Using FAD's to Attract Fish at Coastal Fishing Piers

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Introduction

Several hundred fishing piers line the coast of the United States, providing hundreds of thousands of man days of recreational fishing. The North Carolina coast contains 34 fishing piers (Goldstein, 1978), each providing thousands of man days of recreational fishing per year. These piers contribute significantly to the local economies where they are located.

For many years pier owners have grappled with the idea of improving fishing by concentrating fish near the pier. Traditional artificial reef development has been impossible because: 1) It would place obstructions on the bottom where pier fishermen would lose their gear, 2) it

ABSTRACT—Eighteen midwater fish aggregating devices (FAD's) were deployed alternately off the ends of two piers (one acting as a control) in Wrightsville Beach, N.C., to evaluate their ability to attract coastal fishes. Creel censuses of pier fishermen and diver surveys of FAD's were conducted to determine: 1) The aggregation capabilities of FAD's, by number, size, and fish species; 2) the effect of FAD's on catch per unit of effort by species; and 3) the durability of the FAD's in this environment.

Results of the study were mixed. The FAD's proved to be successful in aggregating baitfish in the nearshore environment. An average of 3.67 ± 8.91 fish, representing 35 different species, appeared on each FAD. The control site had no fish. The FAD units were not successful in improving fishing success at the fishing piers most likely due to the distance of placement from the end of the pier (229 m). The FAD units were durable enough to hold up under normal conditions, but slightly more than half of the FADs were lost and most were damaged during a Category 2 hurricane.

is difficult to obtain permits to place hard rubble on the bottom in the surf zone because of the potential for erosion problems, and 3) the placement of a hardrubble reef would be expensive.

Therefore, about the only method of fish enhancement attempted has been to chum off of piers. However, chum availability and its high costs have been a problem in recent years, and this practice is no longer used.

In recent years, in part because of rising energy costs, there has been increased effort toward the development of midwater fish aggregating devices (FAD's). The purpose has been to aggregate fish to reduce the search time for both commercial and recreational fishermen. Work by Shomura and Matsumoto (1982) demonstrated that such units will aggregate pelagic fish in offshore areas. In most cases, they indicated a doubling or tripling of fish catches. Wickham et al. (1973), Wickman and Russell (1974), and Hammond et al. (1977) showed that various kinds of midwater structures were attractive to coastal pelagic sportfishes off Panama City, Fla., and the central South Carolina coast. Again, these studies indicated a doubling in sportfish catches when compared with unenhanced control areas. A South Caro-

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In the fall of 1983, a grant was obtained from the UNC Sea Grant College to investigate the potential of FAD's to aggregate fish in the nearshore ocean environment and to determine if they would improve the catch per unit of effort on nearby fishing piers. We hypothesized that the FAD units would remain intact in the nearshore environment and that pelagic sportfish would be attracted to the FAD units. We further hypothesized that these fish would move back and forth from the units to the pier and be available to anglers. Specifically, the objectives were to:

1) Determine the FAD aggregation capabilities by number, size, and fish species;

2) Determine the durability of the FAD's in this environment; and

3) Determine the effect of the FADs on catch per unit of effort by species on a North Carolina fishing pier using a control pier as a base.

Materials and Methods

Study Area Description

The primary factors associated with choosing a study site were the proxim-



Figure 1.—Study area at Wrightsville Beach, N.C., showing location of the two fishing piers.

ity and similarity of two adjacent fishing piers. One pier was to be FADenhanced while the other was to act as a control. Similarity factors included pier length, water depth, seasonality, and fishing restrictions. Two piers at Wrightsville Beach, N.C., Johnnie Mercer's Pier¹ and Crystal Pier, were chosen (Fig. 1).

The study sites were located about 220 m off both piers, which are about

2.5 km apart. Mean depth of the study sites varied from 7 to 10 m; the substratum was primarily sand. Each site was marked off using a spar buoy $(115 \times 23 \text{ cm})$ at each corner.

Each site consisted of three 100 m long transects (Fig. 2). The north and south transects contained eight concrete-filled tires, two of which anchored the spar buoys. The remaining six anchored the midwater FAD's. The middle transect consisted of six tires for FAD anchoring. All three transect lines were interconnected using 7 mm nylon line. In addition, a 4S Danforth anchor was tied into the end of each 100 m transect for additional stability (Fig. 3, 4).

The anchoring systems were deployed off Johnnie Mercer's Pier on 1 May 1984 and off Crystal Pier on 2 May 1984. Each of the spar buoys was marked to discourage deep trolling, anchoring, and to designate the area as an artificial reef and research area.

The eighteen midwater FAD's used in this study were supplied by McIntosh Marine, Inc., Fort Lauderdale, Fla. Each FAD consisted of four fiberglass rods, 7 mm knotless netting, a PVC nose cone, a large midwater buoy, and four rod buoys (Fig. 5). If properly balanced, the FAD's positioned themselves horizontally in the water column about 4-5 m below the surface (Fig. 2, 5). The 18 FAD's made up the experimental study site. Although the control site was void of any FAD's, a vertical line and large midwater buoy identical to the experimental site (minus the FAD) were deployed on each transect string. This allowed comparisons between the attracting capabilities of the FAD's, to that of the other components of the array.

All 18 FAD's were transported to Crystal Pier on 3 May 1984. Stringing two or three FAD's together, two divers deployed each of the eighteen FAD's. The pier owners were concerned that as the location of the FAD's spread among fishermen, business on the pier void of FAD's would suffer. Consequently, the FAD's were alternated between both piers every 5-6 weeks. Additionally, the surface marker buoys were left off the ends of both piers during the entire period in order to disguise the location of the FAD's to fishermen.

Another potential problem was the loss of fishing gear and/or fish due to entanglement with the FAD's. The pier owners were quite adamant about placing the FAD's far enough away to avoid this. A 750-foot (229 m) location distance from the end of the pier was agreed upon, since some fishermen using float rigs were capable of fishing that far out. Further, North Carolina pier owners have exclusive rights to

¹Mention of trade names or commercial firms does not imply endorsement by the National Marine Fisheries Service, NOAA.

use of an area 750 feet from the sides and end of their pier. It was theorized that pelagic fish would roam between the perimeter of the units and the pier and be available to catch. This distance may have been unnecessarily restrictive, and will be discussed later.

Pier Survey Procedure

During a 10-week period prior to FAD enhancement (from 1 October to 14 December 1983), pier fishermen were interviewed to obtain catch per unit of effort (CPUE) data on the piers. The purpose was to obtain data to determine whether one pier naturally outfished another and to test the survey instrument. Fishermen were then sampled simultaneously 3 days per week and 3 hours per day from 3 May 1984 to 16 October 1984. The days of the week and the hours of the day were chosen randomly from a random numbers table. Each day was divided into three parts: 0600-1200, 1200-1800, and 1800-2400 hours. Each of the periods was broken into six 1-hour segments, and one time slot for each segment was chosen randomly.

The effective fishing area on each pier was about 229 m. The pier was divided and recorded in three 76 m sections—nearshore, middle, and end. Again, fishermen were interviewed simultaneously at each pier during these times to reduce day, time, and weather variables as much as possible. Attempts were made to interview all fishermen; however, when the pier was too crowded to do so, an equal number of fishermen were chosen from each section of the pier.

The data recorded included the date, time, number of fishermen, number of fishing rods used, wet gear time (minutes \times rods used), number and mean weight of fishes caught by species, and weather conditions (i.e., wave height, wind speed and direction, and water temperature). Weight of fish was recorded using a portable 22.68 kg scale. During the 1984 season the survey was continued while both piers were alternately enhanced with FAD's.

Underwater Fish Assessment

Daylight censusing was performed



Figure 2.—Configuration of the 18 FAD units near the end of the experimental pier. Inset shows location of FAD in water column.



Figure 3.—Anchoring system showing arrangement of concrete-filled tires. Arrows represent small (7S) Danforth anchors. The surface spar buoys are shown.



Figure 4.—Close-up of anchoring system. The 9 mm chain extends through the tire (placed before concrete was poured into tire).

during high tide to take advantage of greater underwater visibility. The dive boat was anchored to the southeast spar buoy, where the water temperature (using a standard mercury thermometer) and underwater visibility (using a Secchi disc) were measured. Three substructures were surveyed, including FADs', spar buoys, and FAD anchor weights. Two divers, positioned as far away as visibility permitted and on opposite sides of the substructures, simultaneously recorded the fish species and their abundance on a biweekly basis. Observations were standardized at 2 minutes at each FAD. Unidentified species were collected using a pole spear or hand net, and preserved in a 10 percent buffered formalin solution for identification in the laboratory.

The abundance and diversity of fishes associated with the three substructures were independently censused by the two divers. Because of the scuba diving time restrictions, only 9 of the 18 FAD's (odd or even numbered) were censused on any one day. Hence, all 18 FAD's were censused once a week. After each FAD was censused, structural damage, encrusting and fouling organism diversity, and abundance were recorded. Once the experimental site censusing was completed, the control site was similarly surveyed using a Pelican Float to assist diver orientation in the water column. Fish behavioral observations were recorded on separate dives and a diel study was also conducted on separate dives to assess nocturnal abundance of fishes.

Fish censusing, begun on 19 May 1984, was intended to continue until 1 December 1984; however, the project was prematurely terminated owing to the effects of Hurricane Diana (12-13 September 1984). The last day of fish censusing was 26 August 1984. Fish

Table 1The average	total	numbers	of	fishes	ob-
served for all substruct	ures	(e.g., 18 F	AD	's, 18	tires,
and 4 spar buoys) for ea	ach s	ample wee	k.		

Study site	5	Substructure						
	FAD	Tire	Spar buoy	Total				
Experimental	638.67	170.29	595.24	1404.20				
Control	0.001	57.78	153.41	211.19				

¹Observations made in the water column corresponding to the location of the experimental FAD. census data were analyzed using the Statistical Analysis System (SAS), and CPUE data were analyzed with the Statistical Package for the Social Sciences (SPSS) subprogram T-TEST (Nie et al., 1975).

Results

Underwater Surveys

Throughout the study, each diver made 67 dives, representing a total of 116.55 hours of underwater observation. During 68.19 hours of underwater observation at the experimental site, an average of 1404.20 fishes were observed for three substructures (Table 1). At the control site, an average of 211.19 fishes were observed for the substructures during 21.43 hours of underwater observation (Table 1). The remaining 26.93 hours involved behavioral and diel/nocturnal observations.

The total fish fauna (Table 2) observed at the experimental site included 35 species (21 families and 31 genera). Of the 35 species, 26 species were encountered solely at the FAD's

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Figure 5.—An individual FAD unit.

during day and night observations (Table 2). Twenty-two species were sighted at the tire anchor weights (Table 2). Thirteen of these species were different from those observed at the FAD's. Species observed at the spar buoys (Table 2) of the experimental site consisted of 14 species.

Blue runners, *Caranx crysos*, and butterfish, *Peprilus triacanthus*, were the most abundant species observed at the FAD's (Table 3). Of the 26 species observed at the FAD's, 10 are considered pelagics, and they represented 79 percent of the mean number of individuals/species observed at the FAD's (Table 3). Three of the 10 pelagics are considered target species or species of prime interest. These species represented 8 percent of the mean number of individuals/species observed at the FAD's (Table 3).

During the study, there was a mean total of 5.76 ± 1.85 species observed

Table 2.—Fish species observed at both the experimental and control sites over the entire study period. A plus (+) indicates fish observed at least once at that site and substructure; a dagger (†) indicates one of the ten pelagic species.

	Ex	perim	ental site	Control site		
Species	FAD	Tire	Spar buoy	Midwater buoys	Tire	Spar buoy
Balistidae						
Scrawled filefish, Aluterus scriptus	+		+			
Planehead filefish, Monacanthus hispidus	+	+	+		+	+
Batrachoididae						
Oyster toadfish, Opsanus tau		+				
Blenniidae Feather blenny, <i>Hypsoblennius hentzi</i>	+	+				
Crested blenny, Hypleurochilus geminatus ¹	+	ат.»				
Bothidae						
Summer flounder, Paralichthys dentatus		+			+	
Carangidae						
Blue runner, Caranx cryso †	+	+	+		+	+
Atlantic bumper, <i>Chloroscombrus chrysurus</i> † Round scad, <i>Decapterus punctatus</i> †	+	+	+			-4
Greater amberjack, Seriola dumerili†	+	т	+			+
Almaco jack, Seriola rivoliana †	+		+			+
Banded rudderfish, Seriola zonata†	+		+			+
Echeneidae						
Remora, Remora remora	+					
Engraulidae						
Striped anchovy, Anchoa hepsetus	+					
Ephippidae						
Atlantic spadefish, Chaetodipterus faber	+					
Gadidae Carolina hake, <i>Urophycis earlli</i> ¹	+					
Carolina nake, <i>Drophycis eanil</i>	+					
Haemulidae						
Tomtate, Haemulon aurolineatum		+			+	
Pigfish, Orthopristis chrysoptera	+	+				
Lutjanidae						
Gray snapper, Lutjanus griseus ¹	+					
, , , , , , , , , , , , , , , , , , , ,						
Pomatomidae						
Bluefish, Pomatomus saltatrix †	+		+			+
Rachycentridae						
Cobia, Rachycentron canadum †	+	+	+			+
Sciaenidae Silver perch, <i>Bairdiella chrysoura</i>					+	
Cubbyu, Equetus umbrosus					+	
Spot, Leiostomus xanthurus	+					
Atlantic croaker, Micropogonias undulatus		+				
Coombridge						
Scombridae Spanish mackerel, Scomberomorus maculatus†	+					
Serranidae						
Rock sea bass, Centropristis philadelphica		+	+			
Black sea bass, <i>Centropristis striata</i> Sand perch, <i>Diplectrum formosum</i>	+	+			++	
Unknown post-larva	+					
Sparidae						
Sheepshead, Archosargus probatocephalus Spottail pinfish, Diplodus holbrooki	+	+				
Pinfish, Lagodon rhomboides	+	+	+		+	+
Scup, Stenotomus chrysops	+	+	+		+	
Stromotoidae						
Stromateidae Butterfish, <i>Peprilus triacanthus†</i>	+	+			4	
batterion, r epinus inacaritrius j	Ŧ	Ť			+	
Synodontidae						
Inshore lizardfish, Synodus foetens		+			+	
Fetraodontidae						
Puffer, Sphoeroides sp.			+			
riglidae						
Leopard searobin, Prionotus scitulus		+	+		+	

¹Observed at the damaged FAD's during post-Hurricane Diana assessment.



Figure 6.—The total number of fish species observed per month at the experimental site (FAD's only).

per sample day in the experimental site and a mean of 3.67 ± 8.91 individuals for each FAD. A total of six different species were observed in May, and a maximum of 15 species observed in July (Fig. 6). Of the 17 species collected, the mean standard length of the summer flounder, *Paralichthys dentatus*, was the largest (Table 4).

Fishes were not observed in the upper section of the water column, analogous to FAD placement, within the control site (Table 2). Fourteen species were observed at the FAD anchor weights at the control site (Table 2). This was five species fewer than observed at the experimental FAD anchor weights. The fish fauna at the spar buoys at the control site consisted of nine species (Table 2).

Of the 12 species associated with the FAD anchor weights at both the experimental and control sites, the abundance of scup, Stenotomus chrysops, and summer flounder was significantly greater at the experimental site. In addition, there was no significant difference in the abundance between the nine species observed at the spar buoys between both the experimental and control sites. Blue runner, the most common species observed at the spar buoys, showed no significant difference in abundance between the spar buoys and FAD's (P>0.05 Wilcoxon Rank Sum Test). In all cases, no fishes were associated with the midwater buoy at the control site. Therefore, no statistical analysis was necessary.

Table 3.—Mean number of individuals per FAD for each species observed during dives (n=30) at the FAD's over the entire study period. Species observed during post-Hurricane Diana assessment are not included.

Species	Mean	(SD)	No. of dives observed
Scrawled filefish	1.43	(1.21)	8
Striped anchovy	1.00	()	1
Blue runner	12.33	(12.32)	24
Black sea bass	1.59	(1.10)	20
Atlantic spadefish	1.56	(0.88)	4
Atlantic bumper ¹	2.08	(1.00)	6
Round scad ¹	2.98	(2.72)	14
Spottail pinfish	1.17	(0.41)	5
Feather blenny	1.00	(0.00)	1
Pinfish	1.26	(0.61)	22
Spot	1.00	(0.00)	2
Planehead filefish	1.89	(1.68)	21
Pigfish	4.00	(1.15)	4
Bluefish ^{1,2}	5.33	(5.86)	1
Butterfish ¹	45.69	(137.12)	4
Cobia ^{1,2}	1.00	(0.00)	1
Remora	1.00	(0.00)	1
Spanish mackerel ^{1,2}	1.50	(1.00)	2
Greater amberjack ¹	1.00	()	1
Almaco jack ¹	1.92	(1.27)	9
Banded rudderfish ¹	1.15	(0.36)	15
Scup	2.00	(0.00)	2
Unknown serranid post larva	1.00	(—)	1

¹Pelagic species. ²Target species.

Water visibility and temperature at the experimental site averaged 4.6 m (range=2.0-7.0 m) and 22.8°C (range=17.2°-25.6°C). There was no significant correlation in the mean number of fishes sighted at the FAD's at varying water visibilities or temperature (P>0.05 GLM and ANOVA). In addition, there was no interaction between water visibility and temperature with respect to the mean number of fishes observed at the FAD's (P>0.05 GLM).

Initial recruitment of fishes on the FAD's did not occur rapidly. Fishes were observed for the first time after the FAD's had been deployed 1 week. The planehead filefish, Monacanthus hispidus; black sea bass, Centropristis striata; pinfish, Lagodon rhomboides; blue runner, round scad, Decapterus punctatus; and the banded rudderfish, Seriola zonata, were the only species observed at the FAD's consistently during the study period (Table 5). Blue runner, black sea bass, and pinfish were not initially observed until 5 June 1984. There was no significant difference in the mean number of individuals per sample day, concerning each of the above six species, when observed at the FAD's over the study period

Table 4.—Mean standard length (SL) and size ranges for specimens collected at the experimental site. Where only one specimen was collected, a dash indicates the range was absent.

Species	Mean size (SL in mm)	Size range (mm)
Striped anchovy	45.0	_
Silver perch	160.0	
Blue runner	115.0	
Black sea bass	98.0	
Atlantic bumper	37.0	_
Round scad	165.0	
Crested blenny	23.6	11-42
Feather blenny	43.0	20-60
Pinfish	85.0	70-100
Planehead filefish	22.8	17-38
Pigfish	152.0	
Summer flounder	197.0	
Butterfish	43.7	43-44
Leopard searobin	85.0	70-100
Almaco jack	145.0	110-215
Banded rudderfish	105.0	60-150
Scup	52.5	45-60

Table 5.—Weekly occurrence of each species observed during dives (n=26) at the FAD's in May (n=2), June (n=8), July (n=11), and August (n=5) during daytime high tide.

		Month and week no.										
	May	May June			_	July			Aug.		g.	
Species	3	1	2	3	4	1	2	3	4	2	3	4
Bluefish	+											
Scup	+											
Butterfish	+	$^{+}$										
Feather blenny			$^{+}$									
Scrawled filefish					+	+	+	+	+			
Spot						+			+			
Atlantic spadefish						+						+
Spottail pinfish							+	$^{+}$	$^{+}$			+
Remora							+					
Greater amberjack							+					
Almaco jack							+	$^{+}$	+		+	+
Striped anchovy									+			
Cobia									$^{+}$			
Atlantic bumper											+	+
Pigfish												+
Spanish mackerel												+
Banded rudderfish	+	+	+	$^{+}$	+	+	+	+	+			
Planehead filefish	+	+	$^{+}$	$^{+}$	+	$^{+}$	$^{+}$	+		$^{+}$	+	+
Round scad	+	$^{+}$	+				+	+	+		+	+
Blue runner		+		$^{+}$	+	+	+	$^{+}$	+	+	+	+
Black sea bass		+	$^{+}$		+	+	+	$^{+}$	+	+	+	
Pinfish		+	+	+		+	+	+	+		+	

(P>0.05 GLM and ANOVA).

Scup and bluefish, *Pomatomus* saltatrix, were observed in May through early June (Table 5). The feather blenny, *Hypsoblennius hentzi*, was observed only in mid June (Table 5). The scrawled filefish, *Aluterus scriptus*, was initially observed in mid June through the end of July. Five species, spot, *Leiostomus xanthurus*; remora, *Remora remora*; greater amberjack, *Seriola dumerili*; striped anchovy, *Anchoa hepsetus*; and cobia, *Rachycentron canadum*, were

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Table 6.—Mean number (SD) of individuals for each species observed during dives (n=7) at the FAD's during a 24-hour diel study.

	C	Day	Ni	No. of dives	
Species	X no.	(SD)	X no.	(SD)	observed
Blue runner	10.14	(8.2)	9.82	(6.02)	7
Black sea bass	2.41	(1.43)	1.00	(0.00)	7
Atlantic spadefish			1.00	(0.00)	2
Atlantic bumper	1.90	(0.32)	1.00	()	5
Round scad	1.50	(0.54)			2
Pinfish	1.22	(0.42)	1.20	(0.44)	6
Planehead filefish	1.00	(0.00)	1.00	(0.00)	7
Pigfish	4.33	(0.82)	2.00	()	4
Spanish mackerel	1.50	(1.00)			2
Almaco jack	3.33	(2.10)			2

observed only in July. The Atlantic spadefish, *Chaetodipterus faber*; spottail pinfish, *Diplodus holbrooki*; and almaco jack, *Seriola rivoliana*, were observed in the latter half of the study. The Atlantic bumper, *Chloroscombrus chrysurus*; pigfish, *Orthopristis chrysoptera*; and Spanish mackerel, *Scomberomoros maculatus*, were observed only in August (Table 5).

During a 24-hour diel study, 10 species (7 families and 10 genera) were observed, four of which were jacks (Table 6). Atlantic bumper, pigfish, Atlantic spadefish, and Spanish mackerel were sighted only during the 24hour diel study. There was no significant difference in the abundance between the 10 species observed during the 24-hour diel study with respect to night and day periods.

Blue runner were not oriented to any specific section of the FAD. Small numbers of 1-35 individuals were commonly observed swimming around the outside of the FAD's, occasionally exiting through the small opening at the nose cone. They appeared to enter the FAD when threatened by larger fish or at the approach of divers. Schools of blue runner were at times intermixed with a few round scad and almaco jack. Blue runner typically remained close to the FAD's, straying only 1-1.5 m away. Many times, however, schools followed the divers from one FAD to another.

Black sea bass were observed in association with the FAD's 2.5 weeks after FAD deployment. They positioned themselves on the FAD netting near the nose cone, and were not observed in pairs or small schools. Several times this species was observed actively grazing on the fouling organisms attached to the FAD netting. No other species was observed inside the FAD when black sea bass were present. On numerous occasions a small school of blue runner would attempt to swim into the FAD, only to suddenly veer away when confronted by the territorial displays (flaring of fins) of black sea bass. Black sea bass were observed ascending the vertical line from the FAD anchor weight, feeding for a few minutes on the underside of the FAD netting and then descending back to the FAD anchor weight by way of the vertical line.

Within two weeks after the FAD's were deployed, fouling organisms and barnacles were found in relatively small numbers on the FAD netting and rod buoys. After 1-1.5 months, the FAD's had a dense growth of encrusting and fouling organisms. Two species of barnacles, Chthamalus fragilis and Balanus amphitrite, were present on the rod buoys, nose cones, and fiberglass rods. The FAD netting was primarily fouled with hydroids, Tubularia crocea and Pennaria tiarella, and bryozoans, Bugula sp. There were many caridean shrimps, Hippolyte sp. and Palaemonetes sp., amphipods, Gammarus sp.; crested blennies, Hypleurochilus geminatus, and spider crabs, Libinia emarginata, associated with the netting and fouling organisms.

Butterfish were primarily observed in large schools of 60-200 individuals of varying sizes. Butterfish were usually found swimming near the upper, open-ended section of the FAD, occasionally straying 2-3 m from the FAD. When divers approached butterfish, they moved into the FAD.

Planehead filefish appeared to use the FAD primarily for protection. Solitary or small schools of 1-2 cm specimens hovered very close to the netting located near the fiberglass rods, rod buoys, or the folds of the nylon netting at the mouth of the FAD. Once a dense growth of fouling organisms was present, small individuals were difficult to observe due to their cryptic coloration. Larger individuals (10-15 cm), which were not as abundant, were usually associated with the nose cone. These larger individuals were rarely observed feeding on the fouling organisms attached to the FAD netting and vertical line.

Single individuals or pairs of banded rudderfish were apparently very territorial around the FAD; no other species were observed when they were present. Banded rudderfish actively patrolled the area around the FAD's, investigating and/or chasing off anything (e.g., fishes; jellyfish, Stomolophus; divers) that came within close proximity of the FAD. Banded rudderfish strayed as far as 5 m away from the midwater FAD to inspect approaching divers, and appeared fearless of them. While the divers were present, banded rudderfish constantly approached, fled and reapproached the divers while simultaneously altering the intensity of their black bars.

Pinfish appeared to use the FAD's primarily for feeding. Large individuals (10 to 20 cm) pecked and nibbled at the fouling organisms attached to the FAD netting, and those feeding on the inside netting showed aggressive behavior if other species attempted to move inside the FAD. One large pinfish was observed successfully deterring a small school of 10 blue runners.

On rare occasions spadefish and remora were observed near the FAD netting. Spadefish oriented to the underside of the netting, rapidly descending along the vertical line and/or intensifying their black bars when frightened. Remora always hovered below the underside of the netting, which was an expected orientation for this commensal species.

Clearly, the FAD's served many different functions with respect to the various species associated with them. Many of these species also showed strong signs of territoriality, which may have altered the diversity and abundance of fishes associated at each FAD. Objects placed in the midwater column may provide fishes with a visual stimulus for orientation in an otherwise void environment. Each species appears to use the FAD's for different purposes (i.e., orientation, feeding, and protection).

Table 7.—Average number of fish landed per minute of wet gear time. Data for October-December 1983 before FAD deployment.

Species	Pier A	¹ (n = 373)	Pier B ¹ (n = 616)		
Bluefish, Pomatomus saltatrix	.0078	(SD = .037)	.0165 P = .524	(SD = .262	
King mackerel, Scomberomorus cavalla	.0002	(SD = .002)		(SD = .000	
Spot, Leiostomus xanthurus	.0090	(SD = .073)	.0125 P = .448	(SD = .069	
Kingfish, ² Menticirrhus spp.	.0016	(SD = .010)	.0004 P = .007	(SD = .004	
Pompano, Trachinotus spp.	.0007	(SD = .009)	.0006 P = .800	(SD = .008	
Spanish mackerel, Scomberomorus maculatus	.0003	(SD = .004)	.0014 P = .553	(SD = .033	
Sheepshead, Archosargus probatocephalus	.0000	(SD = .000)	.0001 P = .339	(SD = .002	
Flounder, Paralichthys spp.	.0078	(SD = .100)		(SD = .009	

 $^{1}\mbox{Pier}$ owners preferred that pier names not be associated with CPUE data. $^{2}\mbox{Statistically significant.}$

Midwater FAD Structural Assessment

When the FAD's were initially deployed, the units were positively buoyant and therefore positioned themselves vertically in the water column, with the open end toward the surface. After 2 months, the growth of fouling and encrusting organisms overcame the FAD floatation, causing eight FAD's to sink. At this time, an additional midwater buoy was tied to the FAD which repositioned them vertically.

The weak link of the entire FAD system appeared to lie in the nose conefiberglass rod connection. Silicone sealant was recommended as an adhesive, but proved to be inadequate. The loss of four FAD's resulted from the fiberglass rods pulling away from the nose cone. In addition, one fiberglass rod pulled away from the nose cone of four different FADs during the 4-month study. When the FAD's were refitted, the silicone sealant was replaced by PVC cement. This worked well, but is permanent. The FAD's cannot be disassembled without cutting the rods. Additional changes were made in the nose cone shackling system (Murray et al., 1985).

The FAD's nylon netting held up very well. Various kinds of fishing tackle (e.g., down riggers, spoons, monofilament line) were commonly observed entangled within the netting. This tackle in turn produced holdes varying from 2 to 13 cm. Except for the initial tear, holes in the nylon netting did not increase in size from wave action.

Although the study area was spared from the most severe environmental conditions resulting from Hurricane Diana (12-13 September), heavy winds and surge affected the site. An assessment of the aftermath of Hurricane Diana revealed that 8 of the 15 remaining FAD's were missing. Of the eight missing FAD's, five had pulled away from their nose cones, two broke away from the trapeze rings, and the nose cone of one had completely collapsed. The seven remaining FAD's were badly entangled in the FAD netting and vertical FAD line. The nylon netting of these seven units had pulled back away from their nose cones, assuming a collapsed position. In addition, numerous FAD anchor weights were flipped over and/or partially or completely buried in the sediment.

CPUE Survey

Tables 7 through 11 present the results of the CPUE comparisons from Piers A and B. Tables 7 and 8 present CPUE data collected during the fall of 1983, a year before the FAD's were placed off either pier. These comparisons were necessary to determine whether or not higher average catches per unit of effort occurred at either pier under natural conditions. For Table 8, we selected those October 1983 cases because they overlapped in time with the 1984 experimental comparisons shown in Table 11.

For the first two tables, the piers' average CPUE statistics for the eight species were compared using two-tailed T-tests.

Table 8.—Catch data for the two piers during October 1983 before FAD deployment.

Species	Pier A	¹ (n = 133)	Pier B ¹ (n = 268)		
Bluefish, Pomatomus saltatrix	.0025	(SD = .013) P =	.0061 .511	(SD = .061)	
King mackerel, ² Scomberomorus cavalla	.0006	(SD = .003) P =	.0000	(SD = .000)	
Spot, Leiostomus xanthurus	.0164	(SD = .010) P =	.0189	(SD = .004)	
Kingfish, Menticirrhus spp.	.0010	(SD = .001) P =	.0007	(SD = .000)	
Pompano, Trachinotus spp.	.0015	(SD = .001) P =	.0007	(SD = .006)	
Spanish mackerel, ² Scomberomorus maculatus	.0010	(SD = .007) P =	.0001	(SD = .001)	
Sheepshead, Archosargus probatocephalus	.0000	(SD = .000) P =	.0000	(SD = .001)	
Flounder, Paralichthys spp.	.0175	(SD = .167) P =	.0010	(SD = .011)	

¹Pier owners preferred that pier names not be associated with catch data. ²Statistically significant.

> The probabilities shown demonstrate that few statistically significant differences exist between the two piers. Mean values which are significantly higher, include kingfish for the total (Table 7) and king and Spanish mackerel for the cases within the October time period (Table 8). In these cases, Pier A CPUE averages are higher.

> Table 9-11 compare the CPUE statistics from the two piers while using the FAD at one of the piers. Probability levels shown here are computed from onetailed t-tests, instead of two-tailed. CPUE, however, cannot be less than zero and hence has a skewed, non-normal distribution. Because of this, we transformed CPUE with the formula for the Z-score:

$$\frac{X_i - \overline{X}}{SD}$$

This generated a new variable with a mean of 0 and a standard deviation of 1. The results of the t-tests following these transformations were analyzed for the catches with the FAD at one of the two piers. These transformations did not affect the ultimate findings of the CPUE analysis, which are presented below.

During the first time period (Table 9), while the FAD was anchored off Pier A, significantly more Spanish mackerel were caught per minute of wet gear time from Pier A than from Pier B. However, the CPUE statistics for the two piers during the October 1983 time slot (Table 8) show that Pier A tends to have more

Table 10.—Catch data for piers from 17 June 1984 to 30 July 1984 when FAD's were at Pier R.

Species		A (n = 145)	Pier B (n = 174)		
Bluefish, Pomatomus saltatrix	.0060	(SD = .016) P =	.0052	(SD = .021)	
King mackerel, Scomberomorus cavalla	.0000	(SD = .000) P =	.0000	(SD = .000)	
Spot, Leiostomus xanthurus	.0001	(SD = .001) P =	.0002	(SD = .001)	
Kingfish, Menticirrhus spp.	.0000	(SD = .000) P =	.0024	(SD = .032)	
Pompano, Trachinotus spp.	.0000	(SD = .000) P :	.0000	(SD = .000)	
Spanish mackerel, ¹ Scomberomorus maculatus	.0020	(SD = .010) P =	.0004	(SD = .003)	
Sheepshead, Archosargus probatocephalus	.0000	(SD = .000) P =	.0000	(SD = .000)	
Flounder, Paralichthys spp.	.0002	(SD = .002) P =	.0001 .37	(SD = .001)	

Species Pier A (n = 251) Pier B (n = 360) Bluefish, Pomatomus saltatrix .0007 (SD = .002) .0069 (SD = .089) 135 King mackerel, Scomberomorus cavalla (SD = .001) .0000 (SD = .000) .0001 P = 108 Spot, Leiostomus xanthurus .0027 (SD = .018) .0055 (SD = .028)P = .075 Kingfish, Menticirrhus spp. (SD = .010)0015 (SD = 026) .0006 P 308 Pompano, Trachinotus spp. .0000 (SD = .000).0000 (SD = .000)= .202 Ρ Spanish mackerel,1 Scomberomorus .0007 (SD .003) .0001 (SD = .001)maculatus P = .002Sheepshead, Archosargus probatocephalus (SD = .001) .0000 (SD = .000).0001 P = .0115 .0012 (SD = .008) Flounder, Paralichthys spp. .0014 (SD = .017) = .45

¹Statistically significant.

¹Statistically significant.

Table 11.-Catch data for piers from 31 July 1984 to 16 October 1984 when FAD's

were at Fiel A.							
Species		A (n = 199)	Pier B (n = 415)				
Bluefish, Pomatomus saltatrix	.0123	(SD = .080) P =	.0428	(SD = .018)			
King mackerel, Scomberomorus cavalla	.0000	(SD = .000)		(SD = .000)			
Spot, Leiostomus xanthurus	.0266	(SD = .126) P =	.0487	(SD = .331)			
Kingfish, ¹ Menticirrhus spp.	.0041	(SD = .040) P =	.0007	(SD = .006)			
Pompano, Trachinotus spp.	.0006	(SD = .003) P =	.0083	(SD = .069)			
Spanish mackerel, Scomberomorus maculatus	.0000	(SD = .000) P =	.0004	(SD = .007)			
Sheepshead, Archosargus probatocephalus	.0001	(SD = .002) P =	.0000	(SD = .000)			
Flounder, Paralichthys spp.	.0002	(SD = .001) P =	.0120 .247	(SD = .243)			

¹Statistically significant.

pelagics (king and Spanish mackerel) than Pier B under natural conditions. Table 10 shows that even when the FAD was moved to Pier B from mid-June to July, there were significantly more Spanish mackerel caught from Pier A than from Pier B. The higher CPUE figures for Spanish mackerel at Pier A cannot be attributed to the FAD.

While more Spanish mackerel per unit of effort tend to be caught from Pier A, Pier B CPUE figures for spot and bluefish are higher throughout the summer and autumn months (Tables 10 and 11) than Pier A's figures, although not statistically significant. Finally, Table 11 shows that the kingfish CPUE was significantly higher than Pier A when the FAD's were at Pier A during the third time period. Again, however, we cannot attribute this difference to the presence of

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the FAD, since significantly more kingfish are caught at Pier A under natural conditions (Table 7). CPUE data were also computed and compared between piers for all species; however, the resulting CPUE values were too low, due to overall poor CPUE at both piers, to be of any use. These findings suggest that the FAD's did not affect CPUE.

Following comparisons of the total samples, we compared various subsamples within the larger sample on the basis of the section of the pier where fishermen were located (end, middle, shore), the wind direction, wave height, and water temperature. Because the FAD's were placed 229 m from the end of the pier, we thought that fishermen fishing from the end of the pier would have the best chance of catching any fish attracted by the FAD's. It would logically follow that

comparisons between the end-of-pier cases from the two piers might yield different CPUE results than those for the entire sample.² In general, however, comparisons between the end-of-pier subsamples generated results similar to those of the entire sample. For example, Spanish mackerel CPUE figures were significantly higher at Pier A, with or without the FAD, and Pier B still had higher CPUE figures (although not significantly higher) for spot and bluefish.

Nevertheless, there was one important difference between the end-of-pier subsample comparisons and those shown in Tables 8-10. While there were more flounder caught per unit of effort from Pier B for the total sample during the third time period (Table 11—FAD at Pier A), Table 12 shows that the flounder CPUE figures for this time period change significantly when we compare only the end-of-pier subsample values with those presented in Table 8. We can see that

Table 9.—Catch data for the two piers from 3 May 1984 to 14 June 1984 when FAD's were at Pier A.

²The end-of-pier subsample comparisons are important not only because they support the total sample comparisons, but also because the number of fishermen are more evenly distributed between the two piers, at least during the first two time periods. In Tables 7-11, it is clear that Pier B was used by about twice as many fishermen as Pier A, while significantly higher CPUE statistics almost always favored Pier A. CPUE may be lower at Pier B because there were twice as many fishermen fishing for the same amount of fish. reducing each fisherman's chances by one-half that of Pier A fishermen. However, with the end-of-pier subsample, where the numbers of fishermen were closer to one another, the mean values for CPUE and the significant findings did not radically change, with the exception of flounder.

Table 12.—Catch data for flounder compared for three sample subsets.

Species	Pier A	Pier B		
1983 Sample (without FAD)	.0078 (SD = .100) .001 (n = 373) P = .097			
31 July - 16 October 1984 Sample (FAD at Pier A)	.0002 (SD = .001) .012 (n = 199) P = .247			
31 July - 16 October 1984 end-of-pier subsample (FAD at Pier A)	.0002 (SD = .001) .000 (n = 115) P = .017	0 (SD = .000 (n = 203)		

during the same time period a year earlier, under natural conditions, there was no significant difference between the two mean values for flounder.

The increase in flounder with presence of the FAD's may be due to the documented increase in bait fish attracted by the FAD's, instead of a direct causal link between number of flounder and the FAD. However, we present these findings with a note of caution. Although the difference between the two means is not significant, Table 7 shows that the mean value for flounder caught per unit of effort was higher off Pier A during the fall of 1983, under natural conditions.

Finally, selecting out subsamples based on wave height and wind direction did not produce any noticeable departures from the findings presented above. There were a few isolated cases of statistical significance which did not appear in earlier comparisons, but these did not always coincide with the presence or absence of the FAD's. On the basis of the computer analysis in general, we would have to conclude that the FAD's, placed 229 m from the end of the pier, had little if any effect on the anglers' CPUE.

Discussion and Conclusions

In general, the results of the study were mixed. The FAD's proved to be successful in aggregating bait fishes in the nearshore environment. An average of 3.67 ± 8.91 fishes appeared on each FAD, representing 35 different species, in comparison with the control site which had no fishes.

Fish schools attracted to the FAD's during our study were not as large as reported by Klima and Wickham (1971). Reasons for the difference are not clear because the artificial units used in both studies were similar in shape and size and were deployed at a similar depth. The

natural habitat of both study sites may have varied greatly. In addition, the rapid recruitment of fishes observed by Klima and Wickham (1971) did not occur in our study. Fishes were not observed until after the FAD's had been deployed for 1 week. This may emphasize the difference between the natural habitats between both studies. Fewer fishes may be present where we deployed the FAD's compared with Klima and Wickham's study site.

Many studies have shown that bottom and midwater artificial reefs increase the CPUE of several pelagic sport fishes (Buchanan et al., 1974; Hammond et al., 1977; Wickham et al., 1973). These studies involved trolling over experimental and control study sites. Unfortunately, trolling was not feasible in our study. Whether or not the CPUE may have been greater at our experimental site concerning pelagic sport fishes using standard trolling methods needs to be investigated. Buchanan (1973), on the other hand, found no significant difference in the CPUE between an artificial reef and the natural habitat for both pelagic and bottom fishes.

The surface areas of an artificial unit and its placement in the water column are important factors governing the diversity and abundance of fishes attracted to it. The aggregation of pelagic fishes near or beneath floating and moored objects is well documented (Gooding and Magnuson, 1967; Hunter and Mitchell, 1966, 1968). A greater abundance and diversity of fishes have been shown to associate with midwater units rather than surface units (Klima and Wickham, 1971). In addition, a greater number of fishes are associated with both simple and complex midwater units than surface structures (Klima and Wickham, 1971). Our results are similar to those of Klima and Wickham (1971); the diversity and abundance of fishes were much greater at the FAD's than at the spar buoys. One exception to this concerns the blue runner which did not exhibit a significant difference in their abundance between the FAD's and spar buoys. The surface area of both the spar buoy and FAD differed greatly which might explain to some extent the difference in the abundance and diversity of fishes observed at each structure.

Wickham and Russell (1974) proposed that fish leave artificial structures at night and that new recruitment occurs daily. Our results show no evidence to support this trend. Due to the frequent diving involved with the 24-hour diel study, it seemed likely that we observed the same fishes at the FAD's rather than new recruits. However, blue runner commonly moved from one FAD to another, using the diver as the attractant. A possible explanation of our results may be linked to the natural habitat where our FAD's were deployed. There was no vertical relief or other structures for the fish to use as spatial references. A substantial migration would have been required of the fish in locating additional structures for orientation purposes (e.g. pier pilings, rock jetty).

The initial attraction of fish to midwater objects probably results from visually detecting the object in an otherwise void environment, providing spatial references (Wickham and Russell, 1974). This theory is supported by our study. Although the fishes were capable of moving beyond sight of the FAD's for a short period of time, they appeared to require almost constant visual contact. Water visibility, however, had no apparent effect on fish abundance in our study. In some instances, the attraction of sport pelagic fish appears to involve specific behavioral mechanisms (Wickham et al., 1973). Our study showed no evidence of any species specific mechansisms.

Territorial behavior may have played an important role in governing the abundance and diversity of fish associated with each FAD. The surface area of each FAD was apparently small enought to enable a single individual, especially banded rudderfish to successfully deter all fish that attempted to approach the FAD. Possibly, if the surface area of the FAD was increased, territorial behavior may have had less affect on the diversity and abundance of fishes associated with the FAD's.

The simple design of the FADs and their relative ease of employment and retrieval make these units feasible for use by individual fisherman and fishing clubs. It is evident though, that the FAD's do require some maintenance (e.g. adding additional floatation) which can be performed easily by divers. Relatively few pelagic sport fish species were seen by divers. One reason for this may include avoidance behavior of pelagic species near divers, making the fishes difficult to see in waters with limited visibility. Another more likely explanation was the general lack of pelagic sport water fishes in nearshore near Wrightsville Beach, N.C., in the summer of 1984. Supporting this conclusion are the very low CPUE statistics. For example, between 17 June and 30 July 1984, a fisherman would have to fish at Pier A 166.6 hours of wet gear time to catch a king mackerel, 23.8 hours to catch a bluefish, and 23.8 hours to catch a Spanish mackerel. At Pier B, which was FAD enhanced, the same fishermen would wait 2.41 hours to catch a bluefish, 166.6 hours to catch a Spanish mackerel, and he would not have caught a king mackerel.

The FAD units were not successful in improving fishing success at the fishing piers. Factors attributed to the poor showing may include the generally poor fishing conditions in the inshore area during 1984. Usually, the fall fishing season produces far more catches of pelagics on the piers. However, Hurricane Diana effectively interrupted the study on 13 September, which may have caused us to miss this important season. Perhaps most important was the distance the units were placed from the piers (229 m). As described, this was a demand placed on us by the pier owners because of their fear of complaints by fishermen who may have lost gear or fish. It may be unrealistic to expect fishes to move this distance and become accessible for catch by fishermen on the piers. If FAD enhancement is attempted by pier owners in the future, it is recommended that the units be moved closer to the pier to just out of casting

distance (perhaps 45 m). Loss of gear problems could be addressed by other methods such as a clearly recognizable buoying system and warning signs placed conspicuously on the piers.

A third objective was to determine whether the FAD units would be durable enough to hold up in the nearshore environment where currents and high energy wave action create more stress on the system. Generally the units performed well. Six of the original 18 units were lost and three were replaced. Four were lost because the fiberglass rods slipped out of the nose cone. The rods were originally glued into the nose cone with a silicone sealant. Using PVC cement worked well and should prevent this problem in the future. A fifth FAD was lost due to fraying of the vertical line at the nose-cone juncture. This problem was solved when the shackle system was substituted. The sixth was lost because of galvanic corrosion. This can be corrected through the proper choice of compatible materials. Eight of the remaining 15 units were lost on 13 September 1984 during Hurricane Diana, a category 2 hurricane with 100 mph sustained winds whose eye passed within 12 miles of the units. Major shoreline damage occurred in theWrightsville Beach area and it was surprising that any of the FAD's survived.

The FAD's were relatively easy to deploy. Once the anchoring system was constructed on land, the 18 units and two anchoring systems were deployed by four people, using a 23-foot outboard in 2 1/2 days. At full retail prices, the total cost of the materials (excluding labor and FAD units) was \$2,021. The 1984 price listed for 18 FAD units was \$2,304. The manufacturer, however, donated the units to the project. Potentially, other homemade designs could be used. Each of the four surface buoys off each pier had its own schools of bait fish, indicating that a single buoy either floating at or below the surface may be effective in aggregating fishes.

Although permits may be difficult to obtain for placing bottom structure in the nearshore environment because of the potential for causing erosion problems, it appeared that bottom structures will also aggregate fishes. Within weeks after placement each concrete-filled tire had black sea bass located on it. The individual tires had only 10 inches of relief, which indicates that a more substantial structure would be quite successful in attracting black sea bass.

Aside from a FAD's ability or inability to aggregate fises at the pier, a further benefit which should not be overlooked is its marketing potential. Although publicity for the project was not sought, the local media discovered the project and wrote several articles about it. FAD enhancement could be used for advertising and marketing purposes and might improve the competitive position of individual piers.

Further Research

The growth in marine recreational fishing participants has outpaced the growth rate of the U.S. population in recent decades by a factor of 2.5 (Chandler, 1984). As more and more fishermen enter the fishery, fisheries-dependent businessmen and fisheries managers will need to develop new and innovative ways to please their customers or constituents. Future research should continue toward improving fishing at public and private access points such as fishing piers, fishing banks, jetties, and bridges. Some questions which surfaced during this study deserve further scrutiny. They include:

1) Acoustic transmitter tagging of pelagic fishes. As midwater reefs and trolling alleys grow in popularity, more work needs to be done to determine the movement patterns of key target species near the attractors. Such information would help in FAD placement decisions near inshore structures such as piers. It would also assist in spacing decisions for individuals units.

The 18 m spacing distance between the individual FAD units chosen for this study was made by "guesswork". We felt that 7.6 m underwater visibility was the maximum for the area and that fish would move from unit to unit by sight. This was obviously not tested. The mechanism that initially attracts fishes to the FAD's is not known. Sight no doubt plays an important factor, but it is also likely that the low frequency sounds generated by currents impinging upon the midwater structures may be the initial attraction to fishes (Westenberg, 1953). Sight may play the main role in maintaining fishes in association with the FAD's, but not necessarily in the initial attraction of fishes to FAD's. If the low frequency sounds can be duplicated or synthesized and played back underwater, these artificial sounds might be used as initial enhancement mechanisms for artificial reefs.

2) Other FAD configurations should be tested. The three six-FAD unit strings with the two end strings angled toward the pier were chosen because it was felt the end strings might act as leads toward the pier for fish migrating along the beach. This did not seem to happen because of the distance from the piers. Other designs should be tested.

3) Controlled fishing over the units. Because of time and funding limitations, no attempt was made to use controlled float fishing from boats over the FAD's. Deep troll fishing was prohibited by a special declaration by the Marine Fisheries Commission to avoid boat fishermen taking fish and anchoring over and destroying the units. However, controlled fishing experiments over the units using float or surface trolling methods may be an effective way of determining pelagic fish availability since they may have avoided the divers. Also, a future use for FAD's may be inshore trolling alleys or float fishing areas. Research is needed to determine fishing success by fishing over them.

4) The FAD's we used in the study were chosen because they had been successfully tested in offshore waters, and they were donated for the project. However, experimentation with other midwater designs should be encouraged. Bottom structure in the nearshore zone appears to show promise particularly for black sea bass. Coastal engineers should experiment with designs which can be placed in this environment without causing erosion. One possibility would be to attach the structure to the pier pilings which would be off the bottom and allow for sand transport below it.

5) Several assumptions were made by the pier owners about the motivations of their pier fishermen. A survey of pier fishermen regarding attitudes toward fish enhancement, loss of gear, etc. should be conducted to help pier owners make informed decisions about constructing FAD's for their users.

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Literature Cited

Buchanan, C. C. 1973 Effects of an artificial habitat on the marine sport fishery and economy of Murrells Inlet, South Carolina. Mar. Fish. Rev. 35(9):15-22. R. B. Stone, and R. O. Parker, Jr. 1974. Effects of artificial reefs on a marine sport fishery off South Carolina. Mar. Fish. Rev. 36(11):32-38.

- Chandler, A. D. 1984. Mixing it up with the sports. Natl. Fisherman 65(3):30-36.
- Goldstein, Robert J. 1978. Pier fishing in North Carolina. John F. Blair, Winston-Salem, 121 p.
- Gooding, R. M., and J. J. Magnuson. 1967. Ecological significance of a drifting object to pelagic fishes. Pac. Sci. 11:486-497.
- Hammond, D. L., D. O. Myatt, and D. M. Cupka. 1977. Evaluation of midwater structures as a potential tool in the management of the fisheries resources on South Carolina's artificial fishing reefs. S. C. Mar. Resour. Cent. Tech. Rep. Ser. 15, 19 p.
- Hunter, J. R., and C. T. Mitchell. 1966. Association of fishes with flotsam in the offshore waters of Central America. Fish. Bull. (U.S.) 66(1):13-29.
- and _____. 1968. Field experiments on the attraction of pelagic fish to floating objects. J. Cons. perm. int. Explor. Mer. 31(3):427-434.
- Klima, E. F., and D. A. Wickham. 1971 Attraction of coastal pelagic fishes with artificial structures. Trans. Am. Fish. Soc. 100(1):86-99.
- Murray, J. D., D. G. Lindquist, D. C. Griffith, and J.C. Howe. 1985. The use of midwater fish aggregating devices to attract marine fish at two North Carolina fishing piers. UNC Sea Grant Publ. UNC-SG-WP-85-1, 54 p.
- Myatt, D. O. 1982. Applications of mid-water fish attractors in the South Atlantic Bight. *In* J. D. Murray (editor), Mid-Atlantic artificial reef conference: A Collection of Abstracts. N. J. Sea Grant, Fort Hancock, Unpagin.
- Nie, N., C. H. Hull, J. G. Jenkins, K. Steinbrenner, and D. H. Brent. 1975. Statistical package for the social sciences. Second Ed. McGraw-Hill Book Co., N.Y., 675 p. Shomura, R. S. and W. M. Matsumoto. 1982.
- Shomura, R. S. and W. M. Matsumoto. 1982. Structured flotsam fish aggregating devices. NOAA Tech. Memo. NMFS, Honolulu, Hawaii, 9 pp.Westenberg, J. 1953. Acoustical aspects of some
- Westenberg, J. 1953. Acoustical aspects of some Indonesian fisheries. J. Cons. 18(3):311-325.Wickham, D. A., J. W. Watson, and L. H.
- Wickham, D. A., J. W. Watson, and L. H. Ogren. 1973. The efficacy of midwater artificial structures for attracting pelagic sport fish. Trans. Am. Fish. Soc. 102(3):563-572.
- and G. M. Russell. 1974. An evaluation of midwater artificial structures for attracting coastal pelagic fishes. Fish. Bull. (U.S.) 72(1):181-191.
- Workman, I. K., A. M. Landry, Jr., J. W. Watson, Jr., and J. W. Blackwell. 1985. A midwater fish attraction device study conducted from hydrolab. Bull. Mar Sci. 37(1):377-386.