Artificial Reefs off Murrells Inlet, South Carolina

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Introduction

In recent years, many State fishery agencies have constructed artificial reefs to enhance recreational fishing. There are approximately 500 artificial reefs off the coasts of the United States (Stone, 1978) and most have been built since 1960. The most effective reefs have been built from tires, vessels, rocks, culverts, and other durable materials.

Research by Federal and State agencies and universities, showing the beneficial effects of artificial reefs on standing crops of fishes and on angular success, has stimulated reef building (Stone and Parker, 1974). Recent publications provide much of the information needed to construct reefs in fresh or salt water (Parker et al., 1974; Stone et al., 1974; Wilbur, 1974; Prince et al., 1977).

However, little information is available on how and why fishes use artificial reefs. What is available usually describes tropical or subtropical reef communities in relatively clear, warm water (Randall, 1963; McVey, 1970; Fast, 1974). Descriptions of fish behavior on artificial reefs in shallow, temperate waters are also scarce, even though these reefs are fished heavily (Buchanan, 1973; Buchanan et al., 1974). Agencies conducting studies in temperate waters are the California Department of Fish and Game (Carlisle et al., 1964; Turner et al., 1969), the New York Department of Environmental Conservation (Briggs and Zawacki, 1974; Briggs, 1975), and the National Marine Fisheries Service (Olla et al., 1974, 1975; Stone et al., 1974).

In the spring of 1971, the National Marine Fisheries Service and South Carolina Wildlife Resources Department began a study of the community structure of fishes on artificial reefs in shallow, temperate waters off Murrells Inlet, S.C., to document changes in community structure as the substrate was changed from a prereef sand bottom to a rough bottom artificial reef habitat. We monitored seasonal changes in the reef community and attempted to determine what changes were caused by recreational fishing pressure. This paper describes changes in activity in the benthic community.

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ABSTRACT—Between the spring of 1971 and the summer of 1974, the benthic community of reefs constructed of vessels and tires in 35 feet (11 m) of water off Murrells Inlet, S.C., was studied by scuba divers. Sixty-three species representing 33 families were observed; the most frequently encountered species were: black sea bass, Centropristis striata; *longspine porgy,* Stenotomus caprinus; *pinfish,* Lagodon rhomboides; spottail pinfish, Diplodus holbrooki; *pigfish,* Orthopristis chrysoptera; *tomtate,* Haemulon aurolineatum; *scad,* Decapterus *sp.; Atlantic spadefish,* Chaetodipterus faber; *cubbyu,* Equetus umbrosus; *Carolina hake,* Urophycis earlii; *sheepshead,* Archosargus probatocephalus; *and summer flounder,* Paralichthys dentatus. *Some species resided on the reefs throughout the year but fluctuated in abundance with the seasons; others were seasonal residents. Several species inhabited specific areas of the reefs. In the summer and fall, tropical fishes occupied the reefs but they rarely over-wintered. In the winter there were fewer species of fish but larger individuals.*

Study Area

Off Murrells Inlet, the natural bottom to a depth of about 35 feet (11 m) is mostly smooth sand or sandy mud with scattered patches of low profile rock outcrops. Struhsaker (1969) defined these small patches of rock outcrops, heavily encrusted with sessile invertebrates such as sponges and sea fans, as live bottom habitat and the sand and sandy mud areas as coastal habitat. He indicated that off the Carolinas the live bottoms occur at depths of 54-180 feet (17-55 m), and that inshore live bottoms near the 60-foot (18-m) contour have an invertebrate fauna less varied than those in deeper water. We found, however, that live bottom patches were scattered throughout the study area in depths less than 35 feet (11 m) and that some extended almost to the beach (Fig. 1).

Study Reefs

When we started our study, there were four artificial reefs within 13 miles (21 km) of Murrells Inlet (Fig. 1). The

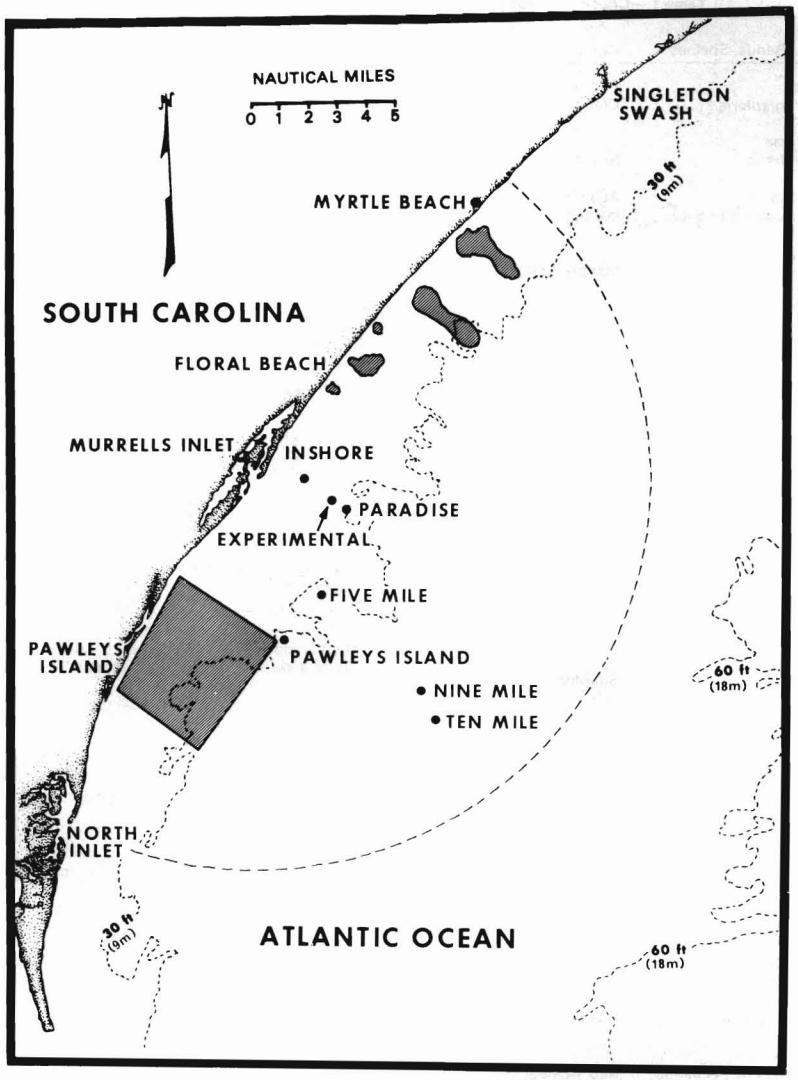


Figure 1.—Location of artificial reefs and natural rock reefs (shaded area) in our study area (dashed line) off Murrells Inlet, S.C.

State of South Carolina has since built other reefs in this area (Myatt, 1978). Paradise Fishing Reef was the largest and received more fishing pressure than the others; it was the first to have buoys maintained. This reef, built in 1968 by the Paradise Fishing Reef Association and expanded by the South Carolina Wildlife Resources Department, is located 3 miles (4.8 km) east of Murrells Inlet in 35 feet (11 m) of water. It consisted of four vessels from 26 to 140 feet (8-43 m) long and about 15,000 tires, which covered 0.01 miles^2 (0.03 km^2) of the bottom. The reef materials protruded from 1 to 15 feet (0.3-5 m) above the bottom and were covered with algae and invertebrates. We confined our studies to this reef and a smooth sandy area at a similar depth, 0.5 miles (0.8 km) inshore, where we constructed five small research reefs.

Sport Fishery

The sport fishery off Murrells Inlet extends from nearshore to nearly 60 miles (100 km) offshore. Most fishing occurs between May and November and peaks during summer. The offshore fishery (15 or more miles (24 km) offshore) comprises a dozen headboats and charter boats, and a few private boats. Headboats usually fish over rough bottom for snappers, groupers, porgies, grunts, and black sea bass. Charter and private boats primarily troll for pelagic species, but occasionally bottom fish. The nearshore fishery is composed primarily of private boats and an occasional headboat or charter boat. Bottom fishing in nearshore water yields mostly black sea bass, porgy, grunt, and summer flounder, while trolling yields chiefly Spanish mackerel and bluefish.

Paradise Artificial Reef and Pawleys Island Artificial Reef provide productive rocky habitat fisheries within easy access of most small boats (Buchanan, 1973; Buchanan et al., 1974). Private boat fishermen extensively use this improved habitat but headboats and charter boats do not. Bottom fishermen expended nearly half of their effort during the summer over the reefs and surface fishermen expended one-fifth. More bottom fish per angler-hour were caught over the reefs than over the sand bottom, but fewer than over live bottoms. The difference in catch rates between artificial and natural reefs may be due to the combined effects of high fishing intensity and more novice fishermen over the artificial reefs.

The reefs also benefited the economy of the local communities. In the summer of 1972, Paradise Artificial Reef attracted nearly 16 percent of the private boat nearshore fishermen to the Murrells Inlet area, and the money spent by these fishermen represented nearly 10 percent of the total spent by all nearshore fishermen.

Methods

In July 1971, we placed five small research reefs about 0.5 mile (0.8 km) inshore of the fishing reef to determine the effect of reefs on the distribution and abundance of fishes unaffected by fishing activities and to minimize interference with anglers on the main portion of the fishing reef. Each reef was constructed of eight-tire units,

placed 100, 150, 250, 400, and 700 feet (30, 45, 75, 121, and 213 m) from the anchor of a buoy. The reefs and anchor were connected with a 0.75-inch (2-cm) steel cable. Tire units were constructed with a base tire full of concrete anchoring three reinforcing rods that held from six to eight other tires in place. Visual, trawl, and bottom fauna surveys using scuba gear, a 15-foot (4.6-m) otter trawl over a 2,000-foot (610-m) transect, and a 0.67-foot[2] (0.06-m[2]) Peterson dredge, were made prior to constructing the experimental reefs. From November 1969 through June 1974, we made 28 trips to the study area and conducted 203 underwater surveys in 76 days. Trips were scheduled once a quarter except for intensive monthly surveys in the spring, summer, and fall of 1972 and 1973.

Fish Population Estimates

We estimated fish populations by direct counts when visibility was more than 4 feet (1.2 m) (it was rarely better than 8 feet (2.4 m)). We divided the reef into sections (size determined by depth of field) and counted fish at midday while stationed off to the side and above each section. Counts by two or more diver-biologists were averaged for nonseclusive fishes and all large schools of fishes (black sea bass[1], sheepshead, Atlantic spadefish, tomtate, jack and most porgy) but the highest counts were used for seclusive fishes and small schools of roving fishes (Carolina hake, cubbyu, jack-knife-fish, oyster toadfish, gag, and flounder). Accuracy of fish counts varies with visibility, time of day, and species (Hobson, 1965, 1968; Stark and Davis, 1966; Turner et al., 1969; McVey, 1970). Since these factors remained relatively constant throughout our surveys, we believe that our counting error also remained constant and our estimates are an indication of true population fluctuations.

To study territorial habits and growth rates, several species were trapped and tagged with a Floy[2] dart tag inserted with a stainless steel applicator or a Floy anchor tag inserted with a tagging gun (Fig. 2). Total lengths were recorded. We offered $1-25 rewards for returned tags and catch and growth information.

Table 1.—Checklist of fishes observed on Murrells Inlet, S.C., artificial reefs.

Family, Genus, Species	Common name
Rajidae	
Raja eglanteria	Clearnose skate
Dasyatidae	
Dasyatis sp.	Stingray
Clupeidae	
Opisthonema oglinum	Atlantic thread herring
Synodontidae	
Synodus foetens	Inshore lizardfish
Batrachoididae	
Opsanus tau	Oyster toadfish
Antennariidae	Frogfish
Gadidae	
Urophycis floridanus	Southern hake
Urophycis earlii	Carolina hake
Syngnathidae	Seahorse
Serranidae	
Centropristis philadelphica	Rock sea bass
Centropristis striata	Black sea bass
Diplectrum formosum	Sand perch
Hypoplectrus sp.	Unidentified
Mycteroperca microlepis	Gag
Serranus subligarius	Belted sandfish
Grammistidae	
Rypticus sp.	Soapfish
Pomatomidae	
Pomatomus saltatrix	Bluefish
Rachycentridae	
Rachycentron canadum	Cobia
Echeneidae	
Remora remora	Remora
Carangidae	
Caranx crysos	Blue runner
Caranx ruber	Bar jack
Chloroscombrus chrysurus	Bumper
Decapterus sp.	Scad
Selene vomer	Lookdown
Seriola dumerili	Greater amberjack
Seriola zonata	Banded rudderfish
Lutjanidae	
Lutjanus campechanus	Red snapper
Lutjanus synagris	Lane snapper
Pomadasyidae	
Anisotremus virginicus	Porkfish
Haemulon aurolineatum	Tomtate
Haemulon sp.	Unidentified
Orthopristis chrysoptera	Pigfish
Sparidae	
Archosargus probatocephalus	Sheepshead
Calamus arctifrons	Grass porgy
Diplodus holbrooki	Spottail pinfish
Lagodon rhomboides	Pinfish
Stenotomus carprinus	Longspine porgy
Sciaenidae	
Cynoscion nebulosus	Spotted seatrout
Equetus lanceolatus	Jackknife-fish
Equetus umbrosus	Cubbyu
Leiostomus xanthurus	Spot
Menticirrhus littoralis	Gulf kingfish
Pogonias cromis	Black drum
Mullidae	
Pseudupeneus maculatus	Spotted goatfish
Ephippidae	
Chaetodipterus faber	Atlantic spadefish
Chaetondontidae	
Chaetodon ocellatus	Spotfin butterfly fish
Labridae	
Halichoeres bivittatus	Slippery dick
Tautoga onitis	Tautog
————————	Unknown
Sphyraenidae	
Sphyraena sp.	Sennet
Blenniidae	Blenny
Gobiidae	Goby
Acanthuridae	
Acanthurus sp.	Surgeonfish
Scombridae	
Scomberomorus cavalla	King mackerel
Scomberomorus maculatus	Spanish mackerel
Scorpaenidae	Scorpionfish
Triglidae	
Prionotus carolinus	Northern searobin
Bothidae	
Paralichthys dentatus	Summer flounder
Paralichthys lethostigma	Southern flounder
Balistidae	
Balistes carpiscus	Gray triggerfish
Monacanthus hispidus	Planehead filefish
Ostraciidae	
Ostracion diaphanum	Spiny boxfish
Tetraodontidae	
Spheriodes maculatus	Northern puffer

Pre-Construction Surveys

The ocean bottom in the survey area was relatively barren sand with less than 10 percent natural rocky bottom (Fig. 1); it contained few encrusting

[1]Scientific names of most fishes mentioned in this paper are listed in Table 1.

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

Table 2.—Number of organisms taken on the experimental reef site during preconstruction survey with a 15-foot (4.6 m) otter trawl over a 2,000-foot (610-m) transect.

	Trawl		
Organisms	1 12 June 1971	2 13 July 1971	3 16 July 1971
Porifera	0	1	0
Crustacea	4	5	7
Mollusca	0	0	1
Echinodermata	47	3	13
Pisces	6	4	4

Table 3.—Checklist of invertebrates observed on Murrells Inlet, S.C., artificial reefs, 1971-74.

Common name	Family, Genus, Species
Sea anemone	Hydrozoa
Sponge	Porifera
Sea whip	*Plexaura flexuosa*
Star coral	*Astrangia danae*
Shortspined sea urchin	*Toxopneustes variegatus*
Longspined sea urchin	*Strongylocentrotus droebachiensis*
Sand dollar	Scutellidae
Common starfish	*Asterias forbesi*
Moss animal	Ectoprocta
Horse mussel	*Modiolus modiolus*
Horse oyster	*Ostrea equestris*
Slipper limpet	*Crepidula* sp.
Segmented worm	Polychaeta
Isopod	Isopoda
Barnacle	*Balanus* sp.
Stone crab	*Menippe mercenaria*
Blue crab	*Callinectes sapidus*
Long clawed crab	*Portunus spinimanus*
Hermit crab	*Pagurus* sp.
Spiny lobster	*Panulirus argus*
Octopus	*Octopus rugosus*
Sea squirt	*Molgula* sp.

organisms, such as oysters, hydroids, corals, sponges, and barnacles, since these animals require hard surfaces for attachment.

Two visual, three trawl, and six bottom fauna samples were obtained in June and July 1971, before construction of the experimental reef, to provide baseline data for our study. Most of the bottom was coarse sand and shell with small ripple marks from 1 to 2 inches (2.5-5 cm) high. A few sea urchins and starfish were seen. In a small patch (approximately 85 feet^2 (8 m^2), of silty bottom near the buoy anchor we saw one sea anemone, numerous tube worms, and two northern searobins. Only one game fish, a southern flounder, was caught during the trawl surveys. Fish made up only 15 percent of the catch and 70 percent of these were northern searobins (Table 2). The majority of the catch consisted of long clawed crabs[3] and shortspined sea urchins. Few invertebrates were taken in grab samples (Table 4).

[3]Scientific names of invertebrates are listed in Table 3.

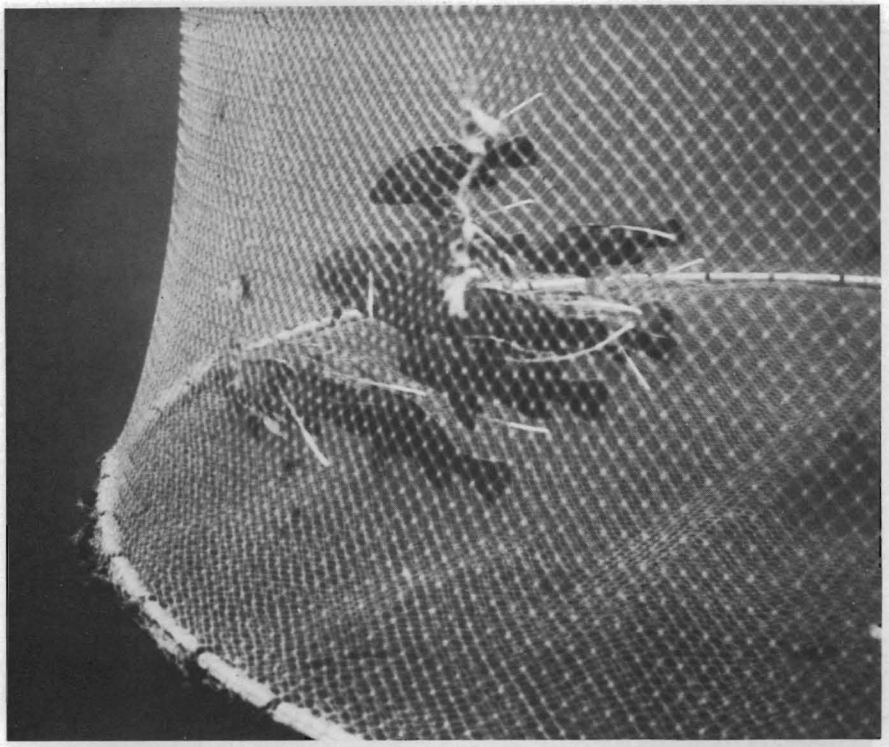


Figure 2.—Tagged black sea bass in holding net.

Description of Artificial Reef Community

Invertebrates and Plants

Encrusting organisms began to set on the reef within a few days after it was installed (Fig. 3). Barnacles, which set in July 1971, attained an average base diameter of 0.5 inches (1.3 cm) by November and a 0.75 inch (2 cm) base diameter by March 1972. Many of the large barnacles were heavily grazed by spring (Fig. 4), probably by sheepshead and black sea bass[4], which were numerous and which frequently feed on these items (McClane, 1965).

During winter, we observed prolific invertebrate growth on the tires, with

[4]Cupka, D. 1972. Aspects of the fishery for and biology of *Centropristis striata* in South Carolina waters. Annu. rep. proj. 2-138-R-1 coop. with Natl. Mar. Fish. Serv. under P.L. 88-309:1-64 (Unpubl.).

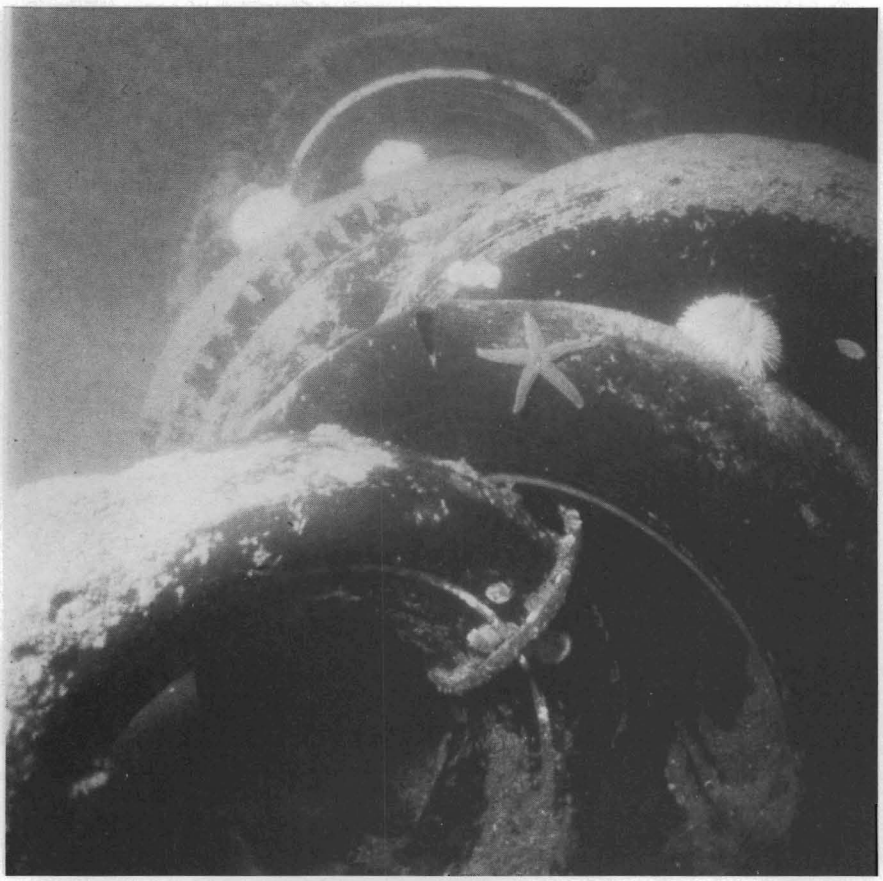


Figure 3.—Bound tires provide good surface area for encrusting organisms and abundant cover for fishes.

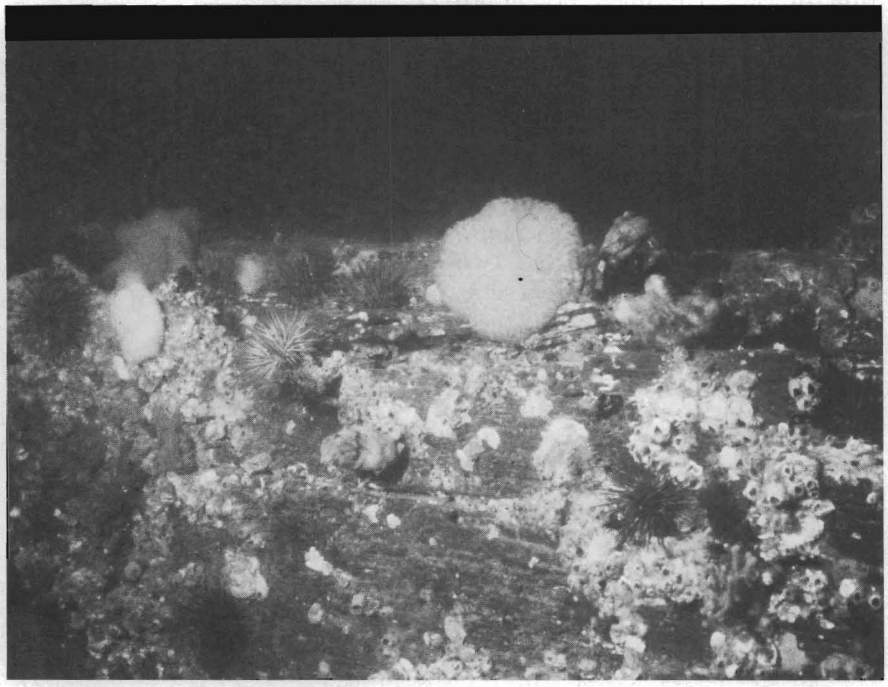


Figure 4.—Encrusting organisms are heavily grazed in winter.

Table 4.—Number of organisms taken on the experimental reef site during preconstruction survey with a 0.67-foot² (0.06-m²) Peterson dredge on 13 July 1971.

	Grab Number					
Organisms	1	2	3	4	5	6
Anthozoa	0	0	several	0	0	0
Bryozoa	0	0	several	0	0	0
Annelida	5	0	1	3	4	1
Crustacea	1	2	2	0	0	2
Mollusca	1	1	0	0	0	0
Echinodermata	1	0	3	1	0	1
Cephalochordata	1	0	0	0	1	0

hydroids and sponges displaying the greatest increase in both abundance and size (Fig. 5). We found small polychaete worms and numerous small isopods and amphipods living in and on hydroids and sponges. Numerous large sea anemones were also present. Portunid crabs, the most abundant motile invertebrates observed, appeared to be occupying the same habitat used by black sea bass, pigfish, and pinfish in the warmer months.

In March 1973, we collected the following algae from the Paradise Fishing Reef: Perennials—*Codium isthmocladium*, *Sargassum filipendula*, *Champia parvula*, and *Callithamnion byssoides;* and winter algae—*Polysiphonia havanensis*, *Ceramium fastigiatum f. flaccida*, and *Bryopsis pennata*. These species are common on the rough bottom in this area.

Fishes

The observed community structure of artificial reef fishes differed considerably from that inferred from catches (Table 5). In June and July 1972, 19 species were observed, 14 were caught, but only 9 were common to both groups. Observed or caught species

composition is related to feeding habits, size of mouth, and fish behavior. Fishes seen but not caught included plankton feeders (blenny, scad, juvenile sennet, and porgy), rooters (spotted goatfish and Carolina hake), and small-mouthed fishes that are hard to hook (jackknife-fish, cubbyu, lookdown, spiny boxfish, and Atlantic spadefish). Fishes caught but not seen by divers were open bottom species (northern searobin, northern puffer, spot, and gulf kingfish) and the pelagic cobia. From 70 to 98 percent of the fish observed on the fishing reef were game fish. A total of 63 species representing 33 families were seen during the study (Table 1).

One year after the preconstruction surveys, we made quantitative estimates of fish abundance by visual counts around one of the groups of tire units on the experimental reef. We estimated 82 fish or 0.27 fish/foot^2 (0.025/m^2), a standing crop 1,814 times greater than that estimated before reef construction.

Fish Movement

Territoriality

To study movement of reef fishes, we tagged, on 14 occasions, 193 fish representing 12 species (Table 6). Most were black sea bass (75 percent). On 27 occasions we observed 132 tagged fish representing 7 species, and only 11 percent of these (14 black sea bass and 1 Atlantic spadefish) were seen away (100-250 feet (30-76 m)) from where they were captured and released (Fig. 6). Some of these fish moved in 1 day and most had moved within 30 days.

To determine if some of these species were residents of a particular reef, we released 18 tagged fish on a group of tires 150 feet (46 m) from where they were caught. Four of eight black sea bass, one of six longspine porgy, and the only cubbyu tagged were observed back at the capture site 2 days after they were released. Inclement weather prohibited diving the day after they were released. On five occasions over a period of 10 months one to three of these tagged fish were observed at the capture site but none were seen at the release site. Some tagged black sea bass remained on the reef throughout the year. A tagged longspine porgy was seen on the reef 33 days (17 August-19 September 1972) after it was released, and a tagged gag grouper remained on the reef from February through July when the study was terminated. Thirty-four tagged black sea bass and one tagged pigfish have been caught by fishermen in the release area. No tagged fish have been seen or caught elsewhere.

Figure 5.—Prolific winter growth of hydroids and sponges.

Recruitment

Two of the experimental reefs, designated "A" and "B" and located 150 feet (46 m) apart (Fig. 7), were selected in June 1973 for a recruitment study. Twenty-five fish were trapped and tagged on reef B: 19 black sea bass, 4 pigfish, 1 longspine porgy, and 1 cubbyu. One hundred twenty-one fish were removed from reef A, leaving only 10 fish (7 black sea bass, 1 pinfish, 1 Carolina hake, and 1 cubbyu). One

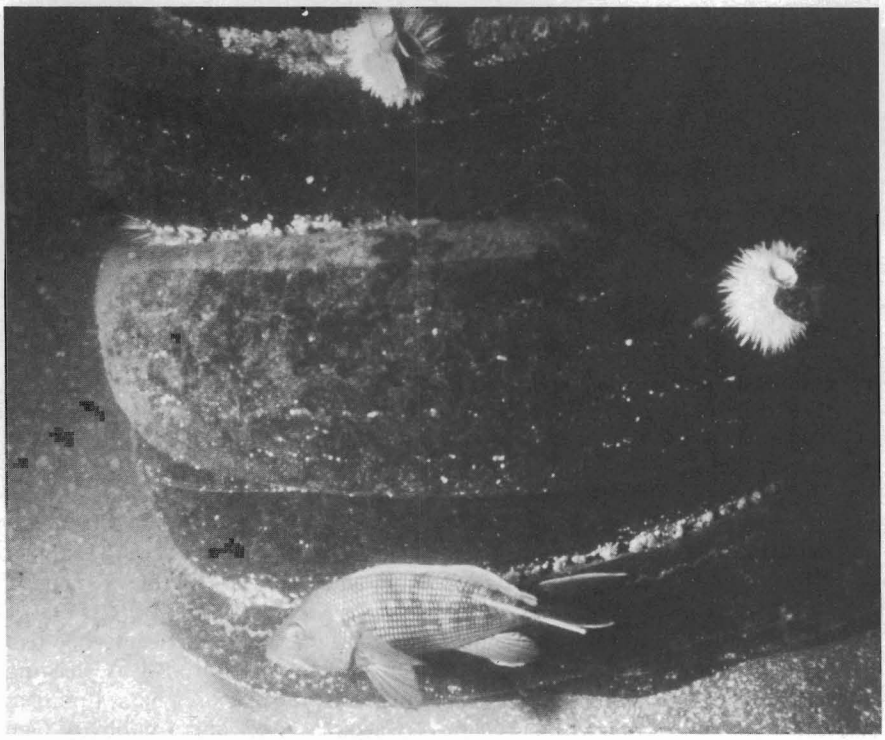
Table 5.—Paradise Artificial Reef fish community structure determined from observation and catch statistics, 1972, in percent.

	Observed			Caught		
Species	June	July	Combined	June	July	Combined
Sea bass	1.1	2.5	2.0	38.1	33.5	36.5
Black sea bass						
Rock sea bass						
Grunt		23.0	11.5	29.4	34.8	31.4
Pigfish, tomtate						
Porgy	45.7	51.8	48.8	9.0	17 2	12.0
Spottail pinfish						
Longspine porgy						
Scup, pinfish						
Flounder		0.2	0.1	7.7	7 2	7.6
Summer flounder						
Southern flounder						
Atlantic spadefish	22.8	11.5	17.2		1.8	0.7
Bluefish		8.6	4.3	0.3	0.5	0.3
Gulf kingfish				6.2	0.5	4 1
Cobia				1.8		1 1
Jack	0.7		0.3	1.0	2.7	1.6
Mackerel	0.1		0.1	0.3		0.2
Northern puffer				2.8		1.8
Oyster toadfish		0.1	0 1	0.5	1.4	0.8
Searobin				2.1		1.3
Sand perch	11.4		5.7			
Scad	11.4		4.7			
Sennet	5.7		2.9			
Lookdown		0.7	0.3			
Cubbyu	0.6	0.1	0.3			
Jackknife-fish	0.3		0.2			
Spiny boxfish	0.1		0.1			
Carolina hake		0.1				
Goatfish	0.1		0.1			
Blenny		0.8	0.4			
Spot				0.8	0.5	0 7

Table 6.—Species and numbers of fish tagged and recovered on a Murrells Inlet, S.C., artificial reef, 1972-74.

Common name	Genus, species	Tagged	Recovered
Black sea bass	*Centropristis striata*	145	34
Pigfish	*Orthopristis chrysoptera*	14	1
Oyster toadfish	*Opsanus tau*	8	
Longspine porgy	*Stenotomus caprinus*	7	
Gray triggerfish	*Balistes capriscus*	5	
Pinfish	*Lagodon rhomboides*	4	
Carolina hake	*Urophycis earlii*	4	
Cubbyu	*Equetus umbrosus*	2	
Atlantic spadefish	*Chaetodipterus faber*	1	
Summer flounder	*Paralichthys dentatus*	1	
Scup	*Stenotomus chrysops*	1	
Gag	*Mycteroperca microlepis*	1	
Total		193	35

Figure 6.—Tagged black sea bass are easily observed underwater.



month later the number of trapable fish (those that could not escape through 7/16- × 9/16-inch mesh) increased threefold on A, to about the same number on B, which remained relatively constant (Fig. 8). This increase was due to recruitment, not growth, since there were no smaller fish observed on A the previous month. The numbers of fish dropped a little through the summer, increased in the fall, dropped in the winter, and increased again the following spring. The fall and spring influxes were also evident in black sea bass populations the previous year. No tagged fish from reef B were seen on reef A (150 feet (46 m) away), although some did move in the opposite direction up to 250 feet (76 m) along reef material spaced at intervals of 100 feet (30 m) or less. It is possible that in this area material separated by 100 feet (30 m) or less may constitute a continuous reef or territory for these species whereas material separated by 150 feet (46 m) or more may represent an isolated reef.

Seasonal Species Composition

Winter

During winter there was less species diversity and greater individual size than during summer. We noted sheepshead, black sea bass, black drum, Carolina hake, spotted seatrout, clearnose skate, sand perch, and a small gag in protected areas of the reef. Only a few black sea bass were seen on the less protected areas of the reef. Sheepshead and black drum used artificial habitat

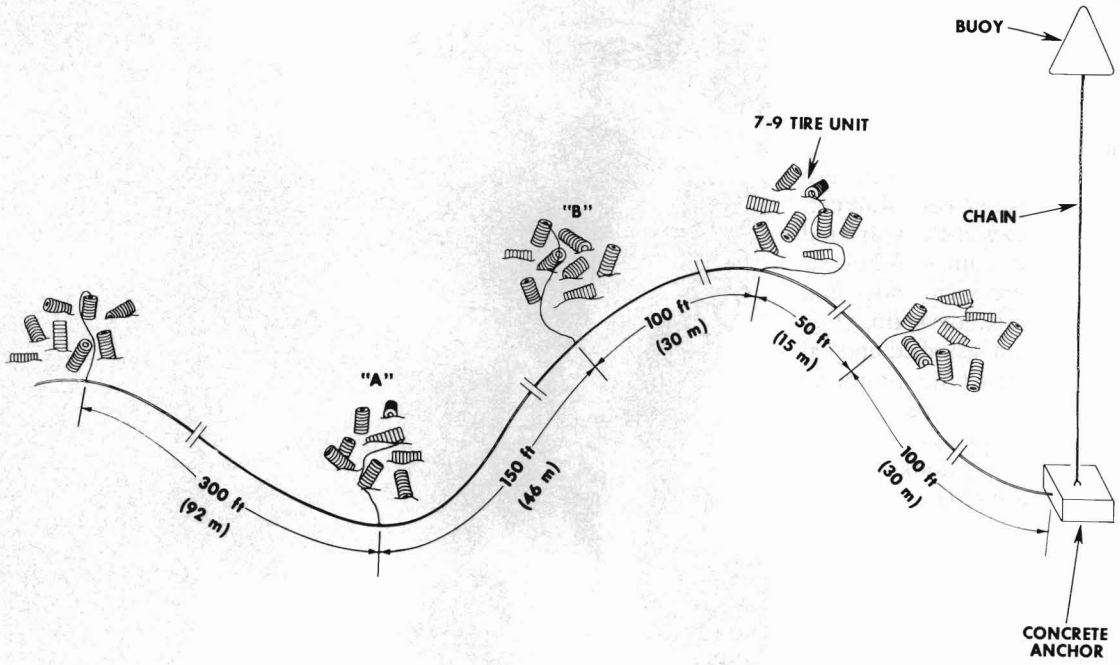


Figure 7.—Experimental reefs layout; "A" and "B" used for recruitment study.

Figure 8.—Monthly fluctuations of trapable fishes on reefs A and B, 1973-74.

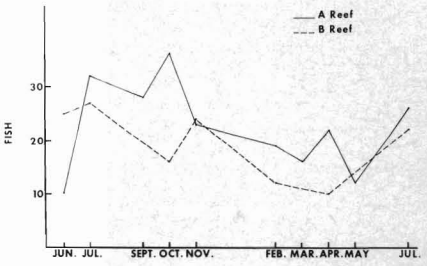
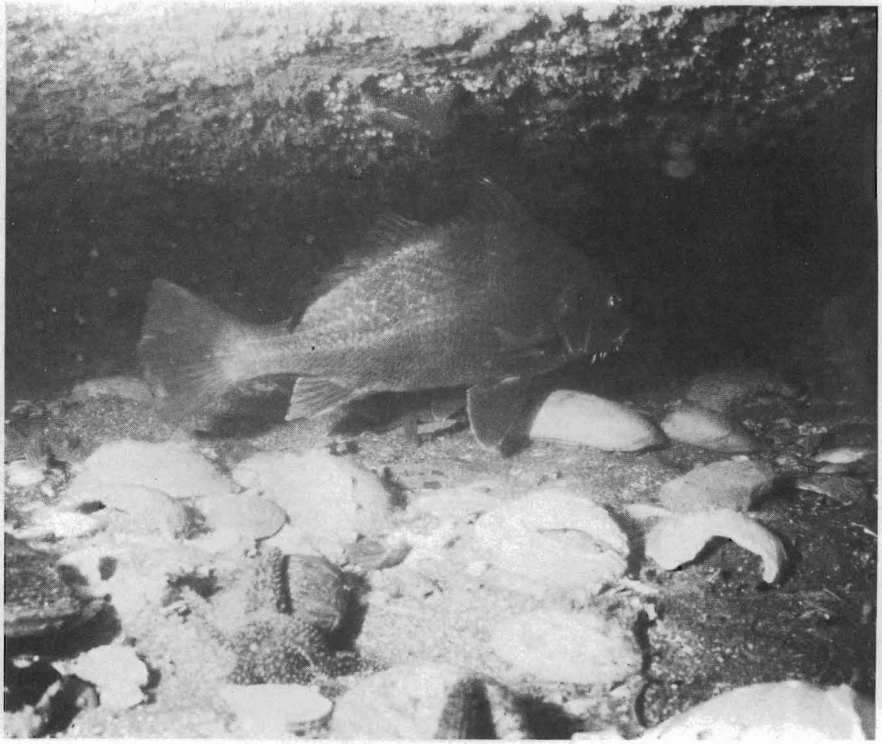


Figure 9.—Wintering black drum under cover of a barge.



mainly for shelter during cold periods (Fig. 9). On two occasions in 45°F (7°C) water, we saw dozens of 2- to 6-pound (0.9- to 2.7-kg) fish lying in a semitorpid state deep under reef material. They moved sluggishly when approached by a diver. Hundreds of active Carolina hake were seen under reef material on two occasions (Fig. 10). Six specimens with bulging abdomens, collected and examined in March, were full of crustacea, mostly crabs. Their gonads were undeveloped.

Spring and Fall

Large numbers of juveniles of several species (black sea bass, longspine porgy, spottail pinfish, pigfish, and tomtate) invaded the reefs in spring and stayed through fall (Fig. 11). Young-of-the-year fishes were also prominent in spring and early summer. Hundreds of young-of-the-year and adult cubbyu and young-of-the-year black sea bass were seen under and around reef material in the spring (Fig. 12). Spotted seatrout schooled and fed around reef material in both spring and fall (Fig. 13). A few specimens, some larger than 27 inches (69 cm) total length, were caught on hook and line by South Carolina biologists.

Summer

In summer there were more species of fish and less individual size than during winter. Tropical fishes (spotfin butterflyfish, hamlet, porkfish, red snapper, slippery dick, and soapfish) used the reefs from midsummer to early fall when the bottom water

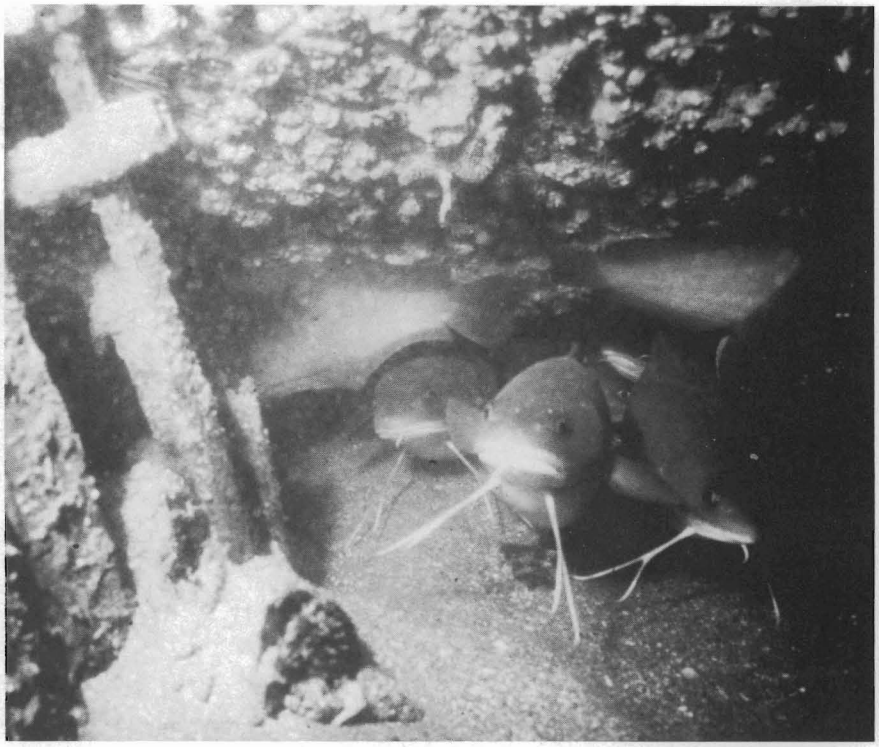
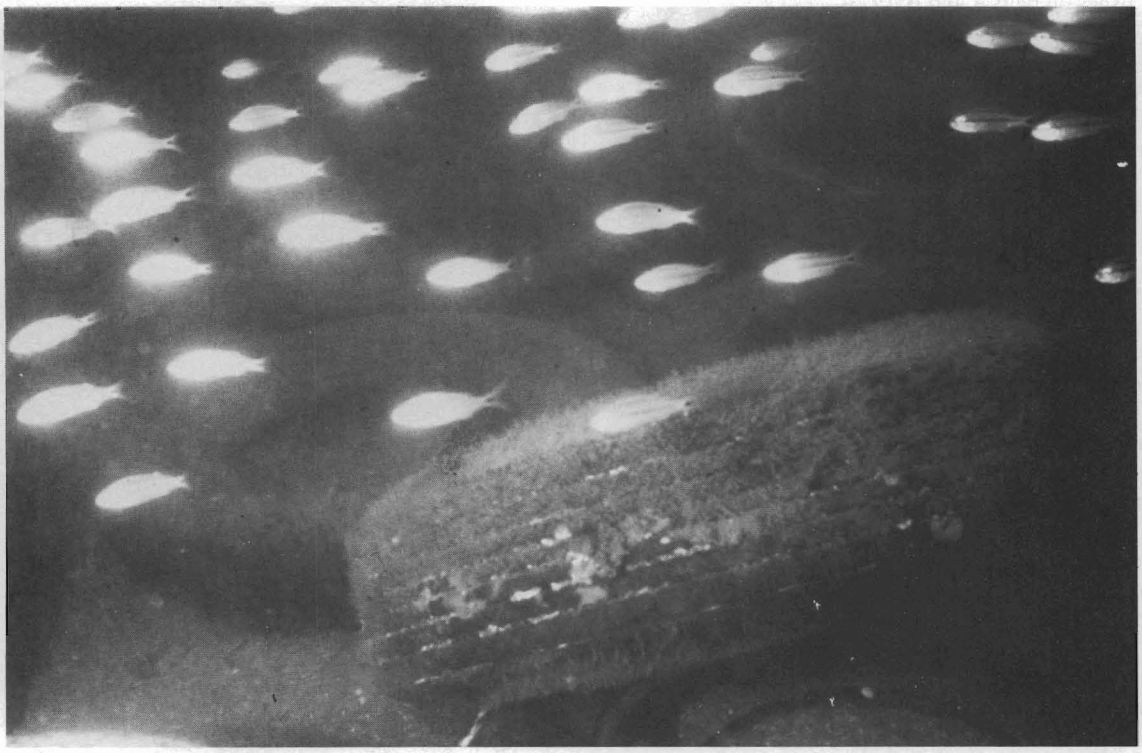


Figure 10.—Carolina hake gather under reef material during the winter for food and shelter.

Figure 11.—Juvenile tomtates are abundant in spring and early summer.



temperature exceeded 80°F (27°C) (Fig. 14). Dozens of flounder were seen during this period in, on, and beside reef material (Fig. 15). A school of 3- to 5-pound (1.4- to 2.3-kg) bluefish were observed using the inside of a landing craft during the summers of 1972, 1973, and 1974 (Fig. 16). These fish did not appear to be feeding; as divers approached, their activity increased rapidly and they quickly left the area.

Other Behavioral Observations

Growth

Three tagged black sea bass were recaptured after 174, 310, and 339 days. They had grown from 7.9 to 9.5 inches (20-24 cm), 5.5 to 8.1 inches (14-21 cm), and 7.0 to 10.1 inches (18-26 cm), respectively, an average of 0.3 inch (0.8 cm) per month. This rate was almost three times that obtained from scale analysis by Cupka (footnote 4) for 229 fish of the same size range in the South Carolina commercial fishery, and twice that obtained from scale analysis by Mercer[5] for 50 fish of the same size range collected from Murrells Inlet artificial reefs during our study.

Mutualism

On 19 September 1972, we observed spottail pinfish cleaning blue runner around a buoy anchor chain about 5 feet (1.5 m) off the bottom. Several single-tire units (ventilated tire with weight) were scattered around the anchor and spottail pinfish were feeding on organisms attached to the tires and anchor chain. As approximately 50 blue runner, 12-16 inches (30-40 cm) long, swam by the anchor chain, one to three would stop suddenly, some in a head down position. Each would then be surrounded by two to four spottail pinfish, 3-5 inches (8-13 cm) long, searching for ectoparasites (Fig. 17). Some blue runners quivered as they were cleaned. After each cleaning, which lasted several seconds, the

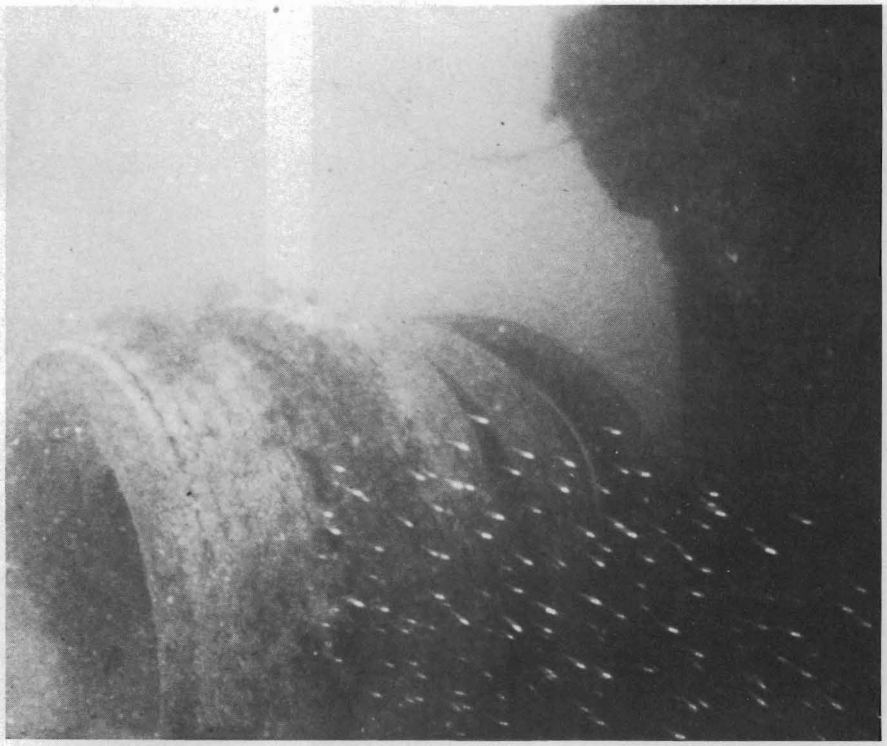
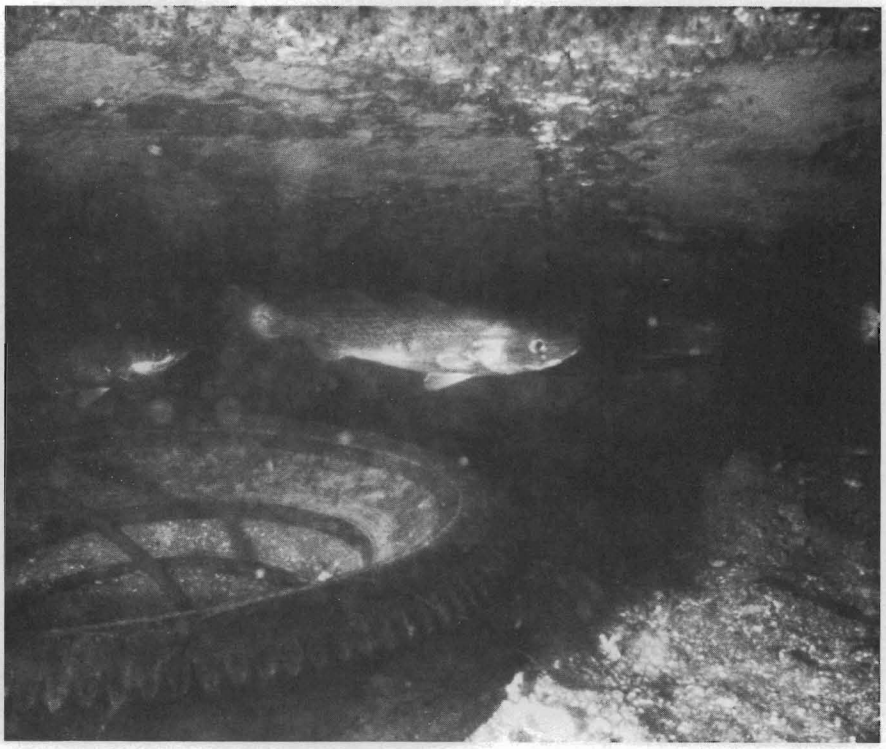


Figure 12.—Young-of-the-year fishes frequent the reefs in spring.

Figure 13.—Spotted seatrout use the reefs in spring and fall.



[5]L. Mercer, Ph.D candidate, Virginia Institute of Marine Science, Gloucester Point, Va. Pers. commun.

Figure 14.—Tropical fishes frequent the reefs from midsummer to early fall.

Figure 15.—Flounder are abundant in and around reef material during summer.

Figure 16.—Large schools of 3- to 5-pound (1.4- to 2.3-kg) bluefish used the inside of a landing craft during the three summers of our study.

Figure 17.—Spottail pinfish cleaning blue runners.

jack continued swimming in 20-30 foot (6-9 m) circles around the buoy chain. We observed over 30 cleanings in a 45-minute period.

Porgies are known to be both cleaners and hosts. Breder (1962) observed a pinfish cleaning striped mullet, *Mugil cephalus*, and Potts (1968) observed a wrasse, *Crenilabrus melanocerus*, cleaning the porgy, *Diplodus vulgaris*. Carr and Adams (1972) found ectoparasites and scales in the stomach contents of juvenile spottail pinfish, 0.8-2.8 inches (2-7 cm) long (S.L.), collected near Crystal River, Fla. They did not find ectoparasites or scales in smaller or larger fish and hence suggested that the spottail pinfish goes through a stage in the first year of its development as a cleaner. Our observations verify that spottail pinfish are cleaners, but the fish we observed off South Carolina were larger than those collected by Carr and Adams. We determined fish sizes from visual observations and photographs of the cleaners feeding on organisms attached to anchor chain links of known dimensions.

Jacks are also known to be both cleaners and hosts; e.g., pilotfish, *Naucrates ductor*; young bar jack; and juvenile leatherjacket, *Oligoplites saurus*; are sometimes cleaners (Hass, 1953; Randall, 1962; Carr and Adams, 1972). An amberjack was observed

being cleaned by an adult porkfish[6] and bar jack have been seen being cleaned by goby, *Gobiosoma evelynae*; Spanish hogfish, *Bodianus rufus*; bluehead wrasse, *Thalassoma bifasciatum*; and juvenile gray angelfish, *Pomacanthus aureus* (Limbaugh, 1961; Collette and Talbot, 1972). However, this is the first time the blue runner has been observed being cleaned.

Summary

The artificial reefs off Murrells Inlet, S.C., provide a productive rough bottom habitat within easy access from Murrells Inlet marinas. The species composition on the reefs appears to be similar to that found on natural rough bottom habitat at the same depth in the study area.

The artificial reefs are occupied by a variety of species; some are seasonal inhabitants while others reside on the reefs throughout the year. In general, there are fewer species and larger individuals in winter than in warmer months when the influx of juveniles and tropical species increases considerably the number of species but reduces the average size.

Several observations were new to us, but are probably indicative of similar occurrences on other rough bottom areas off the Carolinas. Specifically, these were our observations of many black drum and Carolina hake using the protected areas of the reefs during the winter, apparently the same school of bluefish occupying a particular section of reef for several months and the cleaning behavior exhibited by spottail pinfish.

Based on our observations on the artificial reefs and our studies of recreational fishing by private boats out of Murrells Inlet we believe these artificial reefs are being used effectively to increase rough bottom habitat and to improve recreational fishing for species that occupy reef habitat.

[6]J. R. Larson. Unpublished report submitted to Broward Artificial Reef, Inc.

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