Comparing Juvenile Catch Rates among Conventional Fish Traps and Traps Designed to Reduce Fishing Mortality on Juvenile Reef Fishes

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ABSTRACT

The trap fishery in Barbados, which targets nearshore coral reef species, are believed to be overexploited, particularly along the west and south coasts. In recognition of this, the recent Fisheries Management Regulations (1998) in Barbados set a minimum mesh size for fish traps at 3.18 cm (1¼"), and the Fisheries Management Plan (2001-2003) recommends that this be increased to 3.8 cm (1½") mesh over a two-year period to reduce the mortality of juvenile reef fishes. However, fishers have expressed concerns that not only will catch rates be significantly reduced by using a larger mesh, but that the 1½" mesh wire is too soft for trap construction, such that the fishable life of a trap will be much reduced.

Alternative designs to increasing the mesh size of the entire trap have been tested in previous studies, and have been partially successful in reducing mortality of immature fishes. These include the use of: vertical escape slits in conventional traps which reduce the mortality of immature, deep-bodied fishes; and a single large mesh (3.8 cm) panel incorporated into commercial traps which reduces the mortality of immature, round-bodied fishes. This study tests an alternative design (that includes both a vertical escape slit and a large mesh panel), and compares the juvenile catch rates, the size of juveniles captured, and the species composition of the juvenile catches with conventional small mesh (3.18 cm) traps and large mesh (3.8 cm) traps.

Experimental traps caught fewer juvenile reef fish than conventional traps, but significantly more than large mesh traps per haul. Weight of catch per haul also differed significantly among traps showing the same pattern as number of fish. Individual size of juveniles (by fork length, body depth and weight) also differed significantly among traps with mean size of fish becoming increasingly large from conventional to experimental to large mesh traps. All traps caught primarily deep-bodied juveniles and relative abundance of key species in the juvenile catches did not differ significantly among trap designs.

Both the alternative trap designs reduced juvenile catch rates and increased the mean size of juveniles caught, compared with the conventional traps. Experimental traps did not reduce catch rates as sharply as the large mesh traps and were

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considered much stronger by fishers than the large mesh traps. As such they would seem to be a more acceptable alternative than the large mesh traps. However, unlike the large mesh traps, experimental traps failed to reduce the proportion of juveniles in the catch. Reduced juvenile catches were simply a result of reduced catches overall, with potentially high short-term economic impacts on fishers. Reducing gear efficiency does not adequately address the management goal of reduced levels of juvenile mortality with minimum impact on fishers.

KEY WORDS: Fish traps, juveniles, mesh size

Camparación de Tasas de Captura entre Trampas de Peces Convencionales y Trampas Diseñadas para Reducir la Mortalidad de Peces Juveniles

Se cree que la pesca de trampa en Barbados, la cual esta dirigida hacia las especies de coral de aguas costeras, sobre-explota ciertas poblaciones de peces de arrecife, especialmente en las costas del sur y oeste de la isla. Como consecuencia, las recientes Regulaciones de Gestión de Pesca (1998) de Barbados limitan el tamaño de la malla de las trampas a un mínimo de 3.18 cm (1¼"), y el Plan de Gestion de Pesca (2001-2003) recomienda que esta talla de malla sea aumentada a una 1½" en un plazo de dos años con vistas a reducir la mortalidad de peces de arrecife juveniles. Sin embargo, los pescadores han manifestado su preocupación de que no sólo la tasa de captura de peces se vera reducida significativamente debido al uso de esta malla mas grande, sino que tambien, el alambre de la malla de 1½" es demasiado blando para la construcción de trampas, disminuyendo por tanto la vida de estas.

Estudios anteriores has puesto a prueba varios diseños en busca de una alternativa al aumento de la talla de malla de toda la trampa, y han demostrado ciertos niveles de reducción de la mortalidad de peces inmaduros. Estos diseños incluyen el uso de: salidas de escape vertical en trampas convencionales que reducen la mortalidad de peces inmaduros de cuerpos profundos; un unico panel de malla de talla grande (1½ ") integrado en las trampas comerciales que reduce la mortalidad de peces inmaduros de cuerpos redondos. Este estudio pone a prueba un diseño alternativo que incluye una salida de escape vertical y un panel de malla de talla grande integrado en una trampa convencional, y compara las tasas de captura, la composición de las especies pescadas, y la proporción de especies juveniles pescadas con trampas convencionales (1¼") y trampas de malla de talla grande (1½"). Esta comparación es usada para evaluar la eficacia de los distintos diseños alternativos de trampas de peces con vistas a reducir la mortalidad de peces juveniles. Esta comparación tambien se extiende a la vida de los diseños de las trampas y al valor economico de las capturas para evaluar el impacto economico del diseño alternativo sobre el pescador.

PALABRAS CLAVES: Pesca de trampa, malla de las trampas, la tasa de captura

INTRODUCTION

Nearshore fishery resources of the Caribbean are of enormous social and economic importance to low-income coastal communities, and contribute significantly to food security in small island states. However, the widespread, largely unregulated use of fish traps has lead to the overexploitation of reef fish resources in many countries throughout the Caribbean (Munro 1983, FAO 1993, Mahon and Hunte 2001) especially around islands with narrow shelves (Appeldoorn et al. 1987). Over-fishing, where it has occurred, has been attributed to the combined effects of excess fishing effort and trap mesh sizes that are too small, resulting in high mortality of juveniles and a loss of long-term potential yield (Sary et al. 1997). Furthermore, reefs throughout the region are also suffering from habitat degradation and reef fish catches are now characterised by low yields, small mean size-classes, and a scarcity of larger species (Spalding et al. 2001). As such, the trap fisheries of the region are in urgent need of rehabilitation management (FAO 1993).

The trap fishery in Barbados is no exception. It provides a direct source of income and employment for an appreciable number of fishers and other persons in the coastal communities, and is an important source of protein, particularly during the pelagic fishing "off season" (July – October) (Barbados Fisheries Division 2001).

Management of Reef Fish Resources

Regulatory management approaches that deal with over-fishing of multi-species reef populations include: marine protected areas, that prevent fishing; fish size limits, considered unenforceable in most circumstances; effort limitation, an approach that may be politically untenable due to the open access nature of the resource; and trap mesh size regulation, which is considered to be the most feasible approach despite its limitations (Mahon and Drayton 1990). A minimum mesh size is indeed one of the most popular management measures for trap fisheries in the Caribbean (Mahon and Hunte 2001).

Studies on fish trap mesh selectivity show that mesh size is a determinant of catch rates and the size at which fish recruit to traps (Munro 1983, Robichaud et al. 1999). Comparative fishing studies indicate that increasing mesh size not only results in an overall reduction of catch per trap, but catches will consist of significantly bigger fish and a smaller proportion of juvenile fish than smaller mesh traps (Rosario and Sadovy 1991, Sary et al. 1997, Robichaud et al. 1999).

In recognition of this, the recent Fisheries Management Regulations (1998) in Barbados set a minimum mesh size for fish traps at 3.18 cm (1¼"), and the Fisheries Management Plan (2001-2003) recommends that this be increased to 3.8 cm (1½") mesh over a two-year period, to reduce the mortality of juvenile reef fishes. Implementation of an increase in mesh size has been delayed as fishers have expressed concerns that not only will catch rates be significantly reduced by using a larger mesh, but that the 3.8 cm mesh wire is too soft for trap construction, reducing the fishable life of a trap. As such, the Barbados Fisheries Division is interested in exploring alternative trap designs that will reduce growth over-fishing

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by traps, while at the same time minimising the economic effects on fishers.

Alternative Designs

One possible alternative to increasing mesh size of the entire trap is the inclusion of a single large mesh panel within a conventional small mesh trap. This has recently been tested by Robichaud et al. (1999) and was successful in reducing the proportion of immature, round-bodied fish species retained by the trap. Another alternative is the inclusion of vertical escape slits in conventional small mesh fish traps. This has recently been tested in the British Virgin Islands and Jamaica, and was successful in reducing the proportion of immature deep-bodied fish caught (Munro et al. in press).

Study Objectives

In this study we investigated an alternative trap design that incorporates the two features previously tested separately. The new design included a single large mesh panel (after Robichaud et al. 1999) and a single vertical escape slit (after Munro et al. in press) built into a conventional small mesh trap. The rationale for this design was to reduce the proportion of immature fish of both deep- and round-bodied species, whilst retaining the strength and visual image of the conventional small mesh trap.

The primary objective of the study was to investigate whether this alternative experimental design is more effective than the currently recommended large mesh trap for achieving the management objective of reduced juvenile mortality. In judging 'effectiveness' of the trap designs, both the degree to which the capture of immature fish is reduced, and the degree of unnecessary hardship to fishers (through unintended reduction in catch rates of larger individuals or reduction in the fishable life of traps) will be considered. A secondary objective was to integrate the participation of the fishing stakeholders within the study.

METHODS

Public meetings coordinated by the Barbados National Union of Fisherfolk Organisations (BARNUFO) were held to inform, as well as encourage participation in this study.

Trap Design

Three trap designs and a total of 12 traps (four of each design) were used in the study. All traps were of the Antillean arrowhead type with a single horse-neck funnel (the most common type of trap used in Barbados) and were constructed with the assistance of a local fisher appointed by the Barbados Fisheries Division. All traps measured 0.61 m (2 ft) in height, 1.52 m (5 ft) in width, and 1.22 m (4 ft) in length, giving a total volume of 1.13 m^3. All traps were made of galvanised hexagonal mesh wire (chicken wire) supported by a frame of wooden sticks nailed and strapped together with wire. All traps were outfitted with a 15.24 x 27.94 cm (6 x 11") lead weighted escape door, fastened shut with biodegradable hemp string, as required by the current 1998 Fisheries Management Regulations (Selliah et al. 2000). Traps differed from one another only in design details.

Conventional small mesh traps were constructed with 3.18 cm wire mesh with a maximum horizontal aperture of 4.2 cm. Large mesh traps were identical to the conventional traps, but were constructed with 3.8 cm wire mesh with a maximum horizontal aperture of 5.9 cm. Experimental traps were identical to conventional traps except that they were outfitted with both a single escape slit and a single large mesh panel (Figure 1). The escape slit dimensions (7 x 2.5 cm) were selected on the basis of available information on body depth at maturity for a variety of deep-bodied species targeted by the trap fishery in Barbados (Table 1). A vertical height of 7 cm was considered to be appropriate for most deep-bodied species (Table 1) such that a high proportion of immature fish could be expected to escape. All escape slits were rectangular in shape and cut into galvanised sheeting that was strapped onto a head panel of the trap with wire (Figure 1). The head panel was chosen based on the perception of fishers that fish would be most likely to find it at the head of the trap. The large mesh panel was 0.61 x 0.61 m (2 x 2 ft) and comprised 3.8 cm mesh oriented vertically (max. vertical aperture 5.9 cm) and placed in the adjacent head panel to the escape slit (Figure 1).

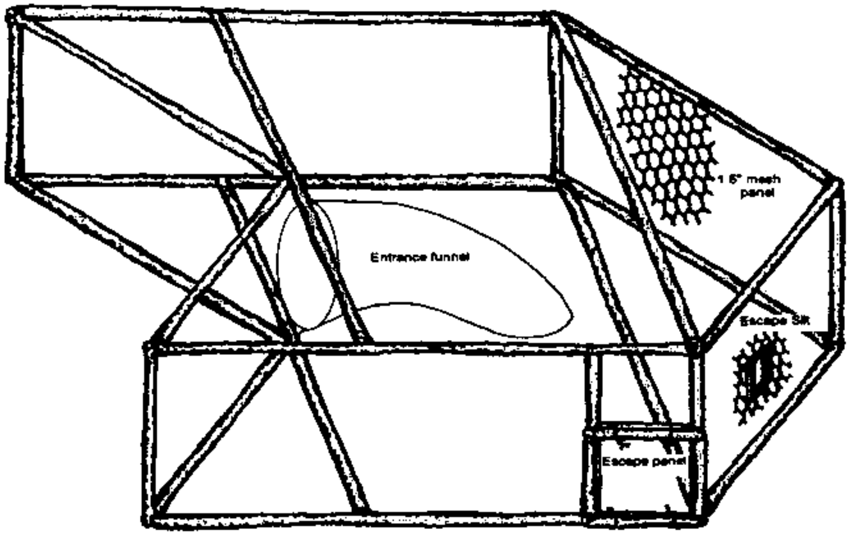

Figure 1. Diagram of the experimental trap design used in this study showing key features of both a single vertical escape slit (7 x 2.5 cm) and a single large 3.8 cm (1.5") mesh panel (0.61 x 0.61 m) on adjacent head panels of a conventional (3.18 cm) mesh Antillean arrowhead trap.

cm) mesh Antillean arrowhead trap.

Sampling Design

All experimental fishing was undertaken in Oistins Bay, located on the south coast of Barbados, from July 2002 – September 2002. The fishing grounds in Oistins Bay are characterised by a coral-rich, relatively shallow (3 - 10 m), flat reef system, located within 1 km of the shore.

The twelve traps of standard dimensions, but differing in design, were fished simultaneously and continuously for three months. Traps were set and hauled in four sets of triplets. Each triplet comprised one trap of each design (i.e. a conventional small mesh trap, an experimental trap and a large mesh trap). Traps within a triplet were set randomly along the reef in similar depth and habitat, and in relatively close proximity to one another. The rationale for this sampling design was to control for the effects of variation in the availability of fish at different trap sites on catch rates. Each triplet was placed in a different location, but all traps were located within the Oistins Bay. Soak time (the time over which the trap was allowed to fish) was identical for all members of a triplet and was typically three days, but varied from 3-7 days for a total of 225 soaks conducted during the study. Traps were hauled on 19 occasions, and giving a sample size of 75 replicates per trap design. However, the data from the first two hauls of every trap were not used in the analyses of catch rate on advice from fishers that the traps were too new (had not "turned colour") and would therefore have reduced catch rates. Data from traps with a soak time in excess of four days were also not used in catch rate analyses. Sample size for catch rate analyses was therefore 55 hauls per trap design. A large number of replicates was included in the sample design in order to increase the statistical power of comparison testing, given the typically high level of variation in trap catch rates.

Data Collection

Traps were hauled and reset unbaited every three days in collaboration with another local fisher based at Oistins. If catch rates were considered low, the triplet of traps was moved to a new location on the same fishing ground. For each soak, the fishing location was recorded by GPS and the weather conditions, water depth, and substrate type were also noted for each triplet.

For each trap hauled, all fish caught (with the exception of pufferfish) were retained and stored in separately marked bags. All retained fish were subsequently measured onshore with technical assistance from staff of the Fisheries Division and UWI, and any interested fishers. The catch was identified to species, and each fish measured for fork length (FL) and body depth (BD) to the nearest 0.1 cm and wet weight to the nearest 1.0 g.

Data Handling and Analysis

All catch data were entered into EXCEL spreadsheets by day and trap number. Statistical analyses were done using the statistical programme SPSS version 10.0. All data sets were checked for normality using the Shapiro Wilk test, and homoscedasticity of variance using the Levene test. Standard data transformations were used in an attempt to normalise and/or homogenise data that did not conform. Since at least one data set in every comparison showed a non-normal distribution and/or heteroscedasticity of variance even after transformation, non-parametric statistical tests were performed throughout.

The following parameters were compared among trap types: juvenile catch rates (as number and weight of juvenile fish caught per haul):

i) Percent of juveniles in the catch (per trap haul)
ii) Number of deep-bodied juveniles in the catch (per trap haul)
iii) Size of juveniles for all species (by fork length, body depth and weight)
iv) Body depth of juveniles for any species with an $n > 5$ in each trap design, and
v) Species composition of juvenile catches.

Catch rate and size comparisons were undertaken using non-parametric ANOVAs (Kruskal-Wallis test) and multiple comparison tests (Nemenyi test for equal sample sizes; Dunn test for unequal sample sizes; Zar 2000). Relative species composition among trap designs was compared using a multiple correlation technique (Kendall's concordance).

Fish were classified as juveniles if they were smaller than the mean size at first maturity (FL_m) given in Table 1. Since size at maturity data were not available for all species taken, only the most important species were classified as juvenile or mature. As such, nine species accounting for 83% of the total conventional trap catch (by number) were selected for analysis. These 'key' species (banded butterflyfish, blue tang, doctorfish, ocean surgeon, mahogany snapper, princess parrotfish, yellow goatfish) were classified as either deep-bodied if they had a mean body aspect ratio (FL/BD) of < 2.5, or round-bodied if they had an aspect ratio of > 3 (Table 1). Linear regressions for the body depth – fork length relationship were calculated for key species and body depth at maturity (BD_m) was recalculated using the literature value of fork length at maturity and our own relationship listed in Table 1.

RESULTS

Total Catch

During this study a total of 3,561 finfish from 19 families and 41 species were caught in 225 trap hauls over the three-month period. Of these, 2,078 fish from 38 species were caught in the conventional traps, 1,003 fish from 25 species were caught in experimental traps and 480 fish from 26 species were caught in large mesh traps (Table 2). For the nine key species selected, 1,543 juvenile finfish were captured, representing 52.8% of the catch of these species. Of these juveniles, 927 fish were caught in the conventional traps, 471 in experimental traps and 145 in large mesh traps (Table 3).

Table 1. Morphometric characteristics and size at first maturity for key species caught by fish traps in the Oistins Bay area in Barbados between July and September, 2002. All dimensions are in cm. FL_m = fork length at maturity; BD_m = body depth at maturity; a and b are constants in the body depth (BD) to fork length (FL) linear relationship (BD = a + bFL) and r^2 is the coefficient of determination for the regression line; AR = mean aspect ratio (FL/BD). The FL_m values are from Munro et al. (in press) or calculated from data given in Munro (1983). BD_m values are estimated from the FL_m values using the BD-FL linear regressions given in FishBase (2002), and also the BD-FL linear regressions derived in this study.

Family	Species	FL_m	BD_{m1}	BD_{m2}	a	b	r^2	AR
Acanthuridae	Blue tang	13	7.1	6.8	1.34	0.42	0.735	1.94
	Doctorfish	21	8.7	8.8	0.65	0.39	0.869	2.33
	Ocean surgeon	15.5	6	6.4	1.11	0.34	0.688	2.44
Chaetodontidae*	Banded butterflyfish	12	5.8	6.7	1.08	0.47	0.790	1.78
Haemulidae	French grunt	15.5	4.4	4.8	-0.43	0.34	0.630	3.21
Lutjanidae*	Mahogany snapper	20	-	5.5	0.87	0.23	0.691	3.67
Mullidae	Yellow goatfish	18	-	4.1	-0.03	0.23	0.666	4.33
Scaridae	Princess parrotfish	15.5	-	3.8	-0.71	0.29	0.704	3.85
	Redband parrotfish	15	-	4	0.35	0.27	0.487	3.46

* FLm data estimated from Munro (1983)

[1] conversions using BD-FL relationships from FishBase (2002)

[2] conversions using BD-FL relationships from this study

Table 2. Summary of finfish catch of conventional, experimental and large mesh traps over 75 hauls for each trap design, sampled at Oistins Bay, Barbados between July and September 2002.

Trap Design		Conventional					Experimental					Large mesh				
FAMILY	SPECIES	No. fish	% total no.	% juv.	Wt (kg)	% total Wt	No. fish	% total no.	% juv.	Wt (kg)	% total Wt.	No. fish	% total no.	% juv.	Wt (kg)	%
Acanthuridae	Blue tang	151	7.27	12.58	13.37	8.10	123	12.26	8.13	10.93	10.49	91	18.96	5.49	8.55	5
	Doctorfish	139	6.69	97.12	12.16	5.55	69	6.88	97.10	5.70	5.47	44	9.17	88.63	5.47	7
	Ocean surgeon	806	38.79	86.50	57.87	28.40	543	54.14	78.45	44.63	42.82	154	32.08	60.39	13.67	87
Aulostomidae	Trumpetfish	1	0.05	-	N/A	N/A	-	-	-	-	-	-	-	-	-	
Carangidae	Bar jack	5	0.24	-	0.247	0.11	-	-	-	-	-	-	-	-	-	
	Horse eye jack	7	0.34	-	11.92	5.44	2	0.20	-	3.49	3.35	1	0.21	-	1.23	3
Chaetodontidae	Banded butterflyfish	90	4.33	25.56	5.28	2.41	40	3.99	30.00	2.45	2.35	47	9.79	17.02	2.92	2
	Foureye butterflyfish	4	0.19	-	0.12	0.05	-	-	-	-	-	-	-	-	-	
	Spotfin butterflyfish	-	-	-	-	-	-	-	-	-	-	2	0.42	-	0.18	8
Dactylopteridae	Flying gurnard	-	-	-	-	-	-	-	-	-	-	1	0.21	-	N/A	A
Ephippidae	Atlantic spadefish	1	0.05	-	0.44	0.20	-	-	-	-	-	-	-	-	-	
Grammistinae	Greater soapfish	8	0.38	-	1.96	0.89	-	-	-	-	-	3	0.63	-	1.06	6
Haemulidae	Caesar grunt	50	2.41	-	5.16	2.35	6	0.60	-	0.75	0.72	13	2.71	-	2.3	3
	French grunt	111	5.34	25.23	9.31	4.25	24	2.39	4.17	2.51	2.41	5	1.04	0.00	0.7	7
	Smallmouth grunt	17	0.82	-	1.30	0.59	4	0.40	-	0.29	0.28	-	-	-	-	
	Tomtate	2	0.10	-	0.24	0.11	-	-	-	-	-	-	-	-	-	
Holocentridae	Blackbar soliderfish	5	0.24	-	0.50	0.23	8	0.80	-	0.9	0.86	-	-	-	-	
	Longspine squirrelfish	17	0.82	-	2.27	1.04	3	0.30	-	0.43	0.41	2	0.42	-	0.32	32
	Squirrelfish	18	0.87	-	3.03	1.38	11	1.10	-	2.17	2.08	16	3.33	-	3.1	1
Lutjanidae	Mahogany snapper	54	2.60	44.44	6.39	2.91	11	1.10	0.00	1.99	1.91	7	1.46	0.00	1.2	2
Monocanthidae	Orangespotted filefish	73	3.51	-	6.08	2.77	25	2.49	-	2.33	2.24	15	3.13	-	1.52	52
	Scrawled filefish	4	0.19	-	2.60	1.19	11	1.10	-	6.07	5.82	3	0.63	-	1.78	78
	Whitespotted filefish	1	0.05	-	0.44	0.20	2	0.20	-	0.67	0.64	-	-	-	-	.
Mullidae	Spotted goatfish	29	1.40	-	4.58	2.09	1	0.10	-	0.16	0.15	2	0.42	-	0.47	47
	Yellow goatfish	81	3.90	0.00	15.12	6.90	1	0.10	0.00	0.29	0.28	4	0.83	-	0.89	89
Ostraciidae	Honeycomb cowfish	4	0.19	-	0.218	0.10	14	1.40	-	2.52	2.42	8	1.67	-	1.62	82
	Smooth trunkfish	30	1.44	-	2.15	0.98	18	1.79	-	1.12	1.07	11	2.29	-	0.84	84
	Spotted trunkfish	1	0.05	-	0.17	0.08	-	-	-	-	-	-	-	-	-	.
Pomacanthidae	French angelfish	18	0.87	-	2.50	1.14	15	1.50	-	3.93	3.77	13	2.71	-	2.01	01
	Rock beauty	1	0.05	-	0.16	0.07	-	-	-	-	-	-	-	-	-	.
Pomacentridae	Sergeant major	24	1.15	-	1.81	0.83	33	3.29	-	2.47	2.37	19	3.96	-	1.41	41
Scaridae	Princess parrotfish	155	7.46	0.00	24.72	11.28	8	0.80	0.00	1.76	1.69	4	0.83	0.00	0.9	.9
	Queen parrotfish	3	0.14		1.27	0.58	-	-	-	-	-	-	-	-	-	
	Redband parrotfish	136	6.54	0.74	17.19	7.84	18	1.79	0.00	3.13	3.00	6	1.25	0.00	1.05	05
	Stoplight parrotfish	1	0.05	-	0.08	0.03	-	-	-	-	-	-	-	-	-	-
	Striped parrotfish	-	-	-	-	-	1	0.10	-	0.18	0.17	-	-	-	-	-
Sciaenidae	Spotted drum	1	0.05	-	N/A	N/A	-	-	-	-	-	-	-	-	-	-
Serranidae	Coney	4	0.19	-	1.40	0.64	-	-	-	-	-	1	0.21	-	0.36	36
	Graysby	25	1.20	-	6.52	2.97	12	1.20	-	3.36	3.22	7	1.46	-	2.01	01
	Red hind	-	-	-	-	-	-	-	-	-	-	1	0.21	-	0.23	23
Sparidae	Saucereye porgy	1	0.05	-	0.82	0.28	-	-	-	-	-	-	-	-	-	-
Totals	40	2078	100		219.18	100	1003	100		104.23	100	480	100		55.79	.79

Table 3. Comparison of fishing performance for juveniles of key fish species among conventional, experimental and large mesh traps at Oistins Bay, Barbados from July to September 2002

Characteristic	Trap Design			K-W test statistics		
	Conventional	Experimental	Large mesh	n	H	p-value
N (no. hauls examined)	55	55	55			
Total number of juveniles caught	927	471	145			
Total weight of juveniles caught (kg)	63.55	36.35	10.24			
Mean number juveniles/trap/haul	13.71	7.76	1.71	165	99.99	< 0.001
Mean weight juveniles/trap/haul (kg)	0.946	0.573	0.149	165	90.76	< 0.001
% by number of juveniles/trap/haul	57.41	57.16	30.24	165	32.62	< 0.001
Mean number of deep-bodied juveniles/trap/haul	13.33	7.75	1.73	165	97.59	< 0.001
Mean fork length of key species juveniles (cm)	14.07	14.30	14.95	1542	73.96	< 0.001
Mean weight of key species juveniles (kg)	0.069	0.074	0.088	1542	108.88	< 0.001
Mean body depth of key species juveniles (cm)	5.80	6.02	6.47	1542	163.75	< 0.001
Mean body depth of banded butterflyfish juveniles (cm)	5.84	6.45	6.61	42	9.85	0.007
Mean body depth of blue tang juveniles (cm)	6.25	6.34	6.56	35	1.91	0.385*
Mean body depth of doctorfish juveniles (cm)	6.39	6.43	6.96	241	22.32	< 0.001
Mean body depth of ocean surgeon juveniles (cm)	5.74	5.96	6.03	1171	90.77	< 0.001

* Indicates no significant differences among trap designs

Juvenile Catch Rates

Juvenile catch rates by number and by weight of fish per trap haul varied significantly among trap designs (Kruskal Wallis tests: for number of fish, $H = 99.99$, $n = 55, 55, 55$, $p < 0.001$; for weight of fish, $H = 90.76$, $n = 55,55,55$, $p = 0.001$). Post hoc multiple comparisons confirmed that catch rates by number and weight differed significantly between each trap design (Table 4). Experimental traps caught considerably fewer juveniles per trap haul (7.76 fish per haul) than conventional traps (13.71 fish per haul), but considerably more juveniles than large mesh traps (1.71 fish per haul) (Table 3). The weight of juveniles caught by experimental traps (0.573 kg per haul) was also much lower than for conventional traps (0.946 kg fish per haul), but much higher than for large mesh traps (0.149 kg fish per haul) (Table 3).

Catch rate comparisons among traps for deep-bodied species were similar to those for all species; differing significantly among traps (Kruskal-Wallis test: $H = 97.59$, $p < 0.001$) and between all trap designs (Nemenyi test: $p < 0.001$ in all cases; Table 4). The experimental and large mesh traps captured too few round-bodied juveniles to justify statistical comparison. It remains possible however, that the alternative trap designs may be selecting against round-bodied juveniles more effectively than conventional traps

Despite the clear difference in catch rates of juveniles among the different trap designs, the proportion of the catch comprising juveniles differed among traps (Kruskal-Wallis test: $H = 32.62$, $n = 55,55,55$, $p < 0.001$; Table 3) but not between all traps (Table 4). Experimental traps caught on average 57.2% of juvenile fish per trap haul, and this did not differ significantly from conventional traps (57.4% juveniles), although both experimental and conventional traps caught a significantly higher proportion of juveniles than the large mesh traps (30.2%) (Tables 3 and 4). This indicates that out of the alternative trap designs, only the large mesh trap was effective in selecting against juveniles in the catch. Experimental traps caught fewer juveniles than conventional traps only because they caught fewer fish in general.

Size of Juveniles

Juveniles differed significantly in size (by body depth, fork length, and weight) among trap designs (Kruskal-Wallis tests, $p < 0.001$ in all cases; Table 3). These differences were significant between each trap design (Dunn tests, $p < 0.001$ in all cases; Table 4). Juveniles caught by experimental traps were slightly larger (by body depth, fork length and weight) than those caught by conventional traps, and slightly smaller than those caught by large mesh traps (Table 3). This pattern also emerged for the BD of all four species examined separately (banded butterflyfish, doctorfish, ocean surgeon, blue tang) but was not significantly different among trap designs for blue tang (Tables 3 and 4).

Table 4. Post hoc non-parametric multiple comparison results for juvenile catch rates and sizes among conventional, experimental and large mesh trap designs in Oistins Bay, Barbados from July to September 2002.

Characteristic	Comparison	Statistical Test	Q_{CAL}	$Q_{0.05,3}$	Sign. difference
Number of juveniles / haul	conventional vs experimental	Nemenyi	44.51	2.394	yes
	conventional vs large mesh		111.10	2.394	yes
	experimental vs large mesh		66.59	2.394	yes
Weight juveniles / haul	conventional vs experimental	Nemenyi	41.50	2.394	yes
	conventional vs large mesh		105.78	2.394	yes
	experimental vs large mesh		64.28	2.394	yes
% juveniles / haul	conventional vs experimental	Nemenyi	0.79	2.394	no
	conventional vs large mesh		54.25	2.394	yes
	experimental vs large mesh		55.04	2.394	yes
Number of deep-bodied juveniles / haul	conventional vs experimental	Nemenyi	84.00	2.394	yes
	conventional vs large mesh		216.14	2.394	yes
	experimental vs large mesh		132.14	2.394	yes
Weight of juveniles	conventional vs experimental	Dunn	515.03	2.394	yes
	conventional vs large mesh		1140.76	2.394	yes
	experimental vs large mesh		625.73	2.394	yes
Fork length of juveniles	conventional vs experimental	Dunn	573.61	2.394	yes
	conventional vs large mesh		1189.18	2.394	yes
	experimental vs large mesh		615.58	2.394	yes
Body depth of juveniles	conventional vs experimental	Dunn	462.53	2.394	yes
	conventional vs large mesh		1084.78	2.394	yes
	experimental vs large mesh		622.25	2.394	yes
Body depth of banded butterflyfish juveniles	conventional vs experimental	Dunn	7.54	2.394	yes
	conventional vs large mesh		10.69	2.394	yes
	experimental vs large mesh		3.14	2.394	yes
Body depth of doctorfish juveniles	conventional vs experimental	Dunn	103.93	2.394	yes
	conventional vs large mesh		119.30	2.394	yes
	experimental vs large mesh		15.37	2.394	yes
Body depth of ocean surgeon juveniles	conventional vs experimental	Dunn	288.35	2.394	yes
	conventional vs large mesh		840.15	2.394	yes
	experimental vs large mesh		551.80	2.394	yes

Species Composition of Juvenile Catches

Species composition of the juvenile catch of key species indicated that the majority (96.5%) of species retained in all trap designs were deep-bodied and the predominant species caught were ocean surgeon and doctorfish in all cases (Table 5). All trap designs caught the same four deep-bodied species, but appeared to differ in the diversity of round-bodied species captured. Experimental traps caught one juvenile round-bodied species, whereas conventional traps caught fifty-three and large mesh traps caught none (Table 5). However, the relative abundance of key species within the catch was similar among trap designs (Kendall's concordance test: $W = 0.735$, $X^2 = 13.23$, $n = 3$, $p = 0.001$), indicating that key species composition of the juvenile catch is not affected by trap design.

DISCUSSION

The experimental trap design clearly caught fewer juvenile fish of all key species, fewer deep-bodied juveniles, and larger sized juveniles than the conventional small mesh trap design currently used by commercial reef fishers in Barbados. This is consistent with expectations based on previous studies using larger mesh in traps (e.g. Rosario and Sadovy 1991, Sary et al. 1997, Robichaud et al. 1999, Mahon and Hunte 2001) or escape slits (e.g. Munro et al. in press). On the face of it, therefore, this alternative trap design would seem to be achieving the management objective of reducing juvenile mortality, at least in the key species taken by the trap fishery. Furthermore, trap fishers involved in the study perceived that the fishable life of the experimental trap would be comparable to the conventional trap and would therefore be acceptable as an alternative. However, the experimental trap design did not reduce juvenile catch rates to the same extent as the large mesh trap design, nor was the mean size of juveniles as large as those retained in the large mesh traps. It would therefore be a less effective design (albeit longer-lasting) than the large mesh trap in reducing juvenile fish mortality, although the economic impacts on fishers in the short-term are likely to be less.

More importantly, the experimental trap design failed to reduce the proportion of juveniles in the catch compared with the conventional trap design, although the large mesh trap design was successful in this regard. This illustrates that the reduction in juvenile catch rates of experimental traps compared with conventional traps comes from a reduction in the overall catch rate of the trap, rather than an effective selection against the capture of juveniles. As such, the experimental trap design will be seen as an inefficient gear for the capture of reef fish, with potential negative economic impacts on fishers. It is therefore unlikely to be acceptable as a viable alternative for the purpose of managing a reduction in juvenile reef fish mortality.

Table 5. Key species composition of juvenile catches shown as numbers of fish and percent of total juveniles caught for conventional, experimental and large mesh trap designs in Oistins Bay, Barbados from July to September 2002

Body Type	Species	Conventional		Experimental		Large Mesh		All Traps	
		No. juv.	% total juv.	No. juv.	% total juv.	No. juv.	% total juv.	No. juv.	% total juv.
Deep-bodied	banded butterflyfish	23	2.48	11	2.34	8	5.52	42	2.82
	blue tang	20	2.05	10	2.12	5	3.45	35	2.35
	Doctorfish	135	14.56	67	14.23	39	26.90	241	16.19
	ocean surgeon	696	75.08	382	81.10	93	64.14	1171	78.64
Sub-total		874	94.17	470	99.79	145	100	1489	96.50
Round-bodied	french grunt	28	3.02	1	0.20	0	0	29	53.70
	mahogany snapper	24	2.59	0	0.00	0	0	24	44.44
	princess parrotfish	0	0.00	0	0.00	0	0	0	0
	redband parrotfish	1	0.11	0	0.00	0	0	1	1.85
	yellow goatfish	0	0.00	0	0.00	0	0	0	0
Sub-total		53	5.72	1	0.20	0	0	54	3.50
Total		927	100	471	100	145	100	1543	100

The low proportion of round-bodied juveniles of the key species taken by all the traps is interesting, particularly given that the maximum vertical aperture of the small mesh (3.18 cm) is less than that of the BD_m of all of the species (Table 1). This suggests that the fish are capable of squeezing through mesh slightly smaller than their maximum body depth (as suggested by Robichaud et al. 1999) and/or escaping by swimming out sideways, given that the maximum horizontal aperture is 4.2 cm. The larger BD_m of french grunt and mahogany snapper compared with the other round-bodied species (Table 1), probably explains why these two species were the most abundant of the round-bodied species in the juvenile catch (Table 5).

By contrast, more juveniles of the deep-bodied species were retained in the experimental trap design than was anticipated, given that the BD_m values for three of the four deep-bodied species were less than 7 cm (the height of the escape slit) (Table 1). This would suggest that they were not using the escape slit effectively. The lower proportion of juveniles in the catches of large mesh traps (compared with experimental and conventional designs) is largely explained by a reduction in the percentage of juvenile ocean surgeon, banded butterflyfish and doctorfish caught (Table 2). This is not easily explained by the BD_m values of these species, especially for doctorfish with a BD_m of 8.8 cm, which is considerably larger than the vertical aperture (3.8 cm) or maximum horizontal aperture (5.9 cm) of the large mesh. These results would suggest (contrary to the general findings of Robichaud et al. 1999) that ingress rates for these species are less in the large mesh traps.

The Barbados 2001-2003 Fisheries Management Plan states the importance of the reef fish resource as primarily for local consumption and employment (harvest use) and secondarily for tourism (non-harvest use), and emphasizes the need for reduced mortality of juveniles. The results of this study indicate that implementing a move to the large mesh fish trap design would effectively reduce catch rates of juvenile fish. However, the economic hardship associated with greatly reduced overall catches, and the need to replace traps more frequently than the stronger small mesh traps currently used by fishers is likely to be unacceptably high. The experimental design would pose less of an economic burden on fishers in terms of the reduction in catch rates and gear replacement costs, but their failure to select against the capture of juveniles negates their usefulness as a management option. In the absence of effort restrictions, fishers could simply fish more of the inefficient traps to maintain the current overall catch levels. Furthermore, reducing gear efficiency does not adequately address the management goal of reduced levels of juvenile mortality with minimum impact on fishers. An overall reduction in catch rates could be equally well achieved by more conventional methods such as limiting the number of traps used in the fishery, rather than reducing the fishing efficiency of the gear itself.

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