Behavioral Dynamics of Coral Reef Fishes in Antillian Fish Traps at Bermuda

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ABSTRACT

Two intensive diving studies, each of 2 weeks duration, were conducted at an inshore location on the reef platform of Bermuda. Wire traps of identical dimensions were made of 3 hexagonal mesh sizes: 3.8 cm (1 1/2"), 5.1 cm (2") and 8.3 cm (3 1/4"). The first study utilized straight funnels in all traps while the second study used horseneck funnels. These traps were used to determine the effect of mesh size on the catch composition and size of fishes. Catch composition with respect to proximity of the trap to reef was studied by setting the traps along transects and locating them at 3m, 20m and 50m from patch reefs. Some significant differences were found in species composition both with respect to mesh size and distance from the reef. Detailed observations showed marked specific differences in ingress and escapement behavior. Escapement from traps with straight funnels was far higher than from those with horseneck funnels. Baiting traps had only short term effects on the catch.

Conspecific attraction appeared to be very important in determining the ingress of a number of species (e.g., Lutjanus griseus, Haemulon sciurus, Diplodus bermudensis). The passage of a tropical storm during one of the studies was associated with a considerable increase in the numbers of two species present in the traps after the storm.

INTRODUCTION

Wire mesh fish traps are extensively used throughout the Caribbean and in Bermuda to harvest a variety of reef fish and spiny lobsters. They capture a wide range of species of fish some of which are not taken by other gear types. This gear is used over a wide depth range, being set in different depths to target different species assemblage. The catch from fish traps provides a very significant proportion of the total fishery landings throughout the Caribbean region. In Bermuda, traps contribute 50-60% of the total landings.

The type of trap used in Bermuda is known as the Antillian fish trap. This and other fish trap designs used throughout the Caribbeban have been described and figured by Munro et al. (1971). The most common funnel design is the "horseneck" style, i.e., the funnel has a downward turn at the inner end, although traps with straight funnels are also used in some localities, including Bermuda.

The dynamics of the operation of Antillian fish traps have been elucidated by Munro et al. (1971) and Munro (1974) from a study carried out in Jamaica. These workers determined that catch levelled off asymptotically after some optimum soak time. They postulated that fish continue to enter a trap at a fairly constant rate, but daily escapement is a fixed proportion of the number of fish in a trap. Catch attains its maximum level when the ingress of fish equals escapement. Catch is therefore thought to be proportional to trap volume, assuming that the number, size and design of entrance funnels remain constant. They also showed that trap catches are affected by lunar phase, presumably because of changes in fish activity levels.

A common feature of the trap fishery is the highly variable catch rates and species composition. This is probably due to a complex set of behavioral attributes exhibited by the large number of reef fish species taken in traps and to the location of the trap in relation to the reef. High and Beardsley (1970) observed the behavior of reef fishes in and near three types of traps during a two week saturation diving study in the Virgin Islands. They reported on behavioral observations of conspecific attraction, use of the trap as a shelter site or territory and predator-prey interactions. Munro et al. (1971) analyzed the results of extensive diving observations of fishes in traps and assessed the dynamic factors affecting the catches. Amongst their conclusions were that the rate of escapement was an important factor in determining catch rates and that conspecific attraction would strongly influence catch magnitude and composition. Munro (1974) made a detailed analysis of the mode of operation of Antillian fish traps and developed a model to explain the relationships between ingress, escapement, catch and soak.

Munro (1983) assumed that the minimum size retained of a given species is a function of the mesh size used and that species' maximum body depth. Using this relationship, he calculated the effects of various mesh sizes on the yield of the Jamaican trap fishery. Hartsuijker and Nicholson (1981) suggested that recruitment to the trap fishery may be more a function of behavioral changes with size than of the mesh size used. Hartsuijker (1982) in a re-survey of Pedro Bank off Jamaica argued that without extensive and continuous observations underwater that it was difficult to state exactly how trap catches were built-up over time. He emphasized the influence of the proximity of the reef on the trap catches. Harper and McClellan (1983) observed the behavior of selected reef fishes in and around fish traps in a large laboratory tank. They examined the effects of mesh size on retention and studied survivorship of confined fishes.

The objective of our study was to make detailed observations of the behavior of trapped fish and to document ingress and escapement by repeated daily diving operations. The two studies were conducted to compare the influence of two funnel types (straight and horseneck) on these behaviors. In addition, we examined the effect of mesh size on catch composition and magnitude and attempted to determine the influence of the proximity of a trap to a reef on the catch.

MATERIALS AND METHODS

Two separate studies conducted in the same location and at the same time of year, but three years apart. The first study was of two weeks duration in August - September 1981. A tropical storm during the second week of this study drastically reduced total observation time. The second study (August 1984) consisted of two one-week studies run consecutively. Over the two study periods, 431 individual trap contents counts were made.

The study site was an inshore location on the north shore of Bermuda, around Gibbet Island at the mouth of Flatts Inlet (Fig. 1). Water depth was 5-7m at high tide. The site consisted of 3 patch reefs (5-8m in diameter) surrounded by a level sandy bottom and extensive Thalassia beds.

The experimental design was to have traps of identical structural dimensions but 3 different mesh sizes laid out on transects radiating out from the 3 patch reef (Fig. 1). These traps were placed at 3m, 20m and 50m from each patch reef with funnel entrances oriented away from the reef. All three transects were across beds of Thalassia, with the traps closest to the patch reefs (station A) were on sand.

The traps were made of galvanized reinforcing rod (6mm diameter) in the traditional arrowhead design. The dimensions were 120 x 120 x 60 cm. Hexagonal galvanized wire mesh (14 gauge) of 3 sizes was used. Mesh sizes, measured as the minimum opening between knots, were 3.8, 5.1 and 8.3 cm. A single door was fitted at the funnel end of each trap. The traps were all fitted initially with straight funnels. For the 1984 study, the funnels were modified and curved downward in the horseneck design. The dimensions of the inner funnel openings were approximately 25 x 16 ± 2cm in both studies.

The traps were positioned by divers and connected by a thin nylon rope for use during periods of poor visibility and at night. Observations of trap contents as well as detailed behaviorable observations were made at all hours of the day. Four dives were made at crepuscular periods and one at night. In the straight funnel study, two divers independently enumerated the trap contents of the same trap and compared results after surfacing. Correspondence between counts was generally very high. In the horseneck funnel study, only one diver censused each trap. This allowed much greater coverage of all the traps for behavioral observations. All the studies with the exception of the second week of the horseneck funnel study, were made using unbaited traps. The bait used consisted of a single plastic bag of small bait fishes (~ 2 kg) placed in the bottom of the trap. All of the bait was eaten in all of the traps in 1 - 2 days.

All traps were not observed for equal amounts of time. The 8.3 cm mesh traps had so few fish that little time was spent observing them. Different traps were observed opportunistically depending on the species present and ongoing behavior patterns.

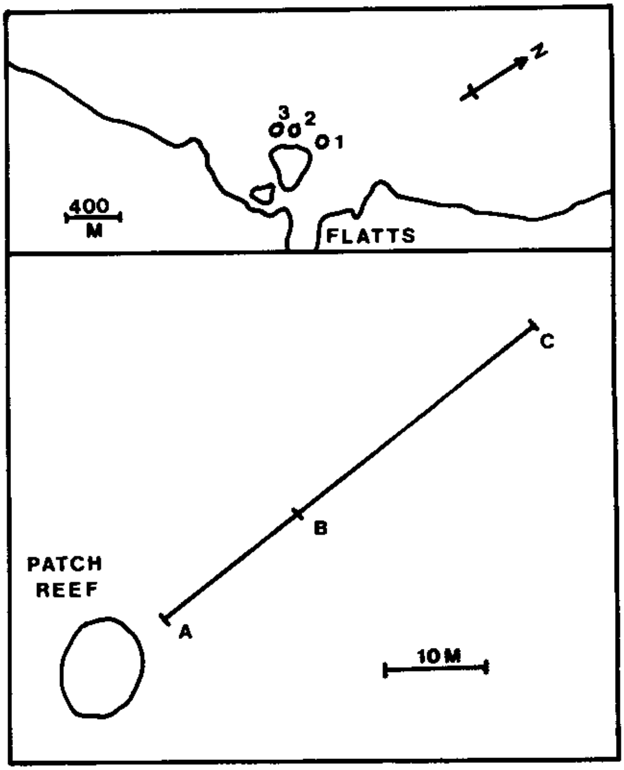

Figure 1. (Upper). Location of study site in Bermuda showing patch reefs 1, 2 and 3 (Lower). Outline of experimental design showing positions of fish traps (A, B, C) along transect.

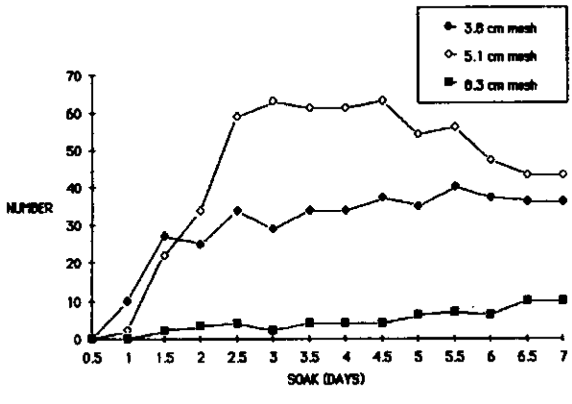

Figure 2. Plots of catch against soak for all species combined for unbaited traps of 3 mesh sizes with straight funnels.

RESULTS AND DISCUSSION

The results of the two studies are presented separately for convenience and because they took place three years apart. Data from both studies are combined in some sections and tables for comparative purposes.

Study 1 - Traps with Straight Funnels

This study was conducted over 14 consecutive days, but due to the passage of a tropical storm, diving operations were much reduced during the second week. As a result, most of the analyses of the data from this study are from the first 7 day period. This facilitated a comparison with the data from the second study which was run for the same time period.

A comparison of the ranked mean abundance of the species observed in traps of the three different mesh sizes (Table 1) reveals that many of the same species were taken in traps of each mesh size but that the 8.3 cm mesh traps caught small numbers of only 6 species. The mean number of individuals per species was highly variable. As *Acanthurus chirurgus* was not always distinguished from *A. bahianus* due to the large number of active individuals which were sometimes present, these two species are lumped under *Acanthurus* spp. No *A. coerulus* were observed in the traps at any time. Although sizes of fishes in the traps were estimated during observations, it was only possible to measure specimens at the termination of the study. Adequate samples to determine if there was a significant difference in the mean size between 3.8 and 5.1 cm mesh traps were available only for two species. *Lutjanus griseus* showed no significant difference ($t = 0.142$, $df = 22$, NS) while *Diplodus bermudensis* did ($t = 2.081$, $df = 57, p < .05$). The 5.1 cm mesh traps caught the larger fish.

Graphs of catch versus soak for traps of the three mesh sizes indicated marked differences (Fig.. 2). The catch built up rapidly in the first 2.5 days. The catch in the 5.1 mesh traps at this time was about double that of the 3.8 cm mesh traps, but by 6-7 days, the catch was similar. The 8.3 cm mesh traps caught only small numbers of fish. We believe that this levelling off after a rapid build-up is due primarily to increased escapement through the straight funnel and to a learning behavior which occurs amongst trapped fishes.

Graphs of the catch versus soak of the four most abundant species in the 3.8 and 5.1 cm mesh traps show several interesting features. The fluctuations in numbers between some consecutive censuses indicate that a number of fish species are both entering the traps and escaping. A good example of this is *Lutjanus griseus* in the 3.8 cm mesh traps (Fig. 3). The rapid build-up of *Diplodus bermudensis* in the 5.1 cm mesh traps over the first 2.5 days is followed by a steady decline in the number to day 7 (Fig. 4). At day 3-4 escapement appeared to be the main factor but, heavy mortality in the trap in subsequent days, was more important in the continued decline. This species was found to be the most susceptible to secondary infections following

Table 1 - Ranked mean abundance and range for species observed over 7 day soak (N=11 observation periods) for traps with straight funnels, data pooled by mesh size.

mesh size

3.8 cm			5.1 cm			8.3 cm		
Species	Mean	Range	Species	Mean	Range	Species	mean	range
Lutjanus griseus	12.6	(8-18)	Diplodus bermudensis	25.0	(15-40)	Rhinosomus triqueter	2.0	(1-6)
Kyphosus sectatrix	8.7	(8-12)	Haemulon sciurus	12.8	(2-21)	Acanthurus spp.	0.8	(1)
Haemulon sciurus	4.8	(2-8)	Lutjanus griseus	2.4	(1-6)	Calamus calamus	0.7	(1)
Diplodus bermudensis	1.5	(1-3)	Rhinosomus triqueter	2.4	(1-5)	Acanthostracion quadricornis	0.4	(1)
Holocentrus ascensionis	1.3	(1-3)	Scarus croicensis	1.0	(1-2)	Caranx hippos	0.4	(1)
Haemulon flavolineatum	1.0	(1)	Acanthurus spp.	0.8	(1-2)	Haemulon album	0.1	(1)
Calamus calamus	0.4	(1-2)	Holacanthus isabelita	0.6	(1-2)			
Haemulon album	0.4	(1-2)	Calamus calamus	0.5	(2)			
Acanthurus spp.	0.4	(2)	Haemulon album	0.2	(1)			
Lutjanus synagris	0.2	(1)	Holocentrus ascensionis	0.1	(1)			
Chaetodon ocellatus	0.1	(1)						
Holacanthus isabelita	0.1	(1)						
Rypticus saponaceus	0.1	(1)						
Total No. of species		13		10			6	
Mean abundance - total no. individuals		31.4		45.8			4.4	

Table 2 - Summary of behavioural events (per 10 hours of observation): ingress (in), escapement (es) and escapement/ingress of the same fish (e/i). Traps with straight funnels observed over 14 day soak period. Data pooled over mesh size. No observations on day 11 due to passage of tropical storm.

Species	Event	1	2	3	4	5	6	7	8	9	10	11	12	13	14	Total
								SOAK (DAYS)								
H. isabelita	es	-	-	4.1	-	-	4.3	-	-	-	-	-	-	-	-	8.4
	e/i	-	-	-	-	-	-	-	-	-	-	-	-	10.0	-	10.0
H. ascensionis	e/i	-	-	-	4.4	-	-	-	-	-	-	-	-	-	-	4.4
L. griseus	in	9.0	-	-	-	8.9	4.3	-	13.3	-	-	-	-	-	-	35.5
	es	-	12.9	8.3	8.9	26.7	8.6	20.0	26.7	5.7	17.3	-		30.0	-	165.1
	e/i	3.0	-	-	13.3	4.4	8.6	-	-	-	-	-	-	-	-	29.3
Acanthurus spp.	in	-	-	-	-	-	-	-	53.3	-	-	-	-	-	8.0	61.3
	es	-	-	-	-	-	4.3	-	26.7	-	-	-	-	-	-	31.0
	e/i	-	-	-	-	-	-	10.0	-	5.7	-	-	-	10.0	-	25.7
D. bermudensis	in	-	-	-	-	4.4	-	-	-	-	-	-	-	-	-	4.4
	es	-	4.3	-	4.4	8.9	4.3	-	-	-	-	-	12.0	20.0	-	53.9
	e/i	-	-	-	-	-	-	-	-	-	-	-	-	10.0	-	10.0
H. sciurus	in	-	-	-	-	4.4	-	-	-	-	-	-	-	-	-	4.4
	es	-	-	8.3	4.4	-	-	-	-	-	-	-	-	10.0	-	22.7
	e/i	-	-	-	-	4.4	4.3	10.0	-	5.7	-	-	-	20.0	16.0	60.4

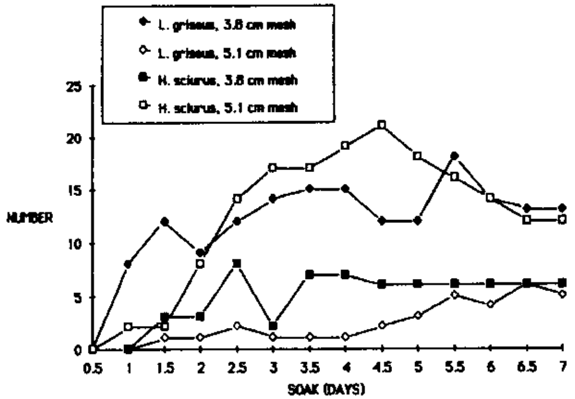

Figure 3. Plots of catch against soak for Lutjanus griseus and Haemulon sciurus in unbaited traps of 2 mesh sizes with straight funnels.

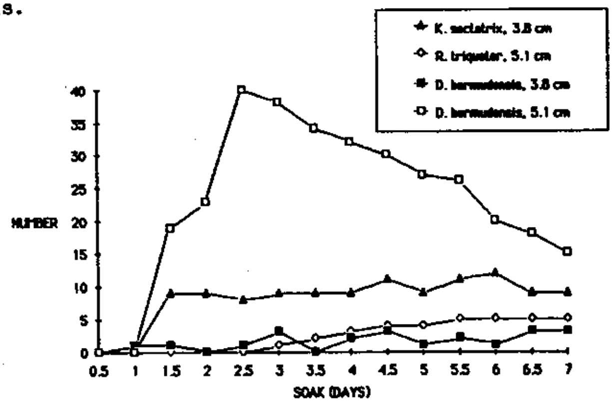

Figure 4. Plots of catch against soak for Kyphosus sectatrix, Rhinosomus triqueter and Diplodus bermudensis in unbaited traps of 2 mesh sizes with straight funnels.

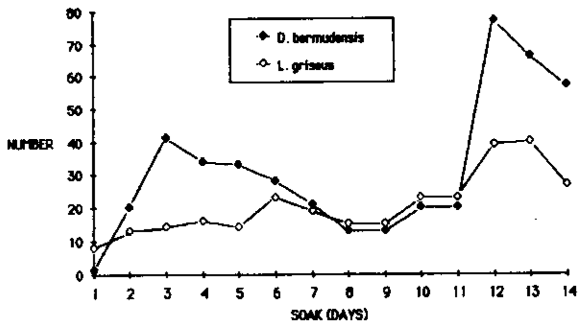

Figure 5. Plots of catch against soak for Diplodus bermudensis and Lutjanus griseus showing increases in catch abundance following the passage of a tropical storm on day 11. Data are pooled for unbaited traps with straight funnels of all 3 mesh sizes.

injury or abrasion. The almost constant number of *Kyphosus sectatrix* over the 7 day soak (Fig. 4) suggests that they were amongst the most inept species at learning to escape. They were observed to swim constantly in a school during the study.

Behavioral Dynamics

Table 2 documents the three classes of behavioral events recorded with respect to the movement of fish in and out of the traps over the 14 day study period. It is noteworthy that a considerable amount of escapement was recorded as early as days 2 to 4 indicating that most of the species were able to find their way out through the straight funnel relatively quickly. The escapement/ingress of the same fish is interpreted to indicate that the fish are using the trap as a shelter site and are able to come and go at will. All six species listed in Table 2 exhibited this behavior at least once. The species most adept at escaping was *L. griseus* several individuals of which were observed leaving the trap together on occasion. The comparatively few ingress events observed may indicate that there is more ingress into the traps at night.

Storm Passage

During the second week of the study, a tropical storm passed close to Bermuda and diving observations were limited over days 10 to 12. No diving was possible on day 11 because of very rough seas over the study site. On day 12 we recorded marked increases in the number of *D. bermudensis* and *L. griseus* (Fig. 5). These dramatic increases were not seen in the other species. We believe that this phenomenon may be the result of wave action disturbing the surface layer of sediments, thereby exposing large numbers of small invertebrates on the sand flats and in the seagrass beds. These are the primary feeding areas of both of these species and it is probable that these fish were more active during this period of abundant prey and that the increased catch rate was a reflection of this increased activity.

Study 2 - Traps with Horseneck Funnels

Two seven day studies were conducted with these traps. The first week unbaited traps were used while for the second week, a single bag of bait was placed in each trap after the traps were emptied. The traps were left in the same positions.

The 3.8 and 5.1 cm mesh unbaited traps caught a large number of fish over the 7 days soak while the 8.3 cm mesh traps caught no fish at all. Table 3 lists the rank order mean abundance of all the species caught; the total number of species and the mean abundance of all individuals were very similar in both mesh sizes. The four most abundant species were the same in both mesh sizes. A comparison of the species taken in the baited traps with those from unbaited traps reveals that almost all the same

Table 3 - Ranked mean abundance and range for species observed over 7 day soak (N = 14 observation periods) for unbaited traps with horseneck funnels, data pooled by mesh size. No fish observed in 8.3 cm mesh traps.

Mesh size					
3.8 cm			5.1 cm		
Species	mean	range	Species	Mean	Range
H. sciurus	31.8	(3-58)	H. sciurus	21.1	(6-31)
L. griseus	24.1	(13-35)	D. bermudensis	20.4	(1-36)
Acanthurus spp.	17.4	(1-35)	Acanthurus spp.	13.5	(4-26)
D. bermudensis	4.8	(4-6)	L. griseus	12.0	(3-22)
H. ascensionis	2.8	(2-5)	Balistes capriscus	5.8	(1-9)
H. flavolineatum	1.4	(1-2)	R. triqueter	4.5	(1-8)
Balistes capriscus	0.9	(1)	C. calamus	2.4	(1-4)
Mycteroperca bonaci	0.9	(1)	C. ocellatus	1.6	(1-2)
Petrometopon cruentatum	0.8	(1)	H. album	0.9	(1-2)
Sparisoma chrysopterum	0.8	(1-3)	S. croicensis	0.9	(1-2)
Echeneis naucrates	0.7	(2)	Holacanthus isabelita	0.6	(3)
S. croicensis	0.7	(1-2)	H. ascensionis	0.6	(1.2
R. triqueter	0.6	(1)	Sparisoma viride	0.5	(1)
C. ocellatus	0.5	(1-2)	Lachnolaimus maximus	0.4	(1-2)
C. calamus	0.1	(1)	Stephanolepis hispidus	0.4	(1)
Gymnothorax moringa	0.1	(1)			
H. album	0.1	(1)			
Total no. species	17			15	
Mean abundance - total no. individuals	88.5			85.6	

species were captured but that there were some notable differences. The numbers of D. bermudensis were considerably higher in baited traps of both mesh sizes and Lagodon rhomboides was only recorded in baited traps. In addition, the numbers of L. griseus were considerably lower in the baited traps.

Adequate sample sizes were available for four species to test for significant differences in mean size between the two mesh sizes. As in the first study, specimens could only be measured at the end of the study. In three of the four species, there were no significant differences: H. sciruus ($t = 0.093$, $df = 54$, NS), L. griseus ($t = 1.078$, $df = 22$, NS), Acanthurus spp. ($t = 1.073$, $df = 61$, NS). As in the straight funnel study, D. bermudensis showed a significant difference in mean size between the 3.8 and 5.1 cm mesh traps ($t = 6.263$, $df = 152$, $p < .001$) with the larger mesh catching the larger fish.

A comparison of catch versus soak for all species combined in traps with horseneck funnels shows that catch is very similar in the 3.8 and 5.1 cm mesh traps (Fig. 6) and the numbers of fish are considerably higher than in traps with straight funnels (Fig. 2). The 8.3 cm mesh unbaited traps caught no fish at all during the 7 day soak and only 3 large specimens of two species when traps were baited. The catch in both smaller mesh sizes increases steadily over the 7 day soak period. From our observations, we believe that this is due largely to the fact that there is generally little escapement from these traps over this period. In addition, conspecific attraction plays an important role in keeping ingress rates high. We have been unable to verify Munro's (1974) assertion that a progressively greater number of fish escape during each successive day of soak as we only observed for a one week period while he generally observed for 14-16 days.

An examination of catch versus soak of the four most abundant species recorded in traps with horseneck funnels indicates similar trends in almost all cases. The rate of build-up of catch of L. griseus and H. sciurus in the 3.8 cm mesh traps appears to be greater than in the 5.1 cm mesh traps (Fig. 7), but the general trend is for a steady increase in all four species. The decline in L. griseus (3.8 cm mesh) at day 6 is probably the result of escapement. Three of the four graphs in Figure 8 indicate a clear build-up over the 7 day soak, while the D. bermudensis (3.8 cm mesh) remained virtually constant over the soak.

Behavioral Dynamics

Table 4 documents the behavioral events recorded with respect to ingress and escapement in traps with horseneck funnels over a 7 day soak. Most striking is the small number of escapement events observed. Horseneck funnels were very effective in reducing escapement amongst the species sampled in our study. It is interesting to note that Acanthurus spp. were behaviorally the most active and the only species observed in which the same fish escaped and then re-entered the trap. These species are well adapted to living around and within complex reef morphology

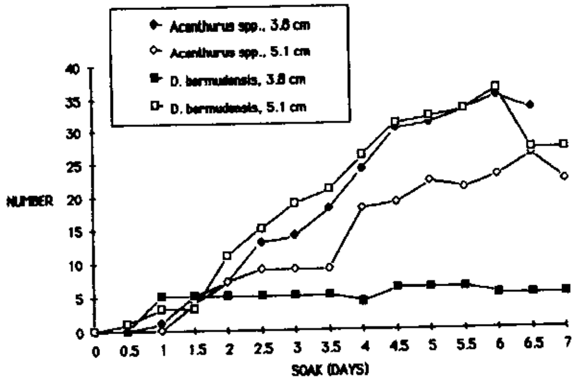

Figure 6. Plots of catch against soak for all species combined in unbaited traps of 2 mesh sizes with horseneck funnels.

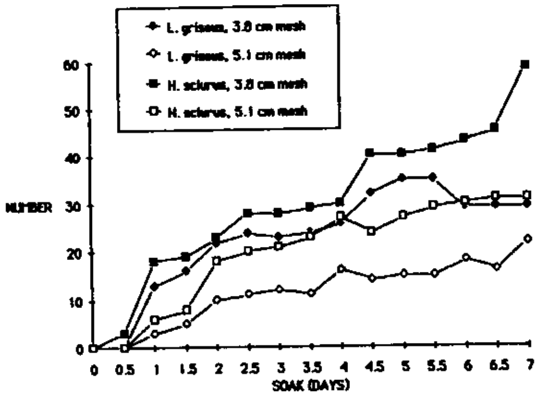

Figure 7. Plots of catch against soak for Lutjanus griseus and Haemulon sciurus in unbaited traps of 2 mesh sizes with horseneck funnels.

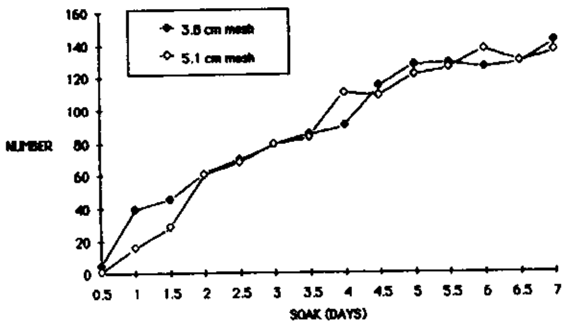

Figure 8. Plots of catch against soak for Acanthurus spp. and Diplodus bermudensis in unbaited traps of 2 mesh sizes (3.8 and 5.1 cm) with horseneck funnels.

Table 4 - Summary of behavioural events (per 10 hours of observation): ingress (in), escapement (es) and escapement/ingress of the same fish (e/i). Traps with horseneck funnels observed over a 7 day soak period, either unbaited (u) or baited (b). Bait gone from all traps within 2 days. Data pooled over mesh size.

Species	Bait	Event	Soak (days) 1	2	3	4	5	6	7	Total
H. isabelita	b	in	5.2	-	-	-	-	-	-	5.2
H. ascensionis	u	in	-	-	-	2.8	3.5	-	-	6.3
L. griseus	u	in	-	-	3.7	2.8	-	-	-	6.5
Acanthurus spp.	u	in	-	-	-	-	3.5	-	4.6	8.1
	b	in	-	-	4.8	3.6	12.0	-	12.4	32.8
		es	-	-	-	3.6	-	-	-	3.6
		e/i	-	-	-	-	4.0	-	4.1	8.1
D. bermudensis	b	in	10.4	-	-	-	-	-	-	10.4
H. sciurus	u	in	-	-	3.7	-	-	-	-	3.7
	b	in	-	-	-	3.6	-	-	-	3.6
		es	-	-	-	-	-	-	4.1	4.1

Table 5 - Summary of observations by divers of ingress and escapement of fish (events per 10 hours) through the funnel of 3.8 cm and 5.1 cm mesh traps. Traps were fitted with either straight (st) or horseneck (hn) funnels and were unbaited unless indicated by a "b" (baited) suffix. All traps were observed over a 7 day soak period. Species ranked by activity index value (see text for details).

Activity index	Species	Funnel	Ingress 3.8	5.1	Escapement 3.8	5.1	Escapement and ingress (same fish) 3.8	5.1
1.46	H. isabelita	st	-	-	-	1.3	-	-
		hn-b	-	0.6	-	-	-	-
0.50	H. ascensionis	st	-	-	-	-	0.6	-
		hn	0.6	1.2	-	-	-	-
0.39	L. griseus	st	3.8	-	10.6	0.6	3.8	-
		hn	1.2	-	-	-	-	-
0.27	C. ocellatus	st	0.6	-	-	-	-	-
0.23	S. croicensis	st	-	0.6	-	-	-	-
0.19	Acanthurus spp	st	-	-	-	0.6	-	0.6
		hn	-	0.6	-	-	-	-
		hn-b	2.5	2.5	-	0.6	-	1.2
0.14	K. sectatrix	st	-	-	1.2	-	-	-
0.10	D. bermudensis	st	-	0.6	0.6	2.5	-	-
		hn-b	1.3	-	-	-	-	-
0.09	H. sciurus	st	0.6	-	-	1.9	1.3	0.6
		hn	0.6	-	-	-	-	-
		hn-b	-	0.6	-	0.6	-	-

and may therefore learn their way in and out of horseneck funnels more quickly than other species. However, we made 11 observations of Acanthurus spp. which entered horseneck funnels but did not subsequently enter the trap, possibly because they did not see the funnel opening. It appears that D. bermudensis was attracted into the trap on day 1 (Table 4) because it was baited. Our observations suggest that most fish do not feed on the bait after first entering the trap, but rather start to search around the trap and ignore the bait. The small juveniles which we observed feeding on the bait probably attract the larger predators into the trap.

A comparison of the behavioral events observed in traps with straight funnels versus those with horseneck funnels is summarized in Table 5. The species are ranked by an activity index. This was derived by dividing the total number of behavioral events recorded for the species in each study by the mean abundance of that species during the study. In examining this assemblage of species, it may be seen that there are more total behavioral events (in each of the three categories) occurring in the 3.8 cm mesh traps than in the 5.1 cm mesh traps, regardless of funnel type. The reasons for this are not obvious, but it may have to do with the presumably stronger visual image presented by the smaller mesh traps allowing the fish to better perceive the funnel opening when compared with traps constructed of the larger mesh. The very small number of fish caught in the 8.3 cm mesh taps may relate to the fact that they provide a relatively weak visual image and many fish may simply not respond to their presence in the same way as the smaller mesh traps.

Table 6. Summary of behavioral events (ingress and escapement per 10 hours of observation) by funnel type (st = straight and hn = horseneck) and mesh size. Data pooled across all species

	Funnel	
Mesh (cm)	st	hn
3.8	23.1	6.2
5.1	9.3	7.9
Total	32.4	14.1

Table 6 provides a summary of all behavioral events by funnel type and mesh size. The total behavioral activity in the straight-funnelled traps is considerably greater than in the horseneck traps, particularly in the 3.8 cm mesh size. This result is to be expected considering the data presented earlier in the individual studies. There is comparatively little difference in the two values in the horseneck category.

Distance of Traps From Reef

High and Beardsley (1970) concluded that the location of a trap in relation to a reef was an important factor determining the number and species of fish caught. Hartsuijker and Nicholson (1981) used the presence and abundance of small grouper species in trap catches as indicators of the proximity of traps to reefs and indicated that catches were best when traps were nearest to the reef. They also pointed out that small individuals made up a larger percentage of the catch when traps were nearer to a reef (smaller home range). Our experimental design incorporated this aspect of the dynamics of trap operation by placing traps of the same mesh size along a transect at 3, 20 and 50m from a patch reef (stations A, B and C respectively).

Table 7. Mean abundance of dominant species and mean total number of fish observed over 7 day soak with respect to distance from a reef. Data pooled by mesh size and funnel type for individual species. Stations and distances from reef, A = 3m, B = 20m, C = 50m

	Station		
Species	A	B	C
H. sciurus	23.41	6.37	40.43
L. griseus	29.52	4.50	17.04
Acanthurus spp.	25.46	0	7.26
D. bermudensis	10.11	31.53	10.41
All species - traps with straight funnels	42.8	26.6	8.4
All species - traps with horseneck funnels	68.6	26.6	77.4

Table 7 gives the mean abundance of the four dominant species and the mean total number of fish in the traps of the two funnel types at the three stations. For L. griseus and Acanthurus spp., the mean abundance is greatest closest to the reef (station A) while for H. sciurus it is greatest at station C. The typical behavior pattern followed by grunts and snappers is to shelter on or near the reef during daylight hours and remain relatively inactive. As night falls, these species leave the shelter of the reef, frequently in groups, and move out over the seagrass beds to feed individually. All of the traps at stations B and C were located on seagrass beds and therefore the abundance of H.

sciurus and L. griseus at station C is to be expected. Our observations at crespuscular periods indicate a movement of the above species out from the patch reefs onto the seagrass beds where they become entrapped while feeding at night.

The mean abundance of all species from straight-funnelled traps shows the highest value nearest the reef and the lowest at station C (Table 7). This is in accordance with the findings of Hartsuijker and Nicholson (1981), however, the pattern of mean abundance of all species in horseneck-funnelled traps is different. The highest value is at station C with a somewhat lower value at A. We believe that this different pattern is probably due to the difference in catch build-up because of reduced escapement in horseneck traps. Haemulon sciurus is an important component of the total catch in these traps (Table 3) and considerable numbers of this species probably enter traps of both types at station C, but many subsequently escape from the straight-funnelled traps, thereby yielding lower mean abundance values in this trap type. Our sample sizes were inadequate to address the issue of changes in mean size of a species with respect to distance from a reef.

The probability of different species of fish entering traps is related to their home range and their behavior. Some species have restricted home ranges and rarely move far away from the reef during any part of their activity cycle, while others may move considerable distances, usually at night, to feeding grounds. Table 8 shows the mean abundance of four reef associated species with respect to distance from a reef. Three of the four species, including the squirrelfish, H. ascensionis, show the expected pattern of abundance, with the highest values being at station A. High and Beardsley (1970) remarked on the much increased catch of squirrelfish when a trap was moved from 15 feet to only 5 feet from the reef.

Table 8. Mean abundance of reef-associated* species observed over 7 day soak with respect to distance from a reef. Data pooled over mesh size and funnel type. Stations and distances from reef, A = 3m, B = 20m, C = 50m

	Station		
Species	A	B	C
Chaetodon ocellatus	1.7	-	2.1
Holacanthus isabelita	1.2	-	0.5
Holocentrus ascensionis	2.4	0.3	0.1
Scarus croicensis	2.3	-	0.1

* Reef associated species as determined by the authors during this study.

Mesh Size Selection

Although the data are insufficient to adequately address the effects of mesh size on size at first capture, it is clear that this is not simply a function of body depth. Size at recruitment is regulated ecologically and behaviorally. The fact that the 2 smaller meshes caught more species, many individuals of which were physically large enough to be retained in the large mesh trap, points out the importance of the way in which fish perceive traps of different mesh sizes. None of these individuals were taken in the large mesh trap. Analyses using body depth and mesh size yield estimates of retainable size but cannot be used to determine the size of first recruitment unlike active fishing methods such as trawling or seining. Passive gear such as traps depend on the behavioral activity of the fish in response to the trap and its occupants.

It is perhaps worthy of note that, from the divers' point of view, the larger mesh size traps present a much diminished visual image when compared with the smaller mesh sizes.

Conspecific Attraction

Our observations during these studies strongly suggest that conspecific attraction is a major factor affecting the species composition and abundance of fish in traps. Munro et al. (1971) indicate the importance of conspecific attraction in increasing ingress rates of species. We have found repeatedly that one to three species usually comprise the great majority of the catch in a trap and that increments in abundance of a species between consecutive observations are often more than one, suggesting the possibility of group behavior. Table 9 lists in rank order the species observed exhibiting conspecific attraction, i.e., responding behaviorally to trapped conspecifics. The most common behavior was when two fish swam side by side on either side of the mesh. We have often observed a fish swimming out from the reef to a trap at station A and "schooling" with a conspecific. This must often result in the fish on the outside being attracted around to the funnel entrance and then subsequently entering, although we have only observed this particular sequence four times. This may be the reason that Munro et al. (1971) found S-traps more effective. We have also observed an L. griseus being attracted out of a trap by a conspecific as well as following a conspecific into a trap. It is clear that many reef fish species exhibit conspecific attraction with individuals in traps, but as Table 9 indicates, the strength of this behavior varies widely between species. It should be noted that the ranking of the species by activity index may sometimes give a distorted impression because it is dependent on mean abundance values, but we consider this to be the most meaningful way of presenting these data. It is interesting to note that Acanthurus spp., which was amongst the most active species in terms of ingress and escapement, is also very active in conspecific behavior.

Interspecific Aggression

Relatively few instances of intra or interspecific aggression were actually observed, but there was visible evidence of aggression in several species. We observed two cases where an obviously injured fish was attacked by conspecifics which made rushes at it and appeared to nip at its flanks. This occurred with two species, Acanthurus chirurgus and H. sciruus.

Table 9. Species exhibiting conspecific behavior between individuals inside and outside the trap. Species ranked by activity index value. Data pooled over funnel type and mesh size for both studies

Species	Activity Index
Sparisoma chrysopterum	2.331
Acanthurus spp.	0.946
H. isabelita	0.691
H. flavolineatum	0.662
R. triqueter	0.503
L. griseus	0.416
B. capriscus	0.194
Lagodon rhomboides	0.192
H. sciurus	0.122
D. bermudensis	0.109

Balistes capriscus appeared to be the most aggressive species when trapped as it made numerous rushes at a wide range of species, often nipping at fins and flanks. It was observed to cause severe damage to several trap occupants including Lachnolaimus maximus and Scarus croicensis. The attempts to avoid these attacks caused considerable abrasion damage through collisions with the mesh. Lagodon rhomboides was observed biting at the fins of L. griseus on several occasions.

The grouper Mycteroperca bonaci often lunged at other trapped species by moving his head laterally in a sweeping motion. The other trap occupants had a tendency to aggregate on the side of the trap opposite from the grouper.

Trap Mortality

We found that many of the species which entered our traps adopted a behavior which we have termed "butting." In seeking to pass through the mesh, they swam into it in the long axis of the hexagonal mesh thus abrading the nape. This behavior was repeated many times over, usually after backing away then swimming forward again into the mesh at a different site. This behavior caused severe abrasion of the nape and often laceration of pectoral and pelvic fins. These areas became sites of secondary infection by fungi and/or bacteria. These infections appeared to be the primary cause of mortality in several species including D. bermudensis, Scarus spp., Sparisoma spp. and H. sciurus. The species which succumbed the quickest were the scarids, Scarus croicensis and Sparisoma chrysopterum. They were observed to be dead or dying within 2-3 days of their entry into the trap. D. bermudensis started to suffer mortality in the traps at day 6-7 of the soak. One large jack, Caranx hippos, in a 8.3 cm mesh trap "beat" itself to death against the mesh over a period of 4 days. Several fish were observed to actually gill themselves in the mesh of the trap in an attempt to escape. They hung there after dying for two days before being eaten. We recorded a number of species feeding on dead carcasses in traps. These included B.capriscus, H. flavolineatum, A. chirurgus, R. triqueter and Echineis naucrates. The latter species appeared to enter the traps specifically to feed on dead carcasses, usually D. bermudensis. In general, it appeared that carcasses remained in the traps, often for 2-3 days, before being consumed. It is probable that the presence of aggressive species such as B. capriscus will increase trap mortality in larger fish, i.e., L. macximus. In areas where such aggressive species are abundant it is quite likely that the optimum soak time for traps will be shorter than in areas where they are rare.

SUMMARY

This study has focussed on the behavioral dynamics of reef fishes in relation to fish traps as well as examining several factors considered to be important in determining trap catches and catch rates. We have not attempted to investigate the interaction of a number of factors which affect trap catches as was done by Stevenson and Stuart-Sharkey (1980) in Puerto Rico because our data set was inadequate for these types of analysis.

One of the conclusions of our study has direct, practical application to the commercial fishery. Antillian fish traps fitted with straight funnels will be less wasteful if left for long soak times as many trapped species learn to escape and will not die in the traps. Such traps are said by fishermen to capture fish quickly but they must be hauled after short soaks in order to have good catches. Traps with horseneck funnels appear to build-up catches to higher levels than those with straight funnels, principally due to reduced escapement, but if left for long soaks, many of the trapped fishes may become injured and infected and may subsequently die. They are therefore lost to the fishery and are a waste of the resource. Traps with horseneck funnels will undoubtedly increase the impact of lost traps on fish stocks.

Our results suggest that the management of fish trap fisheries by simple mesh size regulations will not lead to the optimum utilization of multi-species fishery resources. Factors such as trap design (including funnel shape) and soak time must be included to ensure the best use of the resource. Management decisions should incorporate different trap fishing strategies and their effects on catch composition. High catch rates alone will not provide the best economic return if the trap is filled with low-valued species. Finally, our studies indicate that there is a large interspecific variation in behavior which strongly affects catches and catch rates. Conspecific attraction is an important factor in determining catches and is probably largely responsible for the great inter-trap variability in catch which is commonly seen in this fishery. A better understanding of the interspecific interactions of the species taken in traps will enhance our ability to manage this fishery.

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