

## **Condition of Reef Fish on Jamaica's North Coast Signals Late Stages of Overexploitation**

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### **ABSTRACT**

Jamaica's commercial fishery has long shown signs of overexploitation expressed as reduced CPUE and the disappearance of large-sized fish. Heavy fishing pressure often results in reduced abundance, a change in size structure, and shifts in community structure. We assessed the reefs along ≈305 km of Jamaica's northern shelf and performed visual fish censuses at sixty sites according to the AGRRA protocol. Jamaica's fish community was characterized relative to AGRRA results from other Caribbean regions. Although variable, densities of most fish species were only slightly lower in Jamaica than other regions. Fish size was consistently small along the north coast. Total lengths of commercially valuable fishes (Serranidae, Lutjanidae, Haemulidae; n = 1,191) ranged from 5 - 10 cm smaller in Jamaica than other regions we sampled. As valuable species become increasingly scarce due to overfishing, lower trophic levels (e.g., herbivorous scarids and acanthurids) are targeted by the fishing community. Herbivores play an important role in maintaining coral reefs by keeping macroalgae from becoming competitively dominant. An inadequate abundance of herbivores on Jamaica's reefs has resulted in a shift from a coral-dominated to an algal-dominated community structure. Scaridae and Acanthuridae are smaller (by 4 - 15 cm and 5 - 8 cm, respectively) on Jamaica's reefs than conspecifics from other regions. Mean total length for all scarid species was 12 cm (n = 6158) and acanthurid species averaged 10 cm total length (n = 1950). Terminal phase scarids were not commonly encountered and large individuals (> 30 cm) of any fish species were rarely sited during our assessment. The fish population of Jamaica's north coast may be undergoing a late stage of exploitation, displaying signs of recruitment overfishing and indications of reduced genetic variation for size. Lower potential for reproductive output associated with

small-sized individuals puts Jamaica's fish population at risk and the potential loss of herbivorous fishes threatens the recovery and sustainability of Jamaica's reefs.

KEY WORDS: Jamaica, coral reef fishery, AGRRA

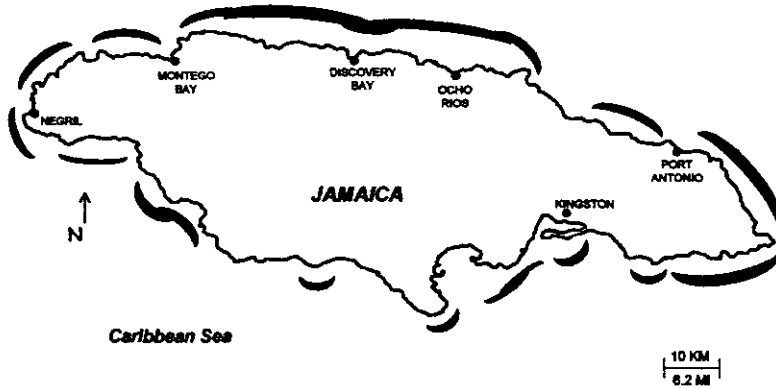
## INTRODUCTION

Jamaica, the third largest island of the Caribbean Sea, is centrally located (18°N, 77°W) and lies at the center of coral diversity in the Atlantic system (Wells and Lang 1973). Coral reefs fringing much of Jamaica's northern coast and occurring less frequently along the southern coast (Figure 1), serve as a foundation for Jamaica's inshore fishery. The declining condition of this fishery has been well documented in recent decades (Hughes 1994, Munro 1983) and evidence exists that Jamaica's fishery resources have been in decline for over a century (Jackson 1997). Jamaica's inshore fishery has undergone changes typical of an overexploited fishery, characterized by declining catch rates, reduction in mean fish size, and a change in species composition of landings (Aiken and Haughton 1987, Munro 1983). Pauly et al. (1998) illustrated that fisheries worldwide, are more frequently targeting organisms in lower trophic levels than was common three decades ago. In Jamaica, this is evidenced as landings are decreasingly composed of valuable species, such as snappers (Lutjanidae) and groupers (Serranidae), and replaced by fishes once considered "trash" species, such as surgeonfishes (Acanthuridae) and parrotfishes (Scaridae) (Aiken and Haughton 1987, Munro 1983).

Reduced herbivory has been implicated as a major contributory factor to macroalgal overgrowth of Jamaica's coral reefs. The 1983 Caribbean-wide mass mortality of the herbivorous, long-spined black sea urchin, *Diadema antillarum* (Hughes et al. 1987) coupled with the destructive forces of Hurricane Allen (1980), resulted in a significant reduction in live coral cover and a shift from a coral-dominated to an algal-dominated community (Hughes 1994, Hughes et al. 1987, Woodley et al. 1998). The inability of *Diadema* to recover and the continuous exploitation of herbivorous scarids and acanthurids from Jamaica's reefs, have prevented recovery of, and threaten the continued existence of, Jamaica's coral reefs.

In this investigation, we sought to ascertain the relative condition of reef fishes of Jamaica's north coast in terms of species composition, size structure and abundance, in order to identify trends of decline associated with characteristics of the coral and algae community. In an effort to uncover factors associated with intense fishing activity in Jamaica, we compared results from our Jamaica assessment to regions that had previously been surveyed using the Atlantic and Gulf Rapid Reef Assessment (AGRRA) protocol. These include the windward Netherlands Antilles (*i.e.* the reefs of St. Maarten, Saba, Saba Bank, and St. Eustatius); Andros Island, Bahamas; and the Tobago Cays, St. Vincent-Grenadines. Since 1987, Saba's fringing reefs and associated fish have been protected from fishing activity and are regulated by the Saba National Marine Park. Likewise, fish from St. Eustatius' reefs

have been protected from fishing in the form of a marine park since 1997. Saba Bank, although regulated at the time of the survey in 1999, has experienced heavy fishing pressure from foreign fishing fleets in recent decades (Klomp and Kooistra In review). Similarly, The Tobago Cays of St. Vincent-Grenadines has suffered from intense local fishing pressure (Deschamps et al. In review).



**Figure 1.** Approximate location of Jamaica's coral reefs (Wells 1988)

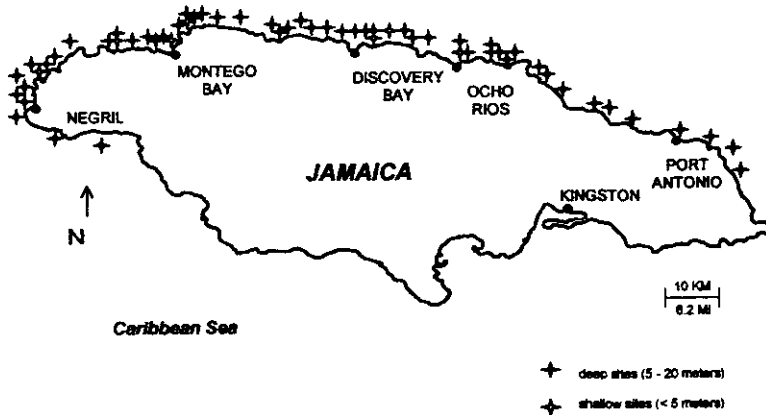
## METHODS

During August 2000, a 7-day training workshop on the Atlantic and Gulf Rapid Reef Assessment (AGRRA) protocol was held in Jamaica at the Discovery Bay Marine Laboratory. Twenty persons, including individuals representing Jamaica's Natural Resources Conservation Authority (NRCA), the University of West Indies, and officials from the Negril and Montego Bay Marie Parks, gathered for classroom instruction and field exercises designed to teach assessment techniques and standardization procedures. Following the workshop, participants were assembled into assessment teams and spent two weeks applying the AGRRA technique to Jamaica's northern coast.

Site selection was made using a combination of color aerial photos (scale 1:5000, 1991), a coastal zone habitat atlas (Norman *et al.* 1997), nautical charts, and knowledgeable local individuals. Sixty sites, eleven shallow (< 5.0 m) and forty-nine deeper (> 5.0 m), were assessed along 305 km (190 miles) of coastline (Figure 2).

The AGRRA protocol (Kramer, P.R. In review) was used to visually assess and quantify condition of corals, algae and fish populations. Stony coral was characterized utilizing line transects (10 m), percent coverage of algae was estimated using quadrats (25 x 25 cm), and belt transects (30 m) were used to estimate fish size and density. We modified the AGRRA protocol to include all colonies  $\geq 10$  cm in maximum diameter to ensure adequate samples sizes. Additionally, counts of serranids (groupers) were restricted to *Epinephelus* and *Mycteroperca*, and scarids

(parrotfishes) and haemulids (grunts) less than 5 cm in length were not tallied. Fish biomass was estimated using length-weight relationships established from prior studies; and for species where prior data was not available, length-weight relationships from similar species were used (Marks and Klomp In review).



**Figure 2.** Location of sampling sites

In total, we assessed corals along 398 transects, algae within 1734 quadrats, and fish size and density for 10,448 individuals along 600 belt transects. Additionally, roving diver censuses of fish were performed at each site to estimate overall species richness. Along each coral transect, vertical relief was measured at 2 meter increments to indicate benthic rugosity and *D. antillarum* were counted to estimate overall density. Macroalgal index values (*i.e.* % macroalgae cover  $\times$  mean macroalgal height) were determined as a proxy for macroalgae biomass.

We evaluated factors affecting Jamaica's reef fishes in terms of fish size, density and biomass, and provide a comparison to other Caribbean regions where AGRRA surveys have been carried out. These regions included Andros Island, Bahamas; Tobago Cays, St. Vincent-Grenadines; and the windward Netherlands Antilles (*i.e.* St. Maarten, Saba, Saba Bank, and St. Eustatius). The Kruskal-Wallis (non-parametric ANOVA) was used to determine differences in fish sizes and densities between Jamaica and other regions of the Caribbean. The Tukey HSD for unequal N was used as a multiple comparison test.

Data was analyzed using a linear regression analysis to detect geographic spatial trends in fish density and total length. Likewise, linear regressions were performed to investigate correlation between fish parameters (*i.e.* fish biomass, density and species richness) and reef parameters (*i.e.* benthic rugosity and percent live coral cover).

## RESULTS

Based on roving diver surveys, a total of 135 fish species were documented among all sites. Fish abundance (Table 1; Figure 3) was dominated by grazing herbivorous species from the Scaridae (17 individuals/100 m<sup>2</sup>) and Acanthuridae (5 individuals/100 m<sup>2</sup>) families, and by the yellowtail damselfish, *Microspathodon chrysurus* (2 individuals/100 m<sup>2</sup>). Fishes with commercial value from the Haemulidae, Serranidae, and Lutjanidae families were present in low densities (0.2 – 2.2 individuals/100 m<sup>2</sup>). Abundance estimates from other families were recorded in very low densities (<0.3 individuals/100 m<sup>2</sup>; Figure 3). Although there was much variability, Jamaica's fish densities (Table 1) were not significantly less than those from other regions (Figure 4). Biomass estimates for Jamaica's fishes followed a pattern similar to total length (Figure 3; Table 1), with scarids accounting for the majority (53%; 670 grams/100 m<sup>2</sup>) of fish biomass within the eight fish families we surveyed. Total biomass of these eight fish families was more than seven times less than total biomass for the same eight families of the windward Netherlands Antilles (Figure 5). In general, scarids, and to a lesser degree, acanthurids, decreased in density from western to eastern sites (Figure 6). Densities of herbivorous fishes were greater at sites along the western coast (Figure 7) than the mean density calculated for herbivorous fishes in Jamaica (> 30 individuals/m<sup>2</sup>).

Mean total length was low for many of the fish species we documented (Table 1). In many cases, fish from Jamaica were significantly smaller than conspecifics from other regions (Figure 8), with the greatest disparity occurring between fish of Jamaica's northern coast and those from the more protected fisheries of the windward Netherlands Antilles. Fish size was consistently low along Jamaica's north coast, and except for *Scarus taeniopterus*, did not exhibit a trend in decreasing size from west to east or vice-versa (linear regression analysis for *S. taeniopterus*:  $p = 0.04$ ;  $r^2 = 0.07$ ). There were no significant correlations detected between benthic rugosity of the reef architecture and fish parameters of biomass, density, or species richness. Likewise, there was not a significant relationship detected between fish densities and live coral cover (Table 2). Species richness, however, displayed a slight, positive correlation with percent live coral cover ( $p = 0.01$ ;  $r^2 = 0.10$ ).

Relative abundance of macroalgae was high (mean index value = 150; Figure 7) at most sites along Jamaica's north coast compared to sites in the Tobago Cays (mean index value = 50) and the windward Netherlands Antilles (mean index value = 10). *Diadema* were present in mean densities of 11 individuals/10 m<sup>2</sup> in the shallow zones and 4 individuals/10 m<sup>2</sup> at the deeper sites. Distributions, however, were patchy and reached densities near 40 individuals/10 m<sup>2</sup> east of Ocho Rios (Figure 7).

**Table 1.** Mean densities ( $\pm 1$  SE) and total length ( $\pm 1$  SE) of key fish species along Jamaica's northern coast.

Species				
Scientific Name	Common Name	n	Density Ind./100 m <sup>2</sup>	Mean Total Length (cm)
<i>Acanthurus coeruleus</i>	blue tang	824	2.3 $\pm$ 1.8	8.8 $\pm$ 3.0
<i>Acanthurus bahianus</i>	ocean surgeon	838	2.5 $\pm$ 2.0	10.9 $\pm$ 3.3
<i>Sparisoma viride</i>	stoplight parrotfish	607	1.7 $\pm$ 1.2	13.1 $\pm$ 2.8
<i>Scarus croicensis</i>	striped parrotfish	2492	6.9 $\pm$ 5.9	11.7 $\pm$ 1.8
<i>Sparisoma eurofrenatum</i>	redband parrotfish	1717	4.8 $\pm$ 2.7	13.1 $\pm$ 1.6
<i>Scarus teeniopterus</i>	princess parrotfish	558	0.6 $\pm$ 0.6	12.4 $\pm$ 2.8
<i>Microspathodon chrysurus</i>	yellowtail damselfish	731	1.9 $\pm$ 1.7	12.5 $\pm$ 2.5
<i>Epinephelus cruentatus</i>	graysby	194	0.8 $\pm$ 0.9	14.8 $\pm$ 1.9
<i>Haemulon Flavolineatum</i>	french grunt	584	2.3 $\pm$ 4.4	15.1 $\pm$ 3.5
<i>Haemulon chrysargyreum</i>	smallmouth grunt	67	1.0 $\pm$ 1.6	13.5 $\pm$ 4.6
<i>Ocyurus chrysurus</i>	yellowtail snapper	11	0.4 $\pm$ 0.4	16.8 $\pm$ 8.1
<i>Epinephelus fulvus</i>	coney	131	0.6 $\pm$ 0.6	12.6 $\pm$ 3.9
<i>Caranx ruber</i>	bar jack	204	1.1 $\pm$ 1.1	14.7 $\pm$ 4.1

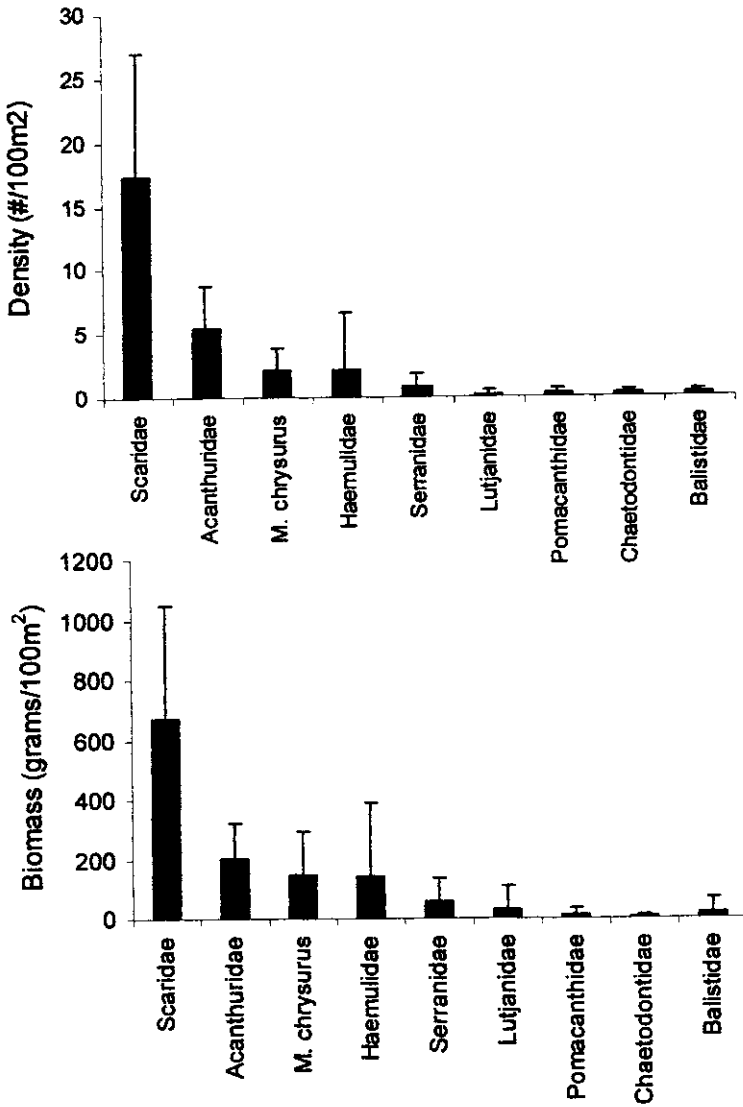


Figure 3. Density and biomass of key fish taxa. Error bars represent  $\pm 1$  SE.

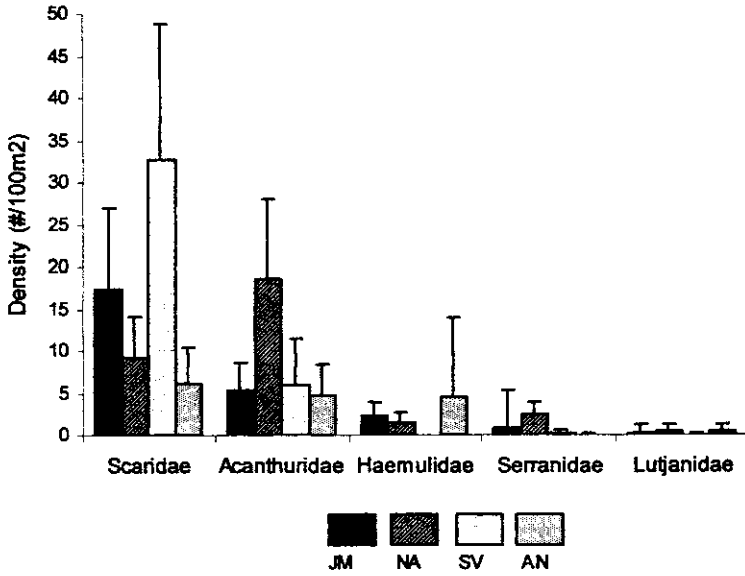


Figure 4. Fish densities ( $\pm 1$  SE) of five major fish families from Jamaica (JM), windward Netherlands Antilles (NA), Tobago Cays, St. Vincent/Grenadines (SV), and Andros Island, Bahamas (AN).

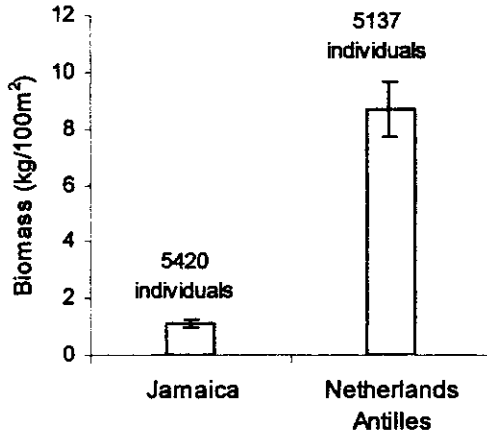


Figure 5. Biomass ( $\pm 1$  SE) of the eight fish families surveyed (Acanthuridae, Balistidae, Chaetodontidae, Haemulidae, Lutjanidae, Pomacanthidae, Scaridae, Serranidae) compared between the windward Netherlands Antilles (1999) and Jamaica (2000).



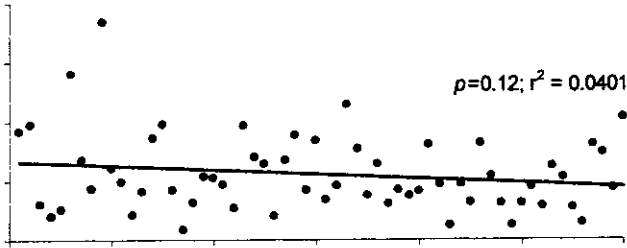


Figure 6. Density of fish from Scaridae and Acanthuridae families at each of the sixty sampling sites. Linear regression results suggest a significant trend for densities to decrease from western to eastern sites.

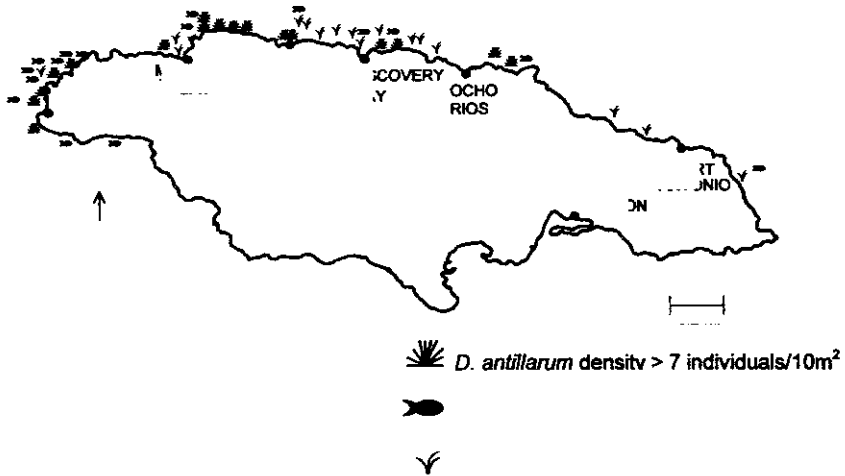
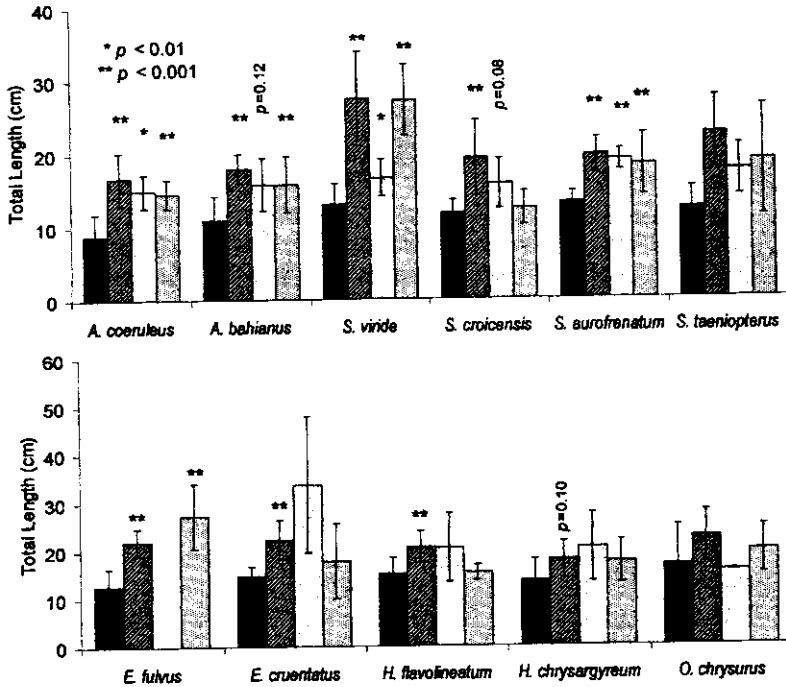


Figure 7. Location of sites where the fleshy macroalgae index, herbivorous fish densities, and *Diadema* densities exceed mean values by more than thirty percent.



**Figure 8.** Fish size of key herbivorous and predacious species (total length  $\pm$  1 SE) from Jamaica (JM), windward Netherlands Antilles (NA), Tobago Cays, St. Vincent/Grenadines (SV), and Andros Island, Bahamas (AN). Asterisks indicate level of significant difference.

**Table 2.** Summary of correlation statistics between fish and reef attributes

Fish Attribute	Reef Attribute	Regression Equation	<i>p</i>	<i>r</i> <sup>2</sup>
Biomass	Structural complexity	$y = -0.0042x + 38.249$	0.306	0.018
Density	Structural complexity	$y = 0.089x + 30.110$	0.628	0.004
Species richness	Structural complexity	$y = 0.2716x + 28.537$	0.742	0.002
Density	Live coral cover	$y = 0.2067x + 26.77$	0.513	0.007
Species richness	Live coral cover	$y = 0.1682x + 13.479$	0.014	0.099

## DISCUSSION

Jamaica's fishery has been in a state of decline for decades. This decline is exhibited by decreased CPUE and reduction in mean fish size (Munro 1983). These are common effects of intense overfishing where fishing pressure selects for the largest individuals (Alcala and Russ 1989, Jennings and Polunin 1996, PDT 1990). Fish density on Jamaica's north coast did not differ significantly from other Caribbean regions assessed (Figure 4). However, the nature of variability in fish density obscures our ability to make statistically meaningful judgments when comparing fish abundance among regions. Fish biomass, on the other hand, which is a function of density and individual size, was strikingly lower on Jamaica's north coast than that of the more protected reefs of the windward Netherlands Antilles (Figure 5). The disparity in biomass between these two regions reflects the relatively small size of Jamaica's reef fish.

While small average size of fish recorded in Jamaica may simply be a reflection of the size composition after fishers have selectively removed larger individuals, a continuous size-selective mode of exploitation can result in populations that are genetically limited to produce small individuals. Bergh and Getz (1989) demonstrate that populations that are initially genetically homogeneous for traits such as those that govern body size lose genetic diversity as genotypes for large body size are selectively removed by intense fishing. As large individuals are continuously removed, the smaller individuals are the ones left to breed, and their genetic contribution will determine the characteristics of future generations. To the extent that body size is heritable, these selectively exploited fish populations are likely to exhibit small body size (Nelson and Soule 1987). This was demonstrated by a reduction in individual size after decades of intense, size-selective fishing pressure on groundfish populations (*i.e.* Atlantic cod *Gadus morhua*, haddock *Melanogrammus aeglefinus*, and pollock *Pollachius virens*) in the northwest Atlantic led to the collapse of the groundfish fishery in the late 1980s (Trippel 1995). Similarly, Ricker (1981) concluded that a genetic component was responsible for a decrease in individual fish size in Pacific pink salmon (*Oncorhynchus gorbuscha*) after a few generations of fish were subjected to harvesting gear that selected for larger individuals. Our assessment confirms the condition of low mean fish size in Jamaica's fishes and establishes the spatial extent of this phenomenon along Jamaica's north coast. Recognizing that conspecifics from other regions in the Caribbean are attaining significantly greater size, suggests that Jamaica's fishes may be under genetic influence for small size.

The small size of Jamaica's fishes raises concern about the capacity of present stocks to replenish populations. Since fecundity in fish is a function of fish size (Charnov 1993, Polunin and Roberts 1993, Sadovy 1996), larger individuals have greater potential to contribute to larval supply. This has been demonstrated in red snapper (*Lutjanus campechanus*) where a single large (61 cm) individual is estimated to produce the same number of eggs as 212 smaller (42 cm) individuals (PDT 1990). Likewise, Pinhorn (1984) reports that a 100 cm Atlantic cod (*G. morhua*) produces more than eight times the eggs spawned by a 50 cm fish. Hence,

diminished fish size with a concomitant decrease of larval production could have strong implications for the potential recovery of Jamaica's exploited fisheries. Indeed, a recent study (1996-2000) carried out by Watson and Munro (in press) provides evidence that larval production near Discovery Bay is compromising stocks. They report that young recruits and juveniles of high-valued commercial species (*i.e.* snappers, grunts, and jacks) were nearly absent from the fish community. In contrast, the abundance of recruits and juveniles was relatively high for species whose larvae have extended pelagic stages (*eg.* Acanthuridae) and for species that mature before recruitment to the fishery (*eg.* *S. iserti (croicensis)*, *Sparisoma aurofrenatum*). The results from our assessment concur with their findings, suggesting relatively higher densities for acanthurids (4.0 individuals/100meter<sup>2</sup>) and scarids (*S. iserti (croicensis)* = 10 individuals/100meter<sup>2</sup> and *S. aurofrenatum* = 4 individuals/100meter<sup>2</sup>) near Discovery Bay. Additionally, our assessment suggests that densities of high-valued species (*i.e.* snappers, grunt, jacks) were consistently low along the north coast and, within the vicinity of Discovery Bay, were absent from our survey transects entirely. Thus, our results support Watson and Munro's conclusion that recruitment overfishing has nearly eliminated some of Jamaica's fish stocks.

An additional concern associated with small-sized fish is that they have relatively higher metabolic rates, a condition that leaves them more susceptible to environmental toxins (Miller 1996). Many pollutants which are known to occur in Jamaica's coastal waters and which have been detected in the aquatic fauna (Mansingh et al. 1997, 2000, Robinson and Mansingh 1999) are recognized as having endocrine disrupting properties which can adversely affect development and reproductive processes. This situation could have a confounding impact on reproductive potential for fishes whose fecundity is compromised by small size.

A characteristic of the Scaridae population which was notably apparent from casual observation, but for which we present no data, was the paucity of terminal phase male scarids. By virtue of their relatively larger size, these individuals would be the first individuals targeted in the fishery. A similar situation has been reported for the rainbow wrasse (*Coris julis*) in the Mediterranean. *C. julis* is a protogynous hermaphrodite of which the terminal phase male is disproportionately targeted, resulting in decreased size, density, and proportion of terminal phase males within the *C. julis* population (Harmelin et al. 1995). According to the size-advantage model for explaining sex change (Ghiselin 1969, Warner 1988), the largest female in the community (assuming it has reached a genetically determined size threshold) should change sex to fill the vacancy of a terminal phase male. The condition we observed, that of scarcity of terminal phase males, would suggest that either fish are being exploited as quickly as sex change can occur, or that females are not reaching the prerequisite threshold size to change sex. Shapiro (1988) provides evidence for an alternative hypothesis to explain the initiation of sex change. He suggests that sex change in protogynous hermaphrodites is regulated by a disinhibitory mechanism whereby females must initially be inhibited from undergoing sex change by the presence of a terminal phase male, before she is disinhibited by the absence of a

terminal phase male. In reference to Jamaica's parrotfish populations, this would suggest that the lack of terminal phase males will perpetuate the condition, so that terminal phase males will also be missing from subsequent generations. It should also be noted that low densities of terminal phase males might be normal in some situations. Warner and Swearer (1991) suggest that individuals of bluehead wrasse, *Thalassoma bifasciatum*, may change sex as a response to a ratio of terminal to initial phase individuals, and that the threshold of this ratio is variable amongst locations. Regardless of the underlying sociobiological explanation, the apparent low abundance of terminal phase males raises questions regarding sperm limitation and the implications for subsequent population growth and structure (Yund 2000).

Grazing herbivores play an important role as primary consumers of benthic algae on Caribbean reefs. In the absence of *D. antillarum*, scarids and acanthurids have become the major herbivores on Jamaica's reefs. Their position at the lower trophic level coupled with the low abundance of predatory fishes, may explain the disproportionate composition of fish biomass allocated to herbivorous fish taxa (*i.e.* Scaridae, Acanthuridae, *M. chrysurus*). The reduced abundance of scarids and acanthurids as a result of overfishing, in addition to the diminished abundance of *D. antillarum*, has not permitted the process of herbivory to substantially control the abundance of algae on Jamaica's reefs. However, we documented *Diadema* at several sites along the coast indicating that there has been some recovery since the 1983 die-off (Figure 8). Of particular interest are stretches of coast where distribution was consistently higher, (*eg.* east of Montego Bay). Our data supports the assertion made by Edmunds and Carpenter (2001) that *Diadema* densities have increased, at least in isolated patches, since the 1983 event.

The positive correlation we detected between live coral cover and species richness, though statistically significant ( $p = 0.01$ ), suggests that only about 10 percent of the variation in species richness is accounted for by the variation of live coral cover. Architectural structure on reefs, regardless of its living condition, provides fish habitat (Grigg 1994). Since we did not find a correlation between fish species richness and benthic rugosity of the reef, we cannot assume that the correlation between live coral and species richness is attributable to additional fish habitat provided by the coral structure itself. Furthermore, only a small fraction of the fishes we sampled are obligate coral feeders (*e.g.* Chaetodontidae < 1.0% of fish composition), suggesting that greater species richness was not a direct result of additional foraging opportunity associated with the coral's living condition. Fishing activity, indicated by the presence of fish traps, was widely observed along Jamaica's coast during our assessment. However, there were tracts where concentration of activity was relatively elevated. It is feasible that the slight correlation we detected between live coral cover and species richness reflects the physical damage to corals associated with areas of greater fishing activity. However, we did not collect data on levels of fish activity, so further investigation would be necessary to support this conclusion.

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