AN ANALYSIS OF THE FISH POPULATIONS OF ARTIFICIAL AND NATURAL REEFS IN THE VIRGIN ISLANDS

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INTRODUCTION

In recent years the concept of the artificial reef as a means of increasing the productivity of fishes that require an irregular bottom of rock or coral, and to create points of concentration for more open water fishes has received much attention. According to Stroud (1961), 12 of the United States have established one or more artificial reefs in their coastal marine waters since 1950. The reefs have been built of such materials as rock, construction rubble, old automobile and street car bodies, old boats, concrete pipe, and oil drums. In Japan, Hawaii, and California box-like structures with openings on each side have been made of reinforced concrete and lowered to the bottom for habitation by fishes.

Experience has shown the advisability of thorough surveys of the areas for which artificial reefs are planned to insure that they are successful in attracting and maintaining a population of valuable fishes. The bottom should not be of soft mud or shifting sand because the reef material may eventually be covered. Other environ. mental factors such as current, salinity and depth of water must also be considered. The water should be deep enough to prevent the effect of heavy surge from surface waves. The structure and composition of the reef itself is also of great importance. The higher it is and the more hiding places that it provides, the greater will be the number of fishes that will live in it. Reef materials of thin ferrous metal or wood should be avoided, for they will disintegrate in a few years.

A survey of the marine environments of St. John, Virgin Islands (Kumpf and Randall, 1961) and of the fishery resources of the island (Idyll and Randall, 1959) has indicated that fishing can be improved if artificial reefs are established, The trapping of reef fishes in pots is the major commercial fishery of the Virgin Islands. Most fishing takes place over the narrow fringing reef that surrounds much of the island. The rock and coral of the reef does not extend more than one-fourth of a mile from shore and is usually considerably less than 200 meters in width. To seaward of the reef the bottom is monotonously flat, consisting of bare sand, gravel, coral rub. ble, or seagrass (but all sufficiently firm to support reef structures). Well developed patch reefs, so conspicuous in other tropical and subtropical western Atlantic localities such as the Bahamas and the Florida Keys, are almost totally lacking. The great expanse of flat bottom of the Virgin Islands shelf area to a maximum depth of 64 meters extends from 4 to 8 miles to the south of St. John and even farther to the north before the sharp drop-off into deep water. Except for a few discontinuities in the bottom, these flats are almost devoid of demersal fishes of any importance to fishermen, The limited fringing reef area receives nearly all of the fishing effort, and as a consequence the effect of overfishing is evident.

PROCEDURE

In order to determine how productive of fishes an artificial reef might be in Virgin Islands waters, one of 800 concrete blocks (each measuring 16 inches by 8 inches by 8 inches and containing two holes 5 inches square) was built in Lesser Lameshur Bay, St. John, on April 6, 1960. The reef is located in line with Boiling House Point and Cabritte Horn Point (see Randall, 1962, Figs. 1 and 2 for charts of the area) 120 meters from Boiling House Point. The depth of the water is 9 meters, and the bottom is seagrass (about half *Thalassia testudinum* and half *Cymodocea manatorum)*

The blocks were arranged to form tunnels with holes 16 inches high and about 8 inches wide. The tunnels were variously interconnected over a roughly circular area of about 125 square meters, but the actual area of the blocks when viewed from above is 50 square meters. After infrequent periods of heavy swells, it was noted that parts of the tunnels had collapsed. The tunnels were rebuilt while the temporary field station at Lameshur was

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still in operation, but after June, 1961, when the station was abandoned, this maintenance was discontinued. When all of the fishes were collected from the reef on August, 1962, most of the tunnels had fallen down, although there was still considerable shelter among the piles of blocks. Local fishermen had been asked not to fish at the artificial reef until the study was concluded, but it is possible that some did, and anchors from their vessels could have caused some of the damage to the reef structure. Nevertheless most if not all have resulted from wave action.

RESULTS

Few fishes had taken up residence in the artificial reef a week after it was established, and with the exception of two queen triggerfishes *(Balistes vetula),* all were small fishes that one can find in the adjacent grass beds.

On April 25, hence 19 days after the reef was built, a concentration of fishes was apparent which was well above that encountered in the seagrasses. The most abundant fishes were young yellowtail snappers *(Ocyurus chrysuru),* which mostly swam free in the water above the reef (they are primarily zooplankton feeders), the three West Indian species of surgeonfishes *(Acanthurus),* all busily grazing on the fine fur of filamentous algae on the blocks, young white grunts *(Haemulon plumieri),* young and subadult goatfish *(Pseudupeneus maculatus)* which were often seen resting on the top of the blocks, and slippery clicks *(Halichoeres bivittatus),* mostly as juveniles. Fishes commonly seen in the adjacent grass beds were also often encountered on the reef. These included the wrasse *Halichoeres poeyi,* the small parrotfish *Sparisoma radians,* juvenile *Sparisoma chrysopterum,* juvenile butter hamlet *(Hypoplectrus puella),* and the small grouper *Alphestes afer,* both as young and adults. The only other fishes present as adults were six individuals of *Balistes vetula* and two of the squirrelfish *Holocentrus ascensionis,* along with a few juveniles. One subadult French angelfish *(Pomacanthus arcuatus),* an unidentified juvenile *Pomacanthus,* and about a 6-inch queen angelfish *(Holacanthus ciliaris)* were present. In addition there were a few juvenile banded butterflyfishes *(Chaetodon striatus)* and sharpnose puffers *(Canthigaster rostrata),* three trumpetfishes *(Aulostomus maculatus)* about 1 foot long, three porcupinefishes *(Diodon holacanthus)* about 4 inches long, three or four juvenile blackbar soldierfishes *(Myripristis jacobus),* one small damselfish (probably *Pomacentrus variabilis),* one juvenile bluehead wrasse *(Thalassoma bifasciatum),* and a small moray *(Gymnothorax vicinus).* Several adult spiny lobsters *(Panulirus argus)* occupied the ends of the tunnels. They were responsible for starting an accumulation of mollusk shells, particularly turkey wings (Area zebra), at the entrances to the tunnels. The lobsters apparently foraged for the mollusks at night and fed on them in the shelter of the reef. Some of the larger turkey wings were alive and intact; evidently they were too large for the lobsters to crush with their mandibles. The lobster population changed from week to week, varying from none to six or seven. Their tendency migrate is well known (Smith, 1958).

On May 6 the reef was visited again. The only obvious new arrivals were a number of iuveniles of the tomtate *(Haemulon aurolieatum).*

One month later the reef was dominated by clouds of *H. aurolineatum* about 2 to 3 inches in length. A small school of yellowbanded goatfish *(Mulloidichthys martinicus),* each about 5 inches long, was seen for the first time. Also not detected previously were juveniles of the following: *Holocentrus coruscus, Holacanthus tricolor, Pomacentrus planifrons, Cantherhines pullus,* and *Hypoplectrus* sp. (undescribed). Single small adults of *Ophioblennius atlanticus, Halichoeres maculipinna* and *Sparisoma rubripinne* were also sighted. Two mutton snappers *(Lutjanus analis),* about 1 foot in length, were observed next to the reef, but were never seen again. Most of the species arriving earlier to the reef had increased in abundance. Of the larger fishes the grouper *Alphestes afer* was dominant.

Three months later (September 4) the reef was again visited. The most abundant fish was still *Haemulon aurotineatum,* in sizes up to a maximum of about 4 inches. The second most abundant species was *H. plumieri,* to lengths of about 5½ inches; then *Pseudupeneus maculatus* and *Ocyurus chrysurus,* mostly as juveniles, but some as subadults. Next in abundance was *Myripristis jacobus* at lengths to 3 inches; then *Thalassoma bifasciatum,* mostly less than 1½ inches in length. Other common fishes were juveniles of *Acanthurus coeruleus,* mostly less than 1½ inches long, *Alphestes afer* of all sizes, *Holocentras ascensionis* from about 3 inches to goodsized adults, *Acanthurus chirurgus* up to about 5 inches, and *Acanthurus bahsianus* to about 3½ inches, There were several 5-inch individuals of *Bulistes vetula* in addition to the adults. Other new species to the reef were *Cephalopholis fulva* (one about 5 inches long), *Haemulon album* (one of 5 inches), *Sparisoma aurofrenatum* (4 inches), *Equetus pulcher* (2 to 4 inches), *Serranus tigrinus* (2 inches), *Chaetodon capistratus, Haemulon flavolineatum, Chilomycterus* sp., and an unidentified small clinid.

On February 23, 1961 the dominant fishes on the reef were still the two species of grunts *(Haemulon)* and small yellowtail snappers *(Ocyurus)*. The relative abundance of the goatfish *Pseudupeneus maculatus* had dropped, and most that were present occurred as subadults and adults. Other fishes that were represented by one or a few adults that could not have grown from juveniles on the reef were *Acanthurus chirurgus, Sparisoma chrysopterum, Haemulon sciurus* (also present as juveniles), and *Haemulon parrai*. One 12-inch Nassau grouper *(Epinephelus striatus)* was also observed, Other new additions were *Halichoeres garnoti, H. radiatus*, and *Pomacentrus pictus*. Still not observed were such common reef fishes as the damsel fish es *Pomacentrus fuscus, Microspathodon chrysurus,* and *Abudefduf saxatilis,* the parrotfishes *Scarus croicensis, S. taeniopterus,* and *Sparisoma viride,* the groupers *Epinephelus guttatus, E. adscensionis,* and *Petrometopon crutentatum*, the snappers *Lutjanus griseus, L. mahogoni, L. apodus,* and *L. synagris,* and cardinalfishes (Apogonidae).

The growth of *Thalassia* and *Cymodocea* immediately adjacent to the concrete blocks was beginning to become sparse, evidently from the grazing by the few large parrotfishes and surgeonfishes.

Ensuing observations of the reef up to June, 1961, when the field station was closed, did not reveal any marked changes in the fish population other than reduction in the number of small fishes and an increase in the larger ones.

On August 17, 1962, 2 years and 4 months after the Lameshur Bay reef was built, the author and associates returned to St. Jonn to collect the fishes from it with poison. As expected, observations showed that there had been a further increase in the number of large fishes on the reef. *Haemulon* plumieri had become the dominant species. Some fishes, such as angelfishes of the genus *Pomacanthus* and trumpetfish *(Aulostomus)*, were no longer seen.

The reef was surrounded by a fine mesh seine 2.5 meters in height which was weighted to the bottom, and all of the fishes were killed with 5 gallons of Pro-Noxfish (a commercial preparation containing rotenone). Some of the fishes floated to the surface and were carried slowly downcurrent. A few of these were lost to frigate birds and laughing gulls before they could be collected by swimmers.

A total of 2754 fishes of 55 species, weighing 87.29 kilograms, were collected from the reef. This represents an average of 1.74 kilograms of reef fishes per square meter of concrete block. The increase in fish biomass with time was definitely not linear. The 87 kilograms may be regarded as the production of fishes of the reef for the 2 year, 4 month period, but this cannot be reduced to an expression such as kilograms per month or year. After 1 year and 2 months, there was much more than half of the mass of fishes present on the reef than after 2 years and 4 months. Ideally, a series of identical reefs should be established in comparable environments, and all of the fishes collected from each at intervals. The production per interval could then be ascertained. It is expected that the increase in biomass of reef fishes would follow a curve similar to that of the growth of a single organism, *i.e.* rapid at first and leveling off asymptotically with time.

Table 1 gives the breakdown of the fishes collected from the artificial reef. It is arranged by family in the order of dominance by weight. The column to the left of the species names represents the number of specimens; the millimeter measurements in parentheses to the right are the extremes in standard length of the specimens. The total weight of the fish of each species was rounded off to the nearest .01 kilograms. Families weighing less then .01 kilograms are listed only by number of specimens and range in standard length.

A few of the small fishes such as the moringuid eels and some of the gobies are sand-dwelling forms that may not properly be regarded as a product of the reef; however their numbers and mass are so insignificant that to omit or retain them is immaterial.

The Pomadasyidae was clearly the dominant family by both weight and numbers, followed by the Serranidae and Holueen-

TABLE 1. ANALYSIS OF FISHES COLLECTED FROM AN ARTIFICIAL REEF IN ST. JOHN, VIRGIN ISLANDS.

POMADASYIDAE			
1267	Haemulon plumieri	(46-218 mm.)	25.65 kg.
577	Haemulon aurolineatum	(46-150 mm.)	7.38 kg.
27	Haemulon sciurus	(125-210 mm.)	4.04 kg.
1	Haemulon flavolineatum	(82 mm.)	.01 kg.
1872			37.08 kg.
SERRANIDAE			
65	Alphestes afer	(155-203 mm.)	10.17 kg.
7	Epinephelus striatus	(212-360 mm.)	6.13 kg.
18	Petrometopon cruentatum	(61-240 mm.)	.98 kg.
6	Serranus tigrinus	(32- 73 mm.)	.03 kg.
3	Hypoplectrus puella	(63- 65 mm.)	.03 kg.
99			16.34 kg.
HOLOCENTRIDAE			
370	Myripristis jacobus	(42-123 mm.)	6.17 kg.
59	Holocentrus ascensions	(57-208 mm.)	4,88 kg.
4	Holocentrus coruscus	(58- 59 mm.)	.02 kg.
1	Holocentrus bahianus	(66 mm.)	— kg.
434			11.07 kg.
ACANTHURIDAE			
29	Acanthurus chirurgus	(60-221 mm.)	2.46 kg.
49	Acanthurus coeruleus	(35-157 mm,)	1.47 kg.
14	Acanthurus bahianus	(58.184 mm.)	1.32 kg.
83			5.25 kg.
BALISTIDAE			
6	Balistes vetula	(215-330 mm.)	4.88 kg.
SCARIDAE			
3	Sparisoma rubripinne	(256-306 mm.)	2.16 kg.
27	Sparisoma aurofrenatum	(42-212 mm.)	1.78 kg.
3	Sparisoma chrysopterum	(139-209 mm.)	.23 kg.
4	Sparisoma viride	(93-132 mm,)	.17 kg.
2	Scarus croicensis	(55- 66 mm.)	— kg.
1	Sparisoma radians	(79 mm.)	— kg.
1	Scarus taeniopterus	(36 mm.)	— kg.
41			4.33 kg.
MURAENIDAE			
3	Gymnothorax moringa	('715-850 mm.)	2.09 kg.
4	Gymnothorax vicinus	(593-822 mm.)	2.01 kg.
7			4.10 kg.
MULLIDAE			
33	Pseudopeneus maculatus	(88-166 mm.)	1.30 kg.
18	Mulloidichthys martinicus	(90-109 mm.)	.43 kg.
51			1.73 kg.
LUTJANIDAE			
25	Ocyurus chrysurus	(61-186 mm.)	.74 kg.
DIODONTIDAE			
3	Diodon holacanthus	(136-160 mm.)	.60 kg.

SCORPAENIDAE			
1	Scorpaena plumieri	(230 mm.)	.58 kg.
2	Scorpaenodes caribbaeus	(55- 66 mm.)	.01 kg.
3			.59 kg.
CHAETODONTIDAE			
17	Holacanthus ciliaris	(40- 66 mm.)	.13 kg.
8	Holacanthus tricolor	(32. 64 mm.)	.06 kg.
1	Chaetodon capistratus	(64 mm.)	.01 kg.
26			.20 kg.
LABRIDAE			
16	Thalassoma bifasciatum	(21. 82 mm.)	.06 kg.
20	Halichoeres garnoti	(27- 68 mm.)	05 kg.
2	Halichoeres maculipinna	(82- 90 mm.)	.03 kg.
8	Halichoeres bivittatus	(25- 71 mm.)	.01 kg.
1	Halichoeres radiatus	(39 mm.)	— kg.
47			.14 kg.
POMACENTRIDAE			
14	Pomacentrus variabilis	(35. 65 mm.)	.14 kg.
5	Chromis cyanea	(18- 34 mm.)	— kg.
19			.14 kg.
MORINGUIDAE			
10	Moringua sp.	(192-349 mm.)	.05 kg.
TETRAODONTIDAE			
1	Sphaeroides spengleri	(60 mm.)	.01 kg.
5	Canthigaster rostrata	(25- 38 mm.)	.01 kg.
6			.02 kg.
CLINIDAE			
7	Labrisomus and Malacoctenus (3 spp.)	(42- 50 mm.)	.01 kg.
GOBIIDAE			
10	Gnatholepis and Coryphoterus (3 spp.)	(23- 44 mm.)	.01 kg.
OPHIDIIDAE			
3	Parophidion and Ogilbia	(39.110 mm.)	.01 kg.
XENOCONGRIDAE			
1	Kaupichthys atlantica	(158 mm.)	—
EMMELICHTHYIDAE			
1	Inermia vittata	(77 mm.)	—
TOTAL SPECIMENS 2754	TOTAL SPECIES 55	TOTAL WEIGHT 87.29 kg.	

tridae. Conspicuous by their absence were snappers of the genus *Lutjanus*, certain damselfishes such as *Pomacentrus fuscus, P. leucostictus, Microspathodon chrysurus* and *Abudefduf saxatilis*, the groupers *Epinephelus guttatus* and *E. adscensionis*, and cardinaIfishes (Apogonidae.)

The succession of algae and invertebrates on the concrete blocks was not studied (such a study will be undertaken by Peter W. Glynn of the Institute of Marine Biology of the University of Puerto Rico), but it was evident from comparison with natural reefs that the climax as. sociation had not been reached in 2 years and 4 months, Only a few small corals were just beginning to grow on the bIocks, and the only gorgonian that was noted was a seafan 3 inches high. Most of the exposed surface of the blocks was covered with sponges (especially *Ircinia strobilina, I. fasciculata, Callyspongia procumbens, C. vaginalis,* and *Dysidea* spp.), algae (primarily *Dictyota bartayresii, Valonia ventricosa, Pocockiella variegata, Amphiroa fragilissima, Ralfsia expansa, Peyssonnelia rubra, Fosliella farinosa,* and *Lithothamnion* sp.), and tunicates (primamarily *Ascidia nigra, Herdmania momus, Aplidium lobatum,* and several didemnids such as *Trididemnum savignii)*. The following mollusks were common: *Spondylus americanus, Cerithium litteratum, Lima lima, Barbatia cancellaria,* and *Chama macerphylla*. The anemone *Condylactus gigantea* and the sabellid worm *Sabellastarte magnifica* were also numerous. Stinging coral *(Millepora alcicornis)* was present but was not so abundant as it is on the rock of the shore reefs. All of the sessile invertebrates were either of the encrusting type or had not developed to the extent that they afforded shelter to small fishes.

Only a few very small individuals of *Diadema antillarum* were seen. This unpleasant urchin is very abundant on fringing reefs of the Virgin Islands except where wave action is heavy, Its low incidence on the artificial reef was probably clue to the presence from the onset of *Balistes vetula* which feeds principally on *Diadema* in reef areas where the urchin is common and in water deep enough to accomodate the triggerfish. Also larger individuals of *Haemulon sciurus* and *H. plumieri* have been found with the crushed remains of *Diadema* in their alimentary tracts. Two large grunts which feed almost exclusively on *Diadema* in the Virgin Islands, the Spanish grunt *(Haemulon macrostomum)* and black margate *(Anisotremus surinamensis),* were never seen on the artificial reef. The urchins are eaten by the queen triggerfish during the day and by the grunts at night.

POPULATION OF FISHES ON NATURAL FRINGING REEF

Some basis for a comparison, both quantitative and qualitative, of the fishes of the artificial reef and the normal fringing reef seemed advisable. Brock (1954) in Hawaii, Odum and Odum (1955) in Eniwetok, and Bardach (1959) in Bermuda obtained estimates of the population of reef fishes by utilizing teams of divers to make direct counts of the living fishes on the reefs. While this is a useful technique for some purposes, it is not desirable for more exact quantitative work. Not only is there a human error in estimating the number and sizes of fishes observed, but the more secretive fishes such as the nocturnal squirrelfishes and eels are mostly not seen by divers during daylight hours. Even the diurnal fishes can be overlooked when the reef has many crevices and caves.

It was decided to run large quantitative poison stations with rotenone for fishes on the deeper sections of the fringing reef of St. John. Because rotenone kills fishes by constricting gill capillaries, the poisoned fishes react as if in oxygen-deficient water. Nearly all hiding in interstices in a reef come out of the reef before they die; consequently a high percentage of the resident fishes is usually obtained. And many of those which die unseen in holes in the reef are eventually swept out by surge to adjacent pockets of sand.

A problem exists, however, when anything less than an entire reef is poisoned. Rotenone does not affect all fishes equally. For example, damselfishes, cardinalfishes, and squirrelfishes succumb at low concentrations, and as a result more of these will be collected in a given area than more resistant species. Furthermore, some fishes such as snappers and parrotfishes, are more prone than others to flee from an advancing cloud of poison than to take refuge in the reef. It was therefore deemed necessary to use a net to wall off parts of a reef before applying the poison.

The first attempt was not successful because the seines used to surround the area to be poisoned did not extend to the surface, and many of the larger fishes escaped. The fishes in the artificial reef would seem to have the same opportunity to get away; however, open bottom without cover lay outside the nets, and the fishes remained in their hiding places among the concrete blocks long enough for the rotenone to exert a lethal effect.

Later two large stations were successfully executed in more shallow sections of reef on the southern shore of St. John where seines could completely surround the fishes. Both of these are areas where the bottom affords more than average shelter, and fishes were numerous. Only about one-tenth of the bottom is sand or coral rubble. The rest consists of boulders of variable size, the exposed portions of which are largely covered with coral and Millepora, Gorgonians are present but not abundant.

The first of these two stations was run

on June 14, 1961 at Beehive Point in Greater Lameshur Bay. An underwater photograph taken in the area may be seen in an article on nurse sharks by Randall (1961: fig. 2). A roughly rectangular sec. tor 50 meters along the shore and an average of 12 meters from the shore was walled off with seines. The maximum depth in the area is 5½ meters and the average depth 3 meters. In the deeper water one seine was doubled back on itself, the first part weighted to the bottom and the second with floats running at the surface. Fifteen gallons of Pro-Noxfish were released in the area, beginning just outside the seines. Seven hours were required by four persons to collect all the dead and dying fishes inside the seines. Two were divers with SCUBA (self contained under water breathing apparatus) gear and two used dipnets at the surface. Few fishes escaped.

Enormous numbers of the dussumierid fish *Jenkinsia lantprotaenia* and many engraulids *(Anchoa* sp.) were killed by the poison. Since these are surface-dwelling, plankton-feeding fishes, they are not included in the analysis (Table 2) of the catch. Nor is one 250 mm. needlefish (Belonidae) that was collected.

TABLE 2. FISHES COLLECTED FROM 600 SQUARE METERS OF FRINGING REEF OF LAMESHUR BAY, ST. JOHN

SCARIDAE			
1	Scarus coelestinus	(512 mm.)	4.75 kg.
10	Scarus vetula	(95 - 286 mm.)	4.36 kg.
8	Sparisoma rubripinne	(198 - 244 mm.)	2.61 kg.
8	Sparisoma viride	(45 - 230 mm.)	1.87 kg.
7	Scarus taeniopterus	(30 - 217 mm.)	1.44 kg.
2	Scarus coeruleus	(220 - 263 mm.)	1.05 kg.
4	Scarus croicensis	(120 - 187 mm.)	.76 kg.
40			16.84 kg.
SERRANIDAE			
20	Petrometopon cruentatum	(54 - 260 mm.)	4.14 kg.
10	Epinephelus adscensionis	(145 - 365 mm.)	3.13 kg.
2	Mycteroperca tigris	(295 - 405 mm.)	2.32 kg.
1	Epinephelus striatus	(377 mm.)	1.70 kg.
4	Cephalopholis fulva	(157 - 220 mm.)	1.25 kg.
1	Mycteroperca venenosa	(365 mm.)	.97 kg.
1	Epinephelus guttatus	(305 mm.)	.68 kg.
3	Hypoplectrus puella	(56 - 90 mm.)	.04 kg.
42			14.23 kg.
POMACENTRIDAE			
107	Abudefduf saxatilis	(78 - 132 mm.)	7.85 kg.
54	Microspathodon chrysurus	(29 - 132 mm.)	4.50 kg.
3	Abudefduf taurus	(123 - 152 mm.)	.63 kg.
42	Pomacentrus fuscus	(42 - 75 mm.)	.51 kg.
31	Pomacentrus leucostictus	(18 - 50 mm.)	.10 kg.
17	Pomacentrus variabilis	(25 - 59 mm.)	.06 kg.
11	Pomacentrus pictus	(29 - 52 mm.)	.06 kg.
265			13.71 kg.
POMADASYIDAE			
4	Anisotremus surinamensis	(236 - 402 mm.)	6.95 kg.
2	Haemulon macrostomum	(330 - 336 mm.)	2.29 kg.
3	Haemulon sciurus	(212 - 254 mm.)	1.10 kg.
3	Haemulon carbonarium	(193 - 247 mm.)	.95 kg.
6	Haemulon flavolineatum	(82 - 141 mm.)	.31 kg.
18			11.60 kg.

HOLOCENTRIDAE

37	Holocentrus rufus	(42 - 175 mm.)	3.62 kg.
122	Holocentrus vexillarius	(56 - 116 mm.)	3.22 kg.
57	Myripristis jacobus	(51 - 130 mm.)	2.45 kg.
3	Holocentrus ascensionis	(101 - 243 mm.)	.69 kg.
18	Holocentrus coruscus	(28 - 97 mm.)	.20 kg.
4	Plectrypops retrospinis	(88 - 107 mm.)	.20 kg.
241			10.38 kg.

LUTJANIDAE

12	Lutjanus apodus	(175 - 356 mm.)	3.50 kg.
4	Lutjanus mahogoni	(245 - 295 mm.)	2.32 kg.
2	Lutjanus griseus	(282 - 325 mm.)	2.06 kg.
8	Ocyurus chrysurus	(80 - 186 mm.)	.68 kg.
26			8.56 kg.

ACANTHURIDAE

56	Acanthurus coeruleus	(27 - 137 mm.)	2.74 kg.
7	Acanthurus bahianus	(30 - 121 mm.)	.28 kg.
63			3.02 kg.

CHAETODONTIDAE

2	Pomacanthus aureus	(254 - 336 mm.)	2.55 kg.
2	Chaetodon striatus	(110 - 118 mm.)	.15 kg.
1	Pomacanthus arcuatus	(133 mm.)	.14 kg.
4	Chaetodon capistratus	(69 - 90 mm.)	.13 kg.
1	Holocanthus tricolor	(45 mm.)	.01 kg.
10			2.98 kg.

MURAENIDAE

1	Gymnothorax funebris	(1030 mm.)	2.26 kg.
6	Gymnothorax moringa	(104 - 430 mm.)	.43 kg.
4	Enchelycore nigricans	(140 - 354 mm.)	.10 kg.
4	Muraena miliaris	(84 - 385 mm.)	.09 kg.
2	Echidna catenata	(160 - 208 mm.)	.03 kg.
2	Gymnothorax sp.	(156 - 234 mm.)	.02 kg.
1	Uropterygius sp.	(197 mm.)	.01 kg.
20			2.94 kg.

DIODONTIDAE

1	Diodon hystrix	(394 mm.)	2.72 kg.

BALISTIDAE

1	Balistes vetula	(334 mm.)	1.89 kg.

AULOSTOMIDAE

14	Aulostomus maculatus	(230 - 420 mm.)	1.64 kg.

PRIACANTHIDAE

6	Priacanthus cruentatus	(80 - 190 mm.)	.96 kg.

BLENNIDAE

96	Ophioblennius atlanticus	(46 - 78 mm.)	.71 kg.
25	Entomacrodus textilis	(32 - 51 mm.)	.03 kg.
7	Blennius cristatus	(29 - 63 mm.)	.02 kg.
128			.76 kg.

SCIAENIDAE

6	Equetus punctatus	(132 - 187 mm.)	.68 kg.
1	Equetus pulcher	(72 mm.)	.01 kg.
7			.69 kg.

GRAMMISTIDAE			
7	Rypticus saponaceus	(45 - 202 mm.)	.63 kg.
3	Rypticus subbifrenatus	(69 - 86 mm.)	.04 kg.
10			.67 kg.
MULLIDAE			
1	Mulloidichthys martinicus	(272 mm.)	.51 kg.
APOGONIDAE			
74	Apogon maculatus	(14 - 62 mm.)	.24 kg.
45	Apogon pigmentarius	(20 - 37 mm.)	.04 kg.
25	Apogon conklini	(20 - 38 mm.)	.03 kg.
18	Apogon sp.	(19 - 53 mm.)	.03 kg.
21	Apogon townsendi	(24 - 37 mm.)	.02 kg.
183			.36 kg.
LABRIDAE			
54	Thalassoma bifasciatum	(14 - 79 mm.)	.20 kg.
3	Halichoeres radiatus	(45 - 150 mm.)	.07 kg.
3	Halichoeres garnoti	(57 - 80 mm.)	.03 kg.
4	Halichoeres bivittatus	(38 - 80 mm.)	.03 kg.
6	Halichoeres maculipinna	(33 - 49 mm.)	.01 kg.
70			.34 kg.
BOTHIDAE			
1	Bothus lunatus	(230 mm.)	.28 kg.
MONACANTHIDAE			
2	Cantherhines pullus	(89 - 139 mm.)	.24 kg.
CLINIDAE			
16	Labrisomus guppyi	(31 - 74 mm.)	.10 kg.
1	Labrisomus nuchipinnis	(136 mm.)	.06 kg.
31	Malacoctenus, Emblemaria, Enneanectes, Acanthemblemaria, Stathmonotus (7 spp.)	(15 - 38 mm.)	.02 kg.
9	Labrisomus gobio	(25 - 47 mm.)	.01 kg.
57			.19 kg.
MORINGUIDAE			
31	Moringua sp.	(120 - 340 mm.)	.18 kg.
SCORPAENIDAE			
14	Scorpaenodes caribbaeus	(45 - 71 mm.)	.14 kg.
CANTHIGASTERIDAE			
10	Canthigaster rostrata	(17 - 67 mm.)	.11 kg.
GOBIIDAE			
56	Gnatholepis, Coryphopterus, Elacatinus, Quisquilius (5 spp.)	(20 - 45 mm.)	.04 kg.
GRAMMIDAE			
12	Gramma loreto	(23 - 52 mm.)	.03 kg.
OPHIDIIDAE			
9	Ogilbia cayorum	(23 - 68 mm.)	.01 kg.
OPHICHTHIDAE			
2	Unidentified	(152 - 203 mm.)	.01 kg.

XENOCONGRIDAE			
4	Kaupichthys atlanticus	(88-171 mm.)	.01 kg.
GOBIESOCIDAE			
4	Arcos, Acyrtus, Tomicodon (3 spp.)	(20- 74 mm.)	.01 kg.
OPISTHOGNATHIDAE			
2	Opisthognathus maxillosus	(48- 60 mm.)	—
CIRRHITIDAE			
1	Amblycirrhitus pinos	(50 mm.)	—
SYNODONTIDAE			
1	Synodus synodus	(80 mm.)	—

TOTAL SPECIMENS 1352 TOTAL SPECIES 103 TOTAL WEIGHT 96.05 kg.

A total of 1352 individuals of 103 species of demersal fishes was taken from the study area. The fishes weighed 96.05 kilograms. This constitutes an average for the area of the station of .160 kilograms per square meter.

The large specimens of *Haemulon macrostomum* and *Anisotremus surinamensis* were taken from two caves of moderate size in the area.

The dense population of the sea urchin *Diadema antillarum* and the masses of dead dussumierids and engraulids on the bottom made the collection of very small fishes difficult; nevertheless it is believed that more than half of these little fishes was recovered,

The day after the poison station two permit *(Trachinotus falcata)* were observed feeding on the dead *Diadema* that littered the area (normally they feed more on mollusks than echinoids). One of these, a 6.8 kg. fish which measured 610 mm. in standard length, was speared. Also taken were two mutton snappers *(Lutjanus analis)*, 380 and 525 mm. in standard length and weighing 1.47 kg. and 3.85 kg., respectively, These two fish had gorged themselves on *Jenkinsia* and *Anchoa*.

The second large poison station was carried out in a very similar environment at the east end of Ram Head Bay near Ram Head Point on August 15, 1962. Both this and the Lameshur Bay site are well protected from the easterly wind and swell, and wave action is usually slight. An approximately rectangular section of the rock and coral shore, 27 meters long and extending an average of 11 meters from the shore to a maximum depth of 4.5 meters was completely surrounded by seines and poisoned with Pro-Noxfish. A total of 1454 fishes of 93 species, weighing 46.87 kilograms, were collected (Table 3). This constitutes .158 kilograms of fish per square meter of the area poisoned, hence almost exactly the same figure obtained from the Lameshur Bay station.

TABLE 3. FISHES COLLECTED FROM 297 SQUARE METERS OF FRINGING REEF OF RAM HEAD BAY, ST. JOHN.

SCARIDAE			
11	Sparisoma rubripinne	(218 - 255 mm.)	4.40 kg.
9	Scarus vetula	(190 - 254 mm.)	3.39 kg.
2	Scarus coelestinus	(214 - 375 mm.)	2.24 kg.
6	Sparisoma aurofrenatum	(139 - 166 mm.)	.71 kg.
5	Sparisoma viride	(30 - 235 mm.)	.57 kg.
2	Scarus taeniopterus	(135 - 200 mm.)	.30 kg.
1	Scarus croicensis	(54 mm.)	—
36			11.61 kg.
POMADASYIDAE			
5	Anisotremus surinamensis	(210 - 420 mm.)	6.26 kg.
2	Haemulon carbonarium	(215 - 220 mm.)	.65 kg.
5	Haemulon flavolineatum	(143 - 165 mm.)	.51 kg.
12			7.42 kg.

HOLOCENTRIDAE			
118	Holocentrus vexillarius	(32-118 mm.)	.340 kg..
12	Holocentrus rufus	(143-183 mm.)	1.13 kg.
20	Myripristis jacobus	(44-145 mm.)	.82 kg.
1	Holocentrus ascensionis	(209 mm.)	.28 kg.
5	Holocentrus coruscus	(54- 60 mm.)	.03 kg.
2	Plectrypops retrospinis	(34- 53 mm.)	.03 kg.
1	Holocentrus marianus	(45 mm.)	— kg.
159			5.69 kg.
SERRANIDAE			
7	Epinephelus adscensionis	(190-376 mm.)	4.55 kg.
4	Petrometopon cruentatum	(83-220 mm.)	.60 kg.
1	Serranus tigrinus	(43 mm.)	— kg.
12			5.15 kg.
LUTJANIDAE			
7	Lutjanus apodus	(250-325 mm.)	3.71 kg.
2	Lutjanus mahogoni	(250-304 mm.)	1.16 kg.
9			4.87 kg.
POMACENTRIDAE			
45	Microspathodon chrysurus	(24-151 mm.)	3.29 kg.
43	Pomacentrus fuscus	(19- 72 mm.)	.38 kg.
12	Abudefduf saxatilis	(29-119 mm.)	.34 kg.
2	Abudefduf taurus	(134.135 mm.)	.17 kg.
52	Pomacentrus leucostictus, variabilis, and planifrons	(12- 52 mm.)	.09 kg.
2	Pomacentrus pictus	(33- 51 mm.)	.01 kg.
2	Chromis multilineata	(26 mm.)	— kg.
158			4.28 kg.
ACANTHURIDAE			
25	Acanthurus coeruleus	(30-137 mm.)	1.18 kg.
22	Acanthurus bahianus	(29-167 mm.)	.68 kg.
47			1.86 kg.
MURAENIDAE			
11	Gymnothorax moringa	(71 - 558 mm.)	.78 kg.
8	Enchelycore nigricans	(74 - 642 mm.)	.81 kg.
12	Muraena miliaris	(63 - 312 mm.)	.14 kg.
4	Echidna catenata	(143 - 392 mm.)	.11 kg.
38	Uropterygius sp.	(83 - 229 mm.)	.09 kg.
73			1.44 kg.
CHAETODONTIDAE			
1	Pomacanthus aureus	(245 mm.)	.98 kg.
2	Chaetodon striatus	(118 - 120 mm.)	.17 kg.
3	Chaetodon capistratus	(88 - 94 mm.)	.11 kg.
4	Holacanthus tricolor	(32 - 84 mm.)	.04 kg.
10			1.28 kg.
BLENNIIDAE			
194	Ophioblennius atlanticus	(34- 72 mm.)	.54 kg.
92	Entomacrodus textilis	(13- 48 mm.)	.01 kg.
17	Blennius cristatus	(23- 56 mm.)	.04 kg.
303			.65 kg.

GRAMMISTIDAE

9	Rypticus saponaceus	(29-169 mm.)	.51 kg.
2	Rypticus subbifrenatus	(67- 77 mm.)	.02 kg.
11			.53 kg.

AULOSTOMIDAE

6	Aulostomus maculatus	(262-442 mm,)	.51 kg.

CLINIDAE

167	Labrisomus and Malacoctenus (6 spp.)	(20- 52 mm.)	.19 kg.
3	Labrisomus nuchipinnis	(80-129 mm.)	.14 kg.
15	Labrisomus guppyi	(80-129 mm.)	.09 kg.
64	Paraclinus, Emblemaria, Enneanectes (6 spp.)	(16- 29 nun.)	.02 kg.
249			.44 kg.

LABRIDAE

80	Thalassoma bifasciatum	(12- 64 mm.)	.23 kg.
15	Halichoeres bivittatus	(26- 42 mm.)	.08 kg.
19	Halichoeres maculipinna	(27- 47 mm.)	.01 kg.
5	Halichoeres radiatus	(26- 53 mm.)	.01 kg.
1	Halichoeres garnoti	(28 mm.)	— kg.
120			.33 kg.

APOGONIDAE

32	Apogon maculatus	(25- 57 mm.)	.13 kg.
9	Apogon conklini	(19- 36 mm.)	.01 kg.
1	Apogon lachneri	(32 mm.)	— kg.
42			.14 kg.

PRIACANTHIDAE

2	Priacanthus cruentatus	(126-147 mm.)	.14 kg.

SCORPAENIDAE

24	Scorpaenodes caribbaeus	(38- 70 mm.)	.12 kg.
3	Scorpaena plumieri	(32- 40 mm.)	.01 kg.
27			.13 kg.

MORINGUIDAE

30	Moringua sp.	(149-308 mm.)	.10 kg.

GOBIESOCIDAE

21	Arcos macrophthalmus	(16- 84 mm,)	.09 kg.
4	Unidentified	(9- 26 mm.)	— kg.
2	Tomicodon fasciatus	(22 nun.)	— kg.
27			.09 kg.

MONACANTHIDAE

1	Cantherhines pullus	(134 mm.)	.08 kg.

GOBIIDAE

43	Gnatholepis thompsoni	(23- 44 mm.)	.04 kg.
43	Coryphopterus, Gobiosoma, Quisquilius, Elacatinus (6 spp.)	(19- 47 mm.)	.03 kg.
86			.07 kg.

ANTENNARIIDAE

1	Antennarius multiocellatus	(54 mm.)	.02 kg.

OPHIDIIDAE			
11	Ogilbia cayorum	(28- 61 mm.)	.01 kg.
GRAMMIDAE			
9	Gramma loreto	(13- 53 mm.)	.01 kg.
XENOCONDRIDAE			
2	Kaupichthys atlanticus	(103-187 nun.)	.01 kg.
CIRRHITIDAE			
4	Amblycirrhitus pinos	(27- 52 mm.)	.01 kg.
TETRAODONTIDAE			
4	Canthigaster rostrata	(22- 34 mm.)	—
SYNGNATHIDAE			
1	Syngnathus dunckeri	(80 mm.)	
MICRODESMIDAE			
2	Microdesmus floridanus	(26- 32 mm.)	

TOTAL SPECIMENS 1454 TOTAL SPECIES 93 TOTAL WEIGHT 46.87 kg.

The standing crop of reef fishes computed from these two large poison stations on St. John seems large compared to the estimate by Bardach (1959) of 490 kilograms per hectare (.049 kg./m.^{2}) for a Bermuda reef, a figure which he has shown corresponds with the estimate for an Eniwetok reef by Odum and Odum (1955). The St. John determinations agree well, however, with the average of the two highest counts of reef fishes obtained by Brock (1954) in Hawaii. His figure, 1653 pounds per acre (.185 kg./m.^{2}), represents the average from two transects made at Keahole Point on the island of Hawaii. Estimates of the mass of fishes from eight other localities in the Hawaiian Islands were considerably lower, however. The lowest, 36 pounds per acre, was the average of five transects at Rabbit Island. This area is level and largely sand, and cannot be regarded as reef.

Nevertheless areas of hard bottom probably occur in Hawaii or elsewhere in tropic seas with a comparable low mass of reef fishes. One need only choose a smooth expanse with few hiding places. No matter how attractive an area might seem from the standpoint of food supply, it will not contain an appreciable number of reef fishes of moderate to large size during daylight hours unless there is enough sculpturing of the reef to provide cover. Most reef fishes move only a limited distance away from some hole or crevice in the reef because of the presence of such open-water predacious fishes as barracuda *(Sphyraena barracuda)*, jacks *(Caranx, Seriola,* etc.), and kingfish *(Scomberomorus cavalla)*. The few fishes coming to the artificial reef as adults reflects the reluctance of reef fishes to cross large flat areas.

Other things in addition to the amount of shelter of a reef affect estimates of the standing crop of fishes. One is the method of measuring the substratum, If only the area in the horizontal plane is determined, which is all that this and previous investigators have done, a considerable error is introduced if comparisons are made with other regions differing in the degree of irregularity of the bottom. As pointed out by Bardach in explanation of the relatively high value of his estimate of Bermuda reef fish populations compared to that of demersal fishes in northern continental shelf regions, the entire surface of a reef, including vertical walls and the area beneath ledges and in caves, should be considered. Admittedly, the area of so complex a surface would be very difficult to estimate with accuracy.

The type of benthic growth on the reef is also important in controlling the population of reef fishes. A high cover of living coral of branching types like *Acropora* may offer substantial shelter but limited food for fishes which feed on attached marine life or organisms therein. Luxurient reefs of living *Acropora palmata* in the West Indies lasking suitable feeding ground nearby may have surprisingly few fishes in spite of all the shelter they afford. Few organisms in the Caribbean region feed directly on live coral.

The effect of man as a fisherman is also of considerable importance to the standing crop of reef fishes. One cannot properly compare two areas which differ significantly in the amount of fishing activity. Because reef fishes are for the most part nonmigratory and their reef environment ordinarily somewhat circumscribed, they are subjected to greater fishing pressure, in general, than the stocks of pelagic or wandering demersal species. It is possible to drastically reduce the fish population of a single reef by fishing, particularly with the use of fish traps. Whereas hook and line fishing may take a heavy toll of many carnivorous and some omnivorous fishes, traps are notoriously nonselective, and most species of reef fishes large enough to be caught by the mesh of the trap can be captured. Fish traps are easily lost by fishermen when their markers sink or are cut off. The untended traps will continue to kill fishes for many years if made of durable materials. Skillful spearfishermen can also be devastating to the resident population of larger species on a reef. Once heavily fished, an isolated reef is slow to recover a population of larger fishes. Fishermen spend much time searching for reefs that have not been fished before, for they know they can expect large catches initially.

Comparison of fishes on artificial and natural St. John reefs

The artificial reef contained 11 times the concentration of fish as the two natural reef areas of the St. John shore. The amount of shelter was not materially different; if anything, it was better on the natural reefs. The food supplies of the artificial and natural reefs themselves, although not the same composition, probably do not differ markedly in quantity. The apparent reason for the much greater mass of fish on the artificial reef is the additional food source of the surrounding seagrass beds. The poisoned reef sectors of Lameshur and Ram Head Bays do not lie next to grass beds, but only to more reef. The artificial reef is surrounded by a broad expanse of *Thalassia* and *Cymodocea*. The grunts (Pomadasyidae), which dominated the population of fishes on the artificial reef, feed in the seagrass at night. The squirrelfishes are also nocturnal, and *Holocentrus ascensionis,* at least, is known to feed on crustaceans typical of seagrass beds, although it evidently stays closer to reefs than the grunts. As previously mentioned, the mutton hamlet *(Alphestes afer) is a* typical grass-bed form. It accounted for over 16 percent of the mass of fish from the artificial reef but was not represented in the two poison stations of reefs at shore. If the large grunts *Anisotremus surinamensis* and *Haemulon macrostomum,* which as adults, feed primarily on echinoids of reefs, are eliminated from Tables 2 and 3, the Pomadasyidae becomes an insignificant component of the biomass of the two shore reef sectors.

Whenever well developed reefs lie adjacent to flats and these fiats are not shared by too many other reefs nearby, the grunts maybe expected to be numerous. Also several species of snappers of the genus *Lutjanus* should be abundant, and the complete absence of these fishes from the artificial reef is therefore all the more enigmatic. Night diving in Lameshur Bay and other areas in the Virgin Islands revealed snappers feeding individually like the grunts on the grass beds and sand flats far from the shelter of fringing reef where they are found by day.

The author first became aware of the dependence of certain grunts and snappers on grass and sand flats for food when viewing patch reefs in southern Florida in 1954, These fishes were in such great abundance on some highly isolated reefs that it was obvious that the reefs alone could not provide food for them all. Indeed, some of the reefs seemed not to have enough cover for all the fishes.

Observations by Longley (1927, 1941) on the behavior and food habits of pomadasyids and lutjanids in Tortugas, Florida also clearly demonstrate that areas extralimital to the reefs are the principal feeding grounds.

An analysis of the food habits of fishes of the artificial reef in terms of the usual categories of herbivorous, omnivorous, or carnivorous and comparison with like data from the natural reefs provide additional evidence of a greater source of food outside the confines of the artificial than the natural reefs. The percentage of carnivores is much higher on the artificial reef (Table 4).

Table 4. Percentage by weight of fishes from artificial and natural reefs on St. John, according to basic food hahits.

	Herbivores	Omnivores	Carnivores
artificial reefs	11.0%	0.4%	88.6%
natural reefs	24.3%	15.8%	59.9%

Herbivorous families from Table 1 to 3 include the Scaridae, Acanthuridae, and

Blenniidae. Those classified as omnivorous are the Pomacentridae, Chaetodontidae, and Monacanthidae. The remaining families are regarded as carnivorous. There are some exceptions within families; for example, some of the pomacentrids appear to be entirely carnivorous. Knowledge of the food habits of Virgin Islands fishes is based on the examination of the stomach contents of 2,524 specimens of 183 species. The data for some of these species, however, are fragmentary. This study is being continued in Puerto Rico.

Bardach (1959) divided his Bermuda transects of reef fishes into two groups, omnivorous (said to be mostly herbivorous) and carnivorous. On a large reef the omnivores outweighed the carnivores by about 9 to 1, while on an isolated reef the weight of the carnivorous fishes was nearly twice that of the omnivores. He added that the latter set of data seems to contradict the classical concept of the biomass pyramid wherein the plant-feeders greatly predominate. He explained this discrepancy by noting the abundance of grunts and snappers on the isolated reef and by pointing out that the largest fraction of herbivorous reef animals are probably mollusk, crustacean, and annelid (echinoids should also be added to this trio). He stated that these invertebrates are the greatest source of food for the carnivorous reef fishes and added, "Carnivorous fish rarely feed upon omnivorous ones: no angelfish or surgeonfish were found in the stomachs of carnivores, and young parrotfish were only rarely ingested."

Stomach contents of piscivorous fishes taken with spears in the Virgin Islands support the part of this statement concerning angelfishes *(Pomacanthus* and *Holacanthus)*. None was found in the stomachs of predators, a fact which may be related to the part-time parasite-picking food habits of the young (Limbaugh, 1961; Randall, 1962b), the deep-bodied form of these fishes, and their large size. It might be noted that the angelfishes, though they may best be classified as omnivorous, feed little on plant material as adults. The stomachs of 38 specimens of the four large species in the Virgin Islands were examined, and the bulk of the food material was sponge, with some tunicate and other sessile invertebrates and algae. The sponges included types with numerous spicules. The food mass in the angelfish stomachs was covered with a thick coat of mucous which may serve to protect the alimentary tract from abrasion by sponge spicules.

On the other hand, data on the occurrence of parrotfishes and surgeonfishes as prey of piscivorous fishes are contradictory to Bardach's statement. Of 242 fishes identified from the stomachs of *Mycteroperca*, *Epinephelus*, *Cephalopholis*, *Petrometopon*, *Lutjanus*, *Caranx*, *Seriola*, *Sphyraena*, and *Aulostomus* in the Virgin Islands, 43 were parrotfishes and 16 were surgeonfishes. It is believed that further studies may show that the Scaridae is the principal family of West Indian reef fishes eaten by predators except on isolated patch reefs where the grunts will probably be the most prominant.

The Scaridae is the largest familiy by weight in both of the natural reef poison stations, and observations at other localities in the Virgin Islands and elsewhere in the West Indies suggest that this dominance may be the rule. The scarids were the sixth largest family of fishes on the artificial reef. In time they might have attained a greater relative mass.

Differences in the species composition Of fishes of the artificial reef and those of the two collections from natural reefs are in part due to the presence of the shore in the natural collecting localities. Species such as the gobiesocids and certain clinid and pomacentrid fishes are intertidal and shallow-water forms and would not be expected in 9 meters of water. A few others such as *Pomacentrus fuscus* may occur as adults in water as deep as 9 meters or more but seem to be tied to shallow zones when young. When a reef extends continuously from shallow to deeper water, fishes may migrate to deeper sections as they grow larger, but a deep reef isolated from shallow water by a broad expanse of flat bottom might not normally receive such fishes.

Some species may have come as juveniles to the artificial reef but not survived because of the high percentage of predaceous fishes and insufficient hiding places for small fishes. The 5-inch squares in the concrete blocks are not small enough to exclude the small groupers and moray eels. The relatively few individuals of the Labridae, Pomacentridae, Gobiidae and other families of small reef fishes may also be due to heavy predation.

Possibly some fishes may be absent from the artificial reef as a direct or indirect result of the lack of certain benthic organisms on the blocks.

Just as many of the pomadasyids and lutjanids are utilizing food from regions away from the reef, so also are some plankton-feeding fishes which dwell in reefs. These include such common West Indian fishes as the damselfishes *Chromis cyanea* and *C. multilineata*, the snapper *Ocyurus chrysurus* (especially when young), the grouper *Paranthias furcifer*, the wrasse *Clepticus parrai*, and the emmelichthyid *Inermia vittata*. Analysis of the stomach contents of these fishes from the Virgin Islands indicates that they feed primarily on pelagic copepods and other planktonic animals of open water and little on mysids and the like found near the reef, Although the copepods are small, they are not strained in clupeoid fashion but are picked individually from the plankton. These fishes have small mouths, more fusiform bodies and more strongly forked caudal fins than their relatives which feed on demersal organisms *(Inermia* probably without such relatives). This may he associated with their need for greater efficiency in swimming. They may be observed high in the water above reefs, but they quickly retire to the shelter of the reefs with the approach of danger. Some other reef fishes such as the sergeant major *(Abudefduf saxatilis),* the bluehead wrasse *(Thalassoma bifasciatum)* and several other fishes when juveniles feed in part on zooplankton. Individual apogonids have been observed swimming well above reefs at night, presumably to feed on planktonic organisms.

These reef-dwelling fishes are dependent on current to bring their planktonic food to them. If a reef is located in an area of adequate current and the water is rich in zooplankton, the reef will probably have a larger population of such fishes than one where current is slight or plank. ton production is low.

These fishes and those feeding on flats away from the reef are not reef fishes in the strict sense. From the trophic standpoint, they are not members of the reef community.

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ABSTRACT

In April, 1960 an artificial reef of 800 concrete blocks was built in Lameshur Bay, St. John, Virgin Islands in 9 meters of water in seagrass. The blocks were arranged to form tunnels whose total surface area is 50 square meters. Observations were made of the kinds and relative abundance of fishes which colonized the reef. The great majority of the fishes came to the reef as juveniles.

On August, 1962 all of the fishes were collected from the reef with rotenone. A total of 2754 individuals of 55 species were taken. These weighed 87.29 kg., which represents an average of 1.75 kg/m.^{2}. The dominant family was the Pomadasyidae, with 1872 individuals of four species of *Haemulon,* weighing a total of 37.08 kg. The most abundant species was *H. plumieri;* 1267 specimens were taken, weighing a total of 25.65 kg. The second largest family was the Serranidae (16.34 kg.), dominated by 65 individuals of *Alphestes afer*. Other important families were the Holocentridae (11:07 kg.), Acanthuridae (5.25 kg.), Balistidae (4.88 kg.), Scaridae (4.33 kg.) and Muraenidae (4.10 kg.). Some common inshore reef fishes such as snappers of the genus Lutjanus were conspicuous by their absence. The Labridae, Pomacentridae, Gobiidae and other families of small fishes were not represented by large numbers.

Two large quantitative poison stations for fishes were carried out on the natural fringing reef of St. John. One of 600 square meters resulted in the taking of 96.05 kg. of fish (1352 individuals of 103 species). The other of 297 square meters totalled 46.87 kg. (1454 individuals of 93 species). The average amount of fish for the two stations is .160 and .158 kg./m.^{2}, respectively. These figures do not correspond well with the .049 kg./m.^{2} estimate of the standing crop of fishes on a Bermuda reef made by Bardach (1959), but they compare favorably with the highest estimates (up to .185 kg./m.^{2}) in Hawaii made by Brock (1954). The areas selected for the poison stations of the natural reefs on St. John appeared to be among those with the greatest density of shore fishes seen around the island.

The numbers and mass of reef fishes vary greatly from area to area within the same region. Many factors combine to control their abundance. One of the most important is the amount of shelter afforded by the reef. Another is the amount of seagrass or sand flat nearby; when extensive, populations of certain fishes such as pomadasyids, which feed on the flats at night and hide in the reef by day, may be large. The broad expanse of seagrass around the artificial reef is the probable reason for the reef having 11 times the concentration of fishes as the sectors of shore reef which were poisoned.

Fishes feeding on the flats surrounding a reef are not reef fishes from the trophic standpoint, In the same sense, fishes such as *Clepticus, Paranthias, Inermia, Ocyurus,* and certain *Chromis* which feed on the plankton of the water mass passing over a reef are not reef fishes.