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SPATIAL AND TEMPORAL VARIABILITY IN THE DISTRIBUTION AND ABUNDANCE OF LARVAL AND JUVENILE FISHES ASSOCIATED WITH PELAGIC SARGASSUM

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ABSTRACT

A survey of the larval and juvenile fishes associated with the pelagic Sargassum habitat in the South Atlantic Bight and adjacent western Atlantic Ocean was conducted from July 1991 through March 1993. Fishes representing 104 taxonomic categories were identified, including reef fishes, coastal demersal, coastal pelagic, epipelagic and mesopelagic species. The most important families were Balistidae and Carangidae, each represented by 15 species. Species composition, species diversity and abundance varied both seasonally and regionally. Diversity was highest during spring through fall over the outer continental shelf and in the Gulf Stream. Abundance decreased from spring through winter and from the continental shelf into offshore waters. The numbers of fishes and fish biomass were found to be positively correlated with the wet weight of algae in most cases examined. The results of this study will be useful to fisheries managers assessing the potential impacts of commercial Sargassum harvesting in the region.

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INTRODUCTION

Within the western North Atlantic, pelagic brown algae of the genus Sargassum (Cyclosporeae: Fucales: Fucaceae) form a dynamic habitat that supports a diverse assemblage of associated flora and fauna (see reviews of Peres, 1982; Butler et al., 1983; Coston-Clements et al., 1991). Two species, S. natans and S. fluitans, are of principal importance (Winge, 1923; Parr, 1939). Both are euhyponeustonic (Zaitsev, 1971). Several benthic species, notably S. filipendula and S. hystrix, detached from coastal areas during storms, are also frequently encountered adrift in the North Atlantic. Similarly, detached Sargassum spp. are often observed adrift in the South Atlantic, North and South Pacific and Indian oceans (Uchida and Shojima, 1958; Besednov, 1960; Oliveira et al., 1979; Kingsford and Choat, 1985). However, benthic species are not adapted for a pelagic existence and they ultimately perish (Hoyt, 1918; Winge, 1923; Parr, 1939; Butler et al., 1983).

Most pelagic Sargassum circulates between 20°N and 40°N latitudes and 30°W longitude and the western edge of the Florida Current/Gulf Stream. The greatest concentrations can be found in the North Atlantic Central Gyre and the Sargasso Sea (Winge, 1923; Parr, 1939; Ryther, 1956; Dooley, 1972; Butler et al., 1983; Butler and Stoner, 1984; Nierman et al., 1986). Total biomass is unknown, but, estimates range from 800 - 2000 kg wet weight km^{-2}. Within the vast Sargasso Sea, this translates into a standing crop of 4 - 11 million metric tons (Parr, 1939; Zaitzev, 1971; Peres, 1982; Butler et al., 1983; Butler and Stoner, 1984; Nierman et al., 1986; Luning, 1990).

Large quantities of <u>Sargassum</u> frequently occur on the continental shelf off the southeastern United States. Depending on prevailing surface currents, this material may remain on the shelf for extended periods, be entrained into the Gulf Stream, or be cast ashore (Hoyt, 1918; Humm, 1951; Howard and Menzies, 1969; Carr and Meylen, 1980; Winston, 1982; Haney, 1986; Baugh, 1991). During calm conditions <u>Sargassum</u> may form large irregular mats or simply be scattered in small clumps. Langmuir circulation, internal waves, and convergence zones along fronts aggregate the algae along with other flotsam into long linear or meandering rows (Winge, 1923; Langmuir, 1938; Ewing, 1950, Faller and Woodcock, 1964; Stommel, 1965; Barstow, 1983; Shanks, 1988; Kingsford, 1990).

<u>Sargassum</u> is harvested commercially off North Carolina during the summer months. Precise landings are unknown, but are estimated at 9,000 kg annually (pers. comm., W. Campbell, Aqua 10 Corp., Beaufort, NC). The processed algae are marketed as fertilizer and animal feed. The effects of commercial harvests on important recreational and commercial fishes is unknown.

The National Marine Fisheries Service and the South Atlantic Fisheries Management Council have expressed concern about the potential impacts of increased and unregulated commercial <u>Sargassum</u> harvests on fishery resources in the

South Atlantic Bight and adjacent offshore waters. Information on species composition, distribution and abundance of fishes associated with Sargassum in this region is inadequate and must be addressed before ecologically sound management decisions can be made.

Does the species composition and abundance of fishes change seasonally and regionally? If so, are these relationships predictable? The fishes associated with pelagic Sargassum in the western North Atlantic have been studied by a number of investigators (Adams, 1960; Parin, 1970; Zaitzev, 1971; Dooley, 1972; Bortone et al., 1977; Fedoryako, 1980, 1989; Gorelova and Fedoryako, 1986). Similar research has also addressed the ichthyofauna of drift Sargassum in the Pacific (Uchida and Shojima, 1958; Besednov, 1960; Shojima and Ueki, 1964; Anraku and Azeta, 1965; Kingsford and Choat, 1985; Kingsford and Milicich, 1987; Nakata et al., 1988). In all cases, juvenile fishes were numerically dominant. Most of these studies, however, failed to quantify seasonal and regional relationships between fish abundance and the algae.

The objective of this research is to survey the early life history stages of fishes associated with Sargassum in the region of commercial exploitation in order to determine seasonal and regional species composition and abundance. I will test the hypotheses that species composition and abundance are seasonally and regionally different, and that the relationships between fish abundance and Sargassum biomass are predictable.

MATERIALS AND METHODS

Pelagic Sargassum was sampled in the South Atlantic Bight and adjacent offshore waters from July 1991 through March 1993. All sampling was done during daylight hours. Samples were collected with a 1 x 2-m neuston net with 947 micron Nitex mesh when the algae were aggregated forming "weedlines" or "rafts", and with a 0.5-m diameter long-handled dip net when algae were scattered. The dip net was fitted with 5-mm mesh. Three samples were also obtained with a 1 x 2-m surface trawl equipped with a 25-mm mesh net. Both the neuston net and surface trawl were towed with approximately half of the net below the surface at 2 knots for 1 to 50 minutes. Most tows were 2 to 3 minutes. Tows were navigated to minimize the straining of open water not immediately adjacent to Sargassum weedlines. The towing bridle of the neuston net was reconfigured about half way through the study to reduce disturbance of algae going into the net. A 2.7-kg depressor was also added to help keep the gear level during tows.

The number of samples collected at each location was variable, being affected by the seasonal variability in the availability and abundance of Sargassum, the local distribution of the algae (e.g., scattered or aggregated), and by available shipboard processing time. For example, multiple relatively small samples were collected with a dip net when algae were scattered, while fewer but larger samples were collected with the neuston net at weedlines.

Sea surface temperature and salinity were measured with a bucket thermometer and refractometer or STD-12 (Applied Microsystems Inc.) at most sampling locations. Sampling dates, positions, sampling methods and characteristics of the Sargassum habitats for each location are given in Appendix A.

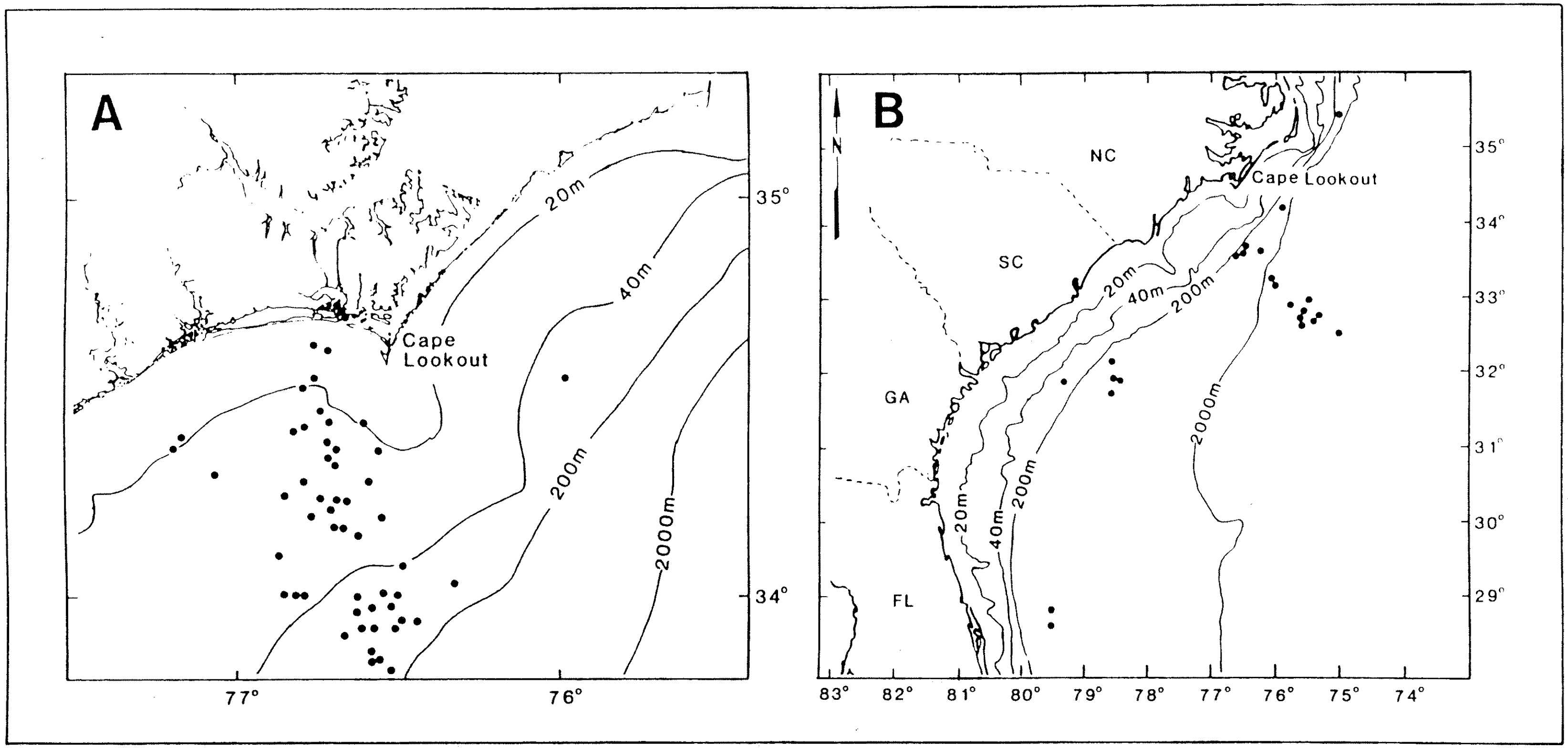
Sargassum was placed into either 7.6-l buckets or 113-l coolers immediately after collection for sorting. The algae was washed with sea water or fresh water depending on availability. Each piece of algae was examined and all visible fishes were removed and preserved in 95% ethanol. The wash water was sieved through a 1-mm mesh and the trapped material was preserved in 95% ethanol for later sorting, identification, and enumerations of larval and juvenile fishes in the laboratory. The algae were kept wet during this shipboard processing, which frequently required several hours, particularly for large neuston net samples. Wet weight of small Sargassum samples (i.e., < 2 kg) was measured to the nearest 0.01 kg on a 2-kg capacity spring scale. Heavier samples were weighed to the nearest 0.2 kg on a larger 27.2-kg capacity spring scale. Sargassum was identified to species and discarded overboard.

In the laboratory, samples were sorted to remove all larval and juvenile fishes. Fishes were identified to species when possible or to higher taxon when specific identity could not be determined. Fishes that were damaged too badly to make family-level identification certain were classified as unknown. Fish from each sample were weighed collectively by taxon to the nearest milligram on an electronic balance.

Larval fish were weighed in a tared petri dish containing a small volume of water to prevent desiccation. This preserved wet weight is hereafter to referred to as fish biomass. Standard length (SL) was measured on up to 50 individuals per taxon for each sampling location. Small fish (< 20 mm) were measured to the nearest 0.1 mm under a stereomicroscope equipped with an ocular micrometer. Larger specimens were measured to the nearest 0.5 mm with dividers. Length and weight measurements were not corrected for changes due to preservation.

Because the purpose of this study was to investigate seasonal and spatial variability in ichthyofauna associated with Sargassum over broad regions, and not to look at within sample location variability, samples were pooled for each of the 78 locations sampled. Each location sample was then assigned to one of five oceanographic regions (inner shelf, middle shelf, outer shelf, Gulf Stream, Sargasso Sea) based upon the depth of water over which it was collected. The inner shelf extends from shore out to < 20 m; the middle shelf extends from 20 m to < 40 m; the outer shelf extends from 40 m to < 200 m; the Gulf Stream encompasses from 200 m to < 2000 m; and the western Sargasso Sea includes depths > 2000 m (Fig. 1). Regional strata were modified after Yoder (1983). Samples were further stratified by astronomical season and resulted in a 4 x 5 factorial design with season and region as main effects. The design was, however, unbalanced due to the lack of sampling in the Sargasso Sea during the spring or

Figure 1. *Sargassum* sampling locations. A) Continental shelf locations off North Carolina. B) Offshore locations and one outer shelf location off South Carolina.


A
Cape Lookout
20m
40m
200m
2000m
35°
34°
77°
76°
B
N
NC
SC
GA
FL
Cape Lookout
20m
40m
200m
2000m
35°
34°
33°
32°
31°
30°
29°
83°
82°
81°
80°
79°
78°
77°
76°
75°
74°

summer and the absence of Sargassum over the inner shelf during winter.

The number of fishes and fish biomass were standardized to fish kg^{-1} algae and biomass kg^{-1} algae for each location. Means were then calculated for each region by season. Linear regression of the variances against the means for both measures revealed severe departures from the equal variance assumption required for parametric statistical analysis. Therefore, the standardized variables were subjected to square root transformation in order achieve homogeneity of variance (Ott, 1988). An analysis of variance for main effects (region and season) and interaction (region by season) was performed on both the transformed standardized abundance and biomass data. The analysis was resolved by fitting complete and reduced models to the data so that the sums of squares for the effects could be adjusted for an unbalanced design (SAS, 1985). Means were analyzed utilizing the Tukey - Krammer multiple-comparison procedure (Ott, 1988).

The relationships between the numbers of fish and wet weight of algae and between fish biomass and wet weight of algae were determined by linear regression for all regions by season where the number of sample locations (N) was 5 or more.

Relative abundance of individual taxa and species diversity were determined for each region by season. Abundance was first standardized to number of fish kg^{-1} algae for each taxon for each location. A mean was then computed for each taxon by season. Relative abundance was assigned as follows:

highly abundant (H) = > 100 fish kg^{-1} algae

abundant (A) = 11 - 100 fish kg^{-1} algae

moderately abundant (M) = 1.1 - 10 fish kg^{-1} algae

common (C) = 0.11 - 1.0 fish kg^{-1} algae

uncommon (U) = 0.01 - 0.10 fish kg^{-1} algae

rare (R) = < 0.01 fish kg^{-1} algae

Shannon's species diversity (H') and evenness (J') were also determined for all regions by season (Pielou, 1969, May, 1975). Indices were computed using the BASIC program in Brower and Zar (1984).

Seasonal and regional changes in the ichthyofauna were further described by examining the percentages of abundant (e.g., moderately to highly), common, and uncommon to rare taxa present. Percentages were calculated by dividing the number of taxa in each abundance classification by the total number of taxa collected in each region by season.

RESULTS

Pelagic Sargassum was collected at 78 locations in coastal and offshore waters from Cape Hatteras, North Carolina south to Cape Canaveral, Florida (Fig. 1). A total of 185 samples was obtained on 22 cruises from 09 August 1991 through 10 March 1993. Fourteen additional samples were collected from Pivers Island bridge located just inside Beaufort Inlet, North Carolina during June and November 1992 (Table 1). The majority of samples were collected south of Cape Lookout,

Table 1. Cruise dates, number of locations sampled (N) and number of Sargassum samples (n) collected during this study.

Platform	Cruise dates	N	n
RV Onslow Bay	09/07/91	2	13
RV Onslow Bay	29/08/91	3	9
RV Onslow Bay	06/09/91	4	13
NOAA Ship Chapman	08-13/10/91	15	37
RV Onslow Bay	15/11/91	2	3
RV Susan Hudson	11/12/91	4	8
NOAA Ship Albatross IV	10-17/01/92	10	12
NOAA Ship Albatross IV	30-31/01/92	1	6
RV Onslow Bay	21/02/92	1	5
RV Susan Hudson	28/02/92	2	10
RV Susan Hudson	24/04/92	3	12
RV Dan Moore	11-15/05/92	4	10
RV Onslow Bay	01/06/92	4	8
Piver Island bridge	08/06/92	1	10
RV Susan Hudson	16/06/92	3	7
Pivers Island bridge	25/06/92	1	3
RV Susan Hudson	30/06/92	4	8
RV Dan Moore	12-23/07/92	3	3
RV Susan Hudson	19/08/92	3	10
RV Onslow Bay	02/10/92	1	1
RVOnslow Bay	19/11/92	1	3
Pivers Island bridge	27/11/92	1	1

Table 1. (Continued)

Vessel	Cruise dates	N	n
NOAA Ship Albatross IV	11-20/12/92	1	1
NOAA Ship Chapman	10-19/02/93	3	5
RV Susan Hudson	10/03/93	1	1

North Carolina in Onslow Bay and adjacent offshore waters.

A total of 855.69 kg of Sargassum was sampled (Table 2). The samples yielded 27,469 fishes from 36 families in 12 orders. Only 0.5% of the fishes could not be identified to some taxon. The remaining fishes were placed in 104 taxonomic categories; 95.7% were identified to species, 1.2% to genus, and 2.6% to family (Table 3). Standard lengths by taxon are presented in Appendix B.

The mean abundance of fishes, expressed as the number of fish kg^{-1} algae, associated with pelagic Sargassum is highly variable (Fig. 2). ANOVA for abundance by region and season was highly significant ($P<0.001$). Both season ($F_{3,61}=5.32$, $P<0.01$) and oceanographic region ($F_{4,61}=5.06$, $P<0.01$) had a significant effect on abundance, but there was also significant interaction between season and region ($F_{9,61}=2.72$, $P<0.01$) (Table 4). Multiple comparisons of seasonal means indicated that abundance during spring (129.5 fish kg^{-1} algae) was significantly greater than both fall (54.2 fish kg^{-1} algae) and winter (8.6 fish kg^{-1} algae), while summer abundance (87.9 fish kg^{-1} algae) was significantly greater than winter (Tukey-Krammer, 61 df, $P<0.05$). Comparison of mean abundance across regions showed that the inner shelf (129.5 fish kg^{-1} algae), middle shelf (89.3 fish kg^{-1} algae) and outer shelf (45.1 fish kg^{-1} algae) were significantly different from both the Gulf Stream (21.6 fish kg^{-1} algae) and Sargasso Sea (1.6 fish kg^{-1} algae), and that the mean abundance over the inner shelf was also greater than the outer shelf (Tukey-Krammer, 61 df,

Table 2. The number of sample locations (N) and wet weight of Sargassum collected by season and region. Note that no Sargassum was observed over the inner shelf during winter and that no sampling was conducted in the Sargasso Sea during spring or summer (ND).

	Spring		Summer		Fall		Winter	
	N	Wet weight (kg)	N	Wet weight (kg)	N	Wet weight (kg)	N	Wet weight (kg)
Inner shelf	3	8.29	3	22.63	3	15.81	0	0
Middle shelf	5	14.65	10	93.26	8	40.28	5	74.42
Outer shelf	4	67.37	2	61.90	7	103.90	5	3.94
Gulf Stream	3	8.15	3	7.71	3	4.00	4	7.07
Sargasso Sea		ND		ND	5	52.45	4	269.86

Table 3. The number, seasonal distribution and relative abundance of larval and juvenile fishes collected in association with pelagic *Sargassum* off North Carolina and the adjacent Atlantic Ocean. Note that no sampling was conducted in the Sargasso Sea during the spring or summer. Abundance codes are (H) highly abundant; (M) moderately abundant; (A) abundant; (C) common; (U) uncommon; and (R) rare. * indicates fishery species.

Taxon	N	Inner Shelf				Middle Shelf				Outer Shelf				Gulf Stream				Sargasso Sea	
		Sp	S	F	W	Sp	S	F	W	Sp	S	F	W	Sp	S	F	W	F	W
Muraenidae																			
Unidentified	1			U															
Clupeidae																			
Sardinella aurita	4		C	U			U												
Gonostomatidae																			
Unidentified	1									U									
Stomiidae																			
Unidentified	1									U									
Myctophidae																			
Unidentified	6									U						M		U	
Gadidae																			
Urophycis chuss	10							U				C							
U. floridana	169								M				M						
U. regia	98					U			M	C		C							

Table 3 (Continued)

Taxon	N	Inner Shelf				Middle Shelf				Outer Shelf				Gulf Stream				Sargasso Sea	
		Sp	S	F	W	Sp	S	F	W	Sp	S	F	W	Sp	S	F	W	F	W
Urophycis sp.	17								C	C									
Antennariidae																			
Histrio histrio	445	M	C			C	C	C	C	M	C	C	C	C		C	C	C	M
Exocoetidae																			
Cypselurus melanurus	313	C	C			C	M		U	M	U	C		C				U	C
Hemiramphus balao	1					U													
H. brasiliensis	9		U							U						C		U	
Hemiramphus sp.	12						C					C							
Hirundichthys affinis	17						C			U									
Hyporhamphus unifasciatus	23						C			U	U			U		C		U	
Hyporhamphus sp.	3											U				M			
Paraexocoetus brachypterus	58		C			U		U			U	C							
Prognichthys gibbifrons	57		C			C	M	U		U	U								
Unidentified	3							U										U	C
Belonidae																			
Tylosurus acus	12					U	C			U		U			C				
Unidentified	1														C				
Syngnathidae																			
Hippocampus erectus	5							U		C									
H. reidi	1											U							
Syngnathus caribbaeus	1													U					
S. floridae	4		U											U					
S. fuscus	1	U																	
S. pelagicus	113		U	U		C	U	C	U	C	R	C	C	C		M	C	C	R
S. springeri	1									U									

Table 3 (Continued)

Taxon	N	Inner Shelf Sp	Inner Shelf S	Inner Shelf F	Inner Shelf W	Middle Shelf Sp	Middle Shelf S	Middle Shelf F	Middle Shelf W	Outer Shelf Sp	Outer Shelf S	Outer Shelf F	Outer Shelf W	Gulf Stream Sp	Gulf Stream S	Gulf Stream F	Gulf Stream W	Sargasso Sea F	Sargasso Sea W
Syngnathus sp.	8						U			U		U							
Priacanthidae																			
*Priacanthus arenatus**	2		U				C												
Pristigenys alta	5		C				C												
Unidentified	4									U	R			U					
Apogonidae																			
Unidentified	9									C									
Carangidae																			
*Caranx bartholomaei**	114	C	U			C		C		C	U	C				C			R
*C. crysos**	284		C	C		M	A	C		C	M	C		C	C				
*C. hippos**	9	C	C			U	R	U				C							
*C. ruber**	122	C	C			C	U	C		C	C	C		C	M	C			
Caranx sp.*	8						C												
Chloroscombrus chrysurus	2									U									
Decapterus punctatus	825	C	A	U		M	C	M	C	M		M		U					
Decapterus sp.	1											U							
*Elagatis bipinnulata**	22						U				C	C		C		M		U	
Selar crumenophthalmus	13									C									
Selene volmer	3					U								U					
*Seriola dumerili**	57	C	C			C				C	R	U							
*S. fasciata**	8		C			U	U							U		C			
*S. rivoliana**	128	M	A				C	C		U	U	C	C	C			C	U	R
*S. zonata**	23	C	C			U	R			C				U					
Seriola spp.*	263	C				M	M	M		M	C	C		U		C			
*Trachinotus falcatus**	15	U					U			U	R	U		U		M			
T. goodei	1									U									

Table 3 (Continued)

Taxon	N	Inner Shelf				Middle Shelf				Outer Shelf				Gulf Stream				Sargasso Sea	
		Sp	S	F	W	Sp	S	F	W	Sp	S	F	W	Sp	S	F	W	F	W
Trachurus lathami	29					U				C									
Unidentified	8									C						M			
Coryphaenidae																			
Coryphaena equisetis*	1													U					
C. hippurus*	26			C		C	U			C	U	U							C
Lutjanidae																			
Lutjanus sp.*	1		U																
Rhomboplites aurorubens*	1							U											
Lobotidae																			
Lobotes surinamensis*	26		U				U			U	C	U						U	
Sparidae																			
Pagrus pagrus*	18									C									
Mullidae																			
Mullus auratus	151	C								M									
Unidentified	109						M	C		M		C		U		A			
Kyphosidae																			
Kyphosus sectatrix	85		C			C	C	C		C	C	U		U		C		U	C
Chaetodontidae																			
Chaetodon sp.	8			U				U	U										
Pomacanthidae																			
Unidentified	3									U									

Table 3 (Continued)

Taxon	N	Inner Shelf				Middle Shelf				Outer Shelf				Gulf Stream				Sargasso Sea	
		Sp	S	F	W	Sp	S	F	W	Sp	S	F	W	Sp	S	F	W	F	W
Pomacentridae																			
<u>Abudefduf</u> <u>saxatilis</u>	323	C	C			M	M	C		M	C	C		U	C	M		U	U
Scaridae																			
Unidentified	1											U							
Mugilidae																			
<u>Mugil</u> <u>cephalus</u>*	7											C							
<u>M</u>. <u>curema</u>*	272					C				M		U						C	
<u>Mugil</u> sp.*	1															M			
Sphyraenidae																			
<u>Sphyraena</u> sp.*	13						U			C						M			
Blenniidae																			
<u>Parablennius</u> <u>marmoreus</u>	40		U			M		U		C		C							
Unidentified	3							C			R								
Acanthuridae																			
<u>Acanthurus</u> sp.	1										R								
Xiphiidae																			
<u>Xiphius</u> <u>gladius</u>*	1															M			
Istiophoridae																			
<u>Makaira</u> <u>nigricans</u>*	2																	U	
Unidentified*	1						U												

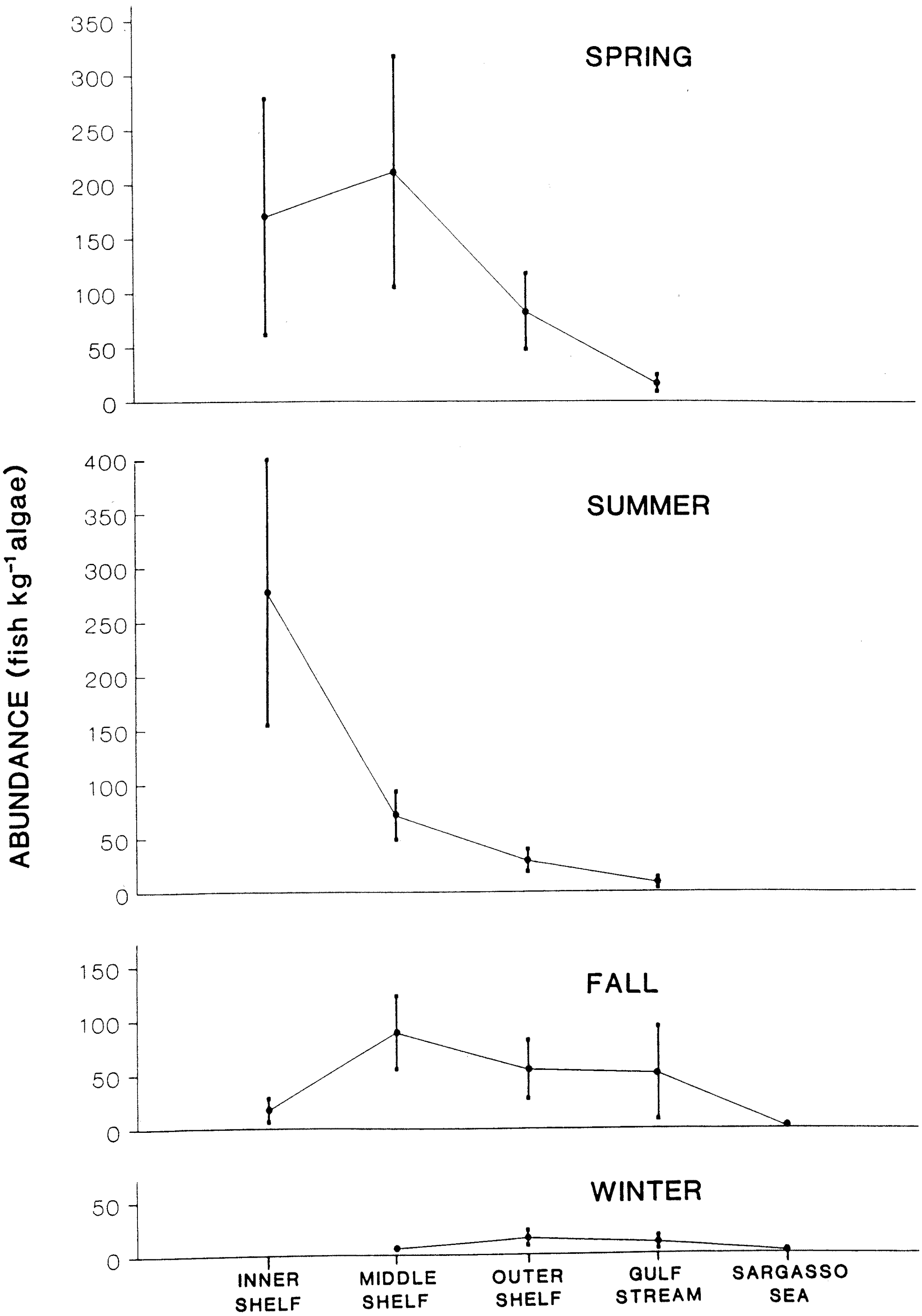
Table 3 (Continued)

Taxon	N	Inner Shelf				Middle Shelf				Outer Shelf				Gulf Stream				Sargasso Sea	
		Sp	S	F	W	Sp	S	F	W	Sp	S	F	W	Sp	S	F	W	F	W
Stromateidae																			
<u>Nomeus</u> <u>gronovii</u>	1									U									
<u>Peprilus</u> <u>triacanthus</u>*	109	A	U			C				U									
<u>Psenes</u> <u>cyanophrys</u>	20	U				C	U			U	C				C				
Scorpaenidae																			
Unidentified	6									C	U								
Dactylopteridae																			
<u>Dactylopterus</u> <u>volitans</u>	11						C			U						C			
Bothidae																			
<u>Bothus</u> sp.	3						U												
<u>Cyclopsetta</u> <u>fimbriata</u>	2						R			U									
Balistidae																			
<u>Aluterus</u> <u>heudeloti</u>	7						R			U	U								
<u>A</u>. <u>monoceros</u>	17						C				U								
<u>A</u>. <u>schoepfi</u>	24		C	U			C	U		U	U	U		U					
<u>A</u>. <u>scriptus</u>	11					C	U			U	U	R		U					
<u>Balistes</u> <u>capriscus</u>*	307		A				M	U		U	M	U						U	R
<u>B</u>. <u>vetula</u>*	3									U			U						
<u>Cantherhines</u> <u>macrocerus</u>	7										C								
<u>C</u>. <u>pullus</u>	30		U				U			U	C	U	C		C	C			
<u>Canthidermis</u> <u>maculatus</u>	27					U	R			U	U	U				M		U	C
<u>C</u>. <u>sufflamen</u>	9	U					U			U					C				
<u>Monacanthus</u> <u>ciliatus</u>	92	C	C	U		C	M	C	R	C	U	C	C						
<u>M</u>. <u>hispidus</u>	21,569	H	H	A		H	A	A	M	A	A	A	A	A		M	A		R
<u>M</u>. <u>setifer</u>	33						U				C			U	C	C			C

Table 3 (Continued)

Taxon	N	Inner Shelf Sp	S	F	W	Middle Shelf Sp	S	F	W	Outer Shelf Sp	S	F	W	Gulf Stream Sp	S	F	W	Sargasso Sea F	W
M. tuckeri	15					U	R	C		U	U	U							
Xanthichthys ringens	1															U			
Unidentified	4					U				U									
Ostraciidae																			
Lactophrys sp.	4									U	R	U		U					
Tetraodontidae																			
Diodon holocanthus	2						U									C			
Sphoeroides spengleri	27							U		C		C							C
Unidentified	553	U	C	C		C	M	C	C	M	C	M				C			C
Unknown	131			U		C				M	U	C							

Figure 2. Abundance (mean ± SE) of larval and juvenile fishes associated with pelagic *Sargassum* in the South Atlantic Bight and adjacent Atlantic Ocean.



ABUNDANCE (fish kg-1 algae)
SPRING
350
300
250
200
150
100
50
0
SUMMER
400
350
300
250
200
150
100
50
0
FALL
150
100
50
0
WINTER
50
0
INNER SHELF
MIDDLE SHELF
OUTER SHELF
GULF STREAM
SARGASSO SEA

Table 4. Analysis of variance for main effects (region and season) and interaction on square root transformed fish abundance (fish kg^{-1} algae). Sums of squares adjusted for unbalanced design.

Source	df	SS	MS	F	P
Model	16	1188.9529	74.3096	4.99	0.0001
Region	4	301.6428	75.4107	5.06	0.0014
Season	3	237.5701	79.1900	5.32	0.0025
Region by season	9	365.3067	40.5896	2.72	0.0097
Error	61	908.6405	14.8957		
Corrected total	77	2097.5934			

$P<0.05$).

The mean abundance across regions by season revealed some interesting patterns (Fig. 2). During spring, mean abundance was high over the inner and middle shelves and declined over the outer shelf and in the Gulf Stream. Mean abundance during summer was greatest over the inner shelf and steadily declined with increased distance offshore. During fall, abundance was low on the inner shelf, increased to a maximum over the middle shelf and then declined offshore. Abundance was very low in the Sargasso Sea. During winter, abundance was low in all regions. Multiple comparisons of means across regions by season indicated that abundances over the middle shelf during spring and the inner shelf during summer were significantly greater than those of the inner shelf, outer shelf, and Sargasso Sea in fall; all regions during winter; and the Gulf Stream during both spring and summer. The abundance over the inner shelf during spring was also greater than that in the Gulf Stream during the fall (Tukey-Krammer, 61 df, $P<0.05$).

The ANOVA for biomass by region and season was also highly significant ($P<0.001$). Seasonal effects ($F_{3,61}=6.16$, $P<0.01$) and regional effects ($F_{4,61}=5.26$, $P<0.01$) exerted significant influence on fish biomass associated with pelagic *Sargassum* (Table 5). Interaction between the effects was not significant ($F_{9,61}=1.89$, $P>0.1$). Multiple comparisons of seasonal means indicated that biomass during spring (21.3 g kg^{-1} algae), summer (30.6 g kg^{-1} algae), and fall (16.9 g kg^{-1} algae) were greater than winter (4.2 g kg^{-1} algae), and that

Table 5. Analysis of variance for main effects (region and season) and interaction on square root transformed fish biomass (g kg^{-1} algae). Sums of squares adjusted for unbalanced design.

Source	df	SS	MS	F	P
Model	16	235.9098	14.7444	5.07	0.0001
Region	4	61.2395	15.3099	5.26	0.0010
Season	3	53.8223	17.9408	6.16	0.0010
Region by season	9	43.9669	4.8852	1.89	0.1139
Error	61	177.5684	2.9110		
Corrected total	77	413.4782			

summer was also greater than the fall (Tukey-Krammer, 61 df, $P<0.05$). Comparisons across regions implied that mean biomass was significantly higher over the inner (38.6 g kg^{-1} algae) and middle (23.7 g kg^{-1} algae) shelf regions compared to either the Gulf Stream (6.3 g kg^{-1} algae) or Sargasso Sea (1.5 g kg^{-1} algae), and that mean biomass on the outer shelf (15.8 g kg^{-1} algae) also exceeded that in the Sargasso Sea (Tukey-Krammer, 61 df, $P<0.05$).

Mean biomass declined from inshore across the continental shelf and into the Gulf Stream during the spring and summer (Fig. 3). During the fall, mean biomass increased from the inner shelf to the middle shelf and then decreased offshore across the outer shelf, Gulf Stream, and Sargasso Sea. In winter the peak was shifted offshore to the outer shelf. Multiple comparisons of mean biomass across regions by season indicated that biomass over the inner shelf during summer was significantly greater than those of all regions during winter, the Gulf Stream during summer and fall, and the Sargasso Sea during fall (Tukey-Krammer, 61 df, $P<0.01$). Biomass on the middle shelf during spring, summer, and fall were greater than biomass in the Sargasso Sea during the fall. Biomass over the middle shelf during summer was also greater than all regions during winter with the exception of the outer shelf (Tukey-Krammer, 61 df, $P<0.05$).

The numbers of fishes and fish biomass were positively correlated with the wet weight of Sargassum over the middle shelf throughout the year (Table 6, Table 7). A significant

Figure 3. Biomass (mean $\pm$ SE) of larval and juvenile fishes associated with pelagic *Sargassum* in the South Atlantic Bight and adjacent Atlantic Ocean.

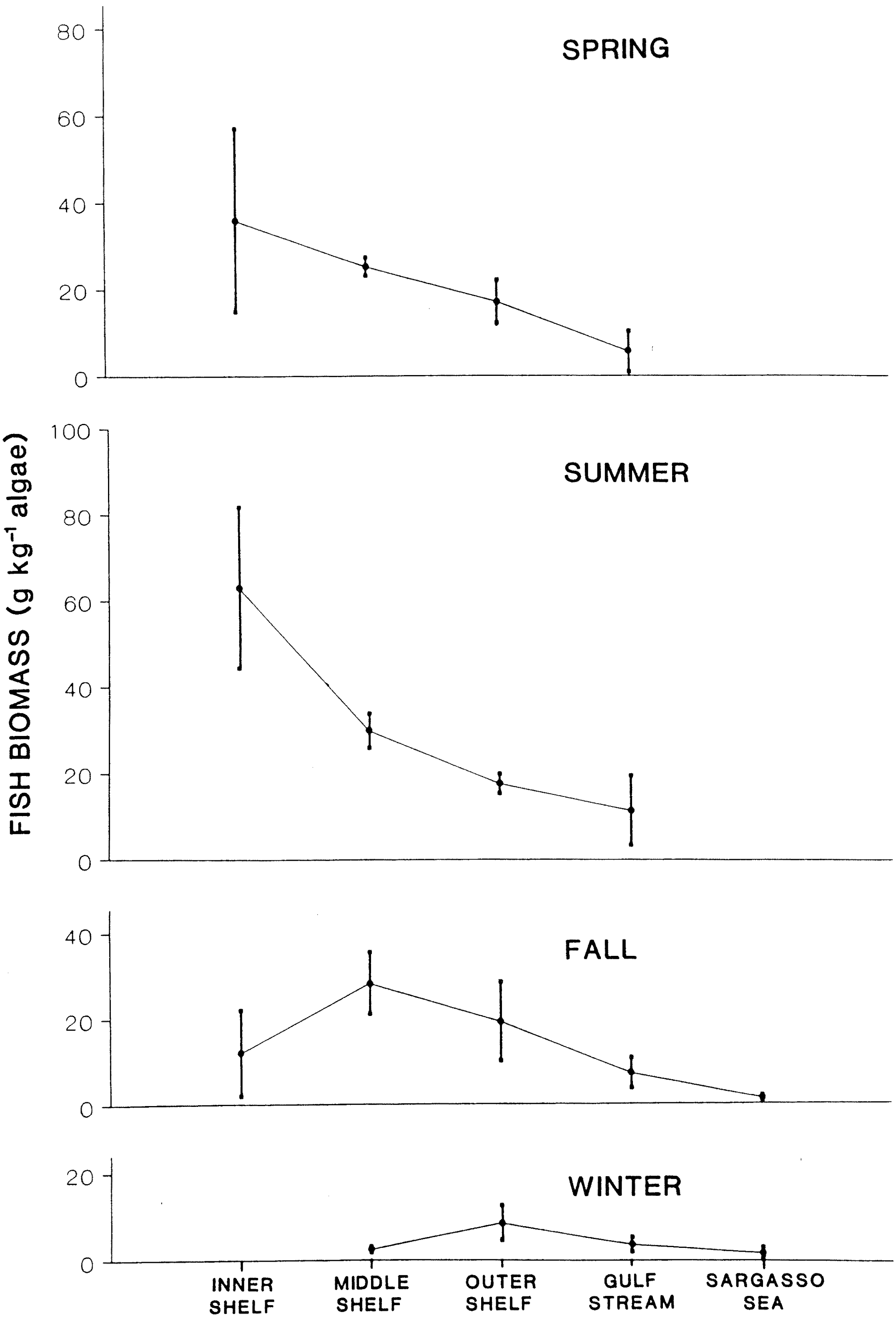

FISH BIOMASS (g kg^{-1} algae)
SPRING
SUMMER
FALL
WINTER
80
60
40
20
0
100
INNER SHELF
MIDDLE SHELF
OUTER SHELF
GULF STREAM
SARGASSO SEA

Table 6. Seasonal and regional relationships between numbers of fish and wet weight of Sargassum determined by linear regression where 5 or more locations (N) were sampled. Parameter estimates are given where the regressions are significant ($P<0.05$). MS = middle shelf, OS = outer shelf and SS = Sargasso Sea.

Season	Region	N	a	b	r	P
Spring	MS	5	0	256.1	0.9951	0.0004
Summer	MS	10	0	28.5	0.6836	0.0293
Fall	MS	8	0	72.5	0.9580	0.0002
Fall	OS	7	-	-	0.6186	0.1386
Fall	SS	5	-	-	0.8335	0.0794
Winter	MS	5	6.3	3.2	0.9994	0.0001
Winter	OS	5	-	-	0.7211	0.1692

Table 7. Seasonal and regional relationships between fish biomass (g) and wet weight of Sargassum determined by linear regression where 5 or more locations (N) were sampled. Parameter estimates are given where the regressions are significant ($P<0.05$). MS = middle shelf, OS = outer shelf and SS = Sargasso Sea.

Season	Region	N	a	b	r	P
Spring	MS	5	0	27.6	0.9954	0.0004
Summer	MS	10	0	24.4	0.9636	0.0001
Fall	MS	8	0	40.3	0.9808	0.0001
Fall	OS	7	0	17.9	0.8014	0.0302
Fall	SS	5	-	-	0.8212	0.0882
Winter	MS	5	0	1.4	0.9945	0.0005
Winter	OS	5	-	-	0.7163	0.1734

relationship was also found between fish biomass and algal biomass over the outer shelf during the fall. No significant relationships could be detected over the outer shelf during winter or in the Sargasso Sea in the fall. The regression equations indicate that fish abundance is seasonally different and predictable, and that the abundance of fishes associated with Sargassum generally exceeds the abundances of fishes in open waters.

The structure of the larval and juvenile fish community associated with pelagic Sargassum varied across seasons and oceanographic regions (Table 3). The number of taxa present increased from the inner shelf to the outer shelf during spring and fall and declined further offshore. The outer shelf during spring was the most speciose. More taxa were present over the inner and middle shelves in summer than either spring or fall, however, species richness declined across the outer shelf and Gulf Stream. Few taxa contributed to the winter ichthyofauna.

In general there were a few moderately abundant to highly abundant taxa (i.e., > 1 fish kg^{-1} algae) and more common to rare species (Table 3). During spring, the percentage of abundant taxa decreased with increased distance offshore from 20% over the inner shelf to 3.8% in the Gulf Stream. The same was true for the common taxa, which declined from 55% to 26.9%. The percentage of uncommon taxa, however, increased from 25% on the inner shelf to 69.2% in the Gulf Stream. During summer, the percentages of abundant taxa exhibited no clear pattern with respect to region. Abundant forms comprised between 7.9 and 20.9% of the fauna with the highest percentage occurring on the middle shelf. The percentage of common taxa declined from inshore (54.8%) to the outer shelf (31.5%) and then increased to 88.9% in the Gulf Stream. Uncommon to rare taxa comprised 32.3% of the ichthyofauna over the inner shelf and increased to 60.5% on the outer shelf. During fall, the highest percentage of abundant taxa (48.1%) occurred in the Gulf Stream. Over the shelf, abundant forms comprised only 7.0 - 10.7% of the community. Common species made up 25% of the fishes on the inner shelf but comprised about 48% of the fauna over the middle shelf, outer shelf and Gulf Stream. Only 18.9% of the species were common in the Sargasso Sea. Uncommon to rare taxa constituted 66.7% of the community over the inner shelf. Their contribution declined across the shelf to 3.7% in the Gulf Stream before and increased to 81.3% in the Sargasso Sea. In winter, abundant taxa comprised about 25% of the communities over the middle and outer shelves and Gulf Stream, but, made up only 6.7% in the Sargasso Sea. The percentage of common taxa increased from the middle shelf (36.4%) to the Gulf Stream (75%) and declined to 53.3% in the Sargasso Sea. Uncommon to rare taxa comprised 36.3% and 40% of the fishes on the middle shelf and Sargasso Sea respectively, but contributed only 12.5% on the outer shelf. No uncommon or rare species were found in the Gulf Stream during winter.

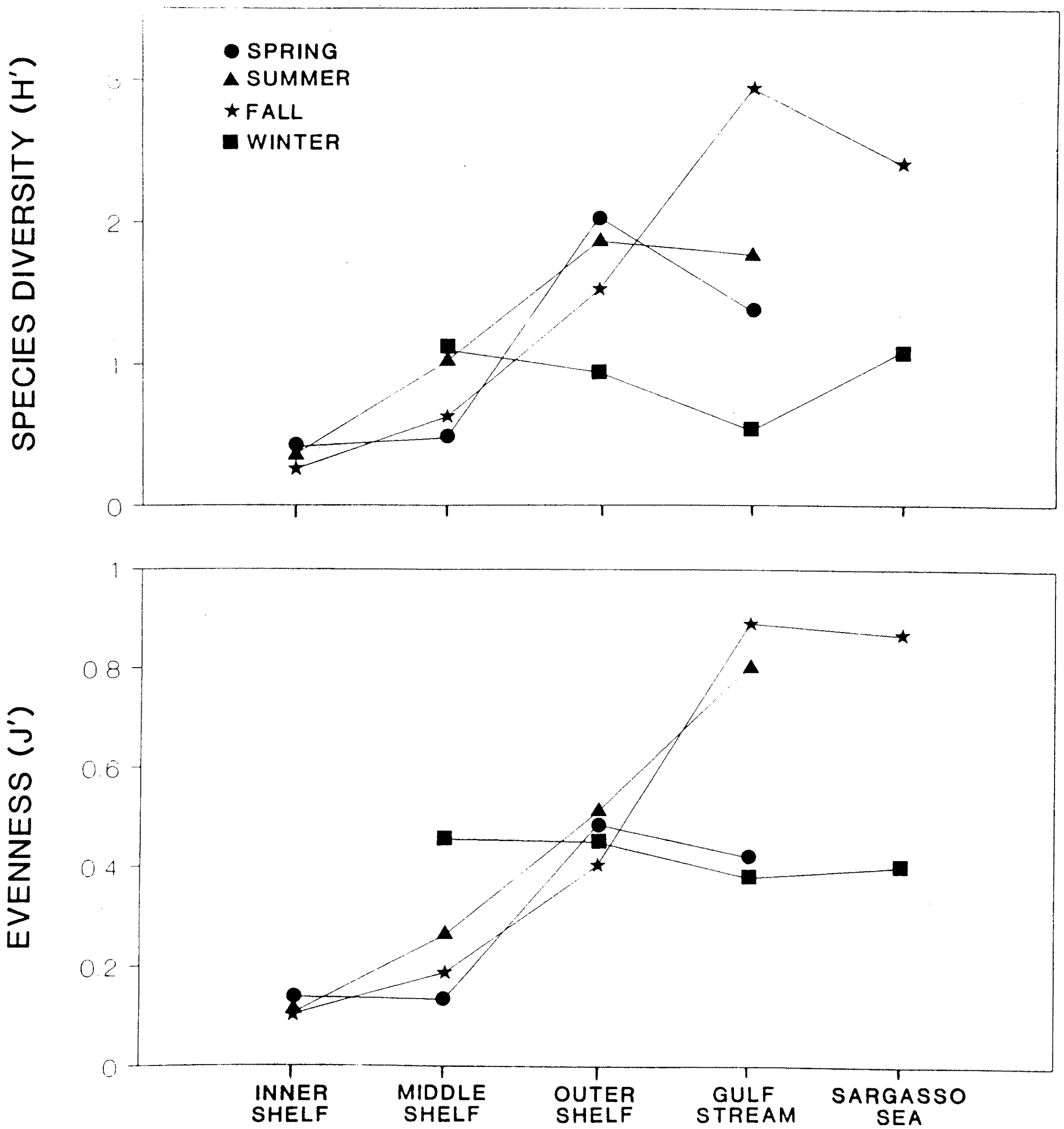
Species diversity (H') was lowest over the inner shelf

(Fig. 4). Diversity increased offshore over the outer shelf during the spring, summer and fall, but decreased slightly in the Gulf Stream during spring and summer, while during fall diversity reached a maximum in the Gulf Stream. Diversity changed little across regions during winter and there was a considerable difference between diversity in the Sargasso Sea in fall (2.4043) and winter (1.0899). Evenness (J') also increased from inshore to offshore, except during winter, when evenness remained rather constant. The ichthyofauna of the Gulf Stream during summer and fall, and the Sargasso Sea during the fall exhibited the highest evenness.

DISCUSSION

This study demonstrates that the abundance of larval and juvenile fishes associated with pelagic Sargassum is affected by season and location, both in terms of numbers of fish and fish biomass (Table 4, Table 5). Other investigators have shown that the invertebrate fauna is similarly variable (Weis, 1968; Fine, 1970; Stoner and Greening, 1984). Regional trends in the mean abundance and biomass of fish show decrease in abundance across the continental shelf and into the Gulf Stream and Sargasso Sea, and a decrease from spring through winter. However, significant differences in fish abundance were not found between all region by season comparisons. This was also true for other studies of larval fishes in the South Atlantic Bight that employed the same design (Yoder, 1983; Collins and Stender, 1989). The lack of significant

Figure 4. Species diversity and evenness of the larval and juvenile fishes associated with pelagic Sargassum in the South Atlantic Bight and adjacent Atlantic Ocean.


SPECIES DIVERSITY (H')
SPRING
SUMMER
FALL
WINTER
0
1
2
3
EVENNESS (J')
0
0.2
0.4
0.6
0.8
1
INNER SHELF
MIDDLE SHELF
OUTER SHELF
GULF STREAM
SARGASSO SEA

differences between all regional and seasonal comparisons may be due to several factors. First, although regional strata based on similar bathymetry has been used to describe the distribution of demersal fishes (Struhsaker, 1969; Lindquist, 1989), such regional stratification may be inappropriate when describing the distribution of pelagic larvae and juveniles. The dynamic physical oceanography in the South Atlantic Bight is likely to have a more pronounced effect on the distribution and abundance of pelagic early life history stages than on demersal species occupying adult habitats. For example, Atkinson and Menzel (1985) noted that the outer shelf region is highly influenced by the Gulf Stream. Topographically induced Rossby waves along the western wall of the Gulf Stream, down stream of the Charleston Bump, impinge upon the outer shelf (Choa and Janowitz, 1979). These meanders in the Gulf Stream front exhibit a periodicity of 2-14 days and have cross-shelf amplitudes of 10's km (Webster, 1961; Brooks and Bane, 1983). Filaments of Gulf Stream water which form as these waves break, can propagate shoreward as far as the inner shelf. Thus, while the regional strata considered here have fixed bathymetric boundaries, the overlying water masses are not independent.

Secondly, the amount of time that Sargassum has been within a given region before it was sampled may have affected the abundance of fishes associated with it. Recruitment of fishes to drift algae and flotsam is initially rapid and continues to increase over time (Senta, 1966a; Hunter and

Mitchell; 1968; Kingsford and Choat, 1985; Kingsford, 1992). The amount of time the algae have been on the surface prior to sampling may also be important. Woodcock (1950) demonstrated that Sargassum sinks in convergence zones when downwelling velocities exceed 4.5 cm sec^{-1}. Buoyancy is not lost however, unless the algae sink below about 100 m or are held under at lesser depths for extended periods. A time-at-depth relationship exists which affects the critical depth at which bladder failure ensues (Johnson and Richardson, 1977). Langmuir cells with their associated convergence zones are set up when wind speeds exceed 4 m sec^{-1} (Langmuir, 1938; Faller and Woodcock, 1964). Such wind forcing is common in the South Atlantic Bight and Sargassum was observed below the surface along these convergence zones on many occasions during this study. Unless the associated fishes, which are predominantly surface forms (Fahay, 1975; Powles and Stender, 1976), remain with the algae during these sinking events, recolonization would have to begin when the algae resurface. Additional sampling with a midwater trawl or opening closing nekton net below and along a convergence might be a good first step in addressing this question. SCUBA techniques or ROV technology could also be useful.

The types of Sargassum habitats sampled (e.g., individual clumps, rafts, weedlines) and the "age" (i.e., growth stage) of algae may have also contributed to the variability. Ida et al.(1967b), Fedoryako (1980), and Gorelova and Fedoryako (1986) described the spatial distribution of fishes in and around clumps of Sargassum. Diodon, Coryphaena, Lobotes, and the exocoetids occupy the outer periphery of the clump, whereas Canthidermis, Balistes, Kyphosus, Abudefduf, Caranx, and Seriola are distributed below the algae. Histrio and Syngnathus are typically hidden within the algae. If such a distribution is maintained when the algae are aggregated into rafts and weedlines, the peripheral species may be undersampled. With regard to algal age, Conover and Sieburth (1964) and Sieburth and Conover (1965) suggest that the Sargassum community could be significantly controlled by the effects of exogenous metabolites on algal epibionts. These substances, which are released during periods of new algal growth, prevent epibiotic colonization, and could alter the trophic resources available to associated macrofauna, including fish (Gorelova and Fedoryako, 1986). Stoner and Greening (1984) examined dip net samples from the Gulf Stream and Sargasso Sea and concluded that algal age did affect the macrofaunal composition, but the abundance of carnivores remained stable. However, since their study dealt primarily with the invertebrate fauna, the effects of these substances on fishes remains unknown.

The numbers of fishes and fish biomass were found to be positively correlated with the wet weight of Sargassum (Table 6, Table 7). Correlations were significant over the middle shelf throughout the year. Fish biomass was also positively correlated over the outer shelf during the fall. The absence of a significant relationship in the Sargasso Sea agrees with the observations of Fedoryako (1980). The slopes of the regressions demonstrate that the seasonal relationships are different, and that the abundance of fishes associated with Sargassum exceed abundance levels in open water. These results indicate that the relationships between fish abundance and Sargassum biomass are predictable, at least over some regions of the continental shelf. This is in general agreement with the finding of Kingsford and Choat (1985) and Kingsford (1992) for fishes and drift algae off New Zealand. Significant correlations were not found by Ida et al. (1967a) or Dooley (1972), but they failed to analyze their data by region and season. It should also be noted that the abundance of motile macrofauna (mostly invertebrates) has also been shown to be related to Sargassum biomass (Stoner and Greening, 1984).

The species composition and relative abundance of individual taxa also varies seasonally and regionally, hence, indices of species diversity are similarly variable (Table 3, Fig. 4). Species diversity was generally highest over the outer shelf during spring and summer and further offshore in the fall. Bortone et al. (1977) also saw an increase in diversity from inshore to offshore in the Gulf of Mexico. H' for his offshore strata was 1.282, which is slightly less than the mean H' (1.5892) for the outer shelf over the course of this study. Species diversity for all Gulf samples was 0.8098. Diversity for all samples in the present study is only slightly higher 1.2491. Thus, it would appear that fish diversity associated with Sargassum habitats over the continental shelf is generally low. Fedoryako (1980; 1989) however, stated that diversity decreases with distance from shore. He apparently was referring only to species richness. The present study clearly shows that while there are numerous taxa utilizing the habitat in shelf waters, they are not equally distributed, and indices of diversity are lowered by the extreme dominance of one or more species (e.g., Monacanthus hispidus).

The balistids and carangids, each represented by 15 species, were the most conspicuous fishes associated with the algae. Both families were also dominant members of the Sargassum ichthyofauna in the Florida Current and Gulf of Mexico (Dooley, 1972; Bortone et al., 1977). Monacanthus hispidus was the most abundant species in the study area and comprised 78.5 % of all fish collected. This species was also found to be the most abundant in the Florida Current (Dooley, 1972) and eastern Gulf of Mexico (Bortone et al., 1977). Of the 104 taxa collected in association with the algae, 26 are recreational or commercial fishery species (Table 3). Not all are common however, but the seasonal abundances of Caranx spp., Elagatis bipinnulata, Seriola spp., Coryphaena hippurus, Pagrus pagrus, Mugil spp., Peprilus triacanthus, and Balistes capriscus clearly indicates the value of the habitat to the early life stages of these species.

The relationships between a number of taxa and the Sargassum habitat remains problematic. The muraenids, gonostomatids, stomiids, myctophids, apogonids, pomacanthids, scarids, acanthurids, istiophorids, scorpaenids, and bothids were represented by one to a few larval specimens. Hippocampus reidi, Syngnathus caribbaeus, S. fuscus, S. springeri, Chloroscombrus chrysurus, Selene volmer, Trachinotes goodei, Coryphaena equisetis, Lutjanus sp., Rhomboplites aurorubens, Chaetodon sp., and Nomeus gronovii were also uncommon to rare. Collectively, these taxa represented only 0.2% of the fishes collected during this study.

Many of the fishes found in association with Sargassum in this study are not restricted to that habitat and are known to frequent various types of drift material, including other species of algae (Besednov, 1960; Mansueti, 1963; Hunter and Mitchell, 1967; Kojima, 1966; Kulczycki et al., 1981; Lenanton et al., 1982; Robertson, 1982; Nakata et al., 1988; Fedoryako, 1989). Some species also associate with fish aggregation devices (FADs) (Rountree, 1989; 1990). Protection, feeding opportunity, cleaning, shade, structural affinity, visual reference, tactile stimulation, historical accident, passive drift and use as a spawning substrate have all been postulated as reasons for such associations (Hirosaki, 1960a; Hunter and Mitchell, 1968; Senta, 1966a; 1966b; 1966c; Dooley, 1972; Helfman, 1981).

Overall the species composition of fishes associated with pelagic Sargassum observed during this study agrees well with earlier reports (Adams, 1960; Parin, 1970; Zaitzev, 1971; Dooley, 1972; Bortone et al., 1977; Fedoryako, 1980). The similarity between the Sargassum ichthyofauna of the Atlantic and that of the Pacific is remarkable. Many of the species are cosmopolitan and while others are represented by congeners (Uchida and Shojima, 1958; Besednov, 1960; Hirosaki, 1960b; Shojima and Ueki, 1964; Ida et al., 1967a; Kingsford, 1992). A comparative study could add to our understanding of the biogeography of marine fishes.

This study has provided an assessment of the species composition, distribution, and abundance of early life history stages of fishes associated with pelagic Sargassum in the South Atlantic Bight and adjacent western Atlantic Ocean. These results should be useful to fisheries management agencies assessing the potential impacts of commercial Sargassum harvests. Based upon the abundance of fishes associated with the algae, it appears that the harvesting of Sargassum in the western Sargasso Sea during the fall and winter would have the least direct impact on larval and juvenile fishes. Additional sampling needs to be conducted during spring and summer to determine if fish abundance in that region remains low throughout the year. The relationship between Gulf Stream intrusions onto the shelf and the distribution of Sargassum should also be investigated. Can the distribution of Sargassum be mapped, quantified, and predicted? Satellite based remote sensing employing multiband radiometry could be useful. Sensors have already been developed and tested that can discriminate Sargassum remotely by its spectral characteristics (Budd, 1982). Other relevant questions also remain unanswered. What affect does the removal of Sargassum from offshore waters have on the availability of the algae as a habitat for young fishes over the continental shelf? How important is the habitat to along-shelf and cross-shelf dispersal and transport of larval and juvenile fishes? Is Sargassum an important factor in reef fish recruitment in the South Atlantic Bight (Kingsford 1990)? Such questions need to be addressed before a clear understanding of the effects of Sargassum harvesting can be realized.

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APPENDIX A

The date, location, sampling method, wet weight of algae and characteristics of *Sargassum* habitats sampled off North Carolina and the adjacent Atlantic Ocean. Gear codes are (D) dip net; (N) neuston net; and (S) surface trawl.

						Description of habitat		
Date	Latitude (°N)	Longitude (°W)	N	Gear	Wet weight of algae (kg)	Temperature (°C)	Salinity (ppt)	algae
09 JUL 91	34.23	076.59	8	D	1.59	27.2	36.0	scattered
09 JUL 91	34.24	076.56	5	D	2.93	27.2	36.0	scattered
29 AUG 91	34.63	076.66	1	N	12.71	26.2	34.4	weedline
29 AUG 91	34.28	076.69	7	D,N	2.72	28.0	36.3	rafts
29 AUG 91	34.34	076.62	1	N	14.53	27.7	36.3	raft
06 SEP 91	34.43	076.63	10	D,N	15.00	28.2	-	weedline
06 SEP 91	34.38	076.62	1	N	0.80	28.2	-	weedline
06 SEP 91	34.32	076.61	1	N	5.79	28.2	-	weedline
06 SEP 91	34.09	076.55	1	N	28.72	-	-	weedline
09 OCT 91	33.12	075.26	1	N	12.71	-	-	weedline

APPENDIX A (Continued)

Date	Latitude (°N)	Longitude (°W)	N	Gear	Wet weight of algae (kg)	Description of habitat: Temperature (°C)	Salinity (ppt)	algae
09 OCT 91	32.87	075.04	2	N	7.04	24.0	35.9	weedline
10 OCT 91	34.11	075.76	1	N	1.20	27.7	-	weedline
10 OCT 91	34.54	075.98	2	D,N	10.28	26.9	-	weedline
11 OCT 91	34.02	076.28	4	D,N	4.75	25.8	35.1	weedline
11 OCT 91	33.91	076.30	2	N	2.61	25.8	35.1	weedline
11 OCT 91	33.65	076.05	1	N	0.19	-	-	weedline
12 OCT 91	32.58	074.85	1	N	18.61	25.1	36.2	weedline
12 OCT 91	32.81	075.17	3	D,N	13.39	26.0	36.6	weedline
12 OCT 91	32.96	075.36	1	N	0.70	-	-	weedline
13 OCT 91	34.39	077.14	3	N	12.30	23.3	35.5	rafts
13 OCT 91	34.29	077.05	13	D,N	18.25	24.0	35.4	weedline
13 OCT 91	34.09	076.75	1	N	2.95	-	-	raft
13 OCT 91	33.96	076.55	1	N	0.30	26.8	35.4	weedline

APPENDIX A (Continued)

Date	Latitude (°N)	Longitude (°W)	N	Gear	Wet weight of algae (kg)	Description of habitat: Temperature (°C)	Salinity (ppt)	algae
13 OCT 91	33.98	076.45	1	N	0.45	26.8	35.4	weedline
15 NOV 91	34.23	076.57	1	N	8.63	22.0	36.1	weedline
15 NOV 91	33.92	076.44	2	N	39.50	22.0	36.2	weedline
11 DEC 91	34.43	076.52	3	D	0.79	21.1	-	scattered
11 DEC 91	34.36	076.48	2	D	1.65	21.1	-	scattered
11 DEC 91	34.07	076.42	2	N	8.40	21.2	-	weedline
11 DEC 91	33.94	076.42	1	N	11.80	24.5	-	weedline
11 JAN 92	34.36	077.16	3	D,N	66.40	18.0	-	rafts
11 JAN 92	34.00	076.72	1	D	0.95	21.0	36.0	scattered
11 JAN 92	33.91	076.58	1	D	0.08	22.9	36.2	scattered
12 JAN 92	33.35	075.98	1	N	263.77	22.0	36.3	rafts
12 JAN 92	33.03	075.66	1	N	2.72	22.0	36.3	rafts
12 JAN 92	32.85	075.50	1	N	2.72	20.4	-	rafts

APPENDIX A (Continued)

Date	Latitude (°N)	Longitude (°W)	N	Gear	Wet weight of algae (kg)	Description of habitat: Temperature (°C)	Salinity (ppt)	algae
12 JAN 92	32.76	075.49	1	N	0.65	20.4	-	scattered
13 JAN 92	33.27	075.90	2	D,N	3.40	22.0	36.2	weedline
15 JAN 92	33.80	076.37	1	N	3.18	23.0	-	weedline
31 JAN 92	35.51	074.72	6	D	2.19	17.0	35.7	scattered
21 FEB 92	33.92	076.39	1	D	0.05	22.5	36.2	scattered
21 FEB 92	34.00	076.44	4	D	1.64	21.1	36.2	scattered
28 FEB 92	34.26	076.54	1	N	1.00	21.9	35.8	weedline
28 FEB 92	34.00	076.41	9	D	0.40	21.1	36.0	scattered
24 APR 92	34.61	076.63	4	D	1.90	21.9	35.2	weedline
24 APR 92	34.19	076.48	6	D,N	15.87	21.9	35.8	weedline
24 APR 92	33.83	076.51	1	N	26.54	25.4	36.0	weedline
12 MAY 92	32.11	078.63	1	D	0.10	23.8	36.3	scattered
12 MAY 92	32.06	078.59	2	D	0.40	23.6	36.3	scattered

APPENDIX A (Continued)

Date	Latitude (°N)	Longitude (°W)	N	Gear	Wet weight of algae (kg)	Description of habitat: Temperature (°C)	Salinity (ppt)	algae
12 MAY 92	32.04	078.55	5	D,N	7.65	23.6	36.3	weedline
12 MAY 92	32.02	079.36	2	N	7.26	23.0	-	weedline
01 JUN 92	34.54	076.66	3	D	1.08	20.9	34.6	scattered
01 JUN 92	34.43	076 64	1	N	5.44	23.0	35.6	weedline
01 JUN 92	34.15	076.58	2	D	0.41	24.2	36.5	scattered
01 JUN 92	34.36	076.61	2	D	0.20	24.5	36.2	scattered
08 JUN 92	34.72	076.67	8	D	5.31	25.3	32.3	weedline
16 JUN 92	34.00	076.74	5	D	0.89	26.2	35.4	scattered
16 JUN 92	33.93	076.53	1	N	17.70	26.0	35.8	weedline
16 JUN 92	34.42	076.69	1	N	7.71	24.1	35.4	weedline
25 JUN 92	34.72	076.67	3	D	6.97	26.4	34.0	scattered
30 JUN 92	34.52	076.69	1	N	2.95	25.5	36.2	weedline
30 JUN 92	34.41	076.72	1	N	24.95	25.4	35.6	weedline

APPENDIX A (Continued)

Date	Latitude (°N)	Longitude (°W)	N	Gear	Wet weight of algae (kg)	Description of habitat: Temperature (°C)	Salinity (ppt)	algae
30 JUN 92	34.00	076.72	4	N,S	25.18	28.1	36.1	rafts
30 JUN 92	33.84	076.51	2	D	1.05	28.4	35.9	scattered
20 JUL 92	28.78	079.55	1	N	2.27	29.9	35.3	raft
20 JUL 92	29.00	079.56	1	N	5.44	30.0	35.5	weedline
21 JUL 92	31.89	078.57	1	N	16.78	29.5	35.5	weedline
19 AUG 92	34.28	076.51	4	D	1.06	28.6	35.5	scattered
19 AUG 92	33.98	076.51	4	D	2.57	28.4	35.7	scattered
19 AUG 92	33.91	076.50	2	N,S	41.50	29.2	35.4	weedline
02 OCT 92	34.46	076.64	1	N	4.99	24.8	-	weedline
19 NOV 92	34.25	076.74	3	D	1.24	21.0	36.3	weedline
27 NOV 92	34.72	076.67	1	D	2.72	19.4	31.6	weedline
20 DEC 92	34.20	076.94	1	D	2.27	17.6	35.3	weedline
18 FEB 93	33.85	076.51	2	D	1.32	22.9	36.1	scattered

APPENDIX A (Continued)

Date	Latitude (°N)	Longitude (°W)	N	Gear	Wet weight of algae (kg)	Description of habitat: Temperature (°C)	Salinity (ppt)	algae
18 FEB 93	33.80	076.45	1	D	0.35	23.0	36.1	scattered
18 FEB 93	33.74	076.38	2	D,N	1.35	22.8	36.3	weedline
10 MAR 93	34.16	076.60	1	D	2.67	17.4	36.2	scattered

APPENDIX B

Size ranges (SL) of larval and juvenile fishes associated with pelagic *Sargassum* in the South Atlantic Bight and adjacent western North Atlantic examined during this study.

Taxa	N	SL (mm)
Muraenidae		
Unidentified	1	56.5
Clupeidae		
Sardinella aurita	4	32.5 - 36.5
Gonostomatidae		
Unidentified	1	13.8
Stomiidae		
Unidentified	1	14.2
Myctophidae		
Unidentified	6	5.5 - 12.5
Gadidae		
Urophycis chuss	10	8.7 - 22.5
U. floridana	169	27.0 - 51.5
U. regia	98	6.7 - 24.0
Urophycis sp.	17	7.5 - 22.0
Antenariidae		
Histrio histrio	445	6.0 - 63.0
Exocoetidae		
Cypselurus melanurus	313	3.2 - 47.0
Hemiramphus balao	1	27.0

Appendix B (Continued)

Taxa	N	SL (mm)
H. brasiliensis	9	19.0 - 68.0
Hemiramphus sp.	12	9.5 - 23.0
Hirundichthys affinis	17	3.1 - 12.8
Hyporhamphus unifasciatus	23	4.2 - 24.0
Hyporhamphus sp.	3	8.8 - 10.5
Paraexocoetus brachypterus	58	3.0 - 23.0
Prognichthys gibbifrons	57	3.0 - 14.2
Unidentified	3	damaged
Belonidae		
Tylosurus acus	12	10.5 - 169.0
Unidentified	1	15.0
Syngnathidae		
Hippocampus erectus	5	21.0 - 30.0
H. reidi	1	15.3
Syngnathus caribbaeus	1	52.5
S. floridae	4	69.5 - 77.5
S. fuscus	1	74.5
S. pelagicus	113	31.0 - 140.0
S. springeri	1	65.5
Syngnathus sp.	8	27.0 - 44.0
Priacanthidae		
Priacanthus arenatus	2	28.0 - 37.5
Pristigenys alta	5	12.0 - 18.0
Unidentified	4	3.7 - 7.5

Taxa	N	SL (mm)
Apogonidae		
Unidentified	9	6.3 - 9.2
Carangidae		
Caranx bartholomaei	114	10.8 - 66.0
C. crysos	284	5.5 - 103.5
C. hippos	9	18.7 - 36.5
C. ruber	122	7.2 - 86.5
Caranx sp.	8	3.6 - 4.3
Chloroscombrus chrysurus	2	6.7 - 6.8
Decapterus punctatus	825	10.0 - 50.5
Decapterus sp.	1	12.5
Elagatis bipinnulata	22	4.6 - 59.5
Selar crumenophthalmus	13	8.8 - 20.7
Selene volmer	3	9.5 - 11.8
Seriola dumerili	57	15.7 - 80.5
S. fasciata	8	16.8 - 50.0
S. rivoliana	128	13.8 - 87.0
S. zonata	23	16.0 - 51.0
Seriola spp.	263	2.5 - 37.0
Trachinotus falcatus	15	5.8 - 12.0
T. goodei	1	9.3
Trachurus lathami	29	6.7 - 15.5
Unidentified	8	4.6 - 8.7
Coryphaenidae		

Appendix B (Continued)

Taxa	N	SL (mm)
Coryphaena equisetis	1	18.5
C. hippurus	26	8.0 - 69.0
Lutjanidae		
Lutjanus sp.	1	15.3
Rhomboplites aurorubens	1	22.5
Lobotidae		
Lobotes surinamensis	26	6.3 - 74.0
Sparidae		
Pagrus pagrus	18	11.1 - 15.7
Mullidae		
Mullus auratus	151	5.5 - 45.0
Unidentified	109	2.9 - 11.2
Kyphosidae		
Kyphosus sactatrix	85	5.8 - 56.5
Chaetodontidae		
Chaetodon sp.	8	4.5 - 11.0
Pomacanthidae		
Unidentified	3	4.3 - 7.5
Pomacentridae		
Abudefduf saxatilis	323	7.5 - 31.5
Scaridae		
Unidentified	1	7.1
Mugilidae		
Mugil cephalus	7	12.7 - 18.7

Taxa	N	SL (mm)
M. curema	272	5.5 - 24.0
Sphyraenidae		
Sphyraena sp.	13	8.3 - 37.5
Blenniidae		
Parablennius marmoreus	40	13.2 - 19.7
Unidentified	3	8.1 - 12.8
Acanthuridae		
Acanthurus sp.	1	4.9
Xiphiidae		
Xiphius gladius	1	23.3
Istiophoridae		
Makaira nigricans	2	8.9 - 16.7
Unidentified	1	6.2
Stromateidae		
Nomeus gronovii	1	14.5
Peprilus triacanthus	109	5.8 - 38.5
Psenes cyanophrys	20	13.7 - 56.5
Scorpaenidae		
Unidentified	6	4.5 - 8.0
Dactylopteridae		
Dactylopterus volitans	11	3.2 - 13.8
Bothidae		
Bothus sp.	3	8.3 - 13.7
Cyclopsetta fimbriata	2	7.2 - 7.8

Appendix B (Continued)

Taxa	N	SL (mm)
Balistidae		
Aluterus heudeloti	7	24.0 - 52.0
A. monoceros	17	16.0 - 87.0
A. schoepfi	24	13.7 - 54.5
A. scriptus	11	30.5 - 161.5
Balistes capriscus	307	8.7 - 103.0
B. vetula	3	34.0 - 37.0
Cantherhines macrocerus	7	42.0 - 61.0
C. pullus	30	25.0 - 59.0
Canthidermis maculatus	27	7.0 - 66.5
C. sufflamen	9	10.8 - 43.0
Monacanthus ciliatus	92	8.7 - 26.0
M. hispidus	21,569	6.5 - 81.5
M. setifer	33	17.3 - 58.0
M. tuckeri	15	16.2 - 25.0
Xanthichthys ringens	1	69.5
Unidentified	4	4.0 - 7.3
Ostraciidae		
Lactophrys sp.	4	5.8 - 7.8
Tetraodontidae		
Diodon holocanthus	2	47.0 - 50.5
Sphoeroides spengleri	27	10.0 - 17.5
Unidentified	553	2.7 - 14.2

BIOGRAPHICAL SKETCH

Lawrence R. Settle was born in Charlottesville, Virginia, on 23 November 1958. In 1979, he graduated from Cape Fear Technical Institute with an A.A.S. in Marine Laboratory Technology. In 1989, he graduated from the University of North Carolina at Wilmington with a B.S. in Marine Biology and was nominated for the Hoggard Medal for Achievement. He entered the graduate program in Marine Biology at the University of North Carolina at Wilmington in 1991 where he worked under the direction of Dr. David G. Lindquist. In 1991, he received a scholarship from the North Carolina Sportfishing Association. Mr. Settle graduated in May 1993. His work experiences include those of summer naturalist at Carolina Beach State Park, lab technician and quality assurance analyst for Mine Safety Appliances Company, field biologist for the North Carolina State Museum of Natural Sciences, and biological technician with the National Marine Fisheries Service in Beaufort, North Carolina. Mr. Settle has co-authored several research papers and reviews on the biology of fishes and reptiles and plans to continue his professional interests in fisheries oceanography and herpetology. He is a member of the Early Life History Section of the American Fisheries Society, the Herpetologists' League, the Society for the Study of Amphibians and Reptiles, the North Carolina Herpetological Society, and the North Carolina Academy of Science.