The Impact of Fishing on the Reef Fish of Pedro Bank and Port Royal, Jamaica: A Comparison of Trap Surveys, 1969 — 73 and 1986

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ABSTRACT

Utilizando nasas y SCUBA se realizaron estudios en la comunidades de peces arrecifales en las plataformas de Jamaica, Pedro Bank, Bahamas y Belize, en áreas que variaron desde fuertemente pescadas hasta áreas de poca actividad pesquera. Los datos sobre los peces en las nasas de Jamaica y Pedro Bank fueron comparados con estudios anteriores y datos históricos de 1971 al 1973 (Munro, 1983) para examinar cambios en las áreas moderadamente y fuertemente pescadas. Se notaron reducciones en las capturas por nasas y peso promedio de las capturas en las áreas donde se pescaba moderadamente y fuertemente. Esto se debe principalmente a las diferencias en la composicion de especies mas que a la estructura por edad de las capturas. Las especies mayores, particularmente de peces depredadores, son marcadamente menos abundante en áreas donde esta ocurriendo pesca desde moderada hasta aquellas con un nivel de explotación intensiva utilizando nasas. Se discuten los efectos secundarios en las comunidades de peces arrecifales debido a la reducción en abundancia de los depredadores.

INTRODUCTION

Reef fish in many parts of the Caribbean are exploited primarily with traps. Data on catch and effort in these fisheries are generally poor, so there are few reports of the effects of exploitation on reef fish communities. Munro (1983) compared trap catches along a gradient of fishing effort and showed that, in heavily exploited areas, catch rates were low and that certain preferred fish, such as groupers, were relatively rare. However, the effects of possible habitat differences could not be taken into account. We address here the question of the effects of exploitation on reef fish communities through comparison of trap fish catches between the periods 1969—73 and 1986 in three areas with varying histories of fishery exploitation: Port Royal lagoon, southeastern and southwestern Pedro Bank (Figure 1).

The reefs of Port Royal lagoon and Pedro Bank are physically quite different; there is little difference in reef habitat between southeast and

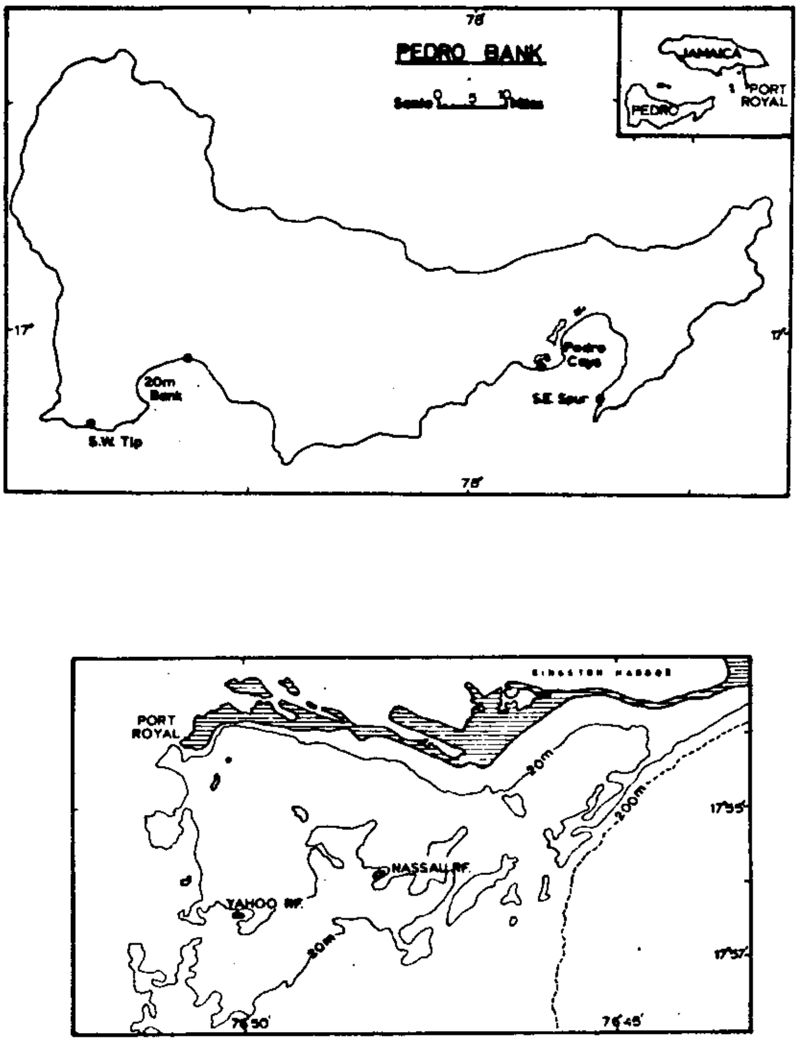


Figure 1. Port Royal lagoon and Pedro Bank showing trap survey sites. The depth contour shown for Pedro Bank is the 200 m isobath, which generally overlies the 50 m isobath.

southwest Pedro Bank. The Port Royal lagoon, which lies in the lee of an outer barrier reef, contains a complex of Cays and large patch reefs. The larger patch reefs, which may extend for several hundred meters, typically contain a shallow (2—5 m) sand and coral flat; a moderate slope extending from approximately 5—15 m, which is often covered by *Acropora cervicornis* at the crest and massive corals (*e.g.* Montastrea) at greater depth; and a sand-silt reef base at

15—20 m with sparser development of massive corals. The lagoon is exposed to outflow from Kingston Harbor, although a westerly alongshore current largely carries the discharge out of the area. This area was not significantly affected by hurricanes in recent decades, which devastated reefs on the north Jamaican coast.

Pedro Bark, on the other hand, is an exposed oceanic bank that, except for fishing, is remote from man's influence. The corals, and therefore the fishery, are only well-developed around the perimeter at depths between 15 and 35 m. The habitat there is generally composed of low coral heads and gorgonians set on relatively flat sand bottom. The edge of the bank drops sharply to depths of hundreds of meters.

Port Royal lagoon, which lies outside Kingston, the major population center in Jamaica, has been heavily exploited over an extended period, first with unmechanized canoes, and by the time of the 1969—73 survey, predominantly by canoes with outboard motors. An estimated 1,079 canoes operated along the entire south Jamaican shelf in 1968, 61 percent of which were motor-powered (the data are not broken down more finely by geographic region) (Munro, 1983, p. 13). On the other hand, significant exploitation of Pedro Bank only began in the 1960's. By 1974, there were approximately 72 canoes involved in the Pedro Bank fishery (Munro, 1983, p. 243), and it was conducted almost entirely in the vicinity of the Pedro Cays along the southeast edge of the bank, where the fishermen were able to set up living quarters.

The number of fishing canoes operating on the south coast of Jamaica only increased 30 percent from 1968 to 1981, but the number of of outboard-powered canoes increased 80 percent to 1,183 (Sahney, 1982, Appendix 4). But, despite the substantial increase in fishing effort, landings from the south Jamaican shelf remained at approximately 3,500 mt/yr (Sahney, 1982; Munro, 1983, p. 13). The number of canoes operating from the Pedro Cays has more than doubled to 150—200, and the area is now exploited also by fishermen making short fishing trips from Jamaica (M. Haughton, Fisheries Division, Kingston, Jamaica, pers. comm.). Catch from the area doubled during the intervening period from 756 to 1,600 mt/yr (Munro, 1983, p. 244; Sahney 1982).

Fishing continues to be concentrated in southeastern Pedro Bank in the vicinity of the Pedro Cays. On our cruise to Pedro Bank, very high densities of traps were found in parts of southeast Pedro Bank (25—40 traps/km^2). Trap densities were approximately 10 percent of this at our stations on southwestern Pedro Bank, where Munro (1983) reported seeing no evidence of trap fishing in the early 1970's. (Traps in the open waters of Pedro Bank must be buoyed to be located, so they can be readily enumerated, but traps in the Port Royal lagoon are never buoyed due to stealing and are located using landmarks.)

It thus appears that in the early 1970's, fishing pressure was high in the Port Royal lagoon, moderate on southeast Pedro Bank, and very low in southwest Pedro Bank; in 1986, fishing pressure was very high in the Port Royal lagoon and on much of southeast Pedro Bank, and fishing was low (but clearly greater than in 1970) on southwest Pedro Bank.

METHODS

Sampling

We chose to resurvey Nassau and Yahoo Reefs, the two primary sites surveyed by Munro (1983) in Port Royal lagoon (Figure 1), using unbaited

Antillean Z-traps with 3.2 cm (1.25 in) mesh, the gear primarily employed in the previous survey (see Munro, 1983 for a description of trap types). Our comparisons with 1969—73 survey data from Port Royal are limited to samples obtained with unbaited traps from these two stations. On Pedro Bank, we resurveyed two stations on the southeastern and two on the southwestern portions of the bank (Figure 1); limited data from 1969—73 for central and northern Pedro Bank were not considered. Munro (1983) relied primarily upon baited, stackable, metal traps with the same mesh aperture for this part of the survey, which we employed along with the unbaited Z traps for comparative purposes; samples from the 1969—73 Pedro Bank survey that were obtained with other types of unbaited traps were not considered.

The surveys of Port Royal and Pedro Bank carried out between 1969 and 1973 were conducted in all seasons in each area. Our survey of reefs in Port Royal lagoon were conducted from March-May and September 1986, and our survey of Pedro Bank was carried out in April, 1986.

During the 1986 survey, the traps set in Port Royal lagoon soaked for 1—5 days, while the traps set on the bank were retrieved after 1 day soak. In the 1969—73 surveys, the traps set in Port Royal lagoon were virtually all retrieved after 1—21 day soak; the traps set on Pedro Bank were retrieved after 1—3 day soak, with most retrieved after 1 day.

All fish were enumerated to species, measured, and the total weight of each species obtained from each trap recorded; however, only the data on species abundance are presented here. Ancillary data recorded at each station were similar to those recorded in the previous survey: date, gear type, depth of trap, and habitat type, as ascertained by SCUBA diving. For the most part, Pedro bank presented only a single habitat type (*i.e.* the sand and coral terrace), but in the lagoon, we recorded whether the traps were set on the shallow reef crest, on the slope, or at the base of the reefs. Depths were subsequently grouped in three depth zones: ≤ 10 m, 11—20 m, and > 20 m.

Data Analysis

The data per trap were first normalized for days of soak. A least squares regression was fit to 1969—73 data from Port Royal lagoon, the largest reasonably homogeneous portion of the data set, for the mean total number of fish caught per day of soak:

$$Y = 0.88(\text{Log}_{10}D) + 0.53 \qquad (1)$$

where Y is the proportion of the overall mean and D is the number of days soak. Thus the number of fish obtained after 1 day's soak is approximately half the overall mean. Inspection of the data indicated that an asymptote was reached after 5 days, so for $D \geq 5$, $Y = 1.15$. The relationship was examined in relation to data from the most numerous species and to 1969—73 data from Pedro Bank and generally fit well. All data were therefore normalized for days of soak by multiplying numbers caught by $1/Y$.

Data for the individual fish species were aggregated by family and, in some cases, by size as well, because of the extreme variability of the trap catches and the relatively infrequent occurrence of most species. The species comprising these fish groups are listed in Table 1. Even after aggregating the data, it is questionable whether there were sufficient data for adequate statistical analysis of several groups of the larger and rarer fishes (*i.e.*, lutjanids, scianids, large serranids, and large scarids), despite their commercial and ecological

Table 1. The aggregated fish groups discussed in the paper and the species whose summed densities (numbers per trap) comprise them. See text for selection criteria for these species. The abbreviations used in Figures 2-4 are shown in parentheses.

Aggregate Group		Species	Species
Holocentridae (Squirrelfish)	(HL)	*Holocentris rufus*	*H. ascensionis*
		Myripristis jacobus	
Large Serranidae (Groupers)	(LSR)	*Epinephelus striatus*	*Mytoperca venenosa*
		M. tigris	*E. mystacinus*
		E. itajara	*M. bonaci*
		M. cidi	
Small Serranidae (Hinds)	(SSR)	*Epinephelus guttatus*	*E. adscensionis*
		E. *cruentatus*	*E. fulvus*
Carangidae (Jacks)	(CR)	*Caranx ruber*	*C. latus*
		C. hippos	*C. bartholomaei*
		Seriola dumerili	
Lutjanidae (Snappers)	(LT)	*Lutjanus apodus*	*L. mahogoni*
		L. griseus	*L. analis*
		L. jocu	*L. buccanella*
		L. synagris	*L. vivanus*
		Ocyurus chrysurus	
Haemulidae (Grunts)	(HM)	*Haemulon album*	*H. carbonarium*
		H. flavolineatum	*H. plumieri*
		H. sciurus	*H. melanurum*
		H. macrostomum	*Anisotremus virginicus*
		H. aurolineatum	*A. surinamensis*
		H. bonariense	
Mullidae (Goatfish)	(ML)	*Pseudopeneus maculatus*	*Mulloidichthys martinicus*
Scianidae (Drums, croakers)	(SN)	*Equetus punctatus*	*Odontoscion dentex*
Pomacanthidae (Angelfish)	(PM)	*Holacanthus tricolor*	*H. ciliaris*
		Pomacanthus paru	*P. arcuatus*
Chaetodontidae (Butterflyfish)	(CH)	*Chaetodon ocellatus*	*C. striatus*
		C. sedentarius	*C. capistratus*
Scaridae (Small) (Parrotfish)	(SSR)	*Scarus croicensis*	*S. taeniopterus*
		Sparisoma chrysopterum	*S. aurofrenatum*
Scaridae (Large)	(LSR)	*Sparisoma viride*	*Scarus coeruleus*
		Scarus coelestinus	*S. guacamaia*
Acanthuridae (Surgeonfish)	(AC)	*Acanthurus coeruleus*	*A. bahianus*
		A. chirurgus	

Table 1 (continued).

Aggregate Group		Species	Species
Balistidae (Triggerfish)	(BL)	*Balistes vetula*	*Xanthichthys ringens*
Tetraodontiformes (Filefish, cowfish, trunkfish, porcupinefish)	(MOT)	*Aluterus schoepfi*	*Cantherhinus pullus*
		A. scriptus	*Lactophrys quadricornis*
		L. polygonia	*Diodon holocanthus*
		D. hystrix	*L. bicaudalis*
		L. triqueter	
Total	(TOT)	All the above plus the following:	
		Ginglymostoma cirratum	*Urolophus jamaicensis*
		Gymnothorax moringa	*G. funebris*
		Sphyraena barracuda	*Gerres cinereus*
		Chaetodipterus faber	*Calamus spp.*
		Abudefduf saxatilis	*Lachnolaimus maximus*

importance. All species were eliminated that did not comprise more than 0.1 percent of the weight or numbers of the total catch in either Munro's Port Royal or Pedro Bank data sets. Aggregate fish groups comprising less than 1 percent of the total catch in either data set were also eliminated.

The trap catch data were highly non-normal even after logarithmic or square-root transformation, so non-parametric statistics were used to test for the significance of differences in mean catches: the Kruskal-Wallis test for differences between several means and the Mann Whitney U test for differences between two means (Sokal and Rohlf, 1969).

We attempted, in our analyses, to take into account factors other than fishing that might significantly affect catch: season, station, trap-type, depth, and in Port Royal, habitat. However, higher-level analysis of variance, which takes account statistically of several factors simultaneously, cannot be performed with non-parametric statistics. We therefore first analyzed the larger 1969—73 data sets for Port Royal and Pedro Bank separately for each species group to determine which factors significantly affected its catch.

In subsequently examining differences between the 1969—73 and 1986 surveys, the data for each fish group from each area were analyzed both in toto and subdivided by those factors for which catch differed significantly during the 1969—73 survey. All fish groups were analyzed separately for southeast and southwest Pedro Bank sites due to generally different trends in catch rate between surveys for the two sides of the bank. Depth was eliminated as a factor because in the Port Royal data, differences by depth zone appeared largely to duplicate habitat differences but were less sensitive; and on Pedro Bank, depth differences were almost entirely related to differences between stations due to an east-west depth gradient. There generally were not sufficient data to further subdivide the data to examine for differences by several subcategories simultaneously (*i.e.*, the equivalent of higher-level analysis of variance).

Table 2. Mean numbers of fish per trap based upon a standardized soak for major fish groups from 1969 -73 and 1986 surveys of Port Royal lagoon and Pedro Bank. The numbers of cases (n) and the significance of the difference based upon the Mann Whitney U test are shown: ns: $p > 0.10$; ? $p \leq 0.10$; * $p \leq 0.05$; ** $p \leq 0.01$; *** $p \leq 0.001$. If preliminary analysis of 1969 -73 data indicated catch varied significantly by sub-categories of season, gear, station, or habitat, results are presented separately for each such sub-category. Sub-categories of season are not shown if sampling in 1986 was not conducted then. The species comprising each fish group are shown in Table 1. Seasons: 1: Months 12, 1, 2; 2: 3-5; 3: 6-8; 4: 9-11; Traps: 1: Unbaited Z; 2: Baited stackable; Station: N: Nassau Reef; Y: Yahoo Reef; E: Pedro - SE Spur & Pedro Cays; W: W Pedro - 20 m Bank & SW Tip; Habitat: 1: Reef crest; 2: Reef slope; 3: Reef base.

	Mean Number of Fish per Trap				
Fish Group	All Cases (69-73, 86)	Season (69-73, 86)	Station (69-73, 86)	Habitat (69-73, 86)	Trap Type (69-73, 88)
PORT ROYAL					
Holocentridae	0.29 0.44 ns	2-4: 0.29 0.44 ns	N: 0.41 0.39 ns		
(n)	(663) (73)	(571) (73)	(333) (37)		
			Y: 0.16 0.50 ns		
			(330) (36)		
Serranidae	0.03 0.00 ns	2: 0.05 0.00 ns			
(Large) (n)	(663) (73)	(159) (25)			
		1,3,4: 0.02 0.00 ns			
		(504) (48)			
Serranidae	0.28 0.17 ?	1,4: 0.17 0.08 *	N: 0.22 0.26 ns	1,2: 0.29 0.23 ns	
(Small) (n)	(663) (73)	(338) (48)	(333) (37)	(636) (48)	
		2,3: 0.40 0.34 ns	Y: 0.35 0.08 *	3: 0.10 0.08 ns	
		(325) (25)	(330) (36)	(27) (25	
Carangidae	0.24 0.28 ns	1,2,4: 0.28 0.28 ns		1: 0.16 0.06 ns	
(n)	(663) (73)	(497) (73)		(266) (17)	
				2,3: 0.29 0.34 ns	
				(397) (56)	
Lutjanidae	0.29 0.07 **				1: 0.32 0.07 **
(n)	(663) (73)				(361) (73)

Table 2 (continued).

Fish Group	All Cases (69-73, 86)	Season (69-73, 86)	Station (69-73, 86)	Habitat (69-73, 86)	Trap Type (69-73, 88)
	Mean Number of Fish per Trap				
Haemulidae	2.38 0.36 ***	1,2,4: 2.06 0.36 ***	N: 2.50 0.32 ***		
(n)	(663) (73)	(497) (73)	(333 (37)		
			Y: 2.26 0.41 ***		
			(330) (36)		
Mullidae	0.26 0.23 ns	1,2,4:0.32 0.23 ns	N: 0.41 0.39 ns	1: 0.09 0.00 ns	1: 0.16 0.23 ns
(n)	(663) (73)	(497) (73)	(333) (37)	(266) (17)	(361) (73)
			Y: 0.11 0.06 ns	2,3: 0.38 0.30 ns	
			(330) (36)	(397) (56)	
Scianidae	0.08 0.06 ns			1,2: 0.08 0.05 ns	
(n)	(663) (73)			(636) (48)	
				3: 0.06 0.08 ns	
				(27) (25)	
Pomacanthidae	0.30 0.44 ns		N: 0.14 0.24 ns		
(n)	(663) (73)		(333) (37)		
			Y: 0.46 0.66 ns		
			(330) (36)		
Chaetodontidae	0.58 1.55 ns			1: 0.76 6.04 ?	
(n)	(663) (73)			(266) (17)	
				2,3: 0.46 0.17 ns	
				(397) (56)	
Scaridae	1.33 1.14 ns	2:1.92 1.40 ns	N: 1.29 1.24 ns	1,2: 1.37 1.31 ns	
(Small) (n)	(663) (73)	(159) (25)	(333) (37)	(636) (48)	
		1,3,4:1.14 1.00 ?	Y: 1.37 1.03 ns	3: 0.32 0.80 ?	
		(504) (48)	(330 (36)	(27) (25)	

Table 2 (continued).

Fish Group	All Cases (69-73, 86)	Mean Number of Fish per Trap Season (69-73, 86)	Station (69-73, 86)	Habitat (69-73, 86)	Trap Type (69-73, 88)
Scaridae	1.23 0.03 ***		N: 1.89 0.00 ***	1: 1.42 0.00 **	
(Large) (n)	(663) (73)		(333) (37)	(266) (17)	
			Y: 0.56 0.05 **	2: 1.18 0.06 ***	
			(330) (36)	(370) (31)	
				3: 0.03 0.00 ns	
				(27) (25)	
Acanthuridae	2.31 0.60 ***		N: 1.68 0.42 ***	1: 3.21 0.68 ***	
(n)	(663) (73)		(333) (37)	(266) (17)	
			Y: 2.93 0.79 ***	2: 1.80 0.56 **	
			(330) (36)	(370) (31)	
				3: 0.29 0.61 ns	
				(27) (25)	
Balistidae	0.04 0.00 ?	2-4:0.03 0.00 ?	N: 0.05 0.00 ns		
(n)	(663) (73)	(571) (73)	(333) (37)		
			Y: 0.03 0.00 ns		
			(330) (36)		
Tetraodonti-	0.71 0.82 ns	1,2,4:0.66 0.82 ns	N: 0.42 0.80 ns	1: 0.85 1.23 ns	
formes (n)	(663) (73)	(497) (73)	(333) (37)	(266 (17)	
			Y: 1.00 0.84 ?	2,3: 0.62 0.69 ns	
			(330) (36)	(397) (56)	
Total	11.40 7.09 ***		N: 10.59 7.45 **	1,2: 11.66 7.52 ***	
(n)	(663) (73)		(333) (37)	(636) (48)	
			Y: 12.22 6.73 ***	3: 5.22 6.26 ns	
			(330) (36)	(27) (25)	

Table 2 (continued).

Fish Group	All Cases (69-73, 86)	Season (69-73, 86)	Station (69-73, 86)	Habitat (69-73, 86)	Trap Type (69-73, 88)
	Mean Number of Fish per Trap				
PEDRO BANK					
Holocentridae	4.05 5.25 ns	1-3:4.41 5.28 ns	E: 3.96 2.94 ***	1,2: 3.00 5.28 ns	
(n)	(195) (70)	(165) (70)	(55) (36)	(59) (70)	
			W: 5.49 7.77 ns		
			(36) (34)		
Serranidae	0.06 0.00 ns		E: 0.03 0.00 ns		
(Large) (n)	(195) (70)		(55) (36)		
			W: 0.08 0.00 ns		
			(36) (34)		
Serranidae	1.84 1.75 ns		E: 0.99 0.26 **		
(Small) (n)	(195) (70)		(55) (36)		
			W: 4.88 3.33 ?		
			(36) (34)		
Carangidae	0.41 0.13 ns		E: 0.41 0.05 ?		
(n)	(195) (70)		(55) (36)		
			W: 0.28 0.22 ns		
			(36) (34)		
Lutjanidae	0.07 0.00 ns		E: 0.05 0.00 ns	1,2: 0.08 0.00 ns	
(n)	(195) (70)		(55)	(59) (70)	
			W: 0.10 (36)		
			(36) 0.00 ns		
Haemulidae	1.98 0.94 **		E: 4.14 (34)		
(n)	(195) (70)		(55) 1.10 ***	1,2: 2.61 0.94 **	
			W: 2.03 (36)	(59) (70)	
			(36) 0.78 **		

Table 2 (continued).

Fish Group	All Cases (69-73, 86)	Season (69-73, 86)	Station (69-73, 86)	Habitat (69-73, 86)	Trap Type (69-73, 88)
	Mean Number of Fish per Trap				
Mullidae	0.64 0.51 ns		E: 1.24 (34)		
(n)	(195) (70)		(55) 0.05 ***		
			W: 0.53 (36)		
			(36) 1.00 ns		
Scianidae	0.04 0.03 ns	2-4:0.06 0.03 ns	E: 0.01 (34)		
(n)	(195) (70)	(87) (70)	(55) 0.00 ns		1,2: 0.10 0.03 ***
			W: 0.14 (36)		(59) (70)
			(36) 0.06 ns		
Pomacan-	0.77 1.00 ns	2-4:1.01 1.00 ns	E: 0.87 (34)		
thidae (n)	(195) (70)	(57) (70)	(55) 0.05 ***		
			W: 1.14 (36)		
			(36) 2.00 ns		
Chaetodon-	1.51 2.40 ns	2-4:1.82 2.40 ns	E: 1.94 (34)		
tidae	(195) (70)	(87) (70	(55) 0.16 ***		1,2: 1.80 1.65 ns
			W: 1.98 (36)		(59) (70)
			(36) 4.77 ns		
Scaridae	0.69 1.73 ns		E: 0.77 (34)		
(Small) (n)	(195) (70)		(55) 0.21 ns		
			W: 1.70 (36)		
			(36) 3.33 ns		
Scaridae	0.03 0.00 ns		E: 0.02 (34)		
(Large) (n)	(195) (70)		(55) 0.00 ns		1,2: 0.06 0.00 ns
			W: 0.01 (36)		(59) (70)
			(36) 0.00 ns		

Table 2 (continued).

Fish Group	All Cases (69-73, 86)	Mean Number of Fish per Trap Season (69-73, 86)	Station (69-73, 86)	Habitat (69-73, 86)	Trap Type (69-73, 88)
Acanthuridae (n)	2.52 1.99 ns (195) (70)	2,3:4.14 1.99 *** (57) (70)	E: 3.34 (34) (55) 0.79 ** W: 4.53 (36) (36) 3.27 *		
Balistidae (n)	11.38 9.57 ** (195) (70)	1,2:14.38 9.57 *** (137) (70)	E: 17.91 (34) (55) 1.10 *** W: 20.17 (36) (36) 18.54 ns		
Tetraodonti- formes (n)	0.43 2.32 *** (195) (70)	2,3:0.58 2.32 *** (57) (70)	E: 0.46 (34) (55) 1.78 *** W: 0.82 (36) (36) 2.89 ***		
Total (n)	26.60 27.78 ns (195) (70)	1-3:28.82 27.72 ns (165) (70)	E: 36.30 (34) (55) 8.75 *** W: 44.38 (36) (36) 47.95 ns (34)		

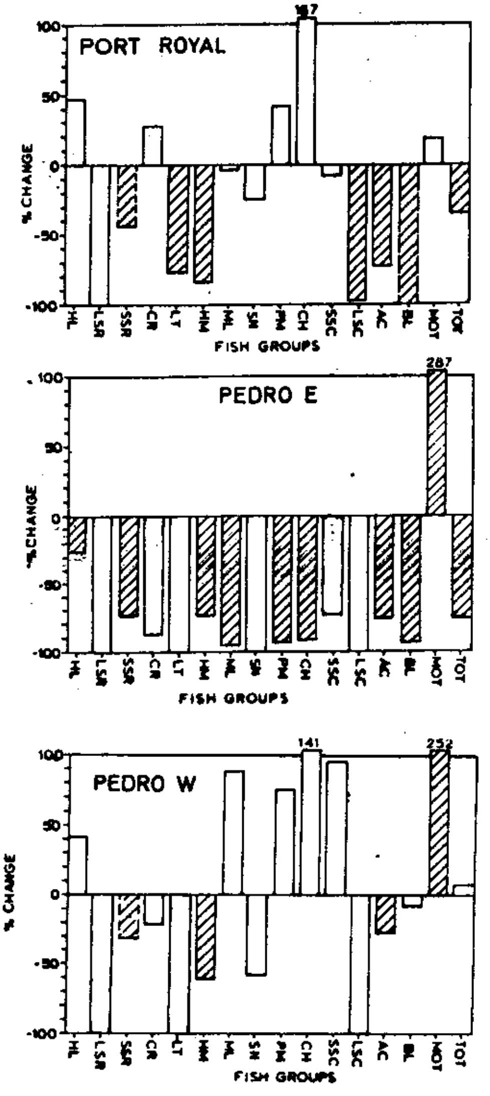


Figure 2. Percent changes in the abundance of major fish groups between 1969-73 and 1986 surveys of Port Royal lagoon and southeast and southwest Pedro Bank. Hatching indicates the changes are significant at $p \leq 0.05$; a broken outline around the hatched bar indicates the difference is significant at $p \leq 0.10$. HL: Holocentridae; LSR: large Serranidae; SSR: small Serranidae; CR: Carangidae; LT: Lutjanidae; HM: Haemulidae; ML: Mullidae; SN: Scianidae; PM: Pomacanthidae; CH: Chaetodontidae; SSC: small Scaridae; LSC: large Scaridae; AC: Acanthuridae; BL: Balistidae; MOT: other Tetraodontiformes; TOT: Total. See Table 1 for species comprising these groups.

RESULTS

Fishing appears to have significantly affected overall catch rates in the survey areas (Table 2, Figures 2 and 3). Overall mean catches per trap declined most severely over southeastern Pedro Bank (76%) which experienced the greatest increase in fishing pressure over the past 15 years. Catch rates also declined significantly (38%) in the Port Royal lagoon. Total catch rates over lightly-fished southwestern Pedro Bank did not change significantly between the two surveys and are now 5.5—6.8 times greater than in the other survey areas. Overall catch rates in heavily fished areas (southeast Pedro Bank and Port Royal lagoon) are now roughly comparable despite the 3.2-fold greater catches over Pedro Bank in 1969—73 when the area was only moderately fished.

Examining changes between 1969—73 and 1986 in individual fish groups in these areas, the largest fish in the community caught in the traps (*i.e.*, large serranids, lutjanids, and large scarids) consistently virtually disappeared from the trap catches, although these declines were often not significant due to low numbers caught even in the initial surveys (Figures 2 and 3). Other commercially preferred groups, such as the grunts and small serranids, declined significantly in all survey areas as well. The surgeon and trigger fishes, which seem particularly vulnerable to capture in the traps, also generally declined significantly. Other than the general decline of almost all groups in southeast Pedro Bank, where fishing increased most markedly, there were few other consistent, statistically significant trends. Although no group, with the possible exception of the non-Balistid Tetraodontiformes, would appear to be increasing to replace the heavily exploited groups, we are only considering here those groups retained by the trap gear.

When the 1969—73 data were analyzed to test for the effect on catch rates of season, habitat, station, and trap type, these factors proved significant in a high proportion of cases. Analysis of these effects per se is beyond the scope of this paper. However, it can be seen from Table 2 that the changes, if any, that are found for particular fish groups between the 1969—73 and 1986 surveys are generally unaffected by these factors. The one exception is, of course, the difference between southeast and southwest Pedro Bank: most fish groups declined significantly only at the heavily-fished southeastern sites. Otherwise, the differences (or lack thereof) in trap catch between the two surveys were generally found consistently over season, habitat, trap-type, and sampling site. Thus, for example, although the abundance of most fish groups was significantly different at Nassau and Yahoo Reefs in 1969—73, changes in abundance between 1969—73 and 1986 generally occurred consistently at the two stations. Our results thus appear to be robust and unbiased by differences that may exist in the frequency of sampling by season, trap type, habitat, or station during the 1969—73 and 1986 surveys. (Minor inconsistencies must be viewed with caution due to the extreme variability of the catch data and relatively few numbers of samples for some subsets of data.)

The changes noted in individual fish groups may lead to an overall change in reef fish community structure. Composition of the fish community (*i.e.*, the contribution of the mean abundance of each fish group to the overall distribution of species groups in the community) changed significantly between 1969—73 and 1986 over southeast Pedro Bank (Kolmogorov-Smirnov (K-S) test, $p < 0.01$), but not in southwest Pedro Bank or Port Royal lagoon (K-S test, ns). As seen from Figures 3 and 4 (and as confirmed by the K-S test), the composition of

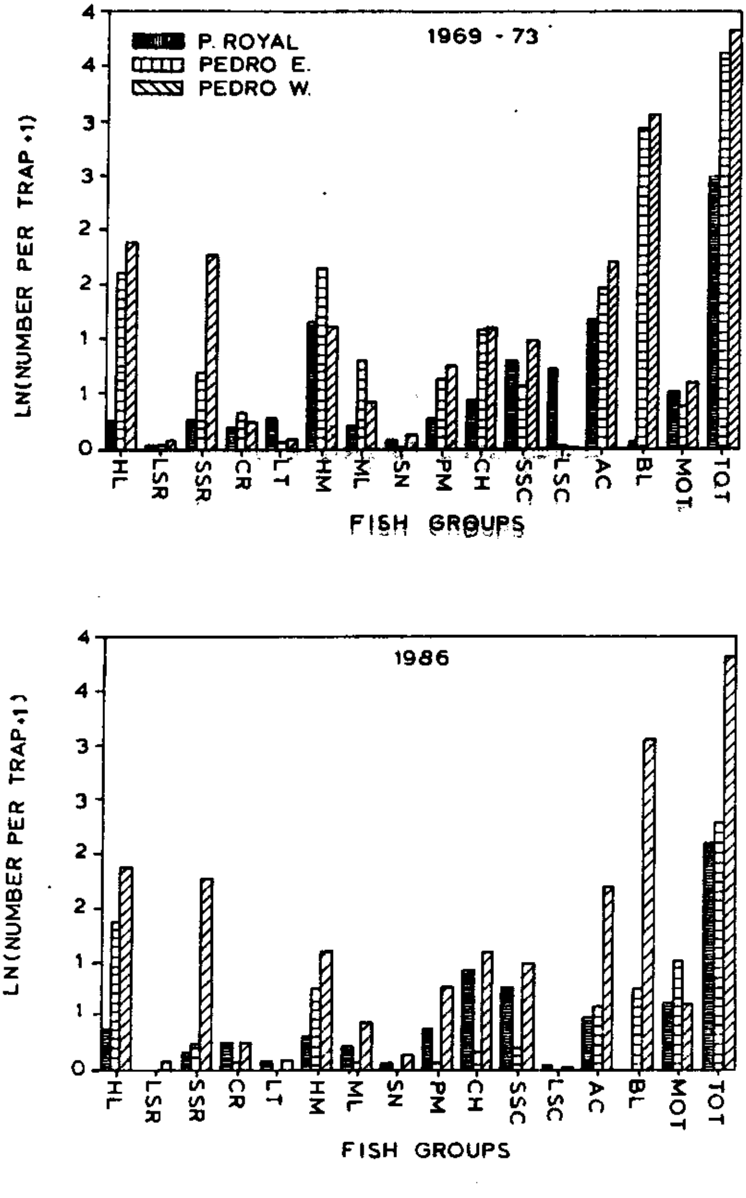


Figure 3. Log$_e$-transformed mean trap catch rates standardized for days of soak for major fish groups in 1969-73 (upper) and 1986 (lower) in Port Royal lagoon, eastern and western Pedro Bank. Abbreviations for fish groups as in Figure 2.

the reef fish communities over southeastern and southwestern Pedro Bank did not differ significantly during the initial survey period, and the overall composition of only the heavily stressed community changed significantly between the two surveys.

DISCUSSION

The changes that we observed in overall catch rate, in catch of individual fish groups, and in overall community structure are consistent with the hypothesis that most changes in the Port Royal and Pedro Bank fish communities between 1969—73 and 1986 were caused by fishing. The area that experienced the greatest increase in fishing, eastern Pedro Bank, exhibited the greatest declines both in overall catch rate (76%) and in number of fish groups that significantly declined (Figure 2). There were few significant changes in individual fish groups over the approximately 15-year period in lightly-fished southwest Pedro Bank, and no significant change in overall catch rate. This interpretation is bolstered by the overall similarity in the composition of the fish communities at the two ends of the bank in 1969—73, during an early phase of the fishery, and the significant change in community composition that had occurred by 1986 only in the heavily-fished area. It is unlikely that the two sides of the bank have experienced significantly different environmental influences, and neither was subject to other forms of human stress. The reefs in Port Royal lagoon, where fishing pressure also increased substantially between surveys, although apparently not as greatly as on southeast Pedro Bank, exhibited changes in overall trap catch rate and catches of individual groups that were intermediate in magnitude. There are no precise measures of fishing effort, but exploitation rates in Port Royal lagoon and southeast Pedro Bank are probably roughly comparable in 1986. The fish community in Port Royal lagoon probably did not change as greatly between surveys only because the fishery there was already well-developed by the time of the 1969—73 survey.

Our resurvey of the Port Royal lagoon and Pedro Bank strongly suggests that intense exploitation of reef fish communities can lead to the decline of a wide spectrum of reef fishes (haemulids, small serranids, acanthurids, and balistids) as well as the virtual elimination of the largest species (*e.g.*, large scarids, lutjanids, and large serranids), which are often the most valuable commercially. Larger species may be more susceptible to the effects of overexploitation due to the greater length of time that they require to attain sexual maturity and, hence, their lower replacement rate. Although trap fishing is not highly selective, these groups are highly prized and may be sought after through selective trap placement. In Port Royal lagoon, these groups are also subject to spear fishing. Holocentrids, chaetodontids, and non-Balistid Tetraodontiformes increasingly predominated in the catches in all areas. In heavily exploited areas, this may lead to significant change in the overall composition of the reef fish community. We were only able to consider here those fish groups that are vulnerable to standard trap fishing gear. Unexploited groups, such as the wrasses or damselfishes that may increase in heavily fished areas due to reduced competition and/or predation, were not sampled by the present survey. It will be important to investigate the changes that occur in the untrapped components of the reef community. We hope to address this question subsequently through a comparison of visual survey data from a range of reef fish communities under varying degrees of exploitation.

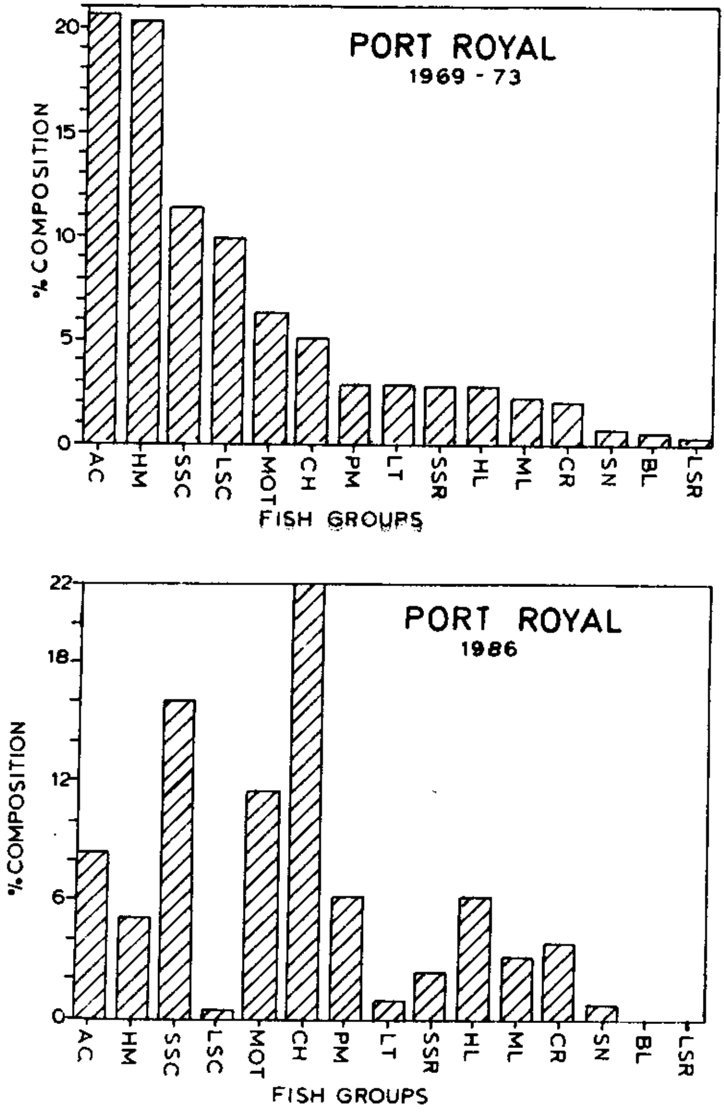


Figure 4. The percent composition of the reef fish communities at Port Royal lagoon and southeast and southwest Pedro Bank based upon 1969-73 and 1986 trap surveys. The composition of the fish community on southeast Pedro Bank is significantly different between the two surveys (Kolmogorov-Smirnov test, $p < 0.05$). Abbreviations for fish groups as in Figure 2.

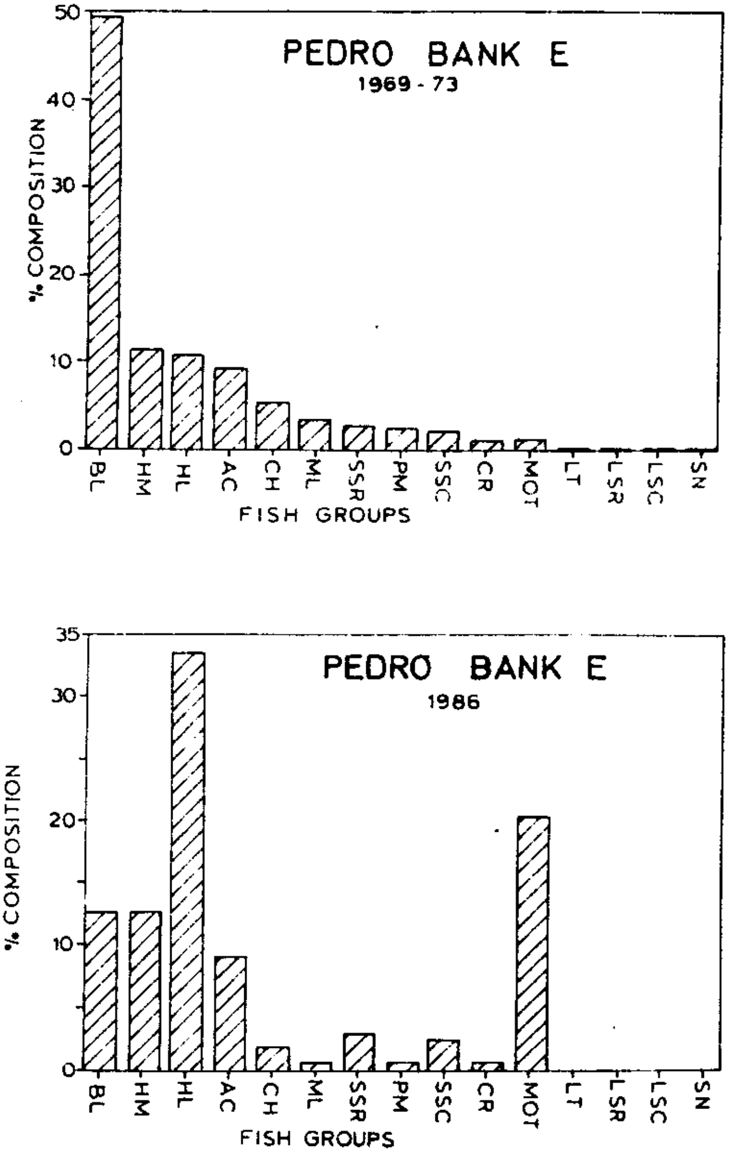
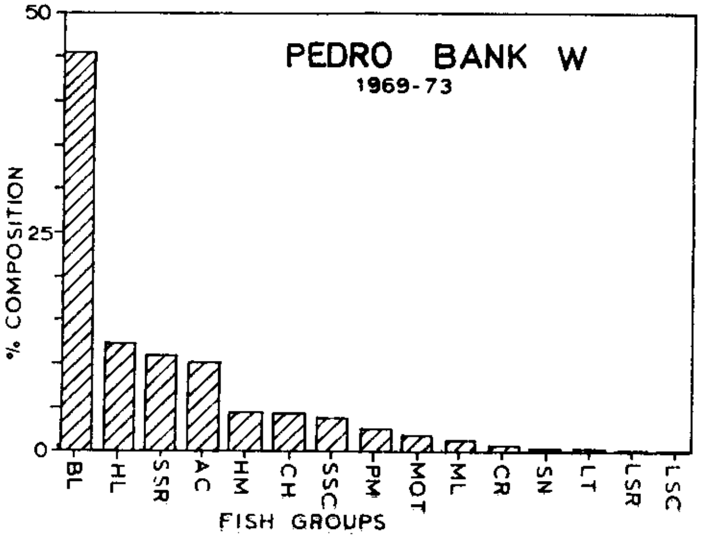


Figure 4. (continued)



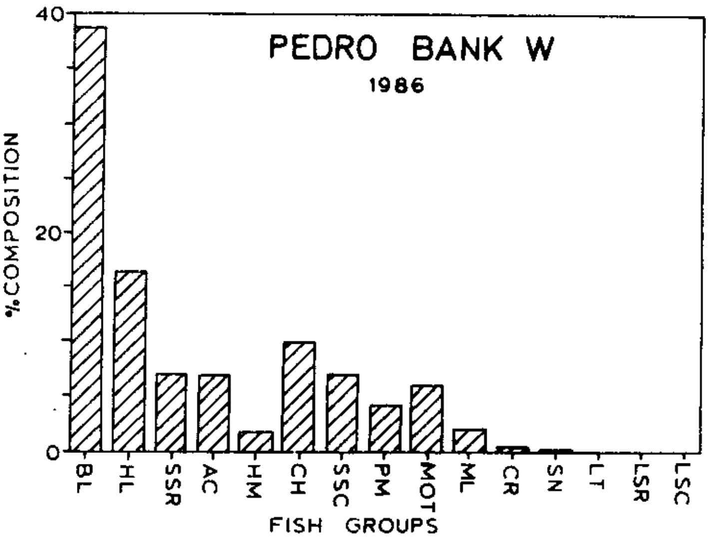


Figure 4. (continued)

These changes in heavily-exploited reef fish communities are a matter of commercial, as well as ecological, concern. Increased fishing effort in the Port Royal lagoon has apparently led to no increase in landings, and the increased landings from southeastern Pedro Bank have come at the cost of an approximate 75% decline in catch per trap. However, these simple fishery statistics do not reveal that the value of the fish landings has significantly declined due to changes in species composition as well, since the general trend is toward reduction of the more-valued species groups and the increasing predominance of so-called "trash fish." (The value of the landings have probably declined due to decreases in size composition, as well, which we have not considered here.) Although these surveys of the fish community do not provide precise measures for fishery management, indications of substantial change in fish community structure should serve to indicate the extent to which overfishing has affected the resource and of the need for management to prevent further degradation.

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