The Effect of Fish Trap Mesh Size on Species Composition and Catch Value in Western Puerto Rico

AIDA ROSARIO JIMÉNEZ[1] and YVONNE SADOVY[2]
[1]*Fisheries Research Laboratory*
Marina Station P.O. Box 3665
Mayaguez, Puerto Rico, 00681
Tel.:(809)833-2025 Fax (809)833-2410
[2]*Fisheries Research Laboratory*
Marina Station P.O. Box. 3665
Mayaguez, Puerto Rico, 00681
Tel.:(809)833-2025 Fax (809)833-2410

ABSTRACT

Catch selectivity of wire mesh fish traps was tested for six different mesh sizes ranging from 0.5" x 0.5" (13 mm x 13 mm) to 3 x 2" (76 mm x 51 mm). A total of 4,471 fish representing 90 species, 35 families, and 1,096 kg were captured during 1,076 trap hauls off the west coast of Puerto Rico from January, 1990 to December, 1990. Significant differences were noted in catches by mesh size. Median commercial value ranged from a minimum of $0.00/haul for the 2" x 3" galvanized mesh to $2.39/haul for the 1.5" x 1.5" mesh. Median value per haul tended to decrease for meshes larger and smaller than 1.5" mesh. Median value per fish as a function of mesh size also tended to decrease with meshes larger and smaller than 1.5" mesh size. While median size tended to increase with mesh size, median price per fish did not increase primarily because individuals caught with larger mesh sizes tended to consist predominantly of species of little or no commercial importance.

Species catch composition was affected by the mesh size used. Smaller mesh sizes accounted for higher species diversity than larger meshes. The percentage of trash fish or bycatch (species with little or no market value) fluctuated from 20% to 35% of total catch by weight. None of the tested mesh sizes was effective in substantially reducing the bycatch, with the possible exception of the 2" x 3" vinyl coated wire.

It was determined that although the 1.5" x 1.5" mesh would likely provide a better economic return to fishermen on a short-term basis, a full analysis of the long-term effects on productivity under these various scenarios is necessary to enable development of a management plan for optimization of yield.

KEY WORDS: fish trap, mesh size, management, artisanal fishery.

RESUMEN

Se experimento con la selectividad de la malla de las nasas con seis diferentes tamaños de malla desde 0.5" x 0.5" (13 mm x 13 mm) hasta 3" x 2" (76 mm x 51 mm). Un total de 4,471 individuos representando 90 especies, 35 familias, y 1,096 kg fueron capturados en 1,076 levas de nasas fuera de la costa oeste de Puerto Rico entre Enero, 1990 a Diciembre, 1990. Diferencias significativas fueron observadas en las capturas por tamaño de malla. La

mediana del valor comercial fluctúo de un minimo de $0.00/leva para la malla galvanizada de 2" x 3" hasta $2.39/leva para la malla de 1.5" x 1.5". Los valores medios por leva tendieron a disminuir con las mallas mayores y menores de 1.5". El valor medio por individuo como función del tamaño de malla tambien desmostró una disminución con mallas mayores y menores de 1.5". Mientras la media en tamaño tendió a aumentar con el tamaño de malla, el precio medio por pescado no aumento debido, primordialmente a que los individuos capturados con las mallas de mayor tamaño consistían mayormente de especies de poca o ninguna importancia comercial.

La composición de especies capturada fue afectada por los tamaños de malla utilizados. La composición de especies capturadas con las mallas mas pequeñas fue mucho mayor que con las mallas mayores. El porciento de "brosa" (especies con poco o ningún valor comercial) fluctuó entre 20 a 35% del total de la captura en términos de peso. Ninguna de las mallas utilizadas fue efectiva en reducir substancialmente la captura de "brosa", con la única posible excepción de la malla recubierta de vinilo de 2" x 3".

Se determinó que aunque la malla de 1.5" x 1.5" podría proveer a los pescadores una ganancia económica mayor a corto plazo, es necesario un an†lisis detallado de los efectos a largo plazo sobre la productividad bajo estos diferentes escenarios que permitan desarrollar un plan de manejo para la optimización de la captura.

PALABRAS CLAVE: nasa, tamano de malla, manejo, pesqueria.

INTRODUCTION

As in most parts of the Caribbean, the fishery in Puerto Rico is almost exclusively artesenal in nature. The fish trap or "nasa" has at least historically been the most important fishing gear in terms of total units of gear fished and in the percentage of total reported landings by weight. In 1976 and the early 1980s traps accounted for two-thirds of total reported production on the Island. By 1988 it was estimated that 37% of the total fishing units were fish traps accounting for one-third of the total landings of fish and shellfish. Average total annual catch per trap reported over the past twelve years has declined steadily from 159 kg in 1976 to 23 kg in 1988 (Weiler and Suarez-Caabro, 1980; García-Moliner and Kimmel, 1986; Matos and Sadovy, 1989).

In Puerto Rico, Stevenson, (1978) and Stevenson and Stuart-Sharkey (1980) demonstrated that the red hind, *Epinephelus guttatus* "cabrilla" and the white grunt, *Haemulon plumieri* "cachicata blanca", were being overfished by the 1" (25 mm) and the 1.25" (32 mm) trap mesh sizes. They tested the effects on catch profile of using three different mesh sizes and found that increasing mesh size led to a significant reduction in the number of fish caught, especially those of smaller size classes, and also to changes in the species composition of the catch. They also found that squirrelfishes (*Holocentrus spp.*) were more effectively harvested by larger meshes. These species are of little or no commercial importance although their removal in high numbers as bycatch "brosa" results in

wasteful loss of biomass. In Puerto Rico, specifically, there is concern over the marked decline in catch per unit effort (pounds taken per trap haul) over the last decade. There is also concern over the sharp increase in the number of traps being used, because of the detrimental aspects of trap fishing on the fishery. As a result of these concerns, the Fisheries Research Laboratory (FRL) of the Department of Natural Resources (DNR) carried out a one year study to address the biological and economic impacts of a total of six different mesh sizes on the standard fish trap of Puerto Rico. In particular, the influence of fish trap mesh size on species composition and catch value was examined.

METHODS

Traps

To determine the effect of trap mesh size on catch composition, value, five galvanized metal mesh sizes were used: 0.5" x 0.5" (13 mm x 13 mm) square mesh, 1.25" x 1.25" (32 mm x 32 mm) hexagonal mesh, 1.5" x 1.5" (38 x 38 mm) square mesh, 2" x 2" (51 mm x 51 mm) square mesh, 2" x 3" (51 mm x 76 mm) rectangular mesh. Since a mesh size of 1.25" is that most commonly used by Puerto Rican fishermen, this size was considered the control mesh size, leaving four experimental mesh sizes. Two additional mesh sizes were subsequently incorporated into the study: 2" x 3" (51 mm x 76 mm) vinyl coated mesh, and 2" x 1" (25 mm x 51 mm) rectangular mesh size. Mesh size characteristics and measurement conversions are listed in Table 1.

Trap design, in terms of dimensions and form of the entrance funnel ("nasilloÆ), was the standard used by pot fishermen on the shallow water platform area of Puerto Rico. Traditional Antillean arrowhead traps of 4' x 4' x 1.5' (122 x 122 x 30 cm) were constructed of galvanized wire mesh and reinforcing rod. Trap doors incorporated an autodestruct component ("pop-up" type fasteners) to comply with Commonwealth Law and to prevent "ghost" fishing by lost traps. Prior to deployment, trap doors were fastened in such a way as to enable detection of pilfering during the soak period.

Sampling Areas

Sampling areas were selected using data from the results of a 1988-1989 Monitoring Project (Rosario, 1989). The selected areas comprised the ten most productive 2 mi. x 2 mi. quadrants sampled during the 1988-1989 Project. Sampling thus covered a total of 40 (not necessarily contiguous) square miles on the platform/shelf break area of the insular platform of western Puerto Rico (Figure 1).

Field Procedure

Two boats were used for sampling. On each boat, for each sampling trip, two traps of each mesh size were deployed between January and December

Table 1. Dimensions of trap meshes used in survey.

Mesh Shape	Width (in)	Length (in)	Area (in)^2	Diagonal (in)	Width (mm)	Length (mm)	Area (cm)^2	Diagonal (mm)
Square	0.5	0.5	0.25	0.71	12.7	12.7	1.6	18.0
Rectangular	1	2	2.00	2.25	25.4	50.8	12.9	57.2
Hexagonal	1.25	1.25	1.56	1.5	21.8	21.8	4.8	38.1
Square	1.5	1.5	2.25	2	38.1	38.1	14.5	50.8
Square	2	2	4.00	2.88	50.8	50.8	25.8	73.2
Rectangular	2	3	6.00	3.75	50.8	76.2	38.7	95.3
Rectangular*	2	3	6.00	3.75	50.8	76.2	38.7	95.3

* vinyl coated mesh

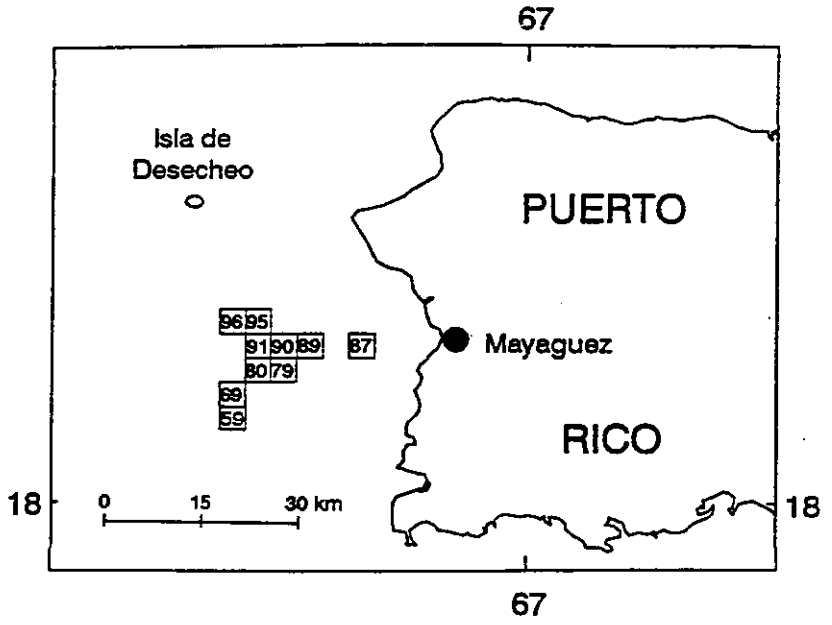

Figure 1. Sampled stations off the west coast of Puerto Rico.

1990, except for the 1" x 2" and 2" x 3" vinyl coated mesh. The 1" x 2" mesh was introduced at the end of July 1990. The traps were deployed, in strings of five each trap a different mesh size to ensure that similar substrate was being sampled on each trip and to aid relocation. Additional trips were scheduled to compensate for trap losses, as necessary. Sampling protocol was designed to partially control for season and weather conditions. A buoy with a timed release marked the location of the trap string. Traps were set no closer than 150 ft. (46 m) apart to prevent possible intertrap interference.

Traps were generally hauled once every five to eight days on a regular basis on the return leg of a subsequent deployment trip. This soak period reflects that commonly used by local fishermen. Soak time varied considerably due to weather and current conditions but averaged seven days (range 1 to 52 days). However, only soak periods of five to eight days were included in the data analysis. Lost, stolen or damaged fish traps were replaced or repaired as needed and different trap units of a given mesh size were rotated into the fishing schedule. Data from traps that were suspected to have been pilfered, or had been damaged, were discarded.

Collection and Analysis of Data

The following data were collected on the day that traps were hauled: 1. Date; 2. Quadrat No; 3. Soak time period (days); 4. Depth of trap deployment (meters); 5. Mesh size; 6. Condition of trap door mechanism (good condition, broken, or pilfered); 7. Total weight of catch for each trap; 8. Species composition for each trap (identification, lengths (FL/mm) and weights (g) of all individuals, and sex and stage of sexual maturation where possible); 9. Total number of individuals in each trap; 10.Gonads and otoliths of selected species were removed to support Laboratory studies on the general biology of commercially important species. In addition, the economic value (in US $) of each catch was determined by using data on average price per pound for each species for the west coast of Puerto Rico, available from the Statistics Division of the Laboratory (Matos and Sadovy, 1989). All data were entered into a DBASE III+ program for storage and sorted prior to analysis. Summaries and analysis were made in LOTUS 123 version 2.1, Statistix version 3.1 and SAS software.

Data were tested for normality. They were found to be non-normal. The high incidence of zero haul catches was a major factor in producing non-normal data. Data transformations did not normalize the data, hence analysis was carried out using non-parametric methods. Non-parametric analyses used were Wilcoxon Ranked Sum test (WRS), similar to the Mann-Whitney U test (Sokal and Rohlf, 1981) when used to compare two samples only. Also used were the Wilcoxon 2-Sample Test (Normal Approximation with continuity of .5), and the Kruskal-Wallis Test (Chi-Square Approximation).

RESULTS

The number of hauls varied from a minimum of 58 for the 2" x 3" vinyl coated wire to a maximum of 207 for the 2" x 3" galvanized mesh. The 2" x 3" galvanized wire resulted in the highest percent of zero catch hauls with 62%, while the 1.25" mesh recorded the lowest with 5% (Table 2).

Economics

The catches were evaluated based on fish dealer categories reported to the F.R.L. Statistics Program (Matos and Sadovy, 1990). First class commercial species had the highest market value (an average of $2.03/lb) and included, in general, groupers (Serranidae), snappers (Lutjanidae), hogfish (*Lachnolaimus maximus*), and trunkfishes (Ostraciidae). Second class species were valued, on average at $0.85/lb, and include, besides small individuals of first class species, grunts (Haemulidae), porgies (Sparidae), triggerfishes (Balistidae), and goatfishes (Mullidae).

Third class species had a low market value (an average of $0.54/lb) and are composed mainly of small second class fishes, and parrotfishes (Scaridae). In

certain areas "third class" includes large individuals of squirrelfishes (Holocentridae), and doctorfishes (Acanthuridae). First class fishes were the major component of total value for most meshes although their relative contribution to the total catch, by weight, varied considerably (Table 3, Figures 2 and 3).

The estimated median commercial value ranged from $0.00/haul for the 2" x 3" galvanized mesh to $2.39/haul for the 1.5" mesh size (Table 2). Catch value tended to decline for meshes smaller and larger than the 1.5". The Kruskal-Wallis Test indicated non-statistically significant results for differences in price per haul for the following mesh sizes: 0.5" and 1.25"; 0.5" and 1" x 2"; 1 x 2" and 1.25" and 2" x 3" gal. and 2 x 3" vinyl (Table 4a, Figure 2).

Differences in median price per fish per haul as a function of mesh size were not statistically significant for the following mesh sizes: 0.5" and 1.25"; 0.5" and 1" x 2"; 0.5" and 2" x 2"; 1.25" and 1" x 2"; 1.25" and 2" x 2"; 1" x 2" and 2" x 2"; 2 x 2" and 2" x 3" gal; and 2" x 3" gal. and 2" x 3" vinyl coated (Table 4b). All other comparisons exhibited significance differences.

Species Composition

The classification by first, second, third and trash fish is the general market value presented by Matos and Sadovy (1990). This classification varies markedly from coast to coast, but in general, reflects the one used by the majority of fishermen. The two categories that tend to vary most in terms of how species are classified according to their market value are third and "trash" ("brosa") fish. The major difference concerns the classification of squirrel fishes. For example, on the west coast, this group is considered to have no market value (trash fish). On the south coast however, it is classified as third class fish. Considering that a single species of holocentrid made up 14.8% by weight of the total catch (all mesh sizes combined), these local market classification of this group could considerably influence total catch value depending on its frequency of capture. The general trends discussed in the following section have not been analyzed statistically.

The species composition by weight for the smaller mesh sizes was similar with respect to the major groups of commercial importance captured (Tables 3, 5; Figure 3). The greatest difference in species composition was observed between the smaller mesh sizes and the 2" x 3" mesh size, both galvanized and vinyl coated (Tables 3, 5; Figure 3). The catch for these two types of traps consisted mainly of species of little or no commercial importance and included few snapper and no grouper. The two major groups of commercial importance in Puerto Rico are snappers and groupers, which represent first class fish.

The combined percentage of these two groups for the 0.5", 1.25", and 1" x 2" mesh sizes were similar (44%), Figure 3a,b, and d. The 1.5" mesh was the mesh with the highest percentage (52%) of snappers and groupers, combined

Table 2. Summary of fish trap catch and effort data by mesh size.

Mesh size (inches)	Trap Total hauls (#)	Trap hauls (0 catch)	Trap catch (#)	Total fish per species ($)	Median Value	Total CPUE g/trap haul (N)
0.5" x 0.5"	206	13	1,227	1.47	55	159.60
1.25" hex	138	7	912	2.19	60	249.80
1" x 2"	133	25	555	1.75	49	146.25
1.5" x 1.5"	144	14	1,018	2.39	52	219.34
2" x 2"	190	39	539	2.06	42	140.72
2" x 3" galv.	207	129	155	0.00	33	50.60
2" x 3" v	58	25	65	0.13	15	65.34
Totals	1,076		4,471		95	

CPUE = g/trap haul: a single trap haul consists of a soak period of five to eight days, inclusive.

Table 3. Value of catch (US $/lbs) by species and mesh size.

Species	Value ($) by mesh size	0.5" x 0.5"	1.25"	1.5"	1" x 2"	2" x 2"	2" x 3"	2" x 3"*	TOTAL $
1 *Epinephelus guttatus*	P	46.04	51.22	32.31	26.04	37.28	0.00	0.00	192.90
2 *Epinephelus striatus*	P	5.28	9.33	0.00	0.00	0.00	0.00	0.00	14.61
3 *Lutjanus analis*	P	38.05	62.51	18.43	13.11	24.54	22.36	0.00	179.00
4 *Lutjanus apodus*	P	0.00	2.02	0.00	0.00	0.00	0.00	0.00	2.02
5 *Lutjanus buccanella*	P	33.44	36.80	27.00	5.02	16.04	0.00	0.00	118.31
6 *Lutjanus mahogoni*	P	0.00	0.30	0.00	0.00	0.00	0.00	0.00	0.30
7 *Lutjanus synagris*	P	46.94	85.25	110.88	84.43	66.17	2.15	0.00	395.81
8 *Lutjanus vivanus*	P	53.13	40.82	132.18	6.69	25.87	0.00	0.00	258.70
9 *Ocyurus chrysurus*	P	38.36	0.75	1.44	15.82	1.04	0.00	0.00	57.41
10 *Rhomboplites aurorubens*	P	10.20	22.25	75.77	4.84	0.00	0.00	0.00	113.06
11 *Acanthostracion quadricornis*	P	11.40	5.69	8.51	18.87	34.79	13.17	10.54	102.97
12 *Acanthostracion polygonius*	P	0.45	7.09	8.50	9.27	27.73	22.88	7.56	83.49
13 *Lactophrys bicaudalis*	P	0.88	1.01	1.68	1.07	3.55	12.18	2.20	22.57
14 *Lactophrys trigonus*	P	1.93	22.22	1.71	3.89	1.49	1.90	0.00	33.15
15 *Lactophrys triqueter*	P	2.27	12.51	18.96	4.20	19.47	9.92	6.13	73.45
16 *Lachnolaimus maximus*	P	0.00	0.00	0.00	10.37	0.00	0.00	0.00	10.37
17 *Ginglymostoma cirratum*	P	2.36	0.00	0.00	0.00	0.00	0.00	0.00	2.36
18 *Panulirus argus*	P	53.60	15.86	38.52	4.92	12.50	35.58	31.72	192.69
19 *Octopus vulgaris*	P	5.15	0.00	0.00	0.00	0.00	0.00	0.00	5.15
20 *Epinephelus adscensionis*	S	0.00	0.00	0.00	0.20	0.00	0.00	0.00	0.20
21 *Alphestes afer*	S	0.19	0.00	0.00	0.00	0.00	0.00	0.00	0.19
22 *Epinephelus cruentatus*	S	0.53	0.00	0.00	0.00	0.00	0.00	0.00	0.53
23 *Epinephelus fulvus*	S	18.19	17.13	10.71	12.20	4.82	0.09	0.00	63.14
24 *Haemulon album*	S	3.99	4.98	9.19	5.70	5.64	5.89	4.23	39.63
25 *Haemulon flavolineatum*	S	0.00	0.00	6.57	0.00	0.00	0.00	0.00	6.57

Table 3. (continued).

Species	Value ($) by mesh size	0.5" x 0.5"	1.25"	1.5"	1" x 2"	2" x 2"	2" x 3"	2" x 3"*	TOTAL $
26 *Haemulon plumieri*	S	3.24	4.62	3.19	7.59	1.73	2.43	0.00	22.80
27 *Calamus pennatula*	S	7.36	13.00	6.35	1.51	16.54	3.30	3.79	51.86
28 *Pseudupeneus maculatus*	S	75.66	9.33	11.25	2.16	1.48	0.00	0.00	99.88
29 *Mulloidichthys martinicus*	S	1.68	1.00	0.07	0.29	0.00	0.00	0.00	3.04
30 *Balistes capriscus*	S	2.26	4.69	2.12	2.41	3.62	0.93	0.00	16.03
31 *Balistes vetula*	S	8.74	9.02	4.92	8.44	22.73	15.19	6.29	75.34
32 *Scyllarides nodifer*	S	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
33 *Carpilius corallinus*	S	9.66	11.78	9.15	3.37	10.06	10.73	0.00	54.75
34 *Mithrax spinossissimus*	S	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
35 *Arenaus cribarius*	S	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
36 *Sparisoma aurofrenatum*	T	3.45	1.38	2.44	7.72	2.91	0.00	0.00	17.91
37 *Sparisoma chrysopterum*	T	2.40	1.44	7.65	7.69	17.20	3.41	0.00	39.79
38 *Sparisoma viride*	T	1.67	1.62	2.86	1.98	8.59	13.09	1.02	30.83
39 *Haemulon aurolineatum*	T	4.61	4.13	0.77	1.99	0.00	0.00	0.00	11.50
40 *Anisostremus virginicus*	T	0.00	1.04	0.00	0.00	0.00	0.00	0.00	1.04
41 *Holocentrus ascensionis*	T	41.46	49.63	50.76	30.06	28.41	0.30	0.00	200.62
42 *Holocentrus rufus*	T	1.35	0.62	1.24	0.47	0.00	0.00	0.00	3.68
43 *Chaetidopterus faber*	T	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
44 *Pomacanthus arcuatus*	T	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
45 *Acanthurus bahianus*	T	0.00	0.76	1.11	1.27	1.39	1.08	0.11	5.72
46 *Acanthurus chirurgus*	T	0.00	0.00	0.00	0.00	1.01	0.00	0.00	1.01
47 *Acanthurus coeruleus*	T	0.21	2.86	0.73	1.52	2.94	1.66	0.56	10.47
48 *Caranx bartholomaei*	T	0.72	0.00	0.00	0.00	0.91	2.04	0.00	3.66
49 *Caranx crysos*	T	1.29	2.48	0.61	1.58	0.38	1.13	0.00	7.47
50 *Serranus tabacarius*	TR	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table 3. (continued).

Species	Value ($) by mesh size	0.5" x 0.5"	1.25"	1.5"	1" x 2"	2" x 2"	2" x 3"	2" x 3"*	TOTAL $
51 *Rypticus saponaceus*	TR	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
52 Priacanthidae	TR	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
53 *Priacanthus arenatus*	TR	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
54 *Priacanthus cruentatus*	TR	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
55 *Xanthichthys ringens*	TR	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
56 *Haemulon striatum*	TR	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
57 *Halichoeres bivittatus*	TR	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
58 *Xyrichthys martinencis*	TR	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
59 Monacanthidae	TR	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
60 *Cantherhines macrocerus*	TR	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
61 *Cantherhines pullus*	TR	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
62 *Alutera schoefii*	TR	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
63 *Alutera scripta*	TR	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
64 *Myripristis jacobus*	TR	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
65 *Chaetodon capistratus*	TR	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
66 *Chaetodon sedentarius*	TR	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
67 *Chaetodon striatus*	TR	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
68 *Chaetodon ocellatus*	TR	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
69 *Equetus lanceolatus*	TR	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
70 *Holacanthus ciliaris*	TR	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
71 *Holacanthus tricolor*	TR	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
72 *Caranx hippos*	TR	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
73 *Seriola dumerilii*	TR	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
74 *Scorpaena plumieri*	TR	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
75 *Scorpaenodes caribbaeus*	TR	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table 3. (continued).

Species	Value ($) by mesh size	0.5" x 0.5"	1.25"	1.5"	1" x 2"	2" x 2"	2" x 3"	2" x 3"*	TOTAL $
76 *Chylomycterus antennatum*	TR	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
77 *Chylomycterus antillarum*	TR	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
78 *Diodon holocanthus*	TR	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
79 *Diodon hystrix*	TR	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
80 *Canthigaster rostrata*	TR	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
81 *Gymnothorax funebris*	TR	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
82 *Gymnothorax moringa*	TR	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
83 *Gymnothorax vicinus*	TR	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
84 *Bothus lunatus*	TR	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
85 *Paralichthys tropicus*	TR	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
86 *Dactylopterus volitans*	TR	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
87 *Dasyatis americana*	TR	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
88 *Stenocionops furcata*	TR	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89 *Calappa flammea*	TR	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
90 *Fasciolaria tulipa*	TR	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TOTALS		$ 538.13	517.18	607.58	306.68	400.51	181.39	74.14	2,625.62
Number of Samples		206	138	144	133	190	207	58	1,076

* 2" x 3" VINYL COATED WIRE

Commercial classification:P = primary; S = secondary; T = third; TR = trash.

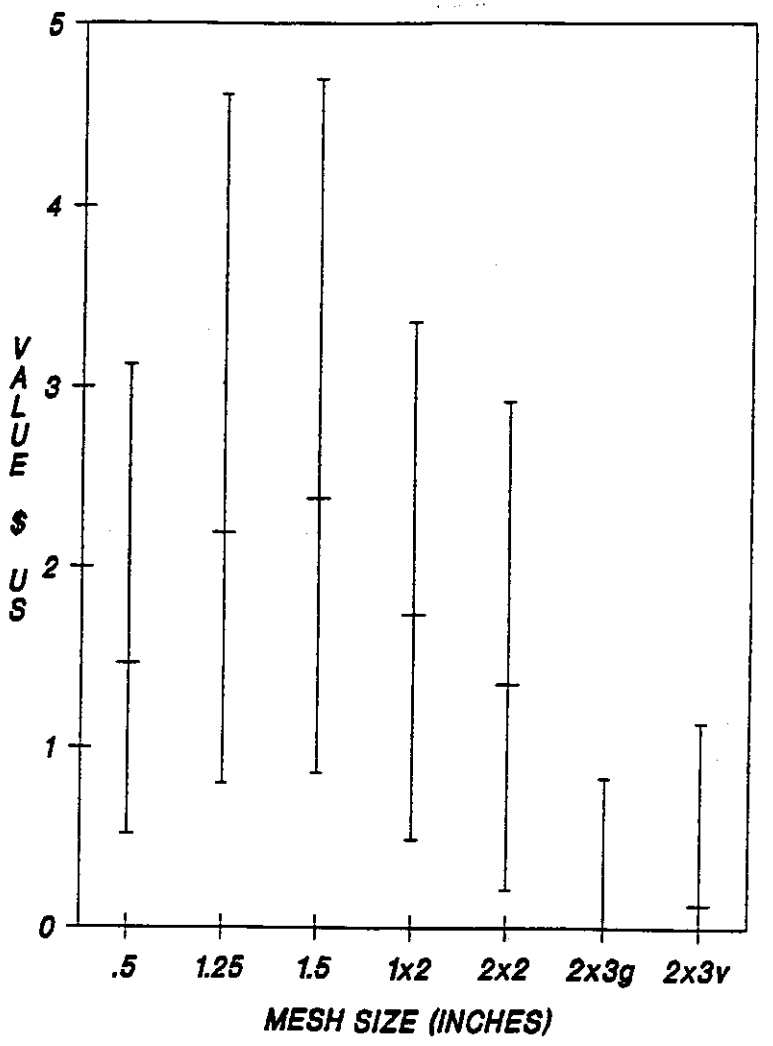

Figure 2. Impact of mesh sizes on median price per haul. Horizontal bars show medians and vertical bars show 25 and 75 percentiles. Sample size are shown in Table 2.

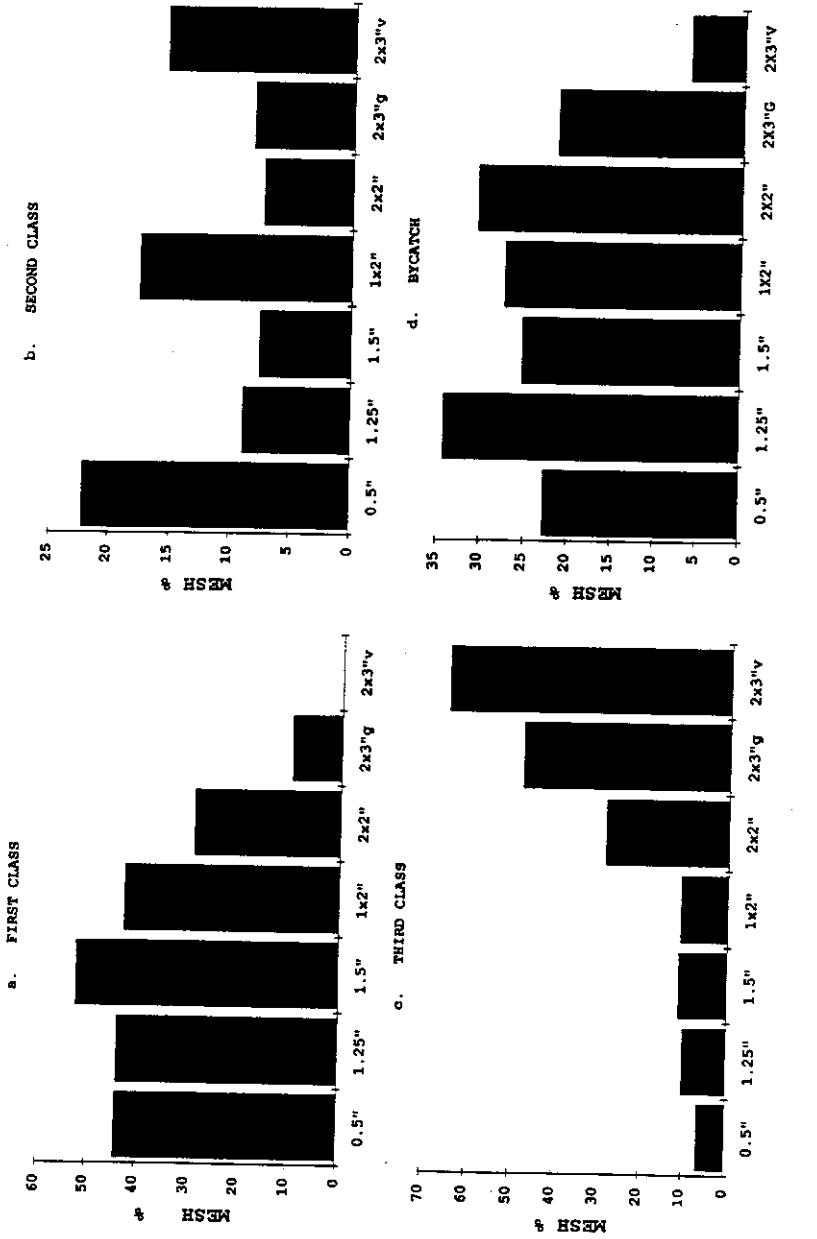

Figure 3. Comparison of percentage of total weight captured with different mesh sizes by market classification: First class (snappers and groupers); second; third; and shellfish (shell) and trash fish. For more details on market classification refer to Matos and Sadovy, 1989, and Table 3.

Table 4a. Kruskal-Wallis Test for differences in price per haul by mesh size.

Mesh Size (inches)							
Mesh Size (inches)	**0.5 x 0.5**	**1.25 x 1.25**	**1.5 x 1.5**	**1 x 2**	**2 x 2**	**2 x 3 g**	**2 x 3 v**
0.5 x 0.5							
1.25 x 1.25	n						
1.5 x 1.5	*	*					
1 x 2	n	n	*				
2 x 2	*	*	*	*			
2 x 3	g	*	*	*	*	*	
2 x 3	v	*	*	*	*	*	n

Table 4b. Kruskal-Wallis Test for differences in price per fish per haul as a function of mesh size.

Mesh Size (inches)							
Mesh Size (inches)	**0.5 x 0.5**	**1.25 x 1.25**	**1.5 x 1.5**	**1 x 2**	**2 x 2**	**2 x 3 g**	**2 x 3 v**
0.5 x 0.5							
1.25 x 1/25	n						
1.5 x 1.5	*	*					
1 x 2	n	n	*				
2 x 2	n	n	*	n			
2 x 3	g	*	*	*	*	*	
2 x 3	v	*	*	*	*	n	n

* = significant difference ($p < 0.05$ Prob > Chi Sq)

(Figure 3c). The 2 x 2" mesh (Figure 3e) yielded 30% of the total catch as snappers and groupers.

The two most abundant species of grouper reported in the catches were the coney (*Epinephelus fulvus*) and the red hind (*E. guttatus*). The percent contribution of each species to total catch by mesh size varied, however. For the 0.5" and 1 x 2" mesh coneys were more abundant in terms of number than red hinds; although in terms of weight red hinds (Table 5) accounted for a higher percentage. For the 1.25", 1.5", and 2 x 2" mesh sizes red hinds were more abundant by both weight and number. The relative percentage contribution to

the catch in terms of weight by mesh size of total sampled coneys decreased as mesh size increased. The red hinds presented a similar trend.

Of total sampled snappers the most abundant species was the lane snapper, (*Lutjanus synagris*), in terms of both number (15.2%) and weight (12.4%). The percent contribution of this species to the different mesh sizes was basically the same, being the second most abundant species retained by all mesh sizes, with the exception of 0.5" mesh. Snappers appeared to be more frequently taken by 1.5" mesh size (Figure 3) compared to other mesh sizes. Catch by weight with this mesh was comprised of over 42% of snappers, similar to the percentage taken with the 0.5", 1.25", and 1" x 2" meshes (44%) of snappers and groupers combined. Similarly, vermillion snapper and silk snapper recorded 68.0%, and 51.1% by weight, respectively. The trend for most mesh sizes was for a higher proportion of the catch by weight to consist of snappers rather than groupers.

Second class fish includes mainly grunts, porgies, triggerfishes and goatfishes. This class of fish varied markedly with the different mesh sizes. The highest recorded percentage was with the 0.5" mesh (Figure 3a) with 22%, followed by the 1" x 2" mesh (Figure 3d) with 18% and the 2" x 3" vinyl coated (Figure 3g) with 16%. The high percentage recorded for the 0.5" mesh was due to a single species, the spotted goatfish (*Pseudupeneus maculatus*). This species was almost exclusively caught with this mesh size, making up 76% of the total sample in terms of weight. The other mesh sizes took a fairly low percentage of second class fish (Figure 3b,c,e,f).

Of the total sampled triggerfishes the 2" x 2" mesh and the 2" x 3" galvanized wire mesh sizes reported a high percentage of capture in terms of weight, 28.8% and 23.4%, respectively. The lowest percentage was recorded with the 2" x 3" vinyl coated wire, with 6.9%.

Third class fish includes parrotfishes, trunkfishes, small grunts and porgies. The recorded percentage of this class of fish presents the reverse situation to that obtained for snappers and groupers. The larger mesh sizes tended to catch greater amounts of this class of fish than the smaller. The highest percentages were reported by both types of wire used of the 2" x 3" mesh (Figure 3f, g), with 65% and 48%, captured with the vinyl coated and galvanized wire, respectively. This was followed by the 2" x 2" mesh (Figure 3e) that recorded 28% of third class fish. The other four mesh sizes reported relatively low percentages of this class of fish. The lowest percentage was taken with the 0.5" mesh size (Figure 3a).

Trunkfishes of the genera *Acanthostracion* and *Lactophrys* constituted 8.0% by weight and 7.5% by number of the total catch of all meshes combined. Of the five species sampled the most abundant in terms of weight were the scrawled cowfish, (*A. quadricornis* , 2.8%), spotted trunkfish, (*L. triqueter*, 1.9%), and the honeycomb cowfish (*A. polygonius*, 1.8%). Three species of parrotfishes belonging to the genus *Sparisoma* constituted 4.3% by weight and 3.4% by

Table 5. List of sampled species with different mesh sizes off the west coast of Puerto Rico during sampling period of January to December 1990.

	Weight of sampled species(g) by mesh size (inches)							
Species	**0.5" x 0.5**	**1.25"**	**1.5"**	**1" x 2"**	**2" x 2"**	**2" x 3"**	**2" x 3"***	**Total Wt.**
1 *Epinephelus guttatus*	18,647	20,745	13,085	10,547	15,091			78,115
2 *Epinephelus striatus*	1,870	3,305						5,175
3 *Lutjanus analis*	10,855	17,833	5,258	3,740	7,000	6,379		51,065
4 *Lutjanus apodus*	865							865
5 *Lutjanus buccanella*	7,398	8,143	5,975	1,110	3,550			26,176
6 *Lutjanus mahogoni*	130							130
7 *Lutjanus synagris*	31,083	25,608	33,307	25,363	19,876	645		135,882
8 *Lutjanus vivanus*	11,756	9,033	29,248	1,480	5,725			57,242
9 *Ocyurus chrysurus*	815	230	440	4,850	320			6,655
10 *Rhomboplites aurorubens*	2,256	4,924	17,550	1,070				25,800
11 *Lactophrys bicaudalis*	255	292	485	310	1,025	3,520	635	6,522
12 *Acanthostracion quadricornis*	3,295	2,050	2,460	5,451	10,051	3,805	3,045	30,157
13 *Acanthostracion polygonius*	130	1,787	2,455	2,679	4,664	6,610	2,185	20,510
14 *Lactophrys trigonus*	558	6,420	495	1,110	430	550		9,563
15 *Lactophrys triqueter*	655	3,615	5,477	1,213	5,624	2,866	1,770	21,220
16 *Lachnolaimus maximus*				2,600				2,600
17 *Ginglymostoma cirratum*	1,205							1,205
18 *Epinephelus adsencionis*				150				150
19 *Alpheste afer*	145							145
20 *Epinephelus cruentatus*	40							40
21 *Epinephelus fulvus*	13,754	12,947	8,100	9,225	3,640	330		47,996
22 *Haemulon album*	1,810	2,260	4,170	2,585	2,560	2,670	1,920	17,975

Table 5. Continued.

Species	0.5" x 0.5	1.25"	1.5"	1" x 2"	2" x 2"	2" x 3"	2" x 3"*		Total Wt.
				Weight of sampled species(g) by mesh size (inches)					
23 *Haemulon flavolineatum*		84	270						354
24 *Haemulon plumieri*	1,794	2,555	1,765	4,196	955	1,345			12,610
25 *Calamus pennatula*	4,122	7,281	3,558	845	9,264	1,850	2,120		29,040
26 *Pseudupeneus maculatus*	37,302	4,599	5,546	1,065	730				49,242
27 *Mulloidichthys martinicus*	828	495	330	145					1,798
28 *Balistes capriscus*	1,190	2,475	1,120	1,270	1,910	490			8,455
29 *Balistes vetula*	4,610	4,760	2,595	4,450	11,990	8,010	3,320		39,735
30 *Sparisoma aurofrenatum*	1,760	705	1,449	3,933	1,485				9,332
31 *Sparisoma chrysopterum*	1,221	735	5,281	3,920	8,765	1,740			21,662
32 *Sparisoma viride*	850	825	1,460	1,008	4,380	6,670	520		15,713
33 *Haemulon aurolineatum*	3,485	3,124	583	1,502					8,694
34 *Anisostremus virginicus*		575							575
35 *Chaetodipterus faber*					535				535
36 *Pomacanthus arcuatus*			1,000						1,000
37 *Acanthurus bahianus*		1,079	1,577	1,804	1,967	1,525	150		8,102
38 *Acanthurus chirurgus*			38		1,425				1,463
39 *Acanthurus coeruleus*	295	4,050	1,029	2,160	4,165	2,350	790		14,839
40 *Caranx bartholomaei*	1,015			740	1,295	2,885		5,935	
41 *Caranx crysos*	1,830	3,520	860	2,235	535	1,605			10,585
42 *Holocentrus ascensionis*	33,585	40,196	41,112	24,351	23,014	240			162,498
43 *Holocentrus rufus*	1,917	882	1,751	671					5,221
44 *Serranus tabacarius*	274								274
45 *Rypticus saponaceus*		825							825

Table 5. Continued.

Species	Weight of sampled species(g) by mesh size (inches)							Total Wt.
	0.5" x 0.5	1.25"	1.5"	1" x 2"	2" x 2"	2" x 3"	2" x 3"*	
46 Priacanthidae						4		4
47 *Priacanthus arenatus*						1,085		1,085
48 *Priacanthus cruentatus*		1,440						1,440
49 *Xanthichthys ringens*		150						150
50 *Haemulon striatum*	76							76
51 *Halichoeres bivittatus*		225						225
52 *Xyrichthys martinensis*	74							74
53 Monachantidae		0						0
54 *Cantherhines macrocerus*	2,636	190	730	645	2,280		3,695	10,176
55 *Cantherhines pullus*	455		184					639
56 *Alutera schoepfii*							1,660	1,660
57 *Alutera scripta*						430		430
58 *Myripristis jacobus*	840	192		148				1,180
59 *Chaetodon capistratus*	136	784	188	38				1,146
60 *Chaetodon sedentarius*	196	374	32					602
61 *Chaetodon striatus*	146	380	366		320			1,212
62 *Chaetodon ocellatus*	60							60
63 *Equetus lanceolatus*	906	872	524	322	86			2,710
64 *Holacanthus ciliaris*		1,775	865	510	530	920		4,600
65 *Holacanthus tricolor*	877	286	118	483				1,764
66 *Caranx hippos*		975						975
67 *Seriola dumerilii*			500	200				700
68 *Scorpaena plumieri*	261	585	1,120		880		410	3,256

Table 5. Continued.

Species	Weight of sampled species(g) by mesh size (inches)							Total Wt.
	0.5" x 0.5	1.25"	1.5"	1" x 2"	2" x 2"	2" x 3"	2" x 3"*	
69 *Scorpaenodes caribbaeus*	530		430			290		1,250
70 *Chylomycterus antennatum*		590		370	314			1,274
71 *Chylomycterus antillarum*		925	170	195	645	940	270	3,145
72 *Diodon holocanthus*		5,335	1,270	850	3,450	485		11,390
73 *Diodon hystrix*	1,735	745			1,515	1,330		5,325
74 *Canthigaster rostrata*	62							62
75 *Gymnothorax funebris*		12,247			9,752			21,999
76 *Gymnothorax moringa*	1,050		910					1,960
77 *Gymnothorax vicinus*	660							660
78 *Bothus lunatus*				352		250		602
79 *Paralichthys tropicus*			82	48				130
80 *Dactylopterus volitans*		1,220	890	975	6,005	1,145		10,235
81 *Dasyatis americana*		1,170						1,170
82 *Panulirus argus*	5,830	1,725	4,190	535	1,360	3,870	3,450	20,960
83 *Scyllarides nodifer*			160					160
84 *Carpilius corallinus*	4,380	5,345	4,150	1,530	4,565	4,865		24,835
85 *Mithrax spinossissimus*					950	400		1,350
86 *Arenaus cribarius*	50			70				120
87 *Stenocionops furcata*		150						150
88 *Calappa flamea*		180						180
89 *Fasciolaria tulipa*				85				85
90 *Octopus vulgaris*	1,150							1,150

Table 5. Continued.

Species	0.5" x 0.5	1.25"	1.5"	1" x 2"	2" x 2"	2" x 3"	2" x 3"*	Total Wt.
	Weight of sampled species(g) by mesh size (inches)							
TOTALS	224,715	236,812	216,708	135,134	184,623	72,099	25,940	1,096,031
Number of Samples	206	138	144	133	190	207	58	1,076

* = 2" x 3" VINYL COATED WIRE

number of the total catch. The most abundant species of parrotfishes, both in terms of weight and number, was the redtail parrotfish, *S. chrysopterum*, 2.0% and 1.4%, respectively. The lowest percentage in terms of weight of sampled trunkfishes was recorded for the 0.5" mesh (5.56%), followed by the 2" x 3" vinyl coated wire (8.7%). The 1.25" mesh reported 16.1%, the 1.5" (12.9%), and the 1" x 2" mesh 12.2%. The highest percentages were recorded with the 2" x 2" mesh (24.8%) and the 2" x 3" galvanized wire mesh size (19.7%).

The percentage of bycatch or trash fish in terms of weight for the smaller mesh sizes fluctuated between 23 to 34% of the total sample (Figure 3). The bycatch consisted mainly of squirrelfishes, surgeonfishes, butterfly fishes, jacks, morays and scorpion fishes. The percentage of bycatch captured by the two types of 2" x 3" mesh differed markedly. The percentage captured by the 2" x 3" galvanized wire was similar to that caught by smaller mesh sizes. The vinyl coated wire, on the other hand, recorded the lowest percentage of bycatch of any mesh (Figure 3g).

The highest percentage of bycatch was taken by the 1.25" mesh. For the 0.5", 1.25", 1.5", 1" x 2", and 2" x 2" mesh sizes the bulk of the bycatch was composed of a single species, the longjaw squirrelfish, *Holocentrus ascensionis*. This was the most abundant species caught in terms of weight and number for all the above mesh sizes, with the exception of the 0.5" mesh.

Three species of the genus *Acanthurus* constituted 2.2% by weight and number of total catch for all meshes. The most abundant species was the blue tang, *Acanthurus coeruleus*, recording 1.4% and 1.1% by weight and number, respectively. The highest reported percent, in terms of weight, of total sampled surgeonfishes were for the 2" x 2" and the 2" x 3" galvanized wire, with 31.0% and 15.9%, respectively. Catches by both types of 2" x 3" wire mesh consisted mainly of trunkfishes, triggerfishes, filefishes, and surgeonfishes. Nevertheless, the groups varied with the different types of wire. For both types of wire the trunkfishes were the most abundant species, both in terms of weight and number taken, with 23.9% by weight for the galvanized wire and 27.1% for the vinyl coated. Triggerfishes made up 11.7% by weight for the galvanized wire, for the vinyl coated wire they constituted 12.8%. Filefishes constituted less than 1% of the galvanized 2" x 3" wire, while making up 20.6% for the vinyl coated wire. On the other hand, surgeonfishes constituted 5.3% of the galvanized wire catch but made up no more than 3.6% of the vinyl coated catch.

DISCUSSION

The efficiency of traps in catching fish depends on many variables, among which the most important are the availability of fish in a determined area. Other factors such as the design of the trap, and the width, length and form of the trap entrance or funnel have been identified as important factors affecting trap catches (Luckhurst and Ward, 1987). One factor which was not tested in this

survey, that has been identified by Luckhurst and Ward (1987) to bias the fish attraction to a trap, is its visual silhouette. This was standardized in the study by Bohnsack *et al*, (1989) by maintaining trap sides at 1.5" and only varying mesh size on trap top and bottom. In the present study, traps were fabricated with a single mesh size in their entirety following local tradition. Nonetheless, results from the two studies were similar.

Economics

The 1.25" mesh yielded significantly less per haul in value than 1.5" mesh, but was similar to the 1" x 2" mesh. Also, the 1.25" mesh yielded more per haul than all other meshes except the 1.5". The 1.5" yielded significantly more in value than all other meshes by haul. On the other hand, 2" x 2" yielded significantly more than 2" x 3" meshes and significantly less than all others.

Species Composition

Species composition is heavily influenced by mesh size. The results of this study are similar to those of Stevenson (1978), Stevenson and Stuart-Sharkey (1980), Hartsuijker and Nicholson (1981), Munro (1983), Ward (1986), and Luckhurst and Ward (1987). In general, larger mesh sizes took fewer species. More importantly many species captured with the largest mesh sizes (2" x 3") were of little or no commercial importance. The most important commercial species (snappers and groupers) are captured in fewer numbers by the largest mesh sizes. None of the mesh sizes tested, with the exception of 2" x 3" vinyl coated wire, is likely to achieve one of the main goals in increasing mesh size, to decrease the number of bycatch or "trash" fish taken. This remained high and fluctuated from 20% to 35% of total catch for all mesh sizes. This result would, however, vary depending on the classification of what constituted bycatch. This classification can vary depending on species availability and market forces.

CONCLUSIONS AND RECOMMENDATIONS

Economic analysis established that although the 1.5" x 1.5" mesh currently likely provides a marginally better economic return to fishermen on a short-term basis, management of the fishery for increased yield on a long-term basis would likely require an increase of the mesh size used on traps to 2" x 2" or more, or even the total elimination of trap fishing if wasteful bycatch is to be avoided. A full economic analysis of yield over a long-term basis is needed to establish the most appropriate management approach to enable the best use of Puerto Rico's fisheries resources.

ACKNOWLEDGMENTS

We wish to express our sincere gratitude to all those who, in one way or another, contributed to the completion of this report. Specials thanks are due to

all the members of the Exploratory Fishing Project for their dedication to their work, which in the most adverse conditions and, for a period, lacking one member of the crew, made this survey possible. Special thanks to Mr. Stephen Meyers, of the Caribbean Fisheries Management Council, who assisted in the statistical analysis of the data.

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