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## ABSTRACT

Three small artificial reefs (1 x 1.5 x 2 m) were deployed during April 1994 in shallow waters (6 m) at Humacao, Puerto Rico, to evaluate their usefulness for enhancing the sportfishery resources for the shorefishermen. Each reef consists of five modules constructed with scrap concrete culvert pipes. Fish populations were monthly visually assessed from May to October 1994. Data from the artificial reefs was compared with data from predeployment censuses, control sites and from a natural reef. A total of 52 species were observed at the artificial reefs with an average of 1354 individuals per reef, most of them juveniles. Fish populations showed a significant difference between artificial reefs and control areas in terms of species composition and abundance. No significant difference was found between the artificials and the natural reef in terms of fish species composition but the abundance estimates were significantly different. Preliminary results show that the artificial reefs have been effective in attracting and maintaining a diverse fish population and that the technique could be used to enhance the sportfishery resources of the area. Evaluation will continue until June 1995 and recommendations will be submitted regarding the above mentioned objectives.

## INTRODUCTION

Marine shore fishing is a very popular outdoor activity in Puerto Rico. Shore fishing is carried out from every possible structure providing access to the water such as bridges, jetties, piers and waterfronts. Although no sites have been specifically designed for shorefishing in the Island, average daily fishing effort for six areas studied during 1985-89 was estimated at 334.8 angler-hours for weekdays and 690.7 angler-hours for weekends (Berríos et al., 1989).

One of the most commonly used areas for shore fishing in Puerto Rico is an old pier located at Punta Santiago, Humacao. Originally this pier was used to unload sugar cane brougth from the nearby island of Vieques. Berríos et al. (1989, 1992) evaluated this area in terms of the fishery resource demand and supply through creel surveys and experimental fishing, respectively. The creel survey study provided information about species catch composition, fish population size structure, average size of the fish, fishing effort, and fishing success (CPUE).

Assessment of the sport fisheries resources provided fishery independent data about species composition, size frequency, fish distribution within the area, substrate composition and habitat condition.

Comparison of the results obtained from the creel survey and the fishery independent data indicated that some desirable sport fish species present in the study areas were not being caught by the anglers or were underrepresented in the catch. Only fifteen (15) species were reported by anglers fishing from the pier, as compared to twenty-eight (28) species captured with gill nets (Berríos et al., 1989). These data suggested that the quality of the fishery, was not being optimally exploited. It was noted that species commonly caught by anglers were those known to seek refuge under the pier such as mojarras (Gerreidae) and corvina (Sciaenidae), or those that occasionally venture around it such as jacks (Carangidae) and mackerel (Scombridae). Factors affecting quality and/or quantity of catch appeared to be related to angler accessibility to the fish, and substrate composition in the immediate vicinity of the pier. Desirable sport fish species were present in the area, but apparently were out of casting range. The substrate in the area surrounding the pier was predominantly composed of sand and mud. Such substrates are not generally considered desirable habitat for sportfish since they provide little cover or food organisms.

The Puerto Rico Department of Natural and Environmental Resources (PRDNER) and the Humacao municipal government are currently considering renovation of the Punta Santiago pier to provide enhanced recreational opportunities to the public (Chaparro, 1992; Nieves, 1992). A feasibility study conducted by the PRDNER to evaluate the structural condition of the pier determined that with minimal restoration it could be converted to a fishing pier (Nieves, 1994).

Nonetheless, enhancement of these facilities will certainly increase fishing effort and fishing pressure upon the existing fishery resources. Increased pressure will necessitate enhancement of habitat productivity and accessibility so that fishing quality is maintained. Species most in need of enhanced accessibility included bottom-dwelling fishes such as corvina (Sciaenidae), grunts (Haemulidae) and snappers (Lutjanidae). Pelagic fishes requiring enhanced accessibility included jacks (Carangidae) and cero (Scomberomorus regalis). It was felt that accessibility to these species might best be attained by means of the utilization of certain techniques for habitat improvement such as the construction of benthic artificial structures.

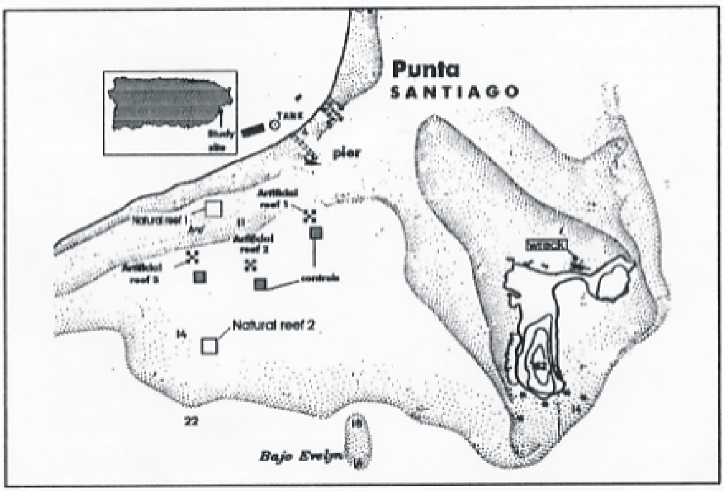



Figure 1.Location of the study areas

During the last 20 years, the construction of artificial structures has become an alternative to improve aquatic habitat for fishes (Alevizon, 1985). Man-made reefs of varying composition and structure have been placed in marine habitats throughout the world, and have generally proven effective at concentrating fishes (Alevizon, 1985). General agreement exists that artificial reefs are effective fish attractants and an important fishery management tool (Bohnsack and Sutherland, 1985). The United States Congress recognized in Section 202 of the National Fishing Enhancement Act that properly designed, constructed and located artificial reefs could enhance the habitat and diversity of fishery resources (Stone, 1985).

| Humacao | ESTACION | FECHA | HORA | VISIBILIDAD |
|---|---|---|---|---|
| | A13 | 7/7/94 | 14:30 | 10' |
| ESPECIE | N | MAX | MIN | MODA |
| ACANTHURUS BAHIANUS | 10 | 3 | 1 | 3 |
| ACANTHURUS CHIRURGUS | 5 | 3 | 2 | 3 |
| ACANTHURUS COERULEUS | 15 | 3 | 2 | 2 |
| ANISOTREMUS VIRGINICUS | 1 | 2 | | |
| BODIANUS RUFUS | | | | |
| CALAMUS SP. | | | | |
| CANTHIGASTER ROSTRATA | | | | |
| CARANX BARTHOLOMAEI | 5 | 8 | 3 | 5 |
| CARANX LATUS | | | | |
| CARANX RUBER | 3 | 5 | 3 | |
| CHAETODON CAPISTRATUS | 2 | 2 | | |
| CHAETODON STRIATUS | 3 | 2 | 2 | |
| CHROMIS MULTILINEATA | | | | |
| EPINEPHELUS MORIO | | | | |
| EQUETUS ACUMINATUS | 3 | 4 | 2 | |
| GERRES CINEREUS | | | | |
| GYMNOTHORAX VICINUS | | | | |
| HAEMULON AUROLINEATUM | + 500 | 8 | 2 | 3 |
| HAEMULON FLAVOLINAETUM | 30 | 5 | 2 | 5 |
| HAEMULON MIXED | | | | |
| HAEMULON PARRAI | | | | |
| HAEMULON PLUMIERI | 250 | 6 | 1 | 3 |
| HAEMULON SCIURUS | 8 | 10 | 3 | 3 |
| HALICHOERES BIVITTATUS | | | | |
| HALICHOERES MACULIPINNA | | | | |
| HALICHOERES POEYI | | | | |
| HALICHOERES RADIATUS | | | | |
| HOLACANTHUS CILIARIS | | | | |
| HOLOCENTRUS ASCENCIONIS | 13 | 7 | 4 | 7 |
| HOLOCENTRUS RUFUS | | | | |
| LACHNOLAIMUS MAXIMUS | 2 | 5 | 5 | |
| LUTJANUS ANALIS | | | | |
| LUTJANUS APODUS | | | | |
| LUTJANUS GRISEUS | | | | |
| LUTJANUS JOCU | 1 | 8 | | |
| LUTJANUS MAHOGONI | | | | |
| LUTJANUS SYNAGRIS | | | | |
| MULLOIDICHTHYS MARTINICUS | 60 | 6 | 3 | |
| MYRIPRISTIS JACOBUS | 100 | 5 | 2 | 3 |
| OCYURUS CHRYSURUS | 17 | 4 | 2 | 4 |
| OPHIOBLENIUS ATLANTICUS | | | | |
| POMACENTRUS FUSCUS | | | | |
| POMACENTRUS PLANIFRONS | | | | |
| PSEUDUPENEUS MACULATUS | 36 | 7 | 4 | 7 |
| SCARUS SP. | | | | |
| SCOMBEROMORUS REGALIS | | | | |
| SELAR CRUMENOPHTHALMUS | | | | |
| SPARISOMA RUBRIPINNE | | | | |
| SPARISOMA SP. | | | | |
| SPARISOMA VIRIDE | 2 | 1 | | |
| SPHYRAENA BARRACUDA | | | | |
| SYNODUS INTERMEDIUS | 1 | 7 | | |
| THALASSOMA BIFASCIATUM | | | | |

Figure 2. Data form used to record fish species composition and abundance.

Artificial reef construction has seldom been used in Puerto Rico for the purpose of fisheries management or habitat improvement. Only two studies related to this subject have been published so far. Fast (1974) compared fish populations on natural and artificial reefs (used-tires) off southwestern Puerto Rico. Bejarano (1975) compared species composition and number of species on different shaped artificial reefs constructed of used tires. None of these reefs currently exist. Another used-tire artificial reef was constructed by a group of divers at Aguadilla, in the early seventies, but it was never monitored. Nevertheless, the reef is still in place and functioning limitedly. Feigenbaum et al. (1986) studied the feasibility of using fish aggregating devices (FADs) for enhancing commercial fisheries in Puerto Rico. They found that FADs enhanced trolling success and could have a positive effect on recreational and commercial fisheries, although they are unlikely to dramatically increase the harvest. Pelagic species such as dolphinfish (Coryphaena sp.), wahoo (Acanthocybium solandri), barracuda (Sphyraena barracuda) and tuna (Scombridae) were the most frequently caught species around these structures.

Literature surveyed shows that most of the marine artificial reef programs around the world have catered only to boaters by building reefs and FADs offshore in deep water. Studies indicate that fishing harvest, from a single site such as a pier, is usually low because shore anglers have to wait for fish to come within casting range. Conversely, boat fishing allows the angler to go anywhere after the fish. Shallow water artificial reefs built in conjunction with fishing piers represent a significant alternative to the improvement of shore-based recreational fisheries.
The present study was established to evaluate the usefulness of shallow, nearshore artificial structures for enhancing the sport fishery resources at Humacao. If it proves to be effective, a permanent artificial reef research and construction program could be implemented around the Island.

Study Areas

The town of Humacao is located in the southeastern corner of Puerto Rico. The study area is located on Naguabo Bay about 0.5 km offshore of Punta Santiago. A small island (Cayo Santiago) is located in the west side of the bay protecting the shoreline from heavy swells. Upcurrent to the study site, three rivers discharge large quantities of organic material producing a plume that extend about 1 km offshore during heavy rains. Ten stations were chosen and monitored during different phases of the study (Fig. 1). The three artificial reef stations and three control areas were located in a shallow Halimeda sand and mud platform with a maximum depth of 6 m. The area is covered with varible quantities of *Thalassia testudinum* (turtle grass) and *Syringodium filiforme* (manatee grass).

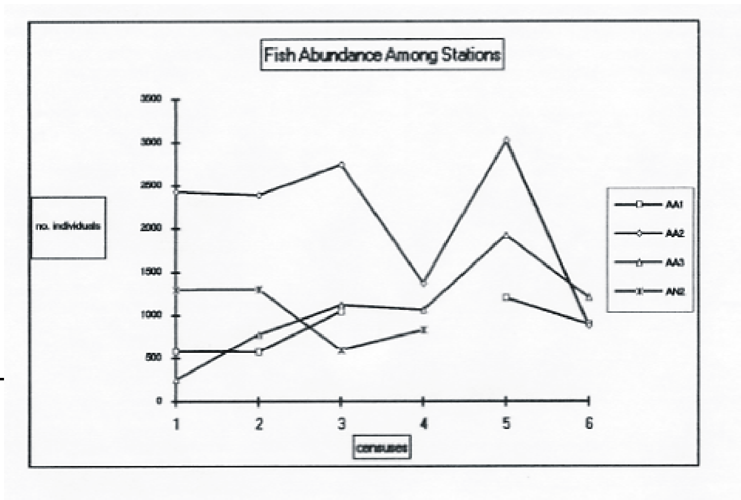
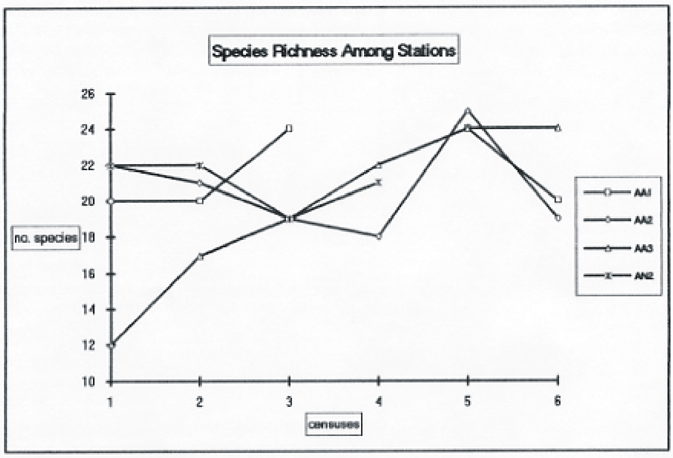



Figure 3. Fish abundance at natural and artificial reefs, from May to Oct 1994.

Most common algae genera in the area included: Penicillus, Caulerpa, Halimeda, Udotea, Dictyota, Amphiroa,and Kalimenia.  A small patch reef at 3.5 m depth very close to the shore and about 150 m to the northwest of the artificial reefs was designated as Natural Reef Station 1 (NR1). Less than 15% of the coral colonies, consisting mainly of Siderastrea siderea were alive. Natural Reef Station 2 (NR2) was located on a patch reef about 250 m to the south of the artificial reefs stations. The principal hermatypes were Montastrea annularis and Siderastrea siderea. Gorgonian genera, especially Pterogorgia, Pseudoterogorgia, and Plexaurella abounded in the area. Sites were chosen that minimized differences in vertical relief between natural and artificial reef stations.

Another station (Wreck Station) was established in the remains of a steel barge grounded in 1 to 3 m of water to the southeast of the artificial reef stations. Many small coral colonies including Favia fragum, Porites astreoides, Porites porites and Montrastrea cavernosa, among others, covered the walls. Surrounding areas were composed of dense stands of turtle grass. An additional station (Pier

Station) was marked in the Punta Santiago pier. It is a 140 m concrete structure located to the northeast of the artificial reefs stations. Pilings were completely covered with sponges and other sessile organisms. A small ship about 12 m in length lay on the bottom beside the pier. Maximum depth in the area was 3.5 m.




Figu
re 4. Number of species at the natural and artificial reefs, from May-Oct 1994.

METHODS AND MATERIALS

Three artificial reefs were constructed with scrap concrete culvert pipes. The use of scrap materials was preferred to reduce the direct costs to the project and to provide a means for recycling waste materials which otherwise will end in the landfills. Fifteen modules were assembled, each consisting of 9 to 11 concrete pipes. After evaluating different alternatives to fasten the pipes into a single unit, a 3/4 inch packing metal strap was chosen as the best wrapping material for the job. This strap proved to be easier to handle, provided the necessary holding power, and cost less than cable or chain which have been used in other studies elsewhere.
Pipes were set and secured on a wooden pallet to ease their manipulation as they were deployed in the field. Each module was constructed onshore in approximately 10 minutes by four persons. Approximate dimensions were 1 x 1.5 x 2 m for a total

volume of 3 m3 and an approximate weight of 545 kg per unit. Various configurations were evaluated for building the modules, and a crossed-pipe configuration made of three tiers of four pipes each was finally chosen because it maximized the use of materials. The design provided more total volume and holes than any other of the configurations.

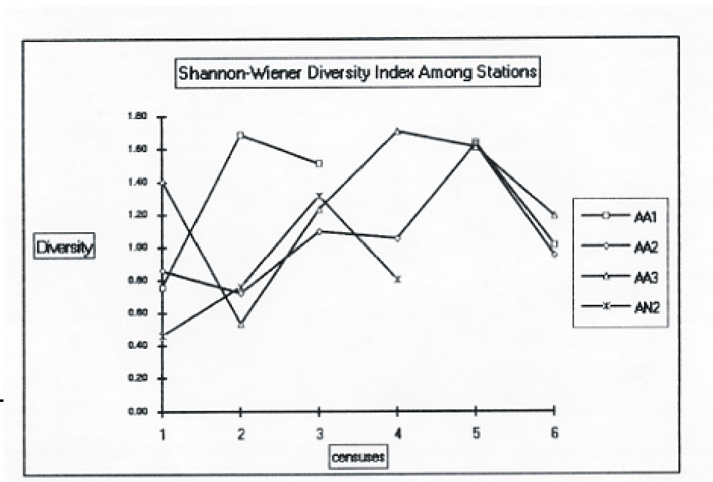



Figure 5. Shannon-Weiner Diversity Index per site.

Modules were deployed by April 22, 1994 in approximately five hours five modules per station, at the three stations previously chosen. Beginning the day after deployment, modules were arranged in a 6 by 6 m square configuration using liftbags and a 22 ft boat to put the modules in the desired place. The last of the three artificial reefs was completed by April 29, 1994 due to the complex logistics involved and the poor underwater visibility in the area during the interim period. The sampling design developed included three replicates of artificial reef stations and controls. These manipulations were set in a 6 x 6 m square area over a seagrass flat with a uniform depth of 6 m. The artificial reefs were set about 200 m from each other. Each reef consists of five modules, with four of these on each corner of the square and the last in the middle. The area for the controls was located about 50 m south of each artificial reef and was framed using rebar spikes and nylon cord. It was assumed that this distance between treatments (artificial reefs) and controls was sufficient to preclude any interference between manipulations. A section of the NR2 with a profile similar to the artificials was framed in a 6 x 6 m square area and studied to compare any differences between their fish populations.

To evaluate the effectiveness of the artificial structures in improving habitat for sportfish species, artificial reefs and controls stations and their surroundings were assessed by gillnetting (day and night) and visual censuses one year before deployment. Fish were identified by species, and those captured in gillnets were measured and weighed. Qualitative fish censuses were also made at NR1, NR2, Pier Station and at Wreck Station in order to have a complete inventory of the species which could potentially colonize the artificial structures. Other marine fauna and flora were also inventoried.

After the structures were deployed, the artificial reef stations, the controls and NR2, were visually censused monthly in a single visit, weather and time permitting. Censuses were conducted between mid-morning and mid-afternoon. Any station left unevaluated during one sampling day, was assigned major priority for the next visit. A minimum visibility of 6 m was required to conduct the censuses. If visibility was insufficient, the sampling was aborted.

Censuses were conducted by two divers covering the complete 6 x 6 m square area. About 45 minutes were required to complete one census, including one artificial reef and its control. Upon surfacing, divers are debriefed and the data was pooled in a single data form. The largest number of individuals observed by any of the two divers was considered as the best abundance estimate.
Biological information gathered included fish species, number per species and approximate total length (maximum, mean, minimum) of individuals. Lengths were estimated to distinguish between juveniles and adults. Data was tabulated on preprinted mylar paper with the scientific names of the fishes listed alphabetically (Fig. 2). As new species appeared, the form was updated.

Underwater photographs of groups of fishes were taken to aid in population estimates. Large schools of fish were estimated by increments of 50 or 100. Haemulon species tended to form mixed schools making it difficult to census individual species. A category named '*Haemulon* mixed' was included in the preprinted form to provide for those situations and was treated as a species in the analysis. The category includes *H. aurolineatum*, *H. flavolineatum*, and *H. plumieri*. Analysis of variance was used to test for significant differences in fish species richness and abundance. Diversity (Shannon-Wiener) and evenness (Pielou) were calculated for each of the census made. The Sorenson measure of similarity was calculated for all possible pairs of stations.

## RESULTS

Table 1 shows fish species composition from visual censuses and gill net sampling (day and night) at all stations sampled before the structures were deployed. A total of 19 species were captured with gill nets. The most abundant species was *Chloroscombrus chrysurus*, with a maximum of only four individuals captured in a single sampling. Thirteen out of these nineteen species (68%) can be regarded as having some value as sport fish species.

Seventeen (17) species were reported by visual observations for the three stations combined. Only three of these (18%) have importance as sport fish species. The most abundant species was *Pseudupeneus maculatus*. Only two species, *Sphyraena barracuda* and *Lutjanus analis,* were common to both gillnet sampling and direct observation.

The highest number of species occurred at NR2 and at Wreck Station with 49 and 47 species respectively. Thirty species were common to both stations. Pomadasyids, especially *Haemulon plumieri,* was the dominant species by number at both areas followed by *Myripristis jacobus.*

A total of 31 species were observed at NR1 and 29 species at Pier Station. Lutjanus griseus was dominant at NR1 and Selene spixii, a schooling species, was the most abundant at the pier. A total of 91 species, which could potentially colonize the artificial structures, were observed at the five areas sampled combined, including stations chosen for artificial reef deployment.

Recruitment of fish, especially juveniles and subadults, occurred very rapidly once the structures were set. Individuals as small as 2 cm could be observed for most of the species present. Eight species were observed at AR1 just four days after the reef was constructed and more than 700 individuals comprising 12 species were censused at AR2 three weeks following deployment.

Extensive visual census surveys began one month after deployment. Species richness and abundance varied between stations (Figs. 3 and 4). Abundance estimates for AR1 ranged from 573 to 1202 individuals with and average of 861 individuals/census. Species richness ranged from 20 to 24 species with and average of 21.6 species/census. Largest fish abundance occurred at AR2. Surveys showed the abundance ranged from 885 to 3025 individuals with and average of 2142 individuals/census. Species richness ranged from 18 to 25 species with an average of 20.7 species/census for this same area. At AR3 the abundance ranged from 253 to 1926 individuals with and average of 1059 individuals/census. Species richness ranged from 12 to 24 species with an average 19.7 species/census. Fish abundance ranged from 593 to 1,304 at NR2 with an average value of 1007 individuals/census. Species richness ranged from 19 to 22 species with an average of 21 species/census. Overall fish abundance for all artificial reefs combined ranged from 253 to 3,025 with an average of 1,383 individuals/census. An ANOVA test showed a significant difference in fish abundance between natural and artificial reefs ($F_{0.05} = 5.9$, df = 3,17).

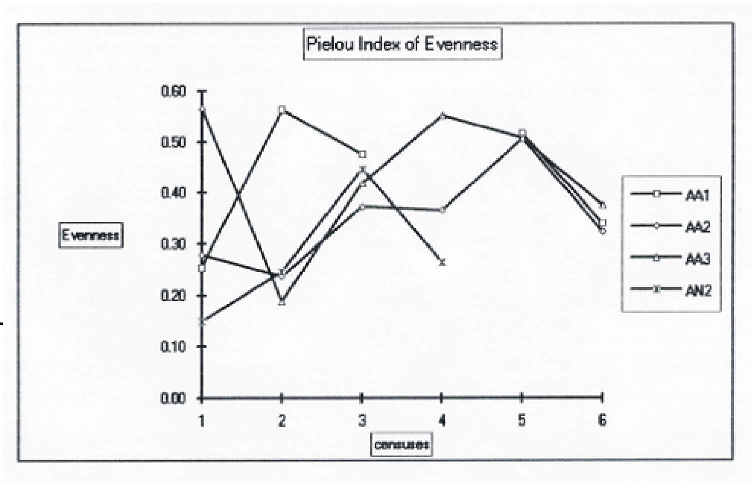



Figure 6. Evenness Index per census of fish per site.

Table 2 shows fish species composition and average abundance per station for the study period. To date, seven months after deployment, a combined total of 52 species have been observed at the three artificial reefs, of which at least 50% have some importance as recreational species. A total of 41 species have been censused at each artificial reef. At the 6 x 6 m square marked on NR2 only 31 species have been observed, 30% of them have some importance as sport species suggesting that the artificial reefs have a species richness larger than the natural

reef, however, an analysis of variance run on all sites did not reflect significant difference (ANOVA, F0.05 = .36, df = 3,17). Most species at the artificial reefs, with the exception of some pelagics, have become permanent residents of the structures.
Pomadasyids (four species) accounted for more than 80% of the individuals at the artificial reefs and about 35% at the natural reef. *Haemulon plumieri* is by far the most abundant species at the artificial reefs and at NR2 followed by *Haemulon aurolineatum. H. plumieri* show affinity for the inside interstices made by the pipes, while *H. aurolineatum* swim in school slightly over the reef. Another species that occurred in abundance was *Myripristis jacobus* which occupies the holes and crevices of the pipes, however, the numbers of *M. jacobus* may be underestimated because of their cryptic and nocturnal habits. Two Mullidae species *(Pseudupeneus maculatus, Mulloidichthys martinicus*) swam in schools around the reefs and occasionally were observed feeding actively over the pipes.

All control stations were almost devoid of fishes, as was the case in artificial reef areas before the structures were deployed. Only 6 species were observed at C1, 8 species at C2 and 2 species at C3. Average abundance per census at control areas was 4 individuals. Almost all individuals observed in control areas were juveniles.

The community parameters (diversity (H') and evenness (E)) of the fish populations recruited to the artificial reefs and those found on the natural reef were calculated for the different censuses. Overall diversity on artificial reefs ranged from 0.72 to 1.69 and from 0.46 to 1.32 at NR2 (Fig. 5). Evenness index increased from low values of .15 during the first two censuses to 0.52, but decreased again to 0.32 during the last sampling in October (Fig. 6).

The Sorenson Index of Similarity (qualitative measure) and number of common species was calculated for all possible pairs of stations based on the cumulative list of species along the study period (Table 3). The index values indicated that artificial reefs were from 83 to 85% similar in terms of species composition. However, percent similarity ranged from 56 to 61% when comparing artificial reefs with NR2 and only from 9 to 33% for artificial and control pairs. If abundance is incorporated in the index, similarity between artificial reefs and controls will tend to lower values than those shown on the table because of the great differences in abundance. Since we speculated that due to high turbidity and sedimentation the artificial reefs were not going to be colonized by sessile organism, we did not make the intent to quantify and study them in detail. However, aside from fishes, many other animals and algae recruited to the artificial reefs (Appendix). Recruitment of algae and invertebrates occurred rapidly, including filamentous algae, barnacles, bryozoan, tritons, spiny lobster, Mithrax crabs, and tunicates. Juvenile and sub-adult spiny lobster were observed inside the wooden pallets below the artificial reefs shortly after deployment.

DISCUSSION

During the last decades artificial reefs have become an important and popular resource enhancement technique and are thought to improve fishing by concentrating fishes and by increasing natural production of biological resources (Bohnsack and Sutherland, 1985). There is wide agreement that properly constructed artificial reefs can enhance fish habitat, provide more accessible quality fishing grounds, benefit anglers, increase total fish biomass within a given area and provide managers with another option for conserving and/or developing fishery resources (Stone, 1985).

Results obtained from this study shows that the artificial reefs constructed at Humacao have been highly successful in attracting and maintaining a diverse population of fish species. Fish recruitment occurred very rapidly once the structures were deployed. Both adults and juvenile fishes were attracted. From the pool of 91 species reported for the ten stations monitored before deployment, a total of 52 species have already recruited to the artificial reefs. At least 50% of these have some value for the recreational fishery. During the study period the density of fish ranged from 7 to 84 individuals/m2. Fish density remained high, except for the last census in October. Nevertheless, after the sharp decrease in abundance, the least fish density reported was 24 individuals/m2.

There are still other important species which were caught with gill nets in the area but were not observed subsequently during the censuses. These differences in fish composition before and after deployment is attributable to the sampling methods used. Certainly, the visual census method employed is biased against these species, most of them pelagic. Also, gill netting was conducted day and night while visual censuses were limited to day light hours.

In contrast to the artificial reefs, all control stations were almost devoid of fishes as it was the case before the structures were deployed. It is evident that the placement of the artificial reefs changed drastically the fish population structure of the area. This may indicate the usefulness of the artificial reef technology as a management tool by concentrating fishes which can be made available to the fishery and also by providing space for the larvae and juveniles to recruit to.

Artificial reefs showed a pattern of fish population structure similar to that found at NR2 and the Wreck Station. Haemulon spp. accounted for more than 70% of the total fish number in these areas. Along with *Haemulon* spp., other two species, (*Myripristis jacobus* and *Mulloidicthys martinicus*), were dominant forming the bases of their fish assemblages. At the Wreck Station *Lutjanus apodus* was also very abundant. Environmental conditions at the pier and at NR1 differ highly from that of artificial reefs, being dirtier and shallower in the former two. Forage and predator species such as *Harengula* spp. and *Lutjanus griseus* respectively, common in these areas, had not been observed at the artificial reefs or its numbers are very low.

Fish abundance and species richness continually increased at the artificial reefs during the first five months of the study, but during the October census a marked decrease was observed. This decrease could be ascribed to a migration of fishes to other areas as their habitat requirements may change during different life stages. Also fishing mortality may cause drastic abundance changes since there are commercial gill netters in the area. Conversely, at NR2, these parameters remained consistent along the study period. However, this station could not be monitored during October which was the period when the decrease in abundance at the artificial reefs occurred.

Although all three artificial reefs are structurally similar, located in the same habitat and relatively close together, some differences in the pattern of recruitment were apparent between units. AR2 always presented a greater fish abundance than the other two artificial reefs. Maybe its location between the other two made it accessible to the fish recruited to the other areas and some migration between reefs did occurr.

Overall diversity on artificial reefs appeared to be higher than on natural reef during the study period while species richness appear more similar ranging from 18 to 25 species for the last three censuses for all stations. Evenness values showed great fluctuations during the study period. These changes in evenness and its low values indicate that the fish community is dominanted by few species as shown by the high abundance of pomadasyids.

An underlying rationale for artificial reef deployment is the production hypothesis: that artificial reefs provide additional critical habitat that increases the environmental carrying capacity and eventually the abundance and biomass of reef fishes. Sale (1978) suggests that habitat is a limiting factor in reef fish recruitment. During the evaluations made before the structures were deployed a lack of adequate cover for fish was manifest. The few existing small patch reefs were crowded. Fishes were found using any hard structure in the bottom (rocks, log, PVC pipes, discarded rope or wire) as cover. It appears that lack of habitat was the major factor affecting population structure. Since natural and artificial reefs were very close it is assumed that both systems recruits from the same species pool. However, it was found that juvenile species and their abundance was greater at the artificial reefs. This may indicate that juvenile fish recruited to the artificial structures because the natural reef space was already occupied and that lack of habitat is a limiting factor.

There is also very much controversy weather the fish recruited to the artificial reefs have been 'stolen' from natural reefs. Although fishes recruited to the artificial reefs may come from nearby natural reefs, it is feasible to assume that the vacant spaces left may be occupied by new recruits or that the decreasing competence for food and/or space may help resident fishes to grow faster or larger augmenting the total biomass in the long run for the benefit of the fishery.

The only risk artificial reefs pose is the potential for overexploitation of the concentrated fishes. Nevertheless the situation can be avoided by designing areas with a large number of artificial structures providing shelter for adult and juvenile reef fishes but at the same time distributing fish more evenly.

Present study preliminary results shows that artificial structures may help to improve recruitment of juvenile and adult fishes in those places where lack of adequate habitat is the major factor affecting fish population abundance. Results show that the artificial reefs could be used to maximize available surface area and structural complexity to enhance colonization and refuge opportunities to the sportfish species in the Humacao area.

Nevertheless we think that results from one study area should not be extrapolated to another because differences in environmental conditions may affect population structure and successional patterns. A small scale pilot study should be conducted at each area to evaluate its functioning before a large scale development is taken over.

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Table 1. continued
NR = natural reef

| species | wreck | pier | NR1 | NR2 | station 1 | station 2 | station 3 | gillnets |
|---|---|---|---|---|---|---|---|---|
| Haemulon macrostomum | x | | | | | | | |
| Haemulon parrai | x | | x | | | | | |
| Haemulon plumieri | x | x | x | x | | | | x |
| Haemulon sciurus | x | | x | x | | | | |
| Halichoeres bivittatus | x | | | x | x | | | |
| Halichoeres garnoti | x | x | | x | | | | |
| Halichoeres maculipinna | x | | | x | | | | |
| Halichoeres poeyi | | | | x | x | | | |
| Halichoeres radiatus | x | | | x | | | | |
| Harengula humeralis | | x | | | | | | |
| Harengula sp. | | x | | | | | | |
| Holocanthus ciliaris | | | | x | | | | |
| Holocentrus ascensionis | x | | | x | | | | |
| Holocentrus rufus | x | x | x | x | | | | |
| Labrisomus nuchipinnis | x | | x | | | | | |
| Lachnolaimus maximus | | | | x | | | | |
| Lutjanus analis | | | x | x | x | | | x |
| Lutjanus apodus | x | | | x | | | | |
| Lutjanus griseus | x | x | x | | | | | |
| Lutjanus jocu | | x | | x | | | | |
| Lutjanus mahogoni | x | x | | | x | | | |
| Lutjanus synagris | x | x | x | | | | | |
| Mugil curema | | | | | | | | x |
| Mugil sp. | | x | | | | | | |
| Mulloidichthys martinicus | x | | x | x | | | | |
| Myripristis jacobus | x | x | x | x | | | x | |
| Ocyurus chrysurus | x | | x | x | | | | x |
| Odontoscion dentex | | | x | | | | | |
| Oligoplites saurus | | x | | | | | | |
| Ophioblennius atlanticus | x | | | x | | | | |
| Opisthonema oglinum | | | | | | | | x |
| Pomacanthus arcuatus | | | | x | | | | |
| Pomacentrus dorsopunicans | x | | | | | | | |
| Pomacentrus fuscus | x | x | x | x | | | x | |
| Pomacentrus leucostictus | x | | | | | | | |
| Pomacentrus planifrons | x | x | x | x | | | | |

**Table 1.** continued
NR = natural reef

| species | wreck | pier | NR1 | NR2 | station 1 | station 2 | station 3 | gillnets |
|---|---|---|---|---|---|---|---|---|
| Pseudupeneus maculatus | x | | x | x | x | | | |
| Rypticus saponaceus | x | | | | | | | |
| Scarus sp. (juv.) | x | | | x | x | | x | |
| Scarus vetula | x | | | | | | | |
| Scomberomorus regalis | | | | | | | | x |
| Scorpaena plumieri | x | | | | | | | |
| Selene spixii | | x | | | | | | x |
| Selene vomer | | | | | | | | x |
| Serranus baldwini | | | | x | | | | |
| Serranus tigrinus | | | | x | | | | |
| Sparisoma aurofrenatum | | | | x | | | | |
| Sparisoma chrysopterum | x | | | x | | | | |
| Sparisoma rubripinne | | x | x | x | | | x | |
| Sparisoma viride | x | x | x | x | | | | |
| Sphyraena barracuda | | | | | x | | | x |
| Sphyrna sp. | | | | | | | | x |
| Synodus intermedius | x | | | x | | | | |
| Thalassoma bifasciatum | x | | | | | | | |
| Umbrina coroides | | | | | | | | x |
| total number of species | 47 | 29 | 31 | 49 | 10 | 4 | 8 | 19 |

Table 2. continued
AR2, AR3, C2, C3: n = 5  AR1, NR2, C1: n = 4
AR = artificial reef, C = control areas, NR = natural reef

| species | AR1 | AR2 | AR3 | NR2 | C1 | C2 | C3 |
|---|---|---|---|---|---|---|---|
| Lutjanus synagris | 1.25 | 4.40 | 0.60 | 0.00 | 0.00 | 0.20 | 0.00 |
| Mulloidichthys martinicus | 137.50 | 60.20 | 15.00 | 7.00 | 0.00 | 0.00 | 0.00 |
| Myripristis jacobus | 53.75 | 116.00 | 54.00 | 28.75 | 0.00 | 0.00 | 0.00 |
| Ocyurus chrysurus | 3.50 | 10.40 | 7.80 | 0.75 | 0.00 | 0.20 | 0.00 |
| Oligoplites saurus | 0.25 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Ophioblennius atlanticus | 0.00 | 0.00 | 0.00 | 0.50 | 0.00 | 0.00 | 0.00 |
| Pomacentrus fuscus | 0.00 | 0.00 | 0.00 | 9.00 | 0.00 | 0.00 | 0.00 |
| Pomacentrus planifrons | 0.00 | 0.00 | 0.00 | 0.50 | 0.00 | 0.00 | 0.00 |
| Pomacentrus leucostictus | 6.50 | 3.00 | 1.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Pseudupeneus maculatus | 8.50 | 66.00 | 38.40 | 4.00 | 0.50 | 2.00 | 1.20 |
| Scarus sp. | 1.50 | 4.00 | 3.80 | 0.00 | 0.25 | 1.40 | 0.00 |
| Scomberomorus regalis | 0.00 | 0.40 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Scorpaena plumieri | 0.00 | 0.00 | 0.00 | 0.25 | 0.00 | 0.00 | 0.00 |
| Selar crumenophthalmus | 0.00 | 0.00 | 0.00 | 3.75 | 0.00 | 0.00 | 0.00 |
| Serranus tigrinus | 0.00 | 0.20 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Sparisoma rubripinne | 3.75 | 6.60 | 2.00 | 0.25 | 0.00 | 0.00 | 0.00 |
| Sparisoma sp. | 2.25 | 5.00 | 3.80 | 0.00 | 0.75 | 2.80 | 0.40 |
| Sparisoma viride | 0.00 | 1.80 | 1.40 | 0.00 | 0.00 | 0.00 | 0.00 |
| Sphyraena barracuda | 0.00 | 0.00 | 0.20 | 0.00 | 0.00 | 0.00 | 0.00 |
| Sphyraena picudilla | 0.00 | 40.00 | 60.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Synodus intermedius | 0.25 | 0.00 | 0.00 | 1.00 | 0.00 | 0.00 | 0.00 |
| total number of species per station | 34 | 36 | 36 | 30 | 6 | 7 | 2 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Haemulon plumieri | 337.75 | 1000.00 | 450.00 | 377.50 | 0.00 | 0.00 | 0.00 |
| Haemulon sciurus | 5.75 | 4.60 | 5.40 | 3.75 | 0.00 | 0.00 | 0.00 |
| Halichoeres poeyi | 0.00 | 0.00 | 0.00 | 0.00 | 0.25 | 0.00 | 0.00 |
| Halichoeres radiatus | 0.00 | 0.60 | 0.00 | 1.25 | 0.00 | 0.00 | 0.00 |
| Holacanthus ciliaris | 0.00 | 0.00 | 0.00 | 0.50 | 0.00 | 0.00 | 0.00 |
| Holocentrus ascensionis | 1.75 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Holocentrus coruscus | 0.75 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Holocentrus rufus | 0.00 | 3.40 | 9.20 | 22.25 | 0.00 | 0.00 | 0.00 |
| Labrisomus nuchipinnis | 0.00 | 0.00 | 0.20 | 0.00 | 0.00 | 0.00 | 0.00 |
| Lachnolaimus maximus | 2.75 | 0.60 | 1.80 | 1.75 | 0.00 | 0.00 | 0.00 |
| Lutjanus analis | 0.50 | 0.00 | 0.20 | 0.00 | 0.00 | 0.20 | 0.00 |
| Lutjanus apodus | 0.00 | 0.00 | 0.00 | 0.75 | 0.00 | 0.00 | 0.00 |
| Lutjanus griseus | 0.25 | 1.00 | 1.40 | 0.00 | 0.00 | 0.00 | 0.00 |
| Lutjanus jocu | 0.00 | 0.20 | 0.60 | 0.25 | 0.00 | 0.00 | 0.00 |
| Lutjanus mahogoni | 1.00 | 0.40 | 0.00 | 0.25 | 0.00 | 0.00 | 0.00 |

Table 3. Sorenson Index of Similarity

| | AA1 | AA2 | AA3 | AN2 | C1 | C2 | C3 |
|---|---|---|---|---|---|---|---|
| AA1 | X | 0.85 | 0.83 | 0.61 | 0.21 | 0.29 | 0.09 |
| AA2 | 35 | X | 0.83 | 0.61 | 0.21 | 0.29 | 0.09 |
| AA3 | 34 | 34 | X | 0.56 | 0.21 | 0.33 | 0.09 |
| AN2 | 22 | 22 | 20 | X | 0.11 | 0.21 | 0.06 |
| C1 | 5 | 5 | 5 | 2 | X | 0.57 | 0.50 |
| C2 | 7 | 7 | 8 | 4 | 4 | X | 0.40 |
| C3 | 2 | 2 | 2 | 1 | 2 | 2 | X |