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Use of Multi-mesh Gillnets and Trammel Nets to Estimate Fish Species Composition in Coral Reef and Mangroves in the Southwest Coast of Puerto Rico

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ABSTRACT.—Fish assemblages in coral reefs and mangroves off La Parguera, Puerto Rico, were sampled using gillnets and trammel nets. Complementary data were obtained from visual counts of fishes in the area where nets were fished. Ninety species were caught by these gears: 86 by gillnets, and 76 by trammel nets. Fifty-six species were recorded from visual censuses. Gillnets and trammel nets yielded 30% more species than visual counts in reef areas and 60% more in mangrove areas. Coefficients of variation were higher for trammel nets than for gillnets in the three areas sampled. These nets sample the commercial fish assemblage more efficiently than visual censuses. However, there are important variations by species. In each habitat, diversity and similarity indices based on the number of fish by species provided similar patterns for both gears and visual censuses. Diversity values were higher in reef areas than in mangrove areas. Similarity values were higher between different reef areas and lower between reef and mangrove areas.

RESUMEN.—Grupos de peces en los arrecifes de coral y en los manglares de La Parguera, Puerto Rico, fueron muestreados utilizando filetes y mayorquines. Se obtuvo información adiccional por medio de censos visuales de peces en las zonas donde las redes fueron colocadas. Noventa especies fueron capturadas con estas artes de pesca: 86 con filetes y 76 con mayorquines. Cincuenta y seis especies fueron observadas con censos visuales. Los filetes y mayorquines produjeron 30% más especies que los censos visuales en las áreas de arrecife y 60% más en el área de manglar. El coeficiente de variación fúe mayor para los mayorquines que para los filetes en las tres áreas muestreadas. Las redes muestrearon el grupo de peces con valor commercial más efficientemente que los censos visuales. Sin embargo, existió gran variabilidad por especies. Los índices de diversidad y similaridad, basados en el número de peces por cada especie, demostraron el mismo patrón para las redes y los censos visuales en las tres áreas estudiadas. Los valores de similaridad y diversidad fueron mayores entre las zonas arrecifales y menores entre los arrecifes y el manglar.

INTRODUCTION

Coral reefs are often associated with other habitats, such as sea grasses, mud bottoms, and mangroves. The interactions of fish populations within these habitats have been reported in several studies (Kimmel, 1985; Gladfelter et al., 1980; Robertson and Duke, 1987). Most fish species in reefs and adjacent areas are distributed as juveniles and adults over a range of habitat types. To understand the distribution of species in such a diverse system, a range of sampling techniques is required to ensure that all major habitats are sampled adequately (Kulbicki and Wantiez, 1990).

The use of various fishing gears in coral reef areas is limited due to the nature of the substrate. In most instances the only convenient methods are passive gears such as nets (gillnets, trammel nets, fyke nets), traps, and hook and line. There is no sampling gear that catches all species and sizes of fishes, and the relative numbers caught may not necessarily reflect proportions of the various fishes in the assemblages (Hubert, 1983). To understand the efficiency of a given gear, it is important to document what species are being caught and their relative distribution in the catch. This would include not only commercially important species, which are landed and recorded in fisheries statistics, but also species constituting the by-catch.

Gillnets and trammel nets have been used to sample species composition in a wide range of habitats. The accuracy of

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such sampling using gillnets has been reported by Bagenal (1979), Marais (1981), and Craig et al. (1986). Bagenal (1979) found that gillnets had the lowest coefficient of variation (74.4%) and that trammel nets had one of the highest (127.2%) when compared with trawls, seines, and fyke nets. Craig et al. (1986) found a coefficient of variation of 75.6% for multi-mesh gillnets. To assess the feasibility of using these nets to characterize species composition, the catch from these nets ideally should be compared to the true species composition of fishes exposed to the gear, or at least to an unbiased estimate of the underlying community. Unfortunately, there is no truly unbiased sampling method, and some of the better gears (e.g., trawls) are not applicable in reef environments. In coral reef areas, visual census offers a practical means of assessing at least the diurnally active fish community, and this method has been used in the past to calibrate fish catches from other gears (Miller and Hunte, 1987; Kulbicki, 1988; Kulbicki and Wantiez, 1990; Recksiek et al., 1991).

Models to estimate size selectivity are well documented (Hamley, 1975; Helser et al., 1991; Henderson and Wong, 1991; Acosta and Appeldoorn, 1995). However, the ability to generate selectivity curves is influenced by the behavior of the fish in relation to the effects of fishing gears. Information on the behavior of the fish escaping from the gear-effective fishing area, the size of the effective fishing area, and the direction of escape are necessary to estimate absolute efficiency of these gears (Acosta and Appeldoorn, 1995). Even if it is impossible to determine the absolute species composition of a community using passive gears because of species and size selectivity (Allen et al., 1960), the relative species composition as measured by passive gears can be used to assess differences between communities and changes in a community over time. Some measures that can be used to describe the species composition of samples include species richness, species diversity and species similarity (Hubert, 1983; Minns and Hurley, 1988). These indices can also be used as variates to compare the performance of gillnets and trammel nets of different designs.

The high species diversity characteristic of reef environments coupled with high habitat diversity, strong and dynamic species-habitat interactions, and complex species-specific behaviors (Galzin and Legendre, 1988; Harmelin-Vivien, 1989) make assessing community structure and catch characteristics difficult, and raise the question of whether results from more homogeneous systems with different species characteristics can be extrapolated to reef environments.

The objective of this study was to describe the effectiveness of gillnets, trammel nets, and visual census for sampling reef and mangrove fishes. The efficiency and sampling attributes of the three methods are discussed. The practical comparison of these methods (nets and visual census) is emphasized.

Materials and Methods

Study Area

The study was conducted in coral reefs and mangroves off La Parguera, in southwestern Puerto Rico (Fig. 1). The reef system was sub-divided into two areas: inshore (inner reef) and offshore (outer reef). The inshore area consisted of emergent and submerged reefs in various stages of development. Offshore, the shelf edge is formed by a continuous submerged reef, that supports a diverse assemblage of corals (Kimmel, 1985). There are numerous patch reefs between the inner reef and shelf edge. The mangrove area is characterized by red mangroves (*Rhizophora mangle*) and seagrass beds (*Thalassia testudinum* and *Syringodium fileforme*).

Experimental Design

Twelve experimental gillnets and trammel nets were used, one each of four mesh sizes (7.6, 8.8, 10.1, and 12.6 cm stretched mesh), in combination with three hanging ratios (1:1, 1:2, and 1:3). The four mesh sizes refer to the small-meshed section of the trammel nets. The mesh size for the large-meshed section of the nets was 35.6 cm (streched mesh). Acosta and Appeldoorn (1995) describe the sampling gear. Each net

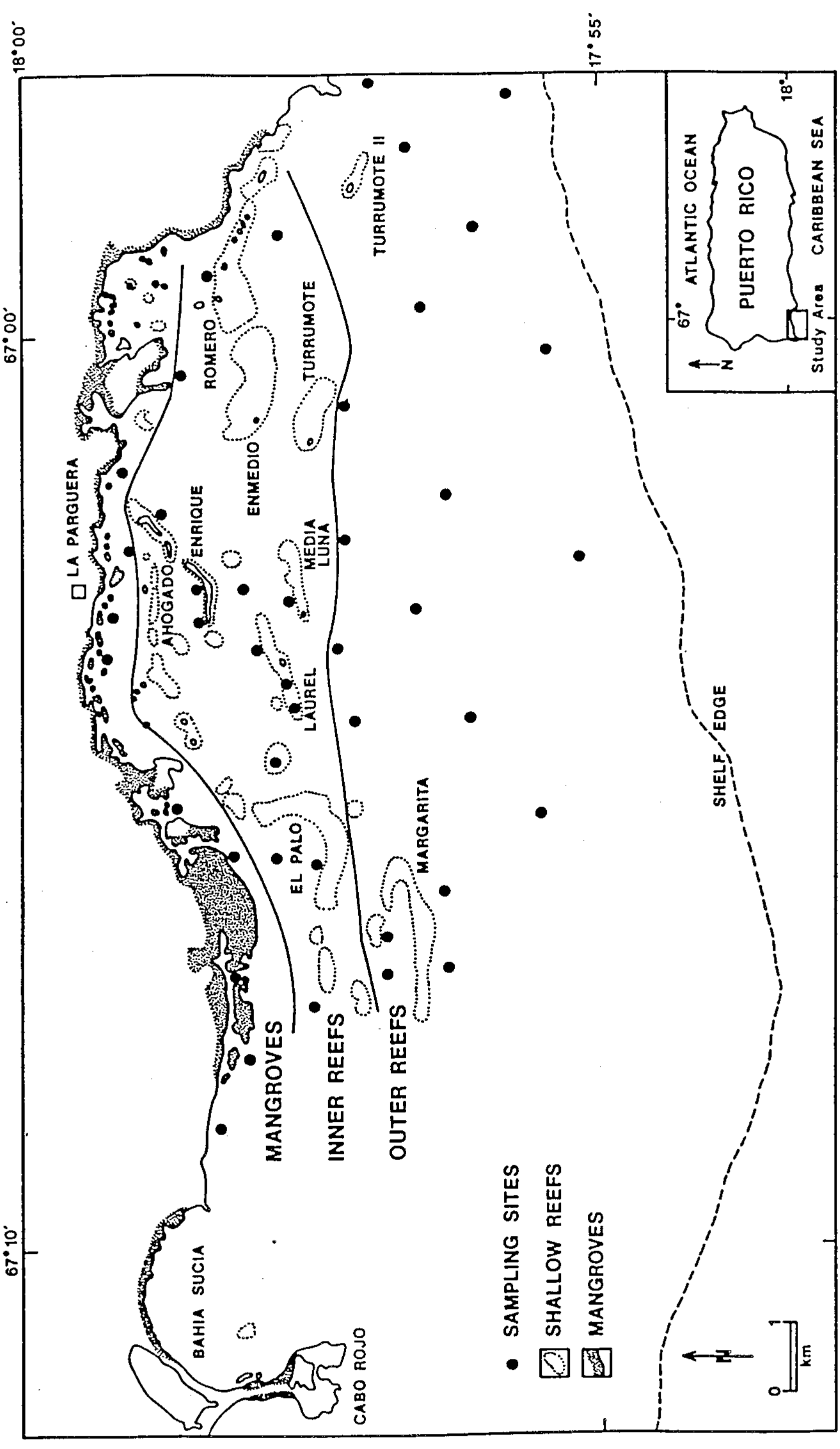

FIG. 1. La Parguera region of southwestern Puerto Rico, showing coral reefs, mangroves, and sampling sites.

was 50 m long. Nets were used in a ganged sequence to create a single composite experimental net 200 m long; successive nets were attached at the top and bottom with a space of approximately 0.5 m in between (Fig. 2). The location of each net within the 200 m experimental net was chosen randomly for each set to minimize any effects of catch saturation and net panel interaction (Hamley, 1975).

The number of sampling stations within areas ranged from 12 on the outer reef area to 22 on the inner reef, with 17 in the mangrove area. Experimental nets were set parallel to the reef track and to the edge of the mangroves in waters ranging from 0.6 to 6.1 m deep. Nets were fished for 12-h periods, i.e., set around sunset and hauled the following day around sunrise. When catches were low, fishes were removed as the net was hauled. When catches were high, fishes were removed after arriving at the dock, approximately 20 to 45 minutes after hauling. One gang of gillnets and one of trammel nets was fished simultaneously in each location for the same period of time. The nets were set at least 25 m apart to essentially eliminate competition among nets.

Visual censuses were conducted in conjunction with net fishing. The nets were set and left to soak for 30 minutes to allow the fish assemblages to recover from any disturbance caused by setting the nets. Next, species and individuals in the immediate vicinity of the net were recorded visually using SCUBA. During each census, two divers swam along the top of the net and recorded fish within 2 m on each side for the length of the net. This width of transect was established because of poor crepuscular visibility. Only species susceptible to being caught (>10 cm in total length) were recorded. Fish already caught were not counted. Five sets of censuses were conducted three times in ramdonly selected stations in each of the sampling areas, for each of the two types of gear.

Analysis of variance tested for differences in abundance of fish species by habitat and sampling gear. Because the number of samples for all gears and areas was not equal, mean abundance values of each species were used to compensate for these dif-

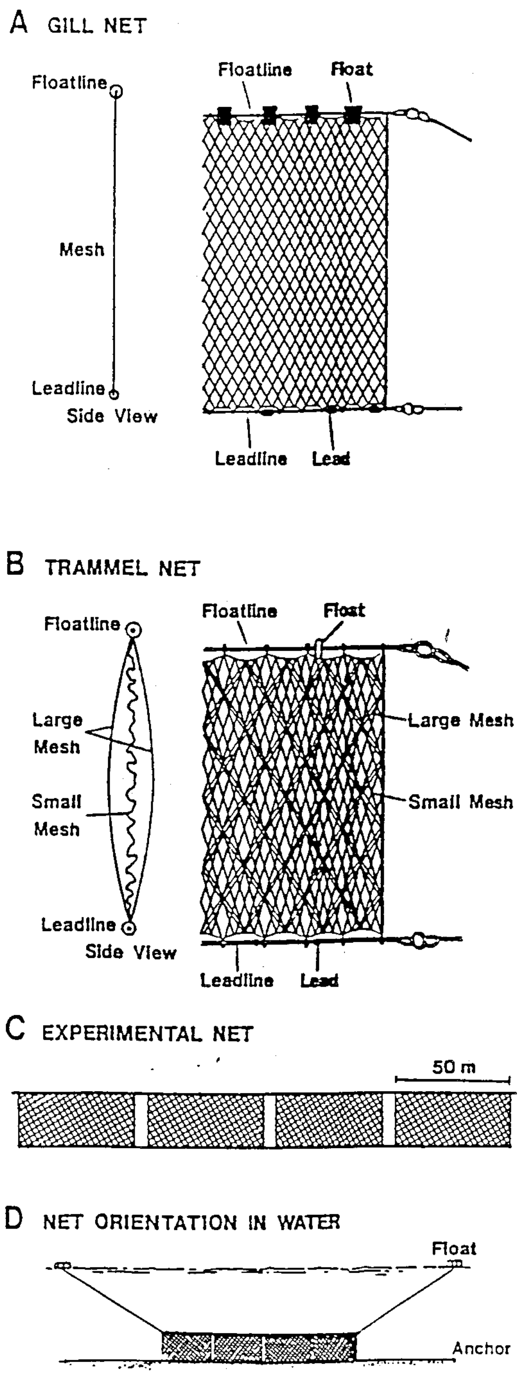

FIG. 2. Diagram showing A)Gillnet, B) Trammel net, C)experimental net composed of four individual nets, and D)orientation of experimental net in water.

ferences in sampling effort. The variances in the catches were larger than the mean catches, so the catches were logarithmically transformed by the equation $y = \log(x + 1)$. Coefficients of abundance variation (CV = (SD/mean)·100) for gillnet and trammel nets were also estimated. Fish diversity was compared using information on the total number of species and the relative abundance of each species in the sample.

The method of rarefaction, which allows comparison of species numbers between gears and communities, was used to estimate species richness (Sanders, 1968; Hurlbert, 1971; Peet, 1974). Rarefaction, which estimates the number of species expected in a random sample of individuals taken from a collection, answers the question: if the sample had consisted of n individuals, what number of species (s) would likely have been seen? Since rarefaction is not concerned with species composition, the samples compared by this method should be taxonomically similar (Krebs, 1989). The rarefaction analysis was implemented using the program RAREFRAC (Ludwig and Reynolds, 1988). The expected number of fish species (S_n) is estimated by the Hurlbert (1971) algorithm:

$$E(S_n) = \sum_{i=1}^{S} \{1 - [((N - n_i)/n)/(N/n)]\}$$

where S = total number of species, N = total number of individuals, n_i = number of individuals of species i, n = number of net sets and number of visual censuses ($n \leq N$). Species diversity was quantified by computing the Shannon and Weaver (1949) diversity index: $H' = -\Sigma[n_i/N \ln(n_i/N)]$, where N is the total number of individuals for all the species, n_i is the number of individuals for the ith species (i = 1 to S, S = total number of species), and ln indicates natural logarithms. The distribution of individual fishes was further analyzed by determining the index of species evenness (J) $J = H'/\ln S$ (Pielou, 1966).

The SIMI similarity coefficient proposed by Stander (1970) and illustrated by Smith et al. (1986) and Saila et al. (1995) was also calculated:

$$\text{SIMI} = \sum_{k=1}^{T} P_{1k} \cdot P_{2k} \Big/ \sqrt{\left(\sum_{k=1} P_{1k}^2 \cdot \sum_{k=1} P_{2k}^2\right)}$$

where T is the total number of species included, and P_{1k} and P_{2k} are the proportions of species k (based on the sum of that species, abundances over all replicates) in communities 1 and 2, respectively. SIMI values and their variances were determined by jackknife techniques and 95% confidence intervals were determined.

Results

The variability among catches was high, with several net hauls yielding only three or four species and a few large catches with 12 to 20 species. This trend was observed for the three areas sampled. The average catch per haul of a 200 m net, in terms of number of species and number of individuals, was 9 and 20 for the inner reef, 11 and 23 for the outer reef, and 6 and 15 for mangroves. Coefficients of variation by area for gillnets were 65% for the inner reef, 35% for the outer reef and 56% for mangroves; for trammel nets they were 68%, 70% and 86%, respectively.

Catch Composition by Gear

A total of 2,279 fishes belonging to 90 species and 41 families were caught by gillnets and trammel nets in the three areas sampled. Table 1 gives the species composition by family for gillnets, trammel nets, and visual censuses. Gillnets yielded 1,163 fishes representing 85 species from 39 families. On the outer reefs, gillnets yielded 382 fishes representing 60 species from 29 families. The inner reefs yielded 570 fishes representing 61 species from 31 families. Mangroves yielded 211 fishes representing 38 species from 22 families.

A total of 1,116 fishes representing 76 species from 37 families were caught by trammel nets. On the outer reefs, trammel nets yielded 504 fishes representing 53 species from 30 families. The inner reef yielded 370 fishes from 57 species representing 30 families. Mangroves yielded 242 fishes from 38 species representing 24 families. The numerically dominant families in terms of number of species in all areas for nets and visual counts were: Haemulidae, Lu-

TABLE 1. Families and number of species captured by gillnet, trammel net and visual census. OR = Outer reef, IR = Inner reef, M = Mangrove areas, T = Total.

	Gillnet				Trammel net				Visual census			
Family	OR	IR	M	T	OR	IR	M	T	OR	IR	M	T
Haemulidae	7	8	3	9	6	5	5	8	5	6	5	9
Acanthuridae	3	3	0	3	3	3	1	3	3	2	2	3
Carangidae	3	5	4	6	2	6	4	8	1	1	0	1
Lutjanidae	8	7	6	9	7	6	4	7	3	4	5	6
Scaridae	8	4	1	8	5	6	2	6	7	5	1	8
Kyphosidae	1	1	0	1	0	1	1	1	0	2	1	2
Sparidae	2	3	4	4	2	3	3	4	1	1	1	1
Gerreidae	1	2	2	2	1	1	2	2	1	1	1	1
Holocentridae	2	2	1	3	2	2	0	2	1	2	0	2
Serranidae	1	2	0	2	3	2	1	3	2	1	0	2
Labridae	1	1	1	1	1	1	1	1	1	1	1	1
Tetraodontidae	2	1	1	2	1	2	1	2	1	1	0	1
Ostraciidae	1	1	1	1	1	1	1	1	1	2	2	4
Balistidae	1	1	0	2	2	0	0	2	2	2	0	3
Scombridae	2	2	2	3	0	1	0	1	0	0	0	0
Priacanthidae	1	1	0	2	1	1	0	2	0	0	0	0
Mullidae	2	2	0	2	1	1	0	1	2	2	0	2
Elopidae	0	1	2	2	1	0	0	1	0	0	0	0
Albulidae	1	1	1	1	0	0	0	0	0	0	0	0
Mugilidae	0	0	1	1	0	0	1	1	0	0	0	0
Centropomidae	0	0	1	1	0	0	1	1	0	0	0	0
Stromateidae	1	0	0	1	1	1	1	1	0	0	0	0
Belonidae	0	1	0	1	0	0	0	0	0	0	0	0
Chaetodontidae	1	1	0	2	1	0	0	1	1	1	1	1
Synodontidae	1	1	1	1	1	1	0	1	1	0	0	1
Triglidae	0	1	0	1	1	1	0	1	0	0	0	0
Pomacanthidae	1	0	1	1	1	1	0	1	1	2	0	2
Ephippidae	1	1	1	1	1	1	1	1	0	0	0	0
Echeneidae	1	1	0	1	1	1	0	1	0	0	0	0
Dasyatidae	1	1	1	1	1	1	1	1	1	1	0	1
Myliobatidae	0	0	1	1	0	1	1	1	0	0	0	0
Carcharhinidae	3	2	0	2	1	2	0	2	1	1	0	1
Orectolobidae	1	0	1	1	1	1	1	1	1	1	0	1
Clupeidae	0	1	0	1	0	1	1	1	0	0	0	0
Scorpaenidae	0	1	0	1	0	1	0	1	0	0	0	0
Muraenidae	1	0	0	1	1	1	1	1	1	0	0	0
Bothidae	1	1	0	1	1	1	1	1	0	0	0	0
Dactylopteridae	0	1	0	1	0	0	0	0	0	0	0	0
Sphyraenidae	0	0	1	1	1	0	1	1	1	0	0	1
Sciaenidae	0	0	0	0	1	0	1	2	0	0	0	0
Aulostomidae	0	0	0	0	0	0	0	0	1	1	0	1
Total	60	61	38	85	53	57	38	76	40	40	20	55

tjanidae, Scaridae, Carangidae and Sparidae (Table 1).

Species overlap between coral reef (outer and inner reef combined) and mangrove areas by gear was similar (27% and 24% of all species for gillnets and trammel nets, respectively, and 24% overall). Few species were restricted to a single habitat (Fig. 3). A number of important families were absent from at least one of the three habitats. For example, Carcharhinidae, Mullidae, and Balistidae were not present in mangrove areas, whereas Mugilidae, Centropomidae, and Sphyraenidae were absent from the inner reef.

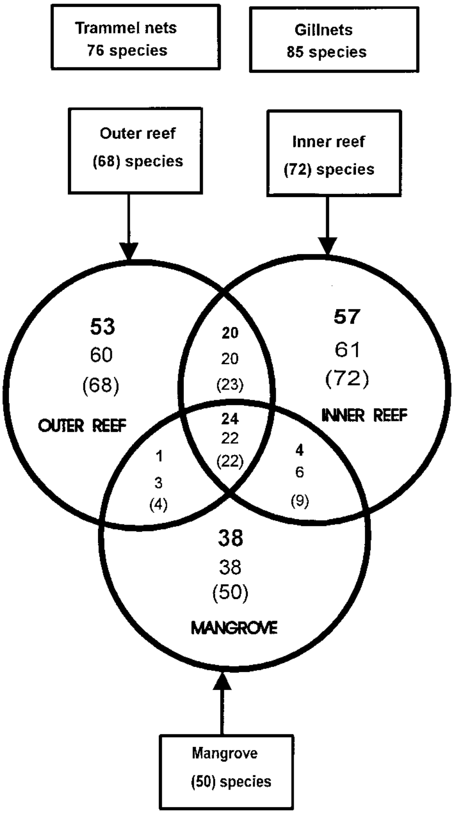

FIG. 3. Species overlap between areas (inner and outer reefs, and mangroves). For each set of numbers, the top represents the total number of species sampled by trammel nets. The middle represents the total number of species sampled by gillnets and the number in parentheses is the total number of species per area regardless of gear. The innermost area shows the number of species common to the three areas. The right and left inner area represents species sampled exclusively between outer reef and mangroves or between inner reefs and mangroves.

The number of species per haul was larger for gillnets than for trammel nets. The ratio was highest in the outer reef (1.46 for gillnets and 1.32 for trammel nets), followed by mangroves (1.27 for both gears) and the inner reef (1.20 for gillnets and 1.12 for trammel nets). Analysis of variance detected no significant difference in the number of species or abundance of fish collected by gillnets or trammel nets between inner reef and outer reef areas ($P > 0.05$). This analysis showed no significant difference ($P > 0.05$) in fish abundances among mangrove and reef habitats in which either of these gears was used.

Nineteen species occurred in 25% or more of the 123 samples taken. Bluestriped grunt (*Haemulon sciurus*), queen parrotfish (*Scarus vetula*) and sharks (Carcharhinidae) were found in more than 50% of the samples. White grunt (*Haemulon plumieri*) occurred in 76% of the samples in the outer reef. Species occurrence differed among the three habitats. Four taxa occurred in 50% or more of the outer reef area: white grunt, bluestriped grunt, queen parrotfish, and sharks. White grunt and bluestriped grunt occurred in 50% or more of the inner reef sample. Sea bream (*Archosargus rhomboidalis*) and yellowfin mojarra (*Gerres cinereus*) occurred in 50% or more of the mangrove samples.

Visual Census

The visual survey of the inner and outer reefs revealed the presence of 55 species in each area, distributed among 23 families (Table 1). The fauna of mangroves consisted of 20 species distributed among 10 families (Table 1). All coral reefs (inner and outer) combined yielded approximately 49% more species than mangrove areas. Some abundant species on both inner and outer reefs, such as ocean surgeon, parrotfishes and squirrel fishes, were not observed in mangrove areas. However, the number of fish observed in mangrove areas was greater than in reef areas. Four species in the mangrove area were not found in coral reef habitat: Lane snapper (*Lutjanus synagris*), dog snapper (*Lutjanus jocu*), and two puffers (Tetraodontidae).

Comparison Among Methods

Table 2 presents a breakdown by sampling method and habitat of the most abundant species, accounting for 75% of the fish taken. Important differences are noticeable among these methods; one of the most significant occurs among parrotfishes. Nets captured the large parrotfishes, such as *Scarus vetula* and *Sparisoma viride,* while visual census recorded small parrotfishes such as *Sparisoma aurofrenatum.*

Analysis of variance was performed for

TABLE 2. Fish species accounting for 75% of the total fish taken, by sampling method and habitat. OR = outer reef, IR = inner reef, M = mangroves.

	Gillnet						Trammel net						Visual counts					
	OR		IR		M		OR		IR		M		OR		IR		M	
Species	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%
Haemulon sciurus																		
Bluestriped grunt	47	12	109	19	10	5	68	13	38	10	8	3	15	3	7	3	64	12
Haemulon plumieri																		
White grunt	64	17	56	10	16	8	82	16	67	18	11	5	9	2	6	3		
Haemulon spp.																		
Grunts																	210	38
Archosargus rhomboidalis																		
Sea bream			19	3	90	43			13	3	84	35			9	4	23	4
Gerres cinereus																		
Yellowfin mojarra	14	4	54	10	11	5	4	1	14	4	21	9			10	5	45	8
Dasyatis americana																		
Southern stingray	6	2	3	1	3	1	29	6	18	5	10	4	2	1	4	2		
Sparisoma aurofrenatum																		
Redband parrotfish	6	2	16	3			1	1	5	1			50	11	34	17		
Scarus vetula																		
Queen parrotfish	26	7	24	4			15	3	9	3	1	1	15	3	6	3		
Calamus calamus																		
Saucereye porgy	8	2	36	6	4	2	2	1	1	1								
Haemulon flavolineatum																		
French grunt	3	1	3	1	1	1	2	1	2	1	3	1	4	1			47	8
Sparisoma viride																		
Stoplight parrotfish	14	4	24	4	1	1	11	2	3	1	1	1	30	7	5	2		
Acanthurus coeruleus																		
Blue tang	9	2	11	2			26	5	6	2			27	6	7	3	10	2
Diodon hystrix																		
Porcupinefish	8	2	4	1	1	1	16	3	13	4	5	2	5	1	1	1		
Lutjanus apodus																		
Schoolmaster	2	1	6	1			4	1	6	2	1	1	4	1	2	1	38	7
Lutjanus griseus																		
Grey snapper	3	1	4	1	7	3	1	1	5	1	14	6			3	2	40	7
Calamus bajonado																		
Jolthead porgy	6	2	15	3	6	3	10	2	14	4	4	2						
Ginglymostoma cirratum																		
Nurse shark	1	1			1	1	17	3	11	3	4	2	1	1	2	1		

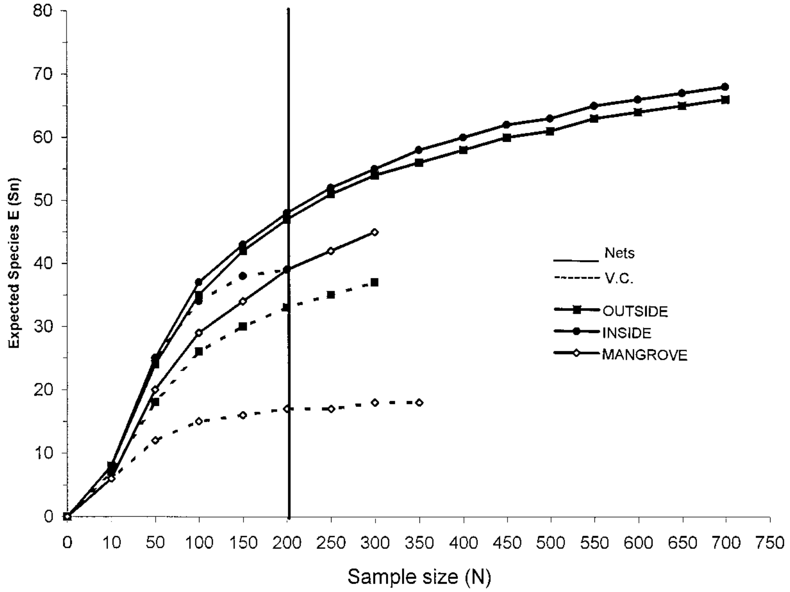

FIG. 4. Rarefaction curves for inner reefs, outer reefs, and mangrove areas, for gillnet and trammel net combined data and visual censuses (V.C.). The vertical line illustrates a sample size of $n = 200$ individuals.

white grunt, bluestriped grunt, sea bream, yellowfin mojarra, and ocean surgeon
to determine whether significant differences in abundance were discernible among methods (gillnet, trammel net and visual census) or areas. White grunt showed no significant difference in abundance between sampling methods or habitats ($P > 0.05$). Bluestriped grunt showed significant differences in abundance by area and sampling method ($P < 0.05$). The bluestriped grunt catch taken by gillnets was significantly larger in the inner reef than in the mangrove area. Trammel net catches were greater on the outer reef than in the mangroves. Visual census abundances were significantly lower in reef areas and higher in mangrove areas ($P < 0.05$). Sea bream were absent from the outer reef area. Significant differences in abundance were found between inner reef area and mangrove areas for both gears ($P < 0.01$). No significant differences were found between gillnet and trammel net catches in both areas ($P > 0.05$).

The abundance of yellowfin mojarra in visual censuses was significantly lower in the inner reef and higher in mangrove areas ($P < 0.05$). No significant differences overall in terms of abundance were found among habitats and among sampling method ($P > 0.05$). Marginally significant differences in abundaces of ocean surgeon from gillnets were observed in the inner reef area ($P < 0.08$). Differences between nets and visual censuses were found when comparing the total number of species in an area, but this is probably due to low sample size with visual census.

Diversity and Similarity Estimates

The rarefaction curves for the combined gear (mean of gillnets and trammel nets) within each area were compared to the rarefaction curves for visual censuses in the area (Fig. 4). The sample size (number of individuals) used to compute rarefaction curves varied from 938 for combined nets on the outer reef to 203 for visual censuses in mangrove areas. For comparison among habitats, $n = 203$ was set as a standard, corresponding to the smallest sample size of all habitats censused. Given this sampling level, the inner reef and outer reef were richest, with expected species richnesses of 45 and 44; mangroves were somewhat depauperate, with an expected richness of 36. The trend in species richness among areas

TABLE 3. Diversity indices for gillnets, trammel nets and visual censuses by habitat.

Habitat	Gear	H′	Evenness (J)
Outer reef	Gillnet	3.41	0.827
	Trammel net	3.25	0.815
	Visual censuses	2.70	0.739
Inner reef	Gillnet	3.24	0.785
	Trammel net	3.40	0.846
	Visual censuses	3.26	0.885
Mangroves	Gillnet	2.52	0.693
	Trammel net	2.70	0.749
	Visual censuses	2.16	0.750

for visual censuses was similar to the trend observed in the net samplings. The inner reef had the highest richness with 39 species, followed by the outer reef with 31 species, and mangroves with 16 species. The diversity index (H′) by gear and habitat ranged from 3.41 at the inner reef to 2.16 at the mangroves (Table 3). The pattern of diversity and evenness for visual censuses was similar to that for the fishing gears. Inner reef and outer reef diversity values were generally similar, with inner reef diversity slightly higher. Mangroves showed the lower diversity (Table 3).

Comparisons of similarity coefficients by area for gillnet and trammel nets combined, and visual censuses, are given in Table 4. The inner reef and outer reef showed the greatest similarity. Thirty species were common to the two habitats. There was little similarity between coral reef (inner or outer) and mangrove assemblages; similarity values were less than half of those observed between the two reef areas. Similarity coefficients for visual censuses produced moderate similarity between inner and outer reef areas. (but the variability was large—Table 4). Visual similarity between reefs and mangroves was low (0.414 for the inner reef and 0.119 for outer reef). Confidence intervals were wide for the inner reef comparison and narrow for the outer reef comparison (Table 4).

TABLE 4. Similarity coefficients (SIMI) between sampling areas (inner reef, outer reef and mangrove) and between sampling methods (gillnet, trammel net and visual census) estimated by SIMI and jackknife methods. (SIMI: see methods)

Gillnet and trammel net	
Inner reef vs. outer reef	
Similarity coefficient (SIMI)	0.902
Jackknife similarity coefficient adjusted for bias	0.990
Variance	0.000159
95% Confidence Intervals	0.963, 1.00
Inner reef vs. mangrove	
Similarity coefficient (SIMI)	0.452
Jackknife similarity coefficient adjusted for bias	0.443
Variance	0.002041
95% Confidence Intervals	0.316, 0.509
Outer reef vs. mangrove	
Similarity coefficient (SIMI)	0.377
Jackknife similarity coefficient adjusted for bias	0.357
Variance	0.010098
95% Confidence Intervals	0.110, 0.538
Visual censuses	
Inner reef vs. outer reef	
Similarity coefficient (SIMI)	0.666
Jackknife similarity coefficient adjusted for bias	0.715
Variance	0.062473
95% Confidence Intervals	0.182, 1.00
Inner reef vs. mangrove	
Similarity coefficient (SIMI)	0.414
Jackknife similarity coefficient adjusted for bias	0.409
Variance	0.049665
95% Confidence Intervals	0.0, 0.884
Outer reef vs. mangrove	
Similarity coefficient (SIMI)	0.119
Jackknife similarity coefficient adjusted for bias	0.123
Variance	0.000308
95% Confidence Intervals	0.086, 0.161

DISCUSSION

Species and Fish Community Characterization

A measure of the effectiveness of a sampling gear is how well its total collection reflects the diversity of the actual fauna in the area (Parrish, 1982). In practice, the total faunal composition is unknown or very poorly known. In the case of reef and mangrove fishes, the southwest coast of Puerto Rico has been surveyed extensively (e.g., Austin, 1971; Austin and Austin, 1971; Kimmel, 1985; Rooker and Dennis, 1991; Turingan and Acosta, 1994).

This study indicates that the fish fauna off La Parguera can be divided into reef and non-reef assemblages. When comparing these results with previous studies of the area, it is clear that gillnets and trammel nets were able to sample the commercial fish community efficiently. Kimmel (1985), using visual census, reported 169 fish species on reefs off La Parguera. His study included species that are not vulnerable to the nets used here due to their size and/or behavior, such as Pomacentridae, Gobiidae, Blenniidae, and Clinidae. A preliminary assessment of the catch composition of gillnets and trammel nets for the south and west coasts of Puerto Rico, made from commercial landing data collected by the Puerto Rico Fisheries Research Laboratory (Acosta, 1992), indicated results similar to those found in this study, in terms of demersal species composition among gear types. Sixty species were caught by gillnets during 1986–87 and 41 by trammel nets. However, non- demersal species present in the catches of the present study, such as sharks (discarded), mackerels, and barracudas, were not reported in the commercial landings data (Acosta, 1992). Kimmel (1985) provided density estimates for the 19 most abundant fish species (84% of total fish abundance) in a line transect survey of reefs off La Parguera; families such as Haemulidae, Lutjanidae, and Sparidae are not present in that list. These families together with the Scaridae were the dominant species in net catches.

Several studies have provided lists of fish species found in Puerto Rican mangroves (Austin, 1971, Austin and Austin, 1971; Kimmel, 1985, Rooker and Dennis, 1991). Sixty species were reported by Austin and Austin (1971), and 38 were reported by Kimmel (1985). In Kimmel's study, sea bream and yellowfin mojarra ranked 13 and 16 in terms of abundance in mangrove areas, while in this study these species ranked first and second.

The present study indicates that biases are present in both methods. Some biases associated with visual census are well documented (Sale and Douglas, 1981; Sale and Sharp, 1983; Bohnsack and Bannerot, 1986). In addition, potential bias in comparisons between net catches and visual census results from differences in the sampling periods for the two methods. Visual census was conducted during daylight periods, when the nets were set and hauled, so it missed species active nocturnally or at twilight (e.g., sea bream). Observations of the catches of gillnets and trammel nets indicated that sea bream were caught at sunrise in mangrove areas. However, this species, together with white grunt, was absent from visual census, probably due to their avoidance reaction to divers and their feeding migrations (Dennis, pers. comm.). Some characteristics of nets as related to visual census are: a) small species are missed; b) species that are more active may be overrepresented (e.g., pelagics, snappers); c) a larger number of samples is required relative to visual census; d) sampling is integrated over time (relative to visual census, which is more nearly instantaneous); e) fish seem not to avoid nets as much as they avoid divers. Gillnet and trammel net catches are affected by the densities of the fish concentrations, the movement of fish in a predominant direction (e.g., migration, feeding activity), and the random movement of individual fish.

Behavioral patterns among fishes vary greatly depending on their physiological status. The process of capturing fish in clear reef waters is especially complicated by factors such as their visual capability and swimming speed of fish, and by environmental variables (e.g., light, currents) involved in determining the reaction of a fish as it approaches the net.

Gillnets and Trammel Nets as Assessment Tools

One aim of this study was to evaluate the efficiency of using gillnets and trammel nets for commercial and scientific sampling. For scientific sampling, net design (mesh size, hanging ratio, type of twine) and how the net is fished should be considered. The coefficients of variation for gillnets and trammel nets within a particular area were lower than those reported by Begenal (1979) and Craig et al. (1986). The difference in variability observed among habitats is probably due to spatial heterogeneity of the habitats sampled, to patterns of behavior (such as schooling behavior) of many of the fish species, or to both. However, perceived differences in assemblages among sites may result from changes in gear biases among habitats and among fish, rather than from actual differences in fish abundances (Weaver et al., 1993).

This study was not designed to calibrate gillnet and trammel net catches with visual census. Studies that have correlated trawls (Kulbicki and Wantiez, 1990) and fish traps (Recksieck et al., 1991; Acosta et al., 1994) with visual census indicate that correlation is weak at the multispecies level but satisfactory for selected species. Similar work comparing longline CPUE and visual census indicated good correlation for all species combined but considerable variation depending on species (Kulbicki, 1988).

The two methods (nets and visual census) used in this study to sample coral reef and mangrove habitats yielded somewhat different results because of biases inherent in each method. From the comparisons of net catches with visual censuses, it is clear that nets used demonstrate strong taxonomic selectivity and that the catches represented only a part of the fish assemblage. Consequently, if reasonably accurate estimates of species composition or density estimates are required for coral reef areas, it is likely that a combination of several methods will be required. The advantage of nets as sampling devices is noticeable when comparing gillnet and trammel net catches with the catches of other passive gears (e.g., fish traps) in reef areas. Nets catch more fish than traps and lines in less time and are less selective in terms of number of species than the other methods (Gobert, 1992). Nets are also efficient at catching large mobile fish.

In conclusion, nets do not sample in a manner similar to visual census, although basic patterns in community structure can be characterized similarly by the two methods (with the important exception of some pelagics). Fisheries biologists should base their choice of sampling gear for these communities on the target species or assemblage, and on the sample size needed to obtain the desired results. As an example, Kimmel (1985) estimated that eight samples were sufficient to include more than 94% of a particular assemblage using visual census. On the other hand, the coefficient of variation observed in this study for gillnets and trammel nets was very high, even though the number of sampling nets (or hauls) was large (over 30 samples in each area). Although gillnets and trammel nets are labor intensive and yield relatively low and variable numbers of fish, they provide reliable estimates of the commercial species composition of coral reefs and mangroves. However, from these results it appears that multi-mesh gillnets and trammel nets do not provide a very accurate estimate of stock abundance.

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