# Escape Gaps: An Option for the Management of Caribbean Trap Fisheries

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## ABSTRACT

The use of escape gaps set in the corners of Antillean fish traps is suggested as a management mechanism for the intensive trap fisheries of the Caribbean. Escape gaps could be rectangular or diamond-shaped. Rectangular apertures provide two dimensions (width and the diagonal) that can be adjusted to permit the escape of deep-bodied slender fishes while retaining round-bodied fishes and crustaceans. Diamond-shaped escape gaps provide height, width and, to a degree, body shape as controlling dimensions.

Previous investigations have suggested that the effectiveness or fishing power of traps might decrease when mesh size is increased. Preliminary indications from a series of tests with rectangular escape gaps are that appropriately sized escape gaps are effective in releasing undersized fish but do not significantly decrease the catchability of target species.

Yields of deep-bodied fishes such as surgeonfish, triggerfish, hogfish, angelfish, spadefish, porgies and some of the grunts and jacks would be increased, because such fishes are invariably harvested at extremely small sizes by the hexagonal wire meshes commonly used in Caribbean trap fisheries. Morphometric information is presented for twenty-one species to estimate size at first capture with various escape gap sizes, and to calculate potential improvements in yield-per-recruit when using escape gaps.

For severely depleted fisheries, the dimensions of the escape gap would need to be progressively changed as stocks of key fishery species recovered and the composition of the fish communities changed.

KEY WORDS: Fish traps, escape gaps, management, mesh size.

## INTRODUCTION

Antillean fish traps or "pots" are the principal fishing gears in most countries in the Caribbean. A wide variety of trap designs are used, ranging from rectangular box traps with a single straight entrance funnel, to more complex designs such as the single-entrance arrowhead trap or the Z or S traps that have two entrances, usually with a down turned entrance funnel (Munro et al. 1971). The arrowhead trap is historically important, having been the main trap design used in the past and one still

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used extensively in Africa and the Middle East. Most modern traps use wire mesh but the original traps were of woven cane.

Some designs of traps might be better than others but they are all exceedingly efficient passive fishing gears. They maintain the catch in good condition until the trap is hauled and do not have to be hauled if the weather is unfavorable. They are relatively inexpensive to construct and, with the advent of plastic coated mesh, quite durable. Almost all species of Caribbean reef fishes will enter traps but catchability (the average fishing mortality caused by one unit of effort) is variable and predatory species tend to be more catchable than herbivores because they often enter traps to prey on the catch (Munro 1999a).

Trap fishing was banned in Bermuda in 1990 (Burnett-Herkes and Barnes 1996) but is largely unregulated elsewhere. Some countries stipulate minimum mesh sizes, ranging from 31 mm to 48 mm and in others a biodegradable panel is mandatory, to ensure that the trap will become inoperable if it is lost. However, there are no limits to the number of traps that can be deployed. This has generally led to a situation in which reef fish stocks suffer from growth and recruitment overfishing in most countries. Deep-bodied species such as surgeonfish, triggerfish, angelfish, hogfish, spadefish, porgies and some species of grunts and jacks are particularly badly affected.

The idea of using escape gaps in traps dates back to the 1950s (Templeman 1958), at which time escape gaps were mandatory in Newfoundland lobster traps. Their use has been investigated in British lobster and crab fisheries (Brown 1982) and in spiny lobster fisheries in Australia (Bowen 1963), Florida (Lyons and Hunt 1991) and Hawaii (Polovina et al. 1991). Escape gaps in lobster and crab traps are now required by law in a number of countries. However, it appears that the concept has never been applied to multi-species trap fisheries, such as those of the Caribbean, in which a wide array of fish and invertebrates are concurrently harvested.

Clearly, the ability of a fish or invertebrate to pass through a gap of a given size and shape depends its relative body proportions. With a rigid circular, hexagonal or square mesh, only one dimension, usually body depth, determines whether of not escapement is possible. In contrast, rectangular or diamond-shaped escape gaps offer more possibilities. Rectangular apertures provide two dimensions (width and the diagonal) that can be adjusted to permit the escape of deep-bodied, slender, fishes while retaining round-bodied fishes and crustaceans. Diamond-shaped escape gaps provide height, width and, to a degree, body shape as controlling dimensions.

In the context of Antillean fish traps, several studies (Olsen et al. 1978, Stevenson and Stuart-Sharkey 1980, Ward 1988, Rosario and Sadovy 1996, Robichaud et al. 1999) have found that increasing mesh sizes appeared to decrease the total catch, including that of fish that should have been retained by the larger mesh. Thus, the catchability of retainable fish appeared to be reduced. This might be attributable to decreased ingress of larger fish as a result of reduced conspecific attraction or because small fishes captured in the trap act as bait for larger fish. Alternatively, it has been suggested that large-meshed traps have a weaker visual impact (Munro 1974), look less like a refuge and therefore attract fewer fish.

Bohnsack et al. (1989) tested this by covering the sides of traps with a standard small mesh and only varied the mesh size of the upper and lower panels. The weight-frequency distributions of fully retainable fish did not differ markedly in 11 different mesh sizes, suggesting that catchability might not be reduced. Ward (1988) compared the frequency distributions of body depth in the total catches (excluding trunkfish and cowfish) of three different mesh sizes in inshore waters at Bermuda, all fished equal amounts. There was no evidence of reduced catching power for fully retainable fish.

Current evidence, therefore, suggests that escape gaps would not reduce catchability. That is, the numbers of fish captured in each size group, above the minimum size expected, would not be significantly decreased. However, there is sufficient ambiguity in available reports to warrant further examination of this aspect.

Escape gaps would be ineffective if fish were simply unwilling to pass through the gaps. The effectiveness of escape gaps would also be reduced if undersized fish used the trap as a refuge and were unable to rapidly discern the escape gap and make an exit when the trap was hauled.

## METHODS

This study was undertaken at Hans Creek, located on the south coast of Beef Island, adjacent to Tortola, British Virgin Islands (BVI) and in Discovery Bay, on the north coast of Jamaica. We used non-standard double-arrowhead (AA) Antillean fish traps constructed of sticks and 25 mm (1") plastic-coated wire mesh. The wire mesh has a maximum aperture of 33 mm. These AA traps have an outer chamber (sometimes called a parlor) and a second, internal, entrance funnel leading to the inner chamber (Figure 1). In theory, such a trap should have reduced escapement rates. The traps are 120 cm across, 150 cm along the side and 60 cm high. The horse neck entrance funnel protrudes 50 cm into the trap and terminates in a downward facing pear-shaped aperture 60 cm in circumference and 12 cm wide. The internal funnel is identical. Escape gaps were made of from rectangles of plexiglass (in Jamaica) or galvanized metal (in BVI), with rectangular apertures cut out of them.

As a preliminary experiment, undertaken at Hans Creek, nine traps were fitted with escape gaps between the parlor and the inner chamber but not in the outer walls of the trap. The inner entrance funnel was blocked. If undersized fish passed freely through the gaps, then the average number in each chamber should be equal, provided that no large predator was concurrently trapped in the parlor. The traps were checked by divers and the fishes in each chamber were identified, counted and their sizes estimated.

After that, escape gaps were located in the outer walls of the traps, close to the floor in the acute corners furthest from the apex of the trap. Traps were hauled with a rope attached above the entrance funnel so that any fish in the outer parlor would descend through the inner funnel as the trap was being hauled.

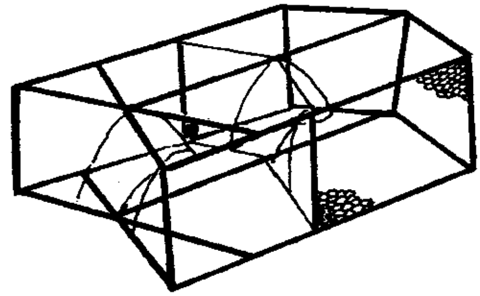

Figure 1. Double arrowhead fish trap fitted with escape gaps. Dimensions are 150 mm along the side, 120 cm wide and 60 cm deep. Plastic-coated hexagonal wire mesh measures 33x25 mm. Wooden poles, fitted externally, support the structure.

Divers inspected traps fitted with escape gaps to count the numbers of fish in the traps, for comparison with the numbers actually caught. Traps were then hauled and reset, once weekly (in BVI) or twice weekly (in Jamaica). All fish were identified and measured for length (to the end of the middle caudal ray), maximum body depth and body width and then returned to the sea. Traps were set in shallow, 2 m, back reef seagrass and patch reef areas in Jamaica and in 5-8 m at the base of the fore reef at Hans Creek. Traps were unbaited. Catch data were supplemented by diver observations of behavior of fish in the traps. The traps in Hans Creek were frequently attacked and damaged by nurse sharks.

We made one series of observations at each site of the catch rates, catch composition and size frequencies in control traps and traps with escape gaps. These are summarized in Table 1.

The morphometric data gathered during our experiments were compiled in a database, supplemented where necessary by information from the literature and measurements made at the BVI Fisheries Complex in Tortola. From these morphometric data we are able to compile a basic analysis of the comparative catch rates of the control traps and of the traps fitted with escape gaps for each of the data sets. This was done by calculating the average catch (numbers and weights of all species) per control trap hauled and, from the size frequency data for the control traps, calculating the proportion of that catch that would have been retained by each of the escape gaps used in that series of observations. This is then repeated for the catch in the trap with the smallest escape gap and then for the next largest. Only one size of escape gap was used at Discovery Bay. If the parts of the catches in the control traps that would have been retained by traps fitted with escape gaps are similar in magnitude to the catches actually taken in the traps with gaps, then the escape gaps can be deemed to not reduce catchability overall.

**Table 1.** Summary of locations, dates, depths, soak times and numbers of traps with escape gaps and control traps.

| Location | Dates | Depth | Soak | Hauls of control AA traps | Hauls of traps with gaps (mm) |
|---|---|---|---|---|---|
| Hans Creek | Mar-Sep 2001 | 6-9 m | 7 d | 53 with 33x25 mm mesh | 58 with 70x28,<br>63 with 80x30,<br>30 with 90x33 |
| Discovery Bay | Feb-May 2000 | 2-8 m | 3-4 d | 166 with 33x25 mm mesh | 78 with 90x25 |

Twenty-one species make up 78% of the current catch in traps in the Discovery Bay area (Sary 2001). An additional 11.4% of the catch is made up of small catches of spiny lobster (1.2%) and Caribbean king crab (0.8%), various eels (3.5%) and occasional catches of groups of large yellowfin grouper (3.2%), Nassau grouper (1.7%), and red hind (1%) that still survive in the area. However, we have not observed juveniles of the large species of groupers in six years of work in the area, and it seems likely that they will eventually become locally extinct. Escape gaps would have little effect on the larger species. A further 10.6% of the catch is made of assorted uncommon fish and invertebrates.

Morphometric data for these 21 most commonly caught species are shown in Table 2. Published values of length at maturity, $L_m$, are included in Table 2, together with estimates of growth parameters that are required for some of our computations. In order to assess the effect that escape gaps might have on the harvest of fish from the intensively fished north coast of Jamaica we effected simple yield per recruit analyses for each species. The total landings of each species in traps in the Discovery Bay area, derived from Sary (2001), was weighted by the calculated yield per recruit in the predominant 43 x 32 mm wire mesh and then recalculated for the three escape gap sizes that we had used in most of our experimental work (70 x 28 mm, 80 x 30 mm and 90 x 33 mm) plus an additional hypothetical size of 100 x 40 mm. For each of the species considered the length at first capture ($l_c$) was determined either by body width or depth.

**Table 2.** Morphometric characteristics of the 21 species of reef fish that yield 78% of the trap catch in the Discovery Bay area in Jamaica. All dimensions are in mm. L = length (either TL = total length or FL = fork length), BD = body depth, BW = body width, $L_c$ = length at first capture in traps with 43x32 mm mesh, $L_m$ = length at maturity, $L_\infty$ = asymptotic length, a and b = values of the length-weight equation ($W = aL^b$), $W_\infty$ = asymptotic weight in g, K = growth coefficient, Z = total mortality rate (calculated from the mean weight of individuals in the catch and the growth parameters). Growth parameters from Munro (1983) and Munro (1999b).

| Family | Species | | BD:L | BW:L | Lc | Lm | Loo | a | b | Woo | K | Z |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Acanthuridae | *Acanthurus bahianus* | FL | 0.477 | 0.113 | 95 | 155 | 280 | 0.0191 | 3.08 | 547 | 0.36 | 1.1 |
| | *A. chirurgus* | FL | 0.428 | 0.107 | 101 | 210 | 313 | 0.0221 | 3.01 | 701 | 0.56 | 1.3 |
| | *A. coeruleus* | FL | 0.518 | 0.144 | 81 | 130 | 333 | 0.0278 | 3.02 | 1101 | 0.24 | 0.8 |
| Balistidae | *Balistes vetula* | FL | 0.468 | 0.144 | 92 | 175 | 496 | 0.0516 | 2.88 | 3941 | 0.28 | 0.4 |
| Carangidae | *Caranx ruber* | FL | 0.289 | 0.113 | 149 | 240 | 540 | 0.0180 | 2.99 | 2724 | 0.19 | 0.9 |
| Holocentridae | *Holocentrus ascensionis* | FL | 0.30 | 0.124 | 145 | 145 | 261 | 0.0198 | 3.00 | 352 | 0.23 | 0.5 |
| | *H. rufus* | FL | 0.265 | 0.121 | 168 | 135 | 188 | 0.0131 | 3.06 | 104 | 0.48 | 1.0 |
| Haemulidae | *Haemulon flavolineatum* | FL | 0.305 | 0.132 | 144 | 155 | 287 | 0.0111 | 3.23 | 568 | 0.25 | 3.1 |
| | *H. plumieri* | FL | 0.328 | 0.147 | 130 | 220 | 400 | 0.0238 | 2.93 | 1177 | 0.26 | 0.8 |
| | *H. sciurus* | FL | 0.313 | 0.137 | 137 | 180 | 370 | 0.0200 | 3.01 | 1050 | 0.26 | 0.4 |
| Lutjanidae | *Lutjanus apodus* | FL | 0.305 | 0.130 | 138 | 250 | 349 | 0.0089 | 3.20 | 770 | 0.35 | 0.3 |
| | *Ocyurus chrysurus* | FL | 0.268 | 0.120 | 148 | 300 | 525 | 0.0145 | 3.03 | 2363 | 0.18 | 0.6 |
| Mullidae | *Mulloidichthys martinicus* | FL | 0.223 | 0.132 | 201 | 180 | 250 | 0.0207 | 3.00 | 323 | 1.07 | >10 |
| | *Pseudopeneus maculatus* | FL | 0.222 | 0.127 | 199 | 185 | 244 | 0.0229 | 2.96 | 293 | 1.14 | >10 |
| Scaridae | *Scarus iserti/taeniopterus* | TL | 0.23 | 0.122 | 182 | 155 | 223 | 0.0166 | 3.02 | 196 | 0.48 | >10 |
| | *Sparisoma aurofrenatum* | TL | 0.287 | 0.138 | 155 | 150 | 260 | 0.0129 | 3.11 | 324 | 1.10 | 6.4 |
| | *S. chrysopterum* | TL | 0.291 | 0.141 | 161 | 240 | 418 | 0.0199 | 3.00 | 1453 | 0.78 | 4.5 |
| | *S. rupripinne* | TL | 0.291 | 0.146 | 158 | 160 | 465 | 0.0194 | 3.00 | 1951 | 0.58 | 1.6 |
| | *S. viride* | TL | 0.325 | 0.140 | 140 | 180 | 549 | 0.0370 | 3.12 | 9901 | 0.27 | 7.8 |
| Serranidae | *Cephalopholis fulva* | TL | 0.26 | 0.142 | 165 | 160 | 325 | 0.0174 | 3.00 | 597 | 0.30 | 1.2 |
| | *C. cruentata* | TL | 0.266 | 0.136 | 161 | 160 | 365 | 0.0121 | 3.08 | 785 | 0.26 | 1.2 |

Total mortality rates, Z, prevailing in the Jamaica fishery were calculated from the mean weight of individuals in the catch (Sary 2001) using the formulation of Gulland (1969), which states that,

$$W_c = W_\infty \sum_{0}^{3} \frac{Un\ Ze^{-nK(tc-to)}}{Z-nK}$$

in which $W_c$ is a function of the asymptotic weight, $W_\infty$, the growth rate, K, the total mortality rate, Z, and the age at entry to the exploited phase, $t_c$. The theoretical point of origin of the growth curve, to, can be set at zero. $U_n$ is the summation variable in which $U_0 = 1$, $U_1 = -3$, $U_2 = 3$ and $U_3 = -1$.

Natural mortality rates, M, are unknown and in an environment in which predators are extremely scarce, natural mortality rates of adult and sub-adult fish are expected to be very low (Munro 1980). We therefore assumed a exploitation rate, E, of 0.9 and estimated natural mortality as

$$M = Z - EZ$$

## RESULTS

Our preliminary observations by divers confirmed that on average nearly equal numbers of undersized fish of all families and genera were found in the inner and outer chambers of the traps that were fitted with internal escape gaps and in which the inner funnel was blocked. This showed that fish would move freely through the escape gaps if they were small enough to do so. There were no instances of fish becoming stuck in the escape gap. Secondly, when traps were fitted with escape gaps in the external walls very few undersized fish were observed to be lingering in the trap. The very few that were observed in the traps usually left by the escape gaps when the traps were being hauled.

Tables 3a and b show the results of the comparisons between control traps and traps with escape gaps in Jamaica and BVI. Table 3b shows, for example, that the control traps captured an average of 1,214 g of fish and invertebrates, including 382 g that were large enough in body width or depth to be retained in a trap with a 90 x 33 mm escape gap and, reading vertically, that there is no pattern of decrease in average catch rates in traps with escape gaps.

The yield per recruit estimates are shown in Figure 2a-d. All combinations of gap height and width will produce increases in the total harvests, ranging from about 18% with the 70 x 28 mm gaps, 19% with the 80 x 30 mm gaps, 22% with the 90 x 33 mm gaps and 42% with the 100 x 40 mm gaps. The value of the catch would increase by somewhat greater amounts owing to the increased catches of snappers and also because larger fish attract better prices, irrespective of species.

**Table 3a.** Average numbers and weight of all species of fish, spiny lobsters, crabs and octopus caught in Discovery Bay, Jamaica, in control traps (33 x 25 mm mesh) and traps with 90 x 25 mm escape gaps. The upper row shows (in boldface) the numbers and weight of fish and invertebrates caught in the control traps and the numbers and weights that would have been retained in traps with 90 x 25 mm escape gaps. The lower row shows the number and weight (in boldface) actually taken in the traps with 90 x 25 mm escape gaps.

| | Numbers/trap | | Weight (g)/trap | |
|---|---|---|---|---|
| | Control | 90 x 25 | Control | 90 x 25 mm |
| Control | **10.2** | 1.8 | **794** | 241 |
| 90 x25 | | **4.2** | | **336** |

**Table 3b.** Average numbers and weight of all species of fish, spiny lobsters, crabs and octopus caught in Hans Creek, BVI, in control traps (33 x 25 mm mesh) and in traps with 70 x 28, 80 x 30 and 90 x 33 mm escape gaps. Each row shows the numbers and weight of fish and invertebrates actually caught (in boldface) and the numbers and weights in that catch that would have been retained in traps with successively larger gap sizes.

| | Numbers/trap | | | | Weight (g)/trap | | | |
|---|---|---|---|---|---|---|---|---|
| | Control | 70x28 | 80x30 | 90x33 | Control | 70x28 | 80x30 | 90x33 |
| Control | **10.0** | 2.6 | 1.7 | 1.0 | **1214** | 615 | 507 | 382 |
| 70 x 28 | | **2.3** | 1.4 | 0.8 | | **496** | 376 | 273 |
| 80 x 30 | | | **1.4** | 1.0 | | | **647** | 598 |
| 90 x 33 | | | | **0.7** | | | | **224** |

In these calculations it has been assumed that the catches of the larger groupers would be unchanged but that is a rather optimistic view in the absence of any significant spawning stock biomass. The crabs and spiny lobsters would be unaffected by any gaps as they become catchable in traps when body depths exceed the largest gap sizes considered here. Harvests of eels would be expected to increase by an unknown amount in response to the gaps but as they have no market value they are discounted from the calculations. Note, however, that "trash" fish such as eels are landed, given away, and consumed.

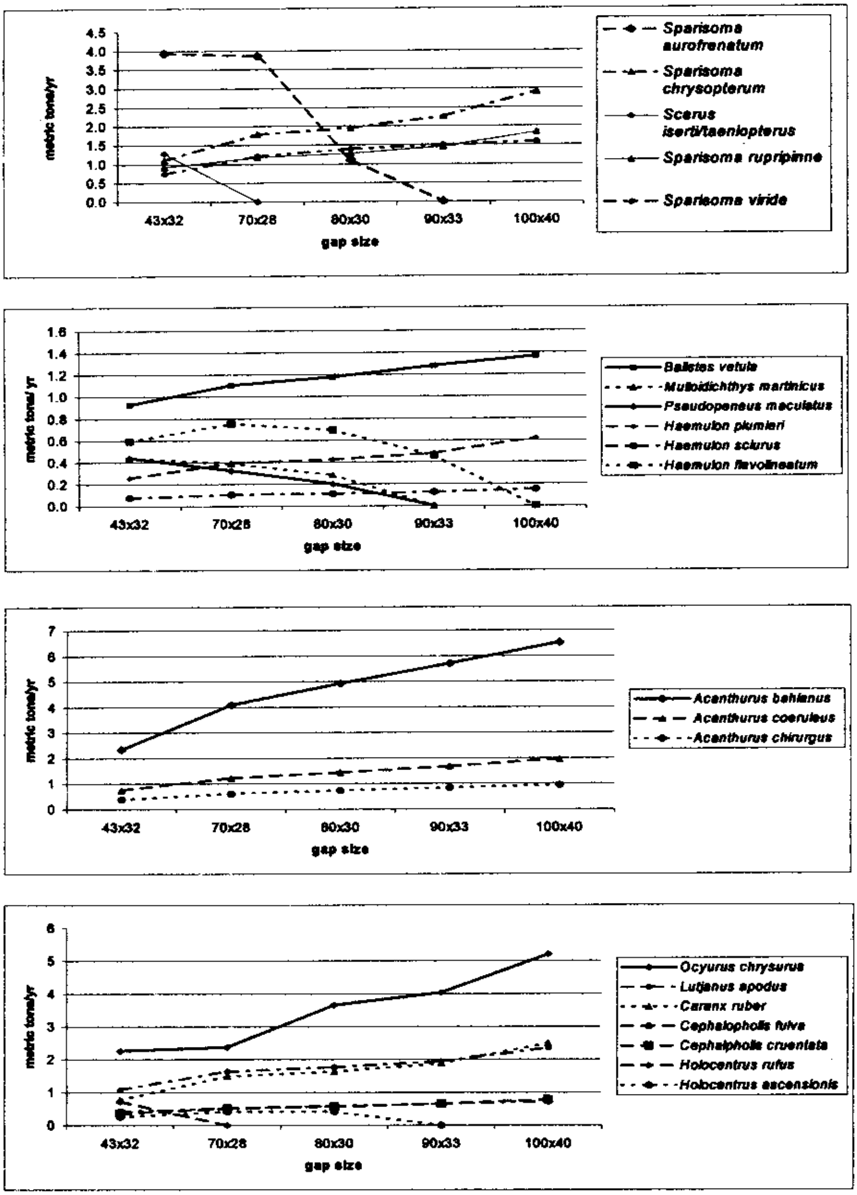

**Figure 2.** Calculated responses of the 21 species that comprise nearly 80% of the catch in the vicinity of Discovery Bay, Jamaica, to the introduction of escape gaps of various sizes.

## DISCUSSION

The yield per recruit estimates (Figure 2) showed that all of the tested gap sizes and the hypothetical 100 x 40 mm gap would produce increases in harvests if they were introduced. The calculated increase would be in the order of 42% if 100 x 40 mm escape gaps were introduced. However, the immediate effect would be to completely eliminate catches of the small parrotfish (*Scarus iserti/taeniopterus* and *Sparisoma aurofrenatum*), goatfish (*Pseudupeneus maculatus* and *Mulloidichthys martinicus*) squirrelfish (*Holocentrus asencionus* and *H. rufus*), and a number of minor species, none of which attain a body width much greater than 28 mm. This would be accompanied by an increase in value because larger fish fetch higher prices per unit weight. Additionally, as most deep bodied species other than acanthurids have been virtually exterminated, we can anticipate some recovery of the other deep-bodied species.

However, it would take several years before the current fish stock grew to sizes at which they would be retained in a 100 x 40 mm gap. The obvious alternative is to progressively increase the gap sizes over a number of years, starting with 70 x 28 mm and making increases in gap sizes in response to changes in the composition of the catches. Figure 3 shows the likely outcome of a possible conservative strategy in which a gap size of 70 x 28 mm is initially adopted, then 80 x 30 mm, after which the gap width is held at 30 mm while gap depth is progressively increased. This would enable catches of small parrotfish, goatfish, and squirrelfish to be maintained at reasonable levels while catches of surgeonfish would treble. Thereafter, gap width could be progressively increased, particularly with a view to improving harvests of snappers, jacks, larger species of grunts, and the smaller groupers.

The calculations are also based upon the current harvests, which are in turn related to recruitment rates and these have been shown to be massively depleted (Watson and Munro in review). Table 2 shows the mean sizes at maturity and the sizes at which fish are currently captured in the Jamaican fishery in pots with a mesh size of 43 mm maximum aperture. Most species are captured well before maturity, and the spawning stock biomasses of all but the smallest species are extremely small and will remain so unless management measures are adopted throughout the country. Table 2 shows that the surgeonfish, that presently comprise 12.5% of the catch, would reach maturity before recruitment if escape gaps were adopted. This presumably would lead to improved recruitment rates and commensurate increases in harvests. However, many of the important jacks, angelfish, porgies, spadefish, and deep-bodied grunts, all of which will be taken by small meshed fish traps well before they reach maturity, have virtually disappeared from the north coast of Jamaica.

Changes in the recruitment rates and community composition would probably have positive effects on the spear, handline and net fisheries (Sary 2001) by making larger fish available to these fishing gears.

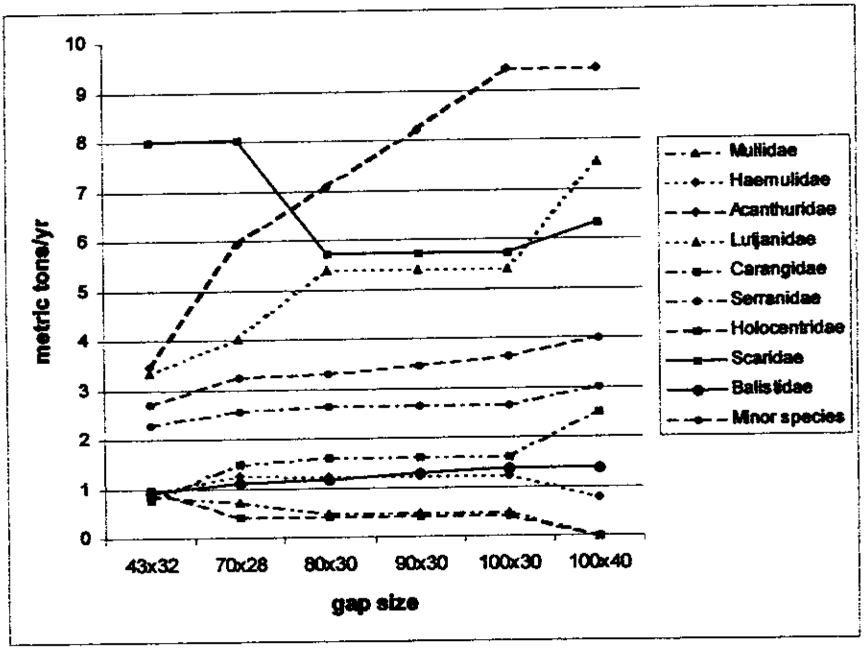

Figure 3. Suggested strategy for the introduction of escape gaps to the Discovery Bay fishery, in which a gap size of 70 x 28 mm is initially introduced, followed by 80 x 30 mm. Thereafter, gap width is held at 30 mm while gap heights are progressively increased to 100 mm. Thereafter gap width could be progressively increased to 40 mm.

We believe that the adoption of escape gaps that are progressively increased in size as catch rates improve and catch compositions change offers a partial solution to the management of Caribbean trap fisheries. Such an undertaking would have to be done in close consultation with the fishing community. It would be a difficult task. However, Parchment (1998) recorded a very widespread acceptance of the need to protect juvenile fish, and this gives some hope that the fishers might be quite receptive to the idea of escape gaps.

Although we have worked with rectangular escape gaps, because the controlling dimensions are easily measured, we recognize that diamond-shaped gaps might give better results by adding body shape as an additional controlling factor.

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## LITERATURE CITED

Bohnsack, J.A., D.L. Sutherland, D.E. Harper, D.B. McClellan, M.W. Hulsbeck and C.M. Holt. 1989. The effects of fish trap mesh size on reef fish catch off southeastern Florida. *Marine Fisheries Review* **51**:36-46.

Bowen, B.K. 1963. Preliminary report on the effectiveness of escape gaps in crayfish pots. Fisheries Dept. of Western Australia. Report II: 14pp.

Brown, C.G. 1982. The effect of escape gaps on trap selectivity in the United Kingdom crab (*Cancer pajucus* L.) and lobster (*Homarus gammarus* L.). *J. Cons. Int. Explor. Mer.* **40**:127-134.

Burnett-Herkes, J. and J. Barnes. 1996. Banning the use of fish pots and other methods introduced in Bermuda to manage declining reef fish stocks. *Proceedings of the Gulf and Caribbean Fisheries Institute* **44**:239-256.

Gulland, J.A. 1969. *Manual of Methods for Fish Stock Assessment. Part 1: Fish Population Analysis*. FAO Manuals for Fishery Science 4. Rome, Italy.

Lyons, W.B., and J.H. Hunt. 1991. Catch rates of spiny lobsters (*Panulirus argus*) in traps equipped with escape gaps and potential benefits to the South Florida fishery. *Proceedings of the Gulf and Caribbean Fisheries Institute* **40**:452-470.

Munro, J.L. 1974. The mode of operation of Antillean fish traps and the relationships between ingress, escapement, catch and soak. *J. Cons. Int. Explor. Mer.* **35**:337-350.

Munro, J.L. 1980. Stock assessment models: Applicability and utility in tropical small-scale fisheries. Pages 35-47 in: S.B. Saila and P.H. Roedel (eds.) *Stock assessment for tropical small-scale fisheries*. Proc. International Workshop, Sept. 1979. Univ. Rhode Island, International Center Marine Resource Development, Kingston, Rhode Island USA 198 pp.

Munro, J.L. 1983. *Caribbean Coral Reef Fishery Resources*. ICLARM Studies and Reviews 7. Manila, Philippines.

Munro, J.L. 1999a. Effects of fishing on coral reef ecosystems. p.143-148 in: P.J. Schei, O.T. Sandlund and R. Strand (eds) *Proc. Norway/UN Conference on the Ecosystem Approach to Sustainable Use of Biological Diversity*. Norwegian Directorate for Nature Management and Norwegian Institute for Nature Research. Trondheim, Norway. September 1999.

Munro, J.L. 1999b. Marine protected areas and the management of coral reef fisheries. ICLARM Technical Report to Inter-American Development Bank. 41 pp.

Munro, J.L., P.H. Reeson, and V.C. Gaut. 1971. Dynamic factors affecting the performance of the Antillean fish trap. *Proceedings of the Gulf and Caribbean Fisheries Institute* 23:184-194.

Olsen, D,A., A.E. Dammann, and J.A. LaPlace. 1978. Mesh selectivity of West Indian fish traps. *Marine Fisheries Review* **40**:15-16.

Parchment, P. 1998. 'Co-management' and contradiction: a case study of fishery reserve management in Discovery Bay, Jamaica. Research Paper for Degree of M.Sc. in Development Studies, University of the West Indies, Kingston. Jamaica.

Polovina, J.J., A.R. Everson, and T.K. Kazama. 1991. Evaluation of circular and rectangular escape vents in a multispecies lobster fishery in Hawaii. *Proceedings of the Gulf and Caribbean Fisheries Institute* **40**:471-481.

Templeman, W. 1958. Lath spacing in lobster traps. *Fisheries Research Board of Canada, Progress Report Atlantic Coast Stations* **69**:22-27.

Robichaud, D., W. Hunte, and H.A. Oxenford. 1999. Effects of increased mesh size on catch and fishing power of coral reef fish traps. *Fisheries Research* **39**:275-294.

Rosario, A. and Y. Sadovy. 1996. Trap mesh selectivity off the west coast of Puerto Rico. *Proceedings of the Gulf and Caribbean Fisheries Institute* **44**:5-30.

Sary, Z. 2001. The small-scale fishery on the central north coast of Jamaica in 2000-01: A biological and socio-economic survey. ICLARM Caribbean/Eastern Pacific Office Technical Report.

Stevenson, D.K. and P. Stuart-Sharkey. 1980. Performance of wire fish traps on the western coast of Puerto Rico. *Proceedings of the Gulf and Caribbean Fisheries Institute* **32**:173-193.

Ward, J. 1988. Mesh size selection in Antillean arrowhead fish traps. Pages 455-467 in: S.C. Venema, J. Muller-Christensen, and D. Pauly (eds.) *Contributions to Tropical Fisheries Biology*. FAO Fish. Rep*ort* 389. Rome, Italy.

Watson. M. and J.L. Munro. [In review]. Settlement and recruitment of coral reef fishes in moderately exploited and overexploited Caribbean coral reef ecosystems: implications for marine protected areas. *Bulletin of Marine Science.*