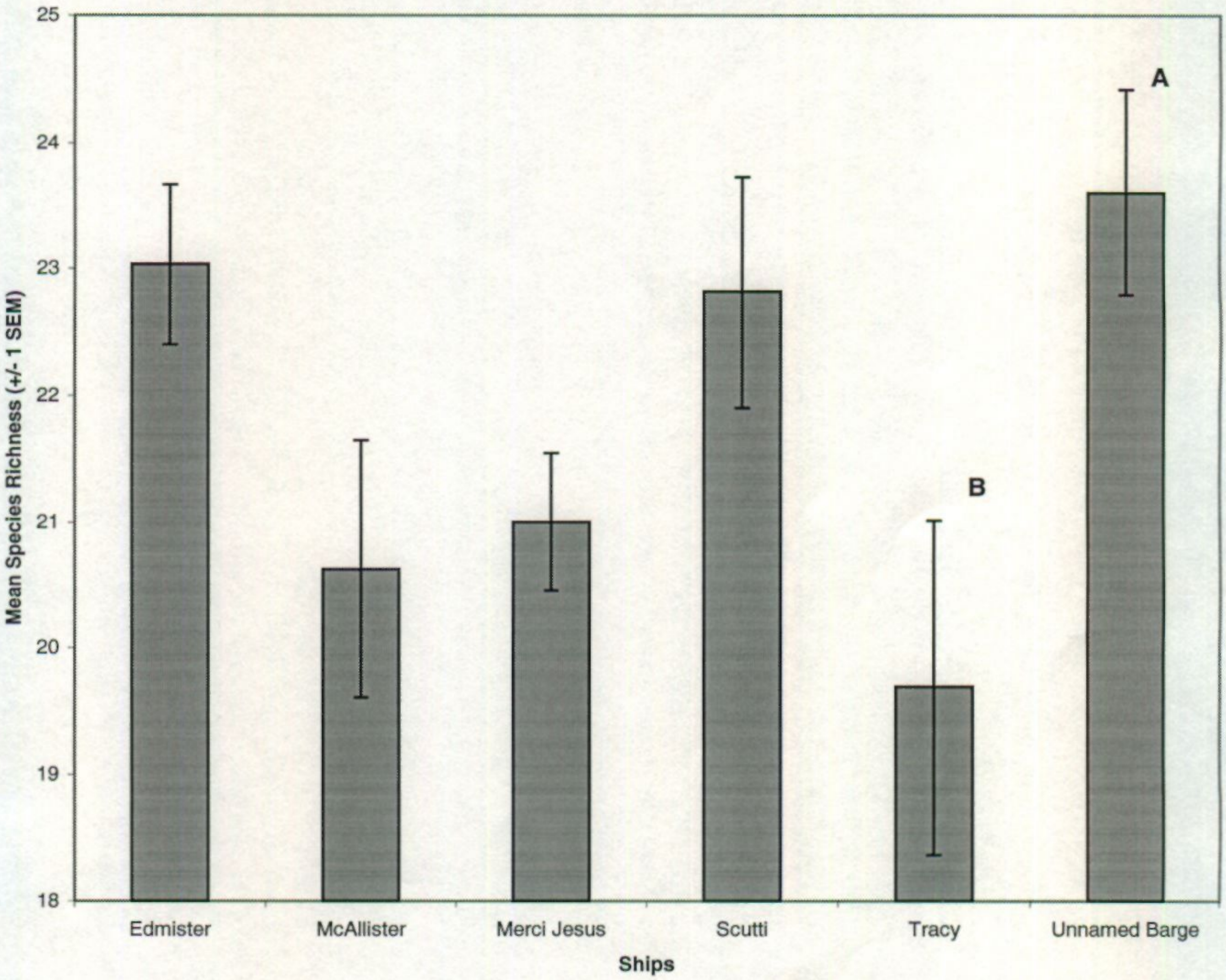


Figure 6. Mean monthly species numbers on ships. Vertical lines represent standard error of the mean. Means with differing letters are statistically different ($p<0.05$; ANOVA, SNK).

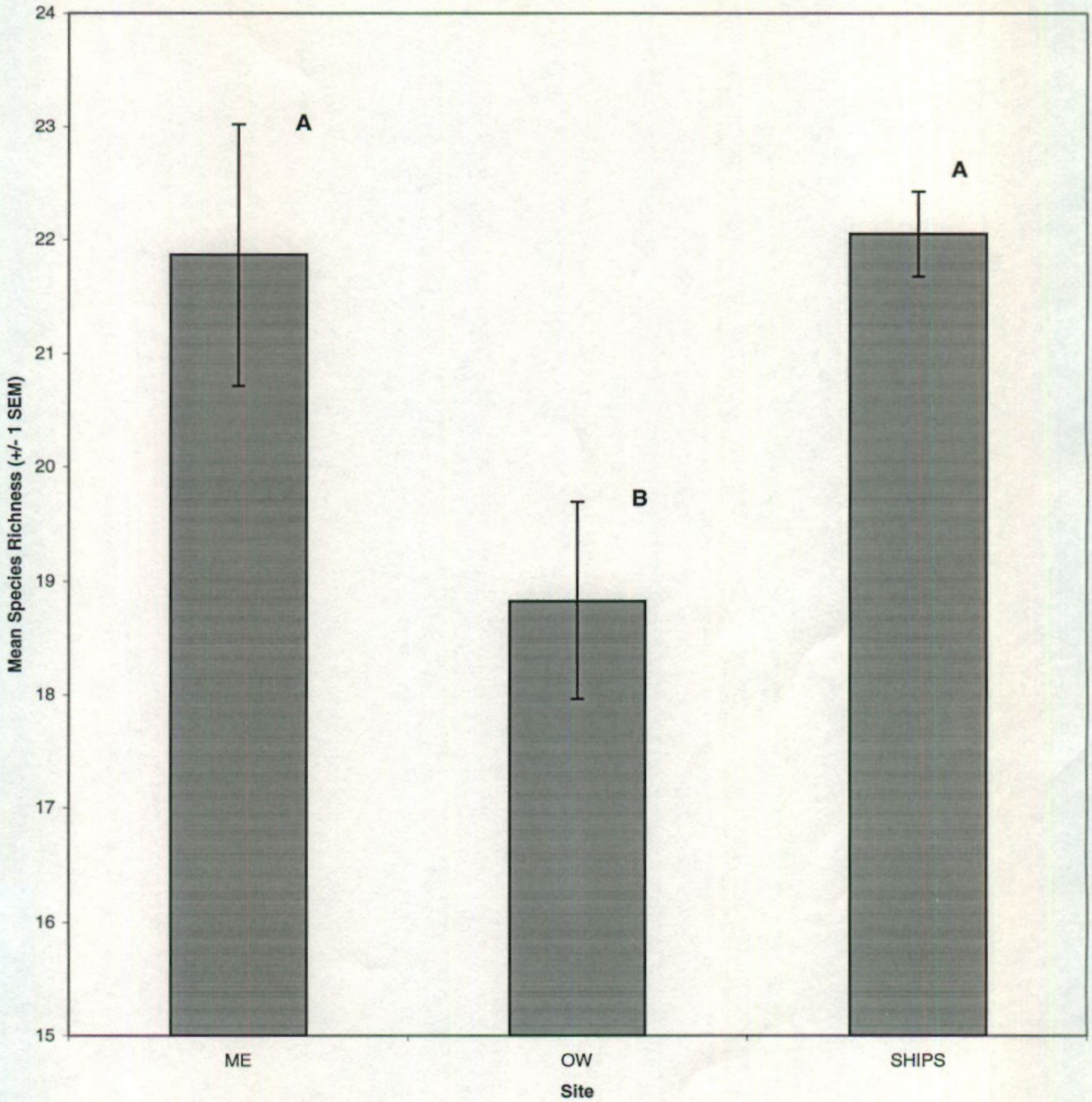


Figure 7. Mean number of species on natural and artificial reef sites, second reef eastern edge = ME, third reef western edge = OW. Vertical lines represent standard error of the mean. Means with differing letters are statistically different ($p<0.05$; ANOVA,SNK).

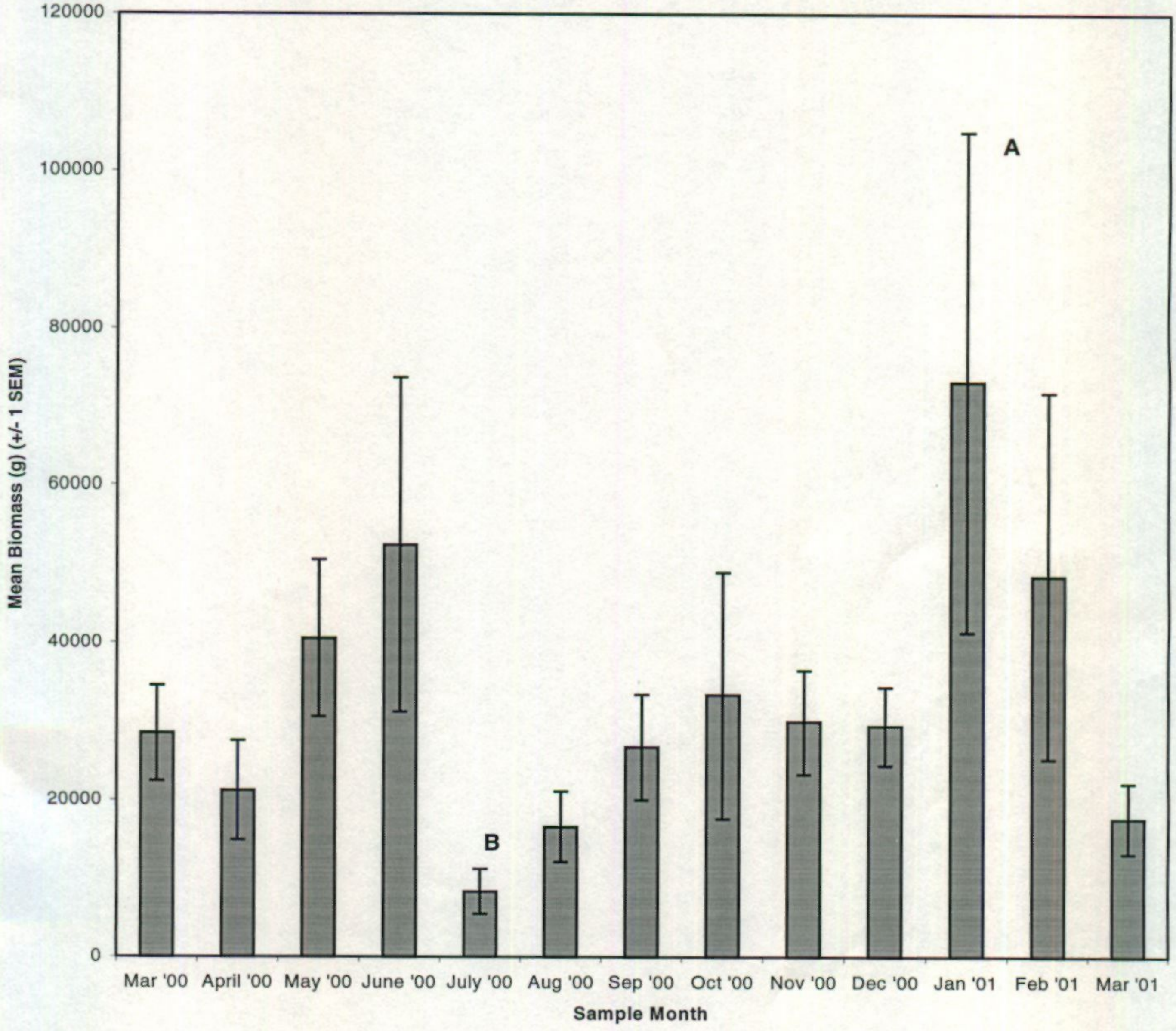


Figure 8. Mean monthly biomass on ships. Vertical lines represent standard error of the mean. Means with differing letters are statistically different ($p<0.05$; ANOVA, SNK).

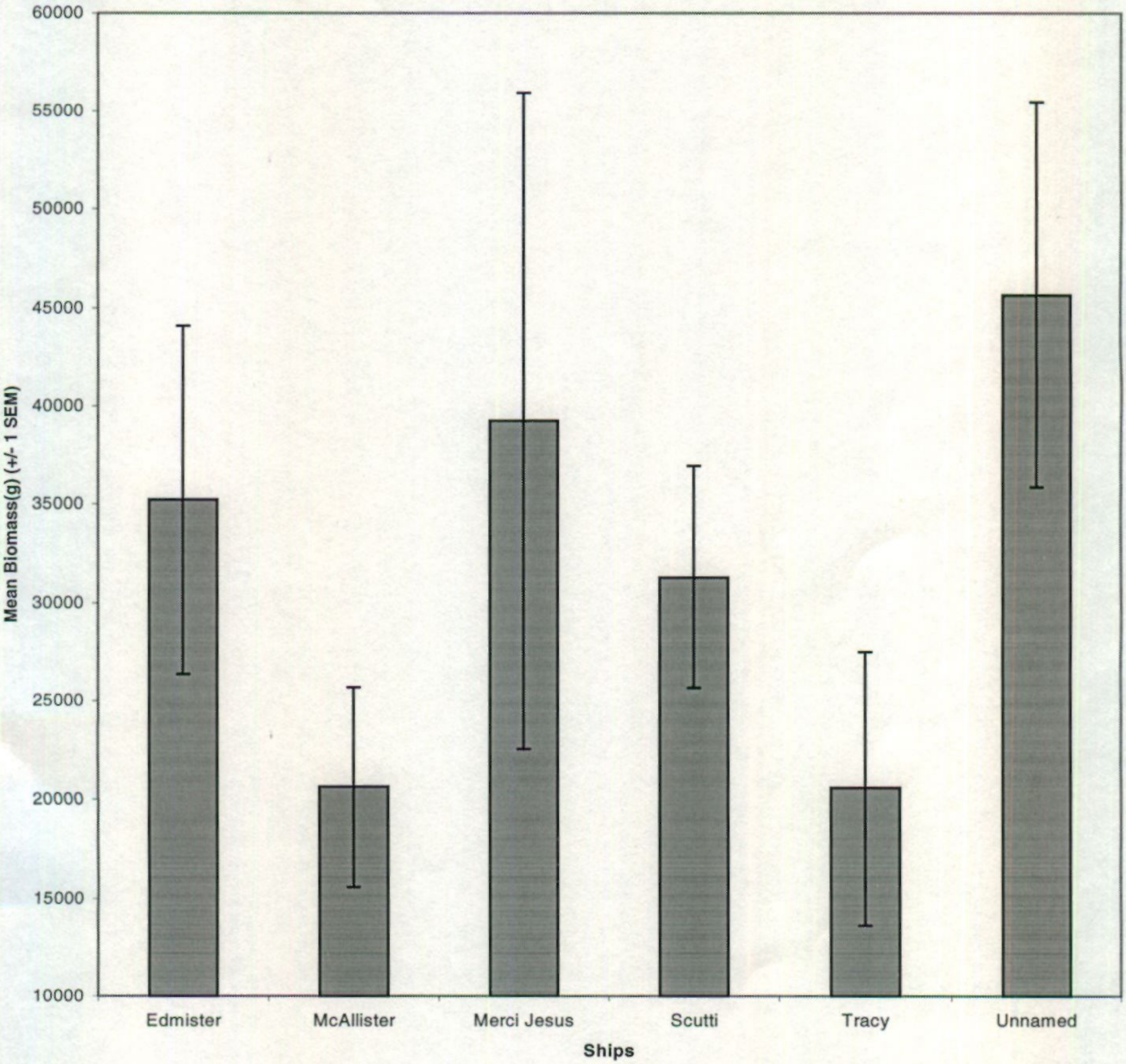
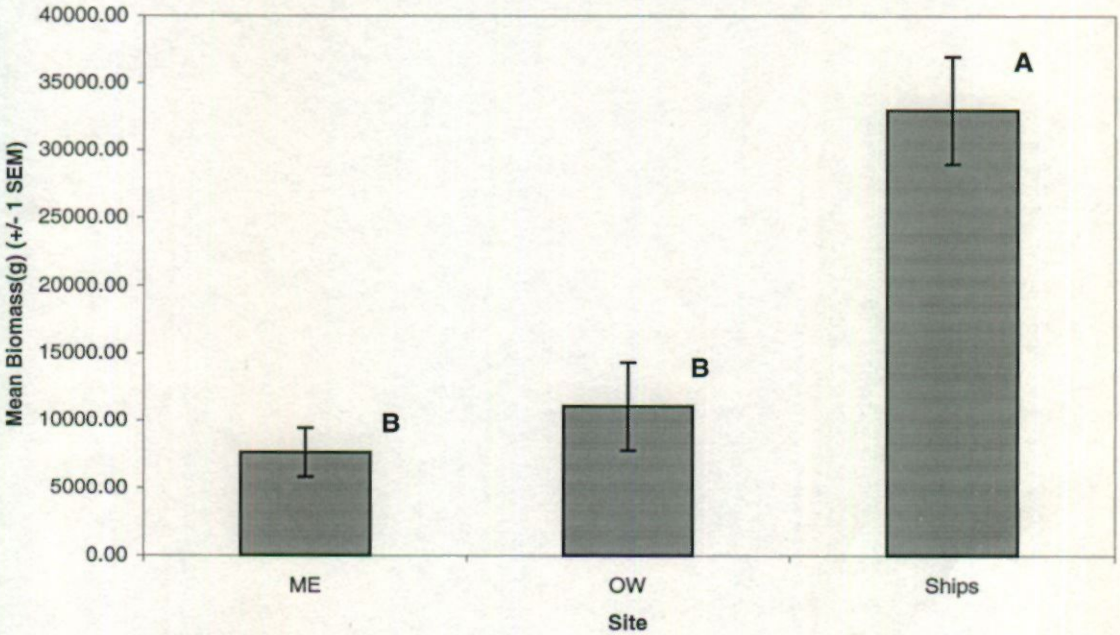


Figure 9. Mean biomass on Ships, vertical lines represent standard error of the mean.



Fiaure 10. Mean biomass on natural and artificial reef . second

Figure 10. Mean biomass on natural and artificial reef sites, second reef eastern edge = ME, third reef western edge = OW. Vertical lines represent standard error of the mean. Means with differing letters are statistically different ($p<0.05$; ANOVA, SNK).