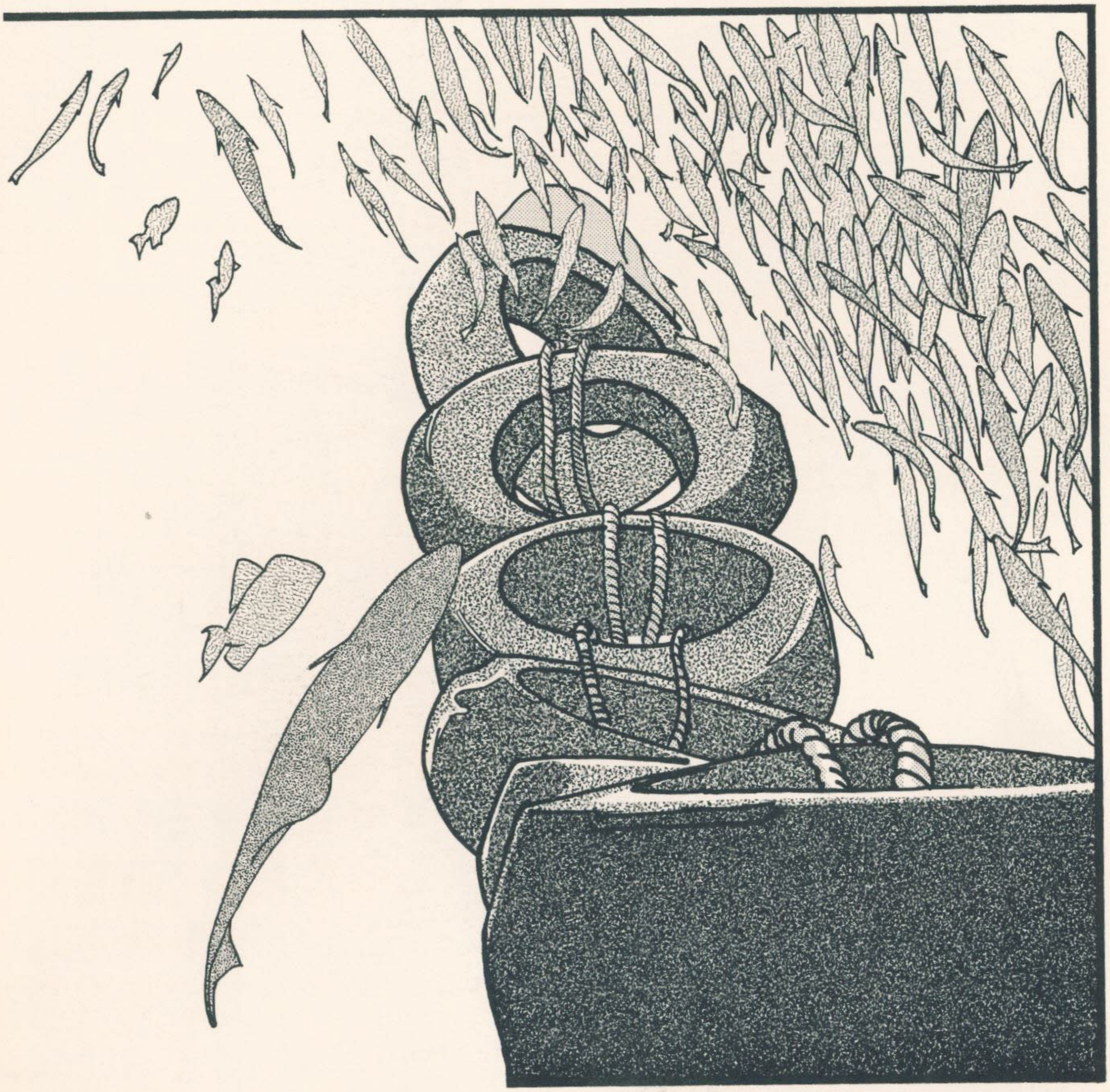
Evaluation of Midwater Structures as a Potential Tool in the Management of the Fisheries Resources on South Carolina's Artificial Fishing Reefs



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EVALUATION OF MIDWATER STRUCTURES AS A POTENTIAL TOOL IN THE MANAGEMENT OF THE FISHERIES RESOURCES ON SOUTH CAROLINA'S ARTIFICIAL FISHING REEFS [1]

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INTRODUCTION

Association of pelagic fishes with floating objects in the oceans is a widely known phenomena among fishermen (von Brandt, 1960; McNeely, 1961; Hunter and Mitchell, 1967). Both commercial and sports fishermen take advantage of this behavioral pattern by regularly checking flotsam for the occurence of fishes.

Previous studies on the use of midwater artificial structures (Hunter and Mitchell, 1968; Klima and Wickham, 1971; and Wickham, Watson and Ogren, 1973) have shown that they are effective in attracting and concentrating certain pelagic fish species. Hunter and Mitchell (1968) found that larger numbers of fishes were attracted to a three dimensional structure than to a two dimensional structure. Klima and Wickham (1971), in their study on the behavior of pelagic baitfish in relation to midwater structures, noted a large daily variation in the number of individuals associated with these structures, suggesting daily recruitment and dispersal. In a later study, Wickham, Watson and Ogren (1973) found that midwater structures could be successfully used to improve pelagic sportfish catches in a designated area.

This project was designed to evaluate the ability of artificial midwater structures to increase the concentrations and availability of coastal pelagic gamefish in the immediate vicinity of a benthic artificial fishing reef; and to investigate the feasibility of using midwater structures as a management tool to reduce fishing pressure on groundfish stocks present on a benthic reef. The project consisted of two phases. Phase one determined the natural attraction of pelagic gamefish to a benthic artificial reef. This work was conducted on the Caper's Reef, Lat. 32°44.4'N., Long. 79°34.5'W. (Figure 1). The vertical relief on Caper's Reef is provided primarily by seven steel hull vessels averaging 4 meters in height and by a caisson measuring 30.5 meters in length and with an average height of 5 meters. Phase two dealt with the productivity of the midwater structures located in the immediate vicinity of a benthic artificial reef. This phase was conducted on Kiawah Reef, Lat. 32°29.05' N., Long. 80°0.3'W. (Figure 2). This reef's vertical profile is provided by three steel hull vessels averaging 3 meters in height and by a wooden dry dock measuring 91.4 meters in length and with an average height of 5 meters.

MATERIALS AND METHODS

Thirty midwater structures (Figure 3) were deployed on Kiawah Reef the first day of May 1975. The structures were deployed in a straight line at 31 meter intervals over a distance of 914 meters and a buoy was placed at each end of the line for reference (Figure 4).

Each midwater structure consisted of six automobile tires which were lashed together with 6.3 mm diameter polypropylene rope and threaded on a 7.5 meter length of 6.3 mm diameter galvanized steel cable. The uppermost tire was secured to the floatation element (an empty 22.2 liter steel freon canister). A 135 kg block of concrete was affixed to the opposite end of the assembly to serve as the mooring element of the unit.

When deployed, the unit assumes a vertical posture in the water with the tires suspended below the hollow steel flotation element and the unit is secured in place by the concrete anchor. Since the buoyancy of the flotation element is less than one-sixth the weight of the anchor and tires, the uppermost portion of the unit can be set to a predetermined subsurface depth by cutting the cable to a length that is less than the charted depth for the location of deployment. The average depth at the

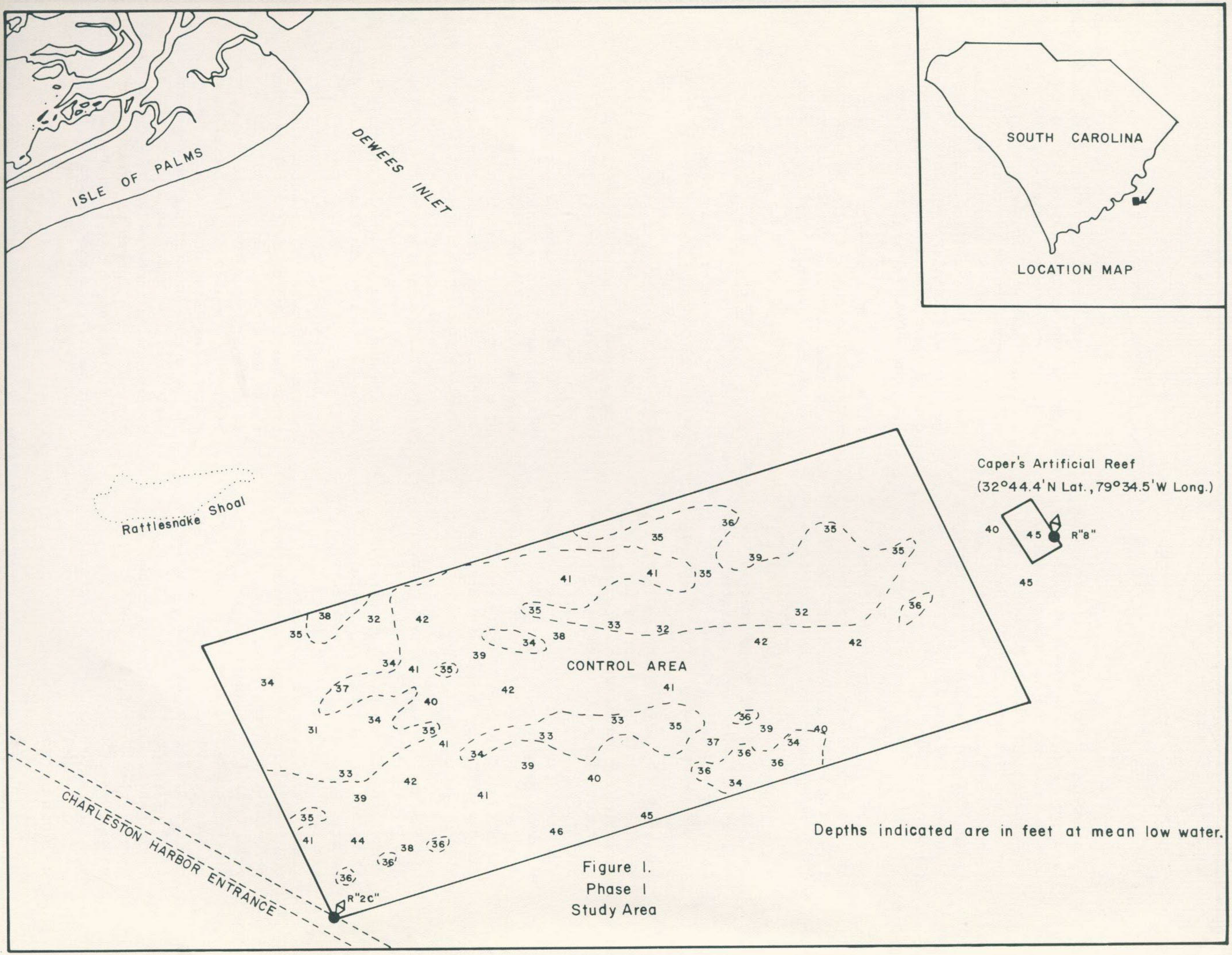


Figure 1.
Phase 1
Study Area

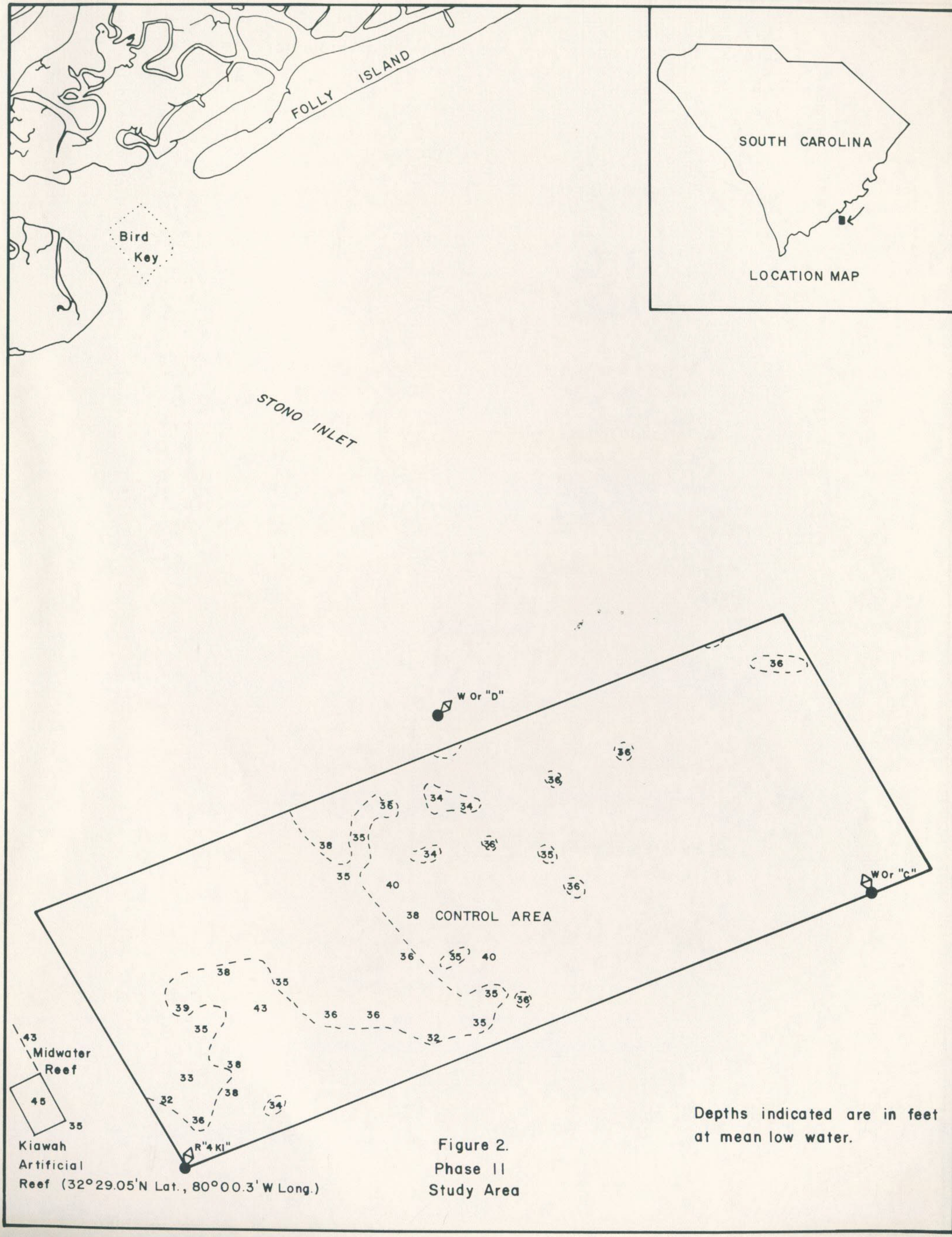


Figure 2.
Phase II
Study Area

Figure 3. Diagrammatic representation of a midwater structure.

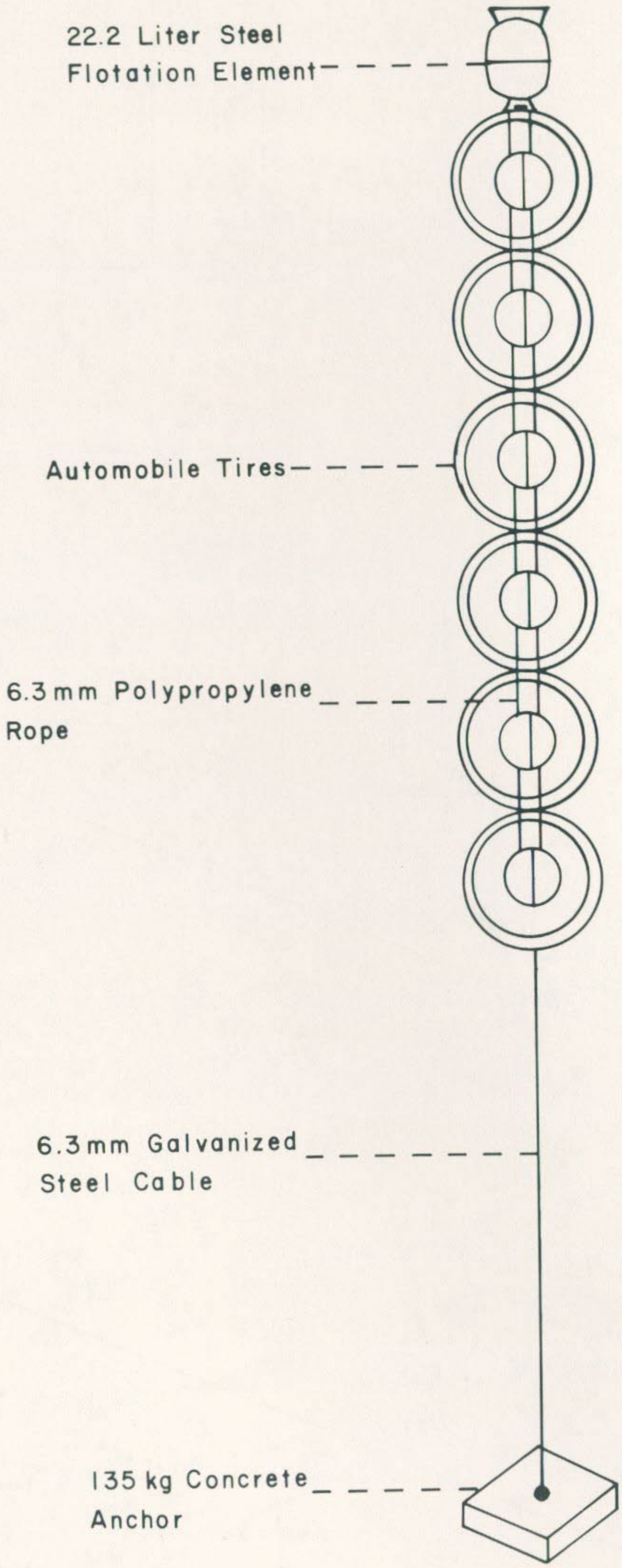
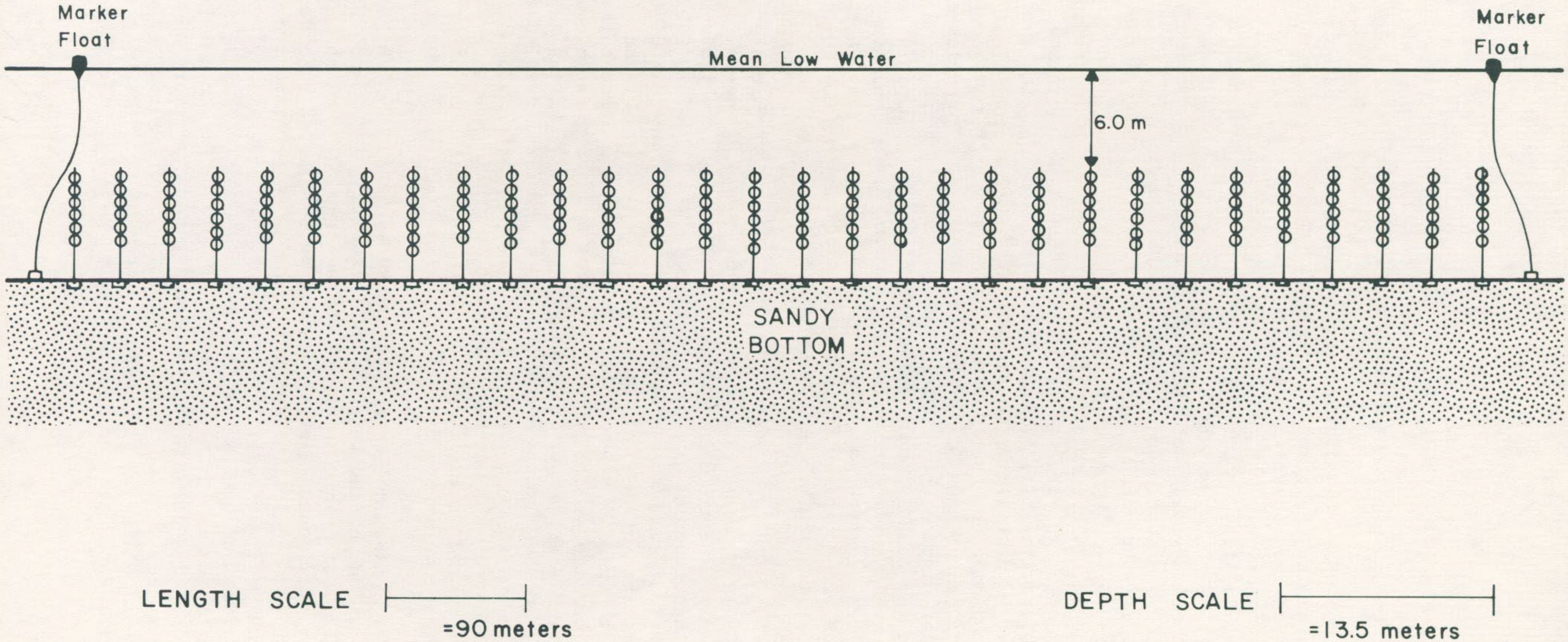


Figure 4. Deployment of midwater structures.



site selected for the study is 13.5 meters, thus the 7.5 meter cable used kept the units 6 meters below the surface.

Each phase (consisting of a control area and an experimental area) was sampled on two consecutive days each month, when possible, from May through September 1975, for a total of 20 sampling days. Each day was broken into two collection periods of three hours duration, one from 0800 to 1100 hours EDST and the second from 1200 to 1500 hours EDST. Two vessels were employed during each sampling day. Sampling was conducted for a total of 240 hours with equal effort, 60 hours, being spent in each of the four areas. In the morning one vessel sampled the experimental area while the second vessel sampled the control area. Then the vessels would rotate sampling areas during the afternoon period. The results from sampling in control areas were combined for analysis since normal fishing procedures were used in both control areas.

Collection methods incorporated standardized trolling speeds and number and types of lures. Lures consisted of two 50 mm spoons, one trolled at the surface and the other trolled one to one and one half meters below the surface, a 200 mm ballyhoo with a plastic skirt ahead of it rigged to skip on the surface and a 115 mm spoon pulled from a down rigger set at a depth of 7 meters. Sampling in the control areas differed only in that attempts were made to fish all schools of fish observed at the surface. Fishes collected were measured (fork length) and weighed when possible, except for Spanish mackerel which were only measured. Weights for Spanish mackerel were calculated using the formula: $W=a+b\cdot \text{Log } L$, where $a=-4.5254$, $b=2.7934$, weight (W) is in grams and length (L) is in mm fork length. This formula was derived from specimens collected earlier in South Carolina waters. All fish lost before being boated were recorded as strikes, even even when lost at the boat. Records were kept on observed species occurence and schooling activities for each of the four areas. Underwater observations and photography were conducted on the midwater structures to document the attraction of bait and predatory fishes to these structures.

RESULTS

A total of 240 fishes was collected during the survey representing 8 families and 14 species (Table 1). An additional ten species of fishes representing 9 families were observed during the survey but not collected (Table 2). Nine species of pelagic gamefish were collected. Five species of baitfish were observed to occur in one or more of the study areas. Spanish mackerel, *Scomberomorus maculatus*, and king mackerel, *S. cavalla*, comprised 91.3 percent of all fishes collected (Table 1).

Of the four areas sampled, the midwater structures produced the highest overall catch per unit of effort (CPUE) which was 1.37 fish per hour (Table 3). This CPUE was 22.1 percent higher than that of the existing benthic reef (Table 4) and 80.3 percent higher than that of the combined control areas (Table 5). The midwater structures also produced the highest monthly CPUE of all the areas sampled (2.50 fish per hour in May and August). The overall CPUE during the entire survey was 1.00 fish per hour. A larger diversity of fishes was noted in the midwater structures area, 19 species, than in the benthic reef area which had 11 species noted (Tables 2, 3 and 4). Eight species were collected in the midwater structures area while the other three areas yielded only five species each.

By combining the strikes with the actual landings, the results are even more significant because a biasing factor is removed, i.e., the ability of a crewman to boat the fish. The midwater structures produced 1.90 strikes per

Table 1. Monthly collections by number caught per species for the entire survey (May through September 1975).

	MAY	JUNE	JULY	AUGUST	SEPTEMBER	TOTAL
Spanish mackerel *Scomberomorus maculatus*	40	55	22	34	28	179
King mackerel *Scomberomorus cavalla*	5	1	4	28	2	40
Little tunny *Euthynnus alletteratus*		1		2	1	4
Banded rudderfish *Seriola zonata*	3			1		4
Inshore lizardfish *Synodus foetens*		2			1	3
Bluefish *Pomatomus salatrix*	2					2
Great barracuda *Sphyraena barracuda*	1					1
Almaco jack *Seriola rivoliana*	1					1
Chub mackerel *Scomber japonicus*	1					1
Greater amberjack *Seriola dumerili*		1				1
Cobia *Rachycentron canadum*		1				1
Dolphin *Coryphaena hippurus*			1			1
Bank sea bass *Centropristis ocyurus*			1			1
Black sea bass *Centropristis striata*			1			1
TOTAL	53	61	29	65	32	240

Table 2. Fish species observed in each study area but not necessarily collected.

	Midwater Structures	Benthic Reef	Combined Control Areas
Requiem sharks - _Carcharhinidae_*	X		X
Hammerhead sharks - _Sphyrnidae_*	X	X	
Sardine - _Sardinella_ sp.*	X	X	X
Anchovy --_Anchoa_ spp.*	X	X	X
Flyingfish - _Cypselurus_ spp*	X		X
Halfbeak - _Hemiramphus_ spp.*	X		X
Needlefish -_Tylosurus_ spp.*	X		
Cobia - _Rachycentron canadum_	X	X	X
Scad - _Decapterus_ spp.*	X	X	
Greater amberjack - _Seriola dumerili_	X	X	
Great barracuda - _Sphyraena barracuda_	X		
Atlantic spadefish - _Chaetodipterus faber_*	X	X	
Little tunny - _Euthynnus alletteratus_	X	X	X
Chub mackerel - _Scomber japonicus_			X
King mackerel - _Scomberomorus cavalla_	X		X
Spanish mackerel - _Scomberomorus maculatus_	X	X	X
Sailfish - _Istiophorus platypterus_*			X
Total number of species	15	9	11

*Observed only

Table 3. Number of fish collected and catch per unit of effort (CPUE) on a monthly basis for the midwater structures area.

	MAY	JUNE	JULY	AUGUST	SEPTEMBER	TOTAL	CPUE
Spanish mackerel *Scomberomorus maculatus*	19	3	10	8	8	48	0.80
King mackerel *Scomberomorus cavalla*	5		1	19		25	0.42
Banded rudderfish *Seriola zonata*	2			1		3	0.05
Bluefish *Pomatomus saltatrix*	2					2	0.03
Great barracuda *Sphyraena barracuda*	1					1	0.02
Almaco jack *Seriola rivoliana*	1					1	0.02
Little tunny *Euthynnus alletteratus*				1		1	0.02
Black sea bass *Centropristis striata*				1		1	0.02
MONTHLY TOTAL CATCH	30	3	11	30	8	82	
MONTHLY EFFORT (HOURS)	12	12	12	12	12	60	
CPUE *	2.50	0.25	0.92	2.50	0.67	1.37	

*Number of fish caught per hour of trolling.

Table 4. Number of fish collected and catch per unit of effort (CPUE) on a monthly basis for the Caper's benthic artificial fishing reef.

	MAY	JUNE	JULY	AUGUST	SEPTEMBER	TOTAL	CPUE
Spanish mackerel *Scomberomorus maculatus*	7	26	8	5	17	63	1.05
King mackerel *Scomberomorus cavalla*		1				1	0.02
Cobia *Rachycentron candadum*		1				1	0.02
Greater amberjack *Seriola dumerili*		1				1	0.02
Bank sea bass *Centropristis ocyurus*				1		1	0.02
MONTHLY TOTAL CATCH	7	29	8	6	17	67	
MONTHLY EFFORT (HOURS)	12	12	12	12	12	60	
CPUE*	0.58	2.42	0.67	0.50	1.42	1.12	

*Number of fish caught per hour of trolling.

Table 5. Number of fish collected and catch per unit of effort (CPUE) on a monthly basis for the combined control areas.

	MAY	JUNE	JULY	AUGUST	SEPTEMBER	TOTAL	CPUE
Spanish mackerel * <u>Scomberomorus</u> <u>maculatus</u>	14	26	4	21	3	68	0.57
King mackerel * <u>Scomberomorus</u> <u>cavalla</u>			3	9	2	14	0.12
Little tunny * <u>Euthynnus</u> <u>alletteratus</u>		1		1	1	3	0.03
Inshore lizardfish** <u>Synodus</u> <u>foetens</u>		2			1	3	0.03
Chub mackerel ** <u>Scomber</u> <u>japonicus</u>	1					1	0.01
Dolphin [t] <u>Coryphaena</u> <u>hippurus</u>			1			1	0.01
Banded rudderfish [t] <u>Seriola</u> <u>zonata</u>	1					1	0.01
MONTHLY TOTAL CATCH	16	29	8	31	7	91	
MONTHLY EFFORT (HOURS)	24	24	24	24	24	120	
CPUE [tt]	0.67	1.21	0.33	1.29	0.29	0.76	

* Fish collected in both control areas.

** Fish collected only in phase one control area.

[t] Fish collected only in phase two control area.

[tt] Number of fish caught per hour of trolling.

hour, which was 110 percent higher than normal fishing in the combined control areas with 0.89 strikes per hour (Table 6). The midwater structures accounted for 37 percent of all strikes while the benthic reef accounted for 29 percent of the strikes and each control area approximately 17 percent of the strikes.

The dominant species for each area sampled was the Spanish mackerel of which 179 specimens were collected (Table 2). In analyzing the collections between phases, the overall range in fork length (FL) for Spanish mackerel was approximately 20 mm higher on both ends of the range in Phase I, than in Phase II (Table 7). The average FL however, was 18.4 mm larger in Phase II, an increase of 4.7 percent. The weight of the average Spanish mackerel was 0.53 kg in Phase I but in Phase II it was 0.61 kg, an increase of 15.1 percent.

A total of 40 king mackerel was harvested during the survey. Phase II accounted for 90 percent of the king mackerel landed with the midwater structures area producing 62.5 percent of the king mackerel harvested. All of the king mackerel collected in Phase I were less than 500 mm FL (Table 7) while each area in Phase II produced one large specimen. The midwater structures area produced a specimen measuring 897 mm FL and weighing 5.44 kg, while the control area produced a specimen measuring 900 mm FL and weighing 4.31 kg. During Phase II, 36 king mackerel were caught which weighed a total of 43.05 kg and measured 434-900 mm FL. Discounting the two largest specimens, the average fork length of Phase II king mackerel was 501 mm as compared to an average fork length of 482 mm for Phase I specimens. The average weight of Phase II fish was 0.99 kg as compared to 0.90 kg for Phase I fish.

Because of the standardized sampling procedure, it was possible not only to compare the catch rates of the areas sampled, but also to examine the productivity of the lures used in the study as well as the different sampling periods. A comparison of lure productivity for the entire survey showed interesting trends. Each type of lure produced approximately the same number of species (six) with the one exception being the 115 mm spoon which produced seven species. The 50 mm surface spoon accounted for 75.5 percent of all Spanish mackerel collected. The larger 115 mm spoon trolled 7 meters below the surface produced 67.5 percent of all king mackerel taken during the study. Little tunny were collected on each of the four types of lures employed.

In regard to overall lure performance, the 50 mm surface spoon produced the highest yield, accounting for 60 percent of the total catch. The 115 mm spoon (trolled at a depth of 7 meters) produced the second highest yield (19 percent of the total catch) and was followed closely by the 50 mm spoon trolled one and one half meters below the surface which yielded 18 percent of all fishes landed. Even though the ballyhoo produced only 3 percent of the fishes caught, it consistently produced the largest fishes such as a 28.5 kg greater amberjack, a 4.3 kg and a 5.4 kg king mackerel, and a 6.8 kg great barracuda.

Overall the morning sampling period (0800 to 1100 hours EDST) produced more fishes and more consistently than did the afternoon (1200 to 1500 hours EDST) period (Table 8). The overall catch rate for Spanish mackerel was higher during the morning period (0.88 fish per hour) than during the afternoon period (0.62 fish per hour). King mackerel displayed a constant catch rate of 0.17 fish per hour over both sample periods. Combining all other species collected, the morning sampling period produced 0.13 fish per hour of trolling which was 2.5 times higher

Table 6. A comparison of strikes and collections by sampling area.

	Midwater Structures	Benthic Reef	Combined Control Areas
Missed strikes	32	23	16
Missed strikes and fish caught	114	90	107
Total Effort (Hours)	60	60	120
Total strikes per hour of effort	1.90	1.50	0.89

Table 7. Lengths and weights by sampling area for Spanish and king mackerel caught during the survey.

		Spanish Mackerel					King Mackerel				
		No. of Specimens	Size Range (mmFL)	Average Length (mm FL)	Weight Range (kg)	Average Weight (kg)	No.of Specimens	Size Range (mm FL)	Average Length (mm FL)	Weight Range (kg)	Average Weight (kg)
Phase I	Benthic Reef	63	320-540	395	0.30-1.28	0.53	1	498	498	0.91	0.91
Phase I	Control Area	32	327-578	396	0.31-1.55	0.54	3	471-486	477	0.86-0.91	0.90
Phase II	Midwater Structures	48	331-555	415	0.33-1.38	0.61	25	434-897	497*	0.68-5.44	0.96*
Phase II	Control Area	36	302-558	412	0.25-1.40	0.60	11	457-900	511*	0.68-4.31	1.02*

*Largest specimen omitted from calculation.

Table 8. Number and percent of fish caught and catch per unit of effort (CPUE) for morning (0800-1100 EDST) and afternoon (1200-1500 EDST) sampling periods.

	Number Caught		Percent Caught		CPUE	
	Morning	Afternoon	Morning	Afternoon	Morning	Afternoon
Spanish mackerel	105	74	58.7	41.3	0.88	0.62
King mackerel	20	20	50.0	50.0	0.17	0.17
All other species caught	15	6	71.4	28.6	0.13	0.05
Total	140	100	58.3	41.7	1.17	0.83
Number of non-productive sampling periods	8	11				

than the rate during the afternoon period. The morning sampling period had an overall catch rate of 1.17 fish per hour as compared to 0.83 fish per hour obtained for the afternoon sample period. In addition, the morning produced fewer non-productive sample periods than did the afternoon (20 percent as compared to 28 percent).

Due to personnel limitations, an insufficient number of samples was collected for a thorough statistical analysis of the catch rates of the different areas sampled. A probability value of $p=.09$ was obtained which lies between the 5% and the 10% level of significance. Thus the data were shown to be significantly different between the midwater and benthic reef areas at the 10% level but not at the 5% level. There was, however, a definite trend towards better catches at the midwater reef and benthic reef areas.

Diving Observations

After their deployment on May 1, the midwater units were inspected by SCUBA divers on two different occasions during the survey. During a dive on May 13, personnel observed that although baitfish were scarce in the area as a whole, that small schools of baitfish, primarily scad (*Decapterus* spp.), were observed around the upper portions of the units. No pelagic gamefish were observed in the area during this dive possibly due to poor visibility (3 meters and less). The units themselves were observed to be in excellent physical condition with little evidence of wear or corrosion. There was no indication that the units had moved despite strong currents and occasional storm surges that are common in the area. Barnacles and hydroids were noted to be already present on the reefs. The barnacles had a base diameter of approximately 3 mm at this time.

A second dive on June 23 revealed that the midwater structures had not moved although a strong (approximately 2.34 km/hour) current was experienced during the observation. Extremely large schools of baitfish, estimated to contain in excess of 100,000 individuals, were seen closely associated with the units. Both king and Spanish mackerel were observed cruising around the outer limits of these schools of baitfish. When a predator approached the unit, the bait school would suddenly constrict in size with its center near the midwater structure. The majority of this predator avoidance response was directed in a downward motion.

The units were observed to be heavily encrusted with barnacles. Base diameters were observed to be from 7 to 12 mm. Several large gray triggerfish, *Balistes capriscus*, and small to medium sized black sea bass, *Centropristis striata*, were observed to be concentrated primarily around the lower tires of the units. Tomtates, *Haemulon aurolineatum*, porgys, *Stenotomus* spp., and small black sea bass, *Centropristis striata*, were seen near the concrete sinker. The visibility was approximately 6 meters during this dive. Although there was an abundance of particulate material in the water, several serviceable photographs of a unit and the fishes associated with it were taken (Figure 5).

DISCUSSION

An important feature of the midwater units, aside from low cost, is that the flotation element with its thin steel walls is the first portion of the unit to fail due to wear or corrosion. When this occurs, the entire assembly sinks to the bottom where the tires remain along with other similar material that exists in that location as part of the benthic artificial reef. This feature diminishes the likelihood of the unit breaking apart and drifting out of its deployed area. The midwater structures are only intended to remain functional

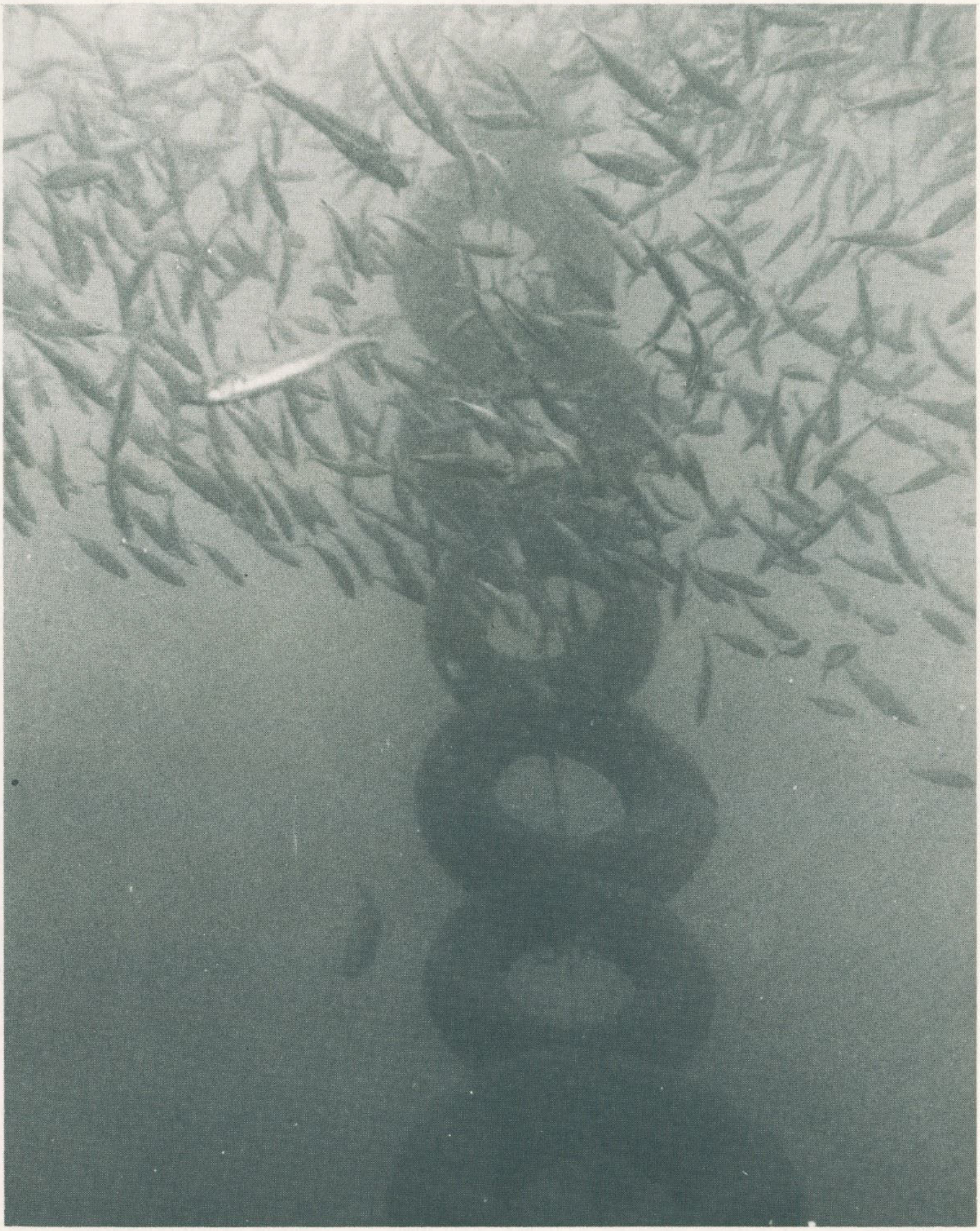


Figure 5. Underwater photograph of a deployed midwater structure. Note large numbers of baitfish associated with the upper portion of the unit.

during the prime fishing months (May through October) so that the short-lived feature of the unit (approximately six months) is important. The effectiveness of units remaining in place much longer than six months is reduced considerably by marine fouling. Because of the low cost involved in constructing and deploying the units, it is more efficient to replace them than to maintain them.

Pelagic gamefish were found to be naturally attracted to the benthic artificial reef and the productivity of this area was the second highest of the four study areas. Schools of baitfish were observed to occur here more consistently than in either of the control areas. Surface feeding schools of pelagic gamefish were also observed in the vicinity of the benthic artificial reef more frequently than in its associated control area. One species (Spanish mackerel) comprised over 93 percent of the total landings while the other four species caught each comprised less than 2 percent of the landings.

The midwater structures used in conjunction with an existing benthic artificial reef were found to enhance the attractability of the reef site to baitfish and gamefish. The midwater structures area produced a markedly higher catch rate than either of the control areas and exceeded the catch rate for the existing benthic reef by 22.1 percent. Consistently, more and larger schools of baitfish and surface feeding gamefish were observed in the vicinity of the midwater structures than on the benthic reef in Phase I. A larger diversity of fishes was also noted near the midwater structures than in any of the other study areas.

King mackerel landings for the midwater structures area showed a dramatic increase over its associated control area and over both areas in Phase I.

Morning sampling periods had a 40 percent higher catch rate than the afternoon sampling periods. Trends in lure preference were exhibited by both king and Spanish mackerel. King mackerel selected the larger 115 mm spoon more frequently while Spanish mackerel showed a strong preference for the 50 mm surface spoon. The most productive lures were the 115 mm spoon (trolled at a depth of 7 meters) and the 50 mm surface spoon. These two lures together accounted for 79 percent of all fishes collected.

The use of midwater structures in conjunction with an existing benthic reef proved a definite value in increasing the concentration and availability of baitfish and pelagic gamefish in the reef area. Even though the existing benthic reef materials located on Caper's reef provided a larger number of high profile objects than did the Kiawah reef, the midwater structures area still produced a significantly larger number of pelagic gamefish. The present study indicates that the incorporation of these midwater structures into a fishing reef area should enhance the pelagic gamefish stocks present in the area. Subsequently, this should aid in reducing the fishing pressure placed on the groundfish stocks that inhabit the benthic reefs by providing anglers an alternative and productive type of fishing (trolling).

These structures offer a new dimension to the construction and management of artificial reefs. Development of a fishing area composed entirely of these midwater structures adjacent to a benthic reef would allow an angler the opportunity to sample either or both the groundfish and the pelagic species without one type of angling interfering with the other. Thus the angling opportunities would be doubled and the productivity of the reef site greatly enhanced.

Further studies should be made into the design of midwater structures, their deployment and the feasibility and productivity of reefs composed entirely of these structures.

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