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Selectivity of experimental gillnets for fourwing flyingfish, *Hirundichthys affinis*, off Barbados

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Synopsis

Four experimental gillnets of stretched mesh sizes 2.54, 3.18, 3.81 and 4.45 cm (1.00, 1.25, 1.50, 1.75 inches) were fished together to allow estimation of gillnet selectivity for *Hirundichthys affinis*, by the method of comparing the catches of fish in the various length classes in the different nets. Only the 3.18 cm and 3.81 cm nets caught appreciable numbers of fish. The combined selectivity of the 3.18 cm and 3.81 cm nets is close to unity for the range of sizes of *H. affinis* which are available to the nets. Therefore, the size distribution of the combined catch for these nets can be used as an estimate of the size distribution of the available stock. The length frequency of fish caught in the 3.81 cm net coincided closely with the selectivity curve, indicating that this net effectively targets the sizes of fish available off Barbados. An increase or decrease in net mesh size by 0.64 cm (0.25″) would be expected to result in a substantial reduction in catch per unit effort.

Introduction

The fourwing flyingfish, *Hirundichthys affinis*, supports the largest single-species fishery in the eastern Caribbean. Seven countries take part in this fishery, with Barbados taking the largest share of the catch (Khokiattiwong et al. 2000). In order to obtain an accurate representation of the size structure of the flyingfish stocks available to the gillnet fishery off Barbados, it was necessary to estimate the selectivity of the commercial gillnet used to capture the fish. This was attempted in the present study. Knowledge of the selectivity of the gillnets is also of importance in deciding whether the regulation of gillnet mesh size could be a useful management tool.

The size selectivity of gillnets is the probability of capturing a certain size of fish in one unit of operation of the gear, and is best considered as a characteristic of the entire fishing operation (Hamley 1975, Gulland 1985, Rudstam et al. 1984). Gillnet selectivity can be expressed as follows:

$$S_{ij} = C_{ij}/{}_{i}N_{j},$$

where S_{ij} = the selectivity of mesh i to size class j; C_{ij} = the number of fish of size class j caught by mesh i; and N_j = the number of fish of size class j in the population sampled.

There are three ways in which a fish can be caught in a gillnet: wedged or held tightly by a mesh around the body; gilled or prevented from backing out of the net, by a mesh caught behind the gill cover; or tangled in the net by teeth, maxillaries, etc. (Baranov 1914). The factors affecting gillnet selectivity have been reviewed by Hamley (1975). These include: characteristics of the net itself; such as its mesh size, stretching of the net material and the knots, colour, hanging coefficient, strength and flexibility of the twine, and visibility of the twine; characteristics of the fish, such as their stage of maturity, their tendency to be meshed at a part of the body other than the pectoral area, and their behaviour; or the method of fishing (Clark & King 1986).

Gillnet selectivity can be estimated directly, indirectly, or inferred from girth measurements. Direct estimates can be made in three ways: fishing a population of known size structure; comparison of the size structure of the catch with the catch of a gear of known selectivity; the use of fishing mortality estimates (Hamley 1975). However, none of these methods is appropriate for estimating gillnet selectivity for flyingfish in the eastern Caribbean, since neither the size structure nor the mortality rate of the population is known, and there are no other fishing gears of known selectivity.

Storey (1983) estimated gillnet selectivity for flyingfish using girth measurements, but found that the estimated selectivity curve gave estimated catch length distributions which were very different from those which were observed. This was probably due to the compressibility of flyingfish tissue, or the stretching of the net material. This is examined further in the present study.

The main purpose of this study is to estimate gillnet selectivity by the indirect method in which the proportion of fish caught in each size class by nets of different mesh sizes are compared (Pauly 1983). This is the most common method of fitting gillnet selectivity curves, and is based on the assumptions that: (i) the selectivity curves for both mesh sizes are normally distributed; (ii) the two selection curves have the same standard deviation; (iii) the two nets have overlapping selection ranges; and (iv) optimum length is proportional to mesh size.

Methods

Experimental fishing was carried out using four monofilament nylon gillnets (each 30 m long and 3 m deep) of different stretched mesh sizes, 2.54, 3.18, 3.81 and 4.45 cm, as described by Khokiattiwong et al. (2000). The nets were set in two gangs of two nets each, which were fished concurrently. The nets in each gang were placed 10 m apart in order to minimise their competition for capture of the same fish, and the order of the nets was rotated with each sampling trip to reduce any possible bias due to their position (Clarke & King 1986). The nets were fished between 9:00 and 13:00 h with a standard soak of three hours, in the usual fishing area of the fishing fleet from Speightstown, Barbados. The study was conducted between August 1987 and October 1988, with fishing being distributed evenly over the year.

H. affinis were removed from the nets and their fork length measured to the nearest 0.5 cm. The right hand side of the gillnet length frequency distribution represents large fish, usually caught by the head; whereas the left side represents smaller fish, usually caught by the body (Hamley 1975). If the proportions of fish caught by head and body differed between the two nets, this could account for the unexpectedly small difference in mean size of fish, and separate selectivity curves should be calculated for fish caught each way. The position of the mesh mark on each fish was recorded in three categories: before the operculum or by some projection (tangling), just behind the operculum (head girth), and on the body (body girth).

The details of the method for fitting the selectivity curve, as given by Pauly (1983), are as follows. The optimum selection lengths of the two nets A and B (L_A, L_B), were estimated from the catch in each length class (C_A, C_B) by regression of $\ln C_B/C_A$ on L (length class midpoint). The ratio C_B/C_A is called the catch ratio.

The intercept (a) and slope (b) of this regression can be used to estimate the optimum lengths as follows:

$$L_A = -2a.A/b(B + A),$$
$$L_B = -2a.B/b(B + A),$$

while the standard deviation of both selection curves is estimated from:

$$SD = \sqrt{2a.(A - B)/b^2.(A + B)}.$$

Once L_A and L_B and SD were estimated, the probability of capture (P) at each length L for each mesh size, was estimated as follows:

$$P_A = \exp - ((L - L_A)^2/2SD^2),$$
$$P_B = \exp - ((L - L_B)^2/2SD^2),$$

to produce selectivity curves for the two nets. These selectivity values were then summed to give a combined selectivity for the two nets. The combined selectivity was then used to estimate the actual population size structure of flyingfish from the size structure of the catch by dividing the number of fish caught in each length class by the combined probability of capture of that length class.

It is also possible to estimate gillnet selectivity for flyingfish from girth measurements, and this has been attempted by Storey (1983). However, the compressibility of the fish body and the flexibility of twine are important considerations in the method (Hamley 1975, Storey 1983, Clarke & King 1986), and the body of flyingfish is very soft. Consequently, this method is probably not ideal for use with flyingfish. To verify this, percent body compressibility/twine flexibility (BC-TF) for flyingfish in gillnets was quantified during this study.

$$\mathrm{BC-TF} = \frac{\text{meshmark girth (cm)} - \text{mesh perimeter of retaining mesh (cm)}}{\text{meshmark girth (cm)}} \times 100$$

Results

The length frequencies of *H. affinis* caught throughout the year by four experimental gillnets with different stretched mesh sizes (2.54, 3.18, 3.81 and 4.45 cm) are shown in Figure 1. The mean lengths of fish caught by the nets, and other statistics relating to the catches are shown in Table 1. A Scheffe's multiple range test (Sokal & Rohlf 1981) of the length distributions of fish in the nets of different mesh sizes showed significant differences ($F = 44.002$, d.f. $= 3$, $p < 0.05$) between the 2.54 cm and 3.18 cm nets and between the 3.81 cm and 4.45 cm nets.

The proportion of fish caught by tangling was highest in the 2.54 cm mesh size and decreased with increasing mesh size (Table 1). The method for estimating gillnet selectivity used in this study excludes fish which are caught by tangling. Since the selection range of fish caught by the 2.54 cm net almost coincides with that by the 3.18 cm net and the selection range of fish caught by the 3.81 cm net almost coincides with that by the 4.45 cm nets, fish caught in the 3.18 cm and 3.81 cm nets are considered adequate for estimating gillnet selectivity for *H. affinis*.

There was no significant difference in the proportions of fish caught by head and body girth in the 3.18 cm and 3.81 cm mesh size nets ($X^2 = 1.307$, d.f. $= 1$, $p > 0.05$). Therefore, fish caught in both ways were combined for the analysis.

The linear regression of ln C_B/C_A on the length-class midpoint gave a slope of 1.53 and an intercept of −30.68 (Figure 2). Only the points in the area of overlap between the peaks of the two length frequency

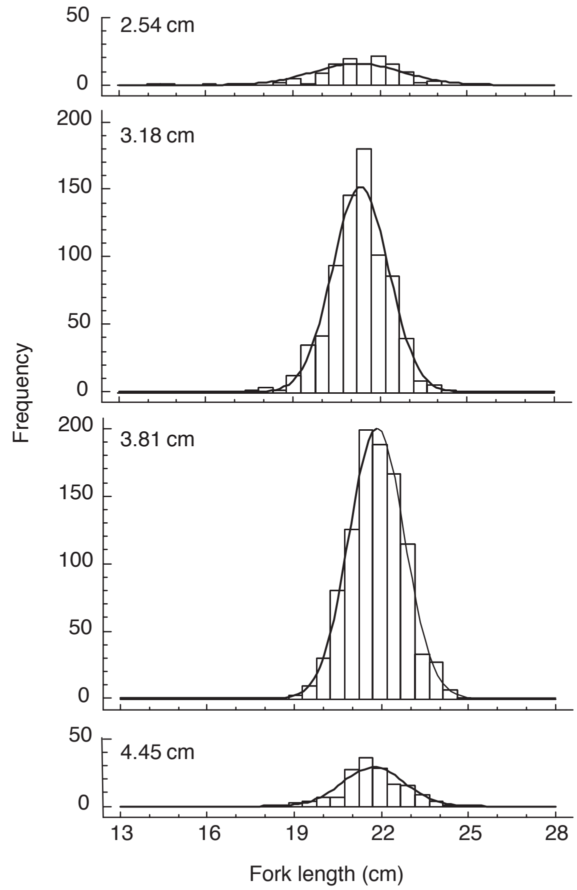

Figure 1. Length frequency distributions of *Hirundichthys affinis* caught throughout the year by the four experimental gillnets: a- 2.54 cm, b- 3.18 cm, c- 3.81 cm and d- 4.45 cm. Normal distribution curves are fitted to the data.

Table 1. Statistics for the catch of *Hirundichthys affinis* by the four experimental gillnets (BC-TF = body compressibility/twine flexibility, all lengths are fork lengths).

Statistic	Mesh sizes (cm)			
	2.54	3.18	3.81	4.45
Sample size	126	757	985	158
Mean length (cm)	21.2	21.3	21.8	21.7
SD	1.5	1.0	1.0	1.0
Minimum (cm)	14.0	17.6	18.2	19.1
Maximum (cm)	24.1	24.5	24.8	24.8
% tangled	94	87	65	35
% caught by: head	5	16		24
body	6	8	19	41
% BC-TF at head	43	24	9	
% BC-TF at body	42	43	26	9

distributions were used (Table 2). The r^2 is 0.990, therefore the linear relationship was considered to be appropriate, and the log transformation described by Pauly (1983) was not examined.

The optimum lengths ($L_{1.25}$ and $L_{1.50}$) of the 3.18 cm and 3.81 cm nets are 18.23 and 21.88 cm respectively, and the co-standard deviation is 1.54. The probabilities of capture of fish in each length class by each mesh size (Table 2) give the individual and combined selectivity curves shown in Figure 3. The combined selectivity of the two nets was used to adjust the combined catch of the nets, to provide an estimate of the actual length frequency distribution of the *H. affinis* stock (Table 2). In the case of the 3.18 cm net only the part of the curve up to the optimum length of the 3.81 cm mesh size was used. The adjusted length frequency and that of the catch do not differ significantly ($X^2 = 7.340$, d.f. = 13, $p > 0.05$) (Figure 4).

Discussion

Only two of four mesh sizes of experimental nets, the 3.18 cm and 3.81 cm mesh nets, caught appreciable numbers of flyingfish. The selectivity curves and the length distributions of fish caught by these two nets show that the former net is too small for commercial

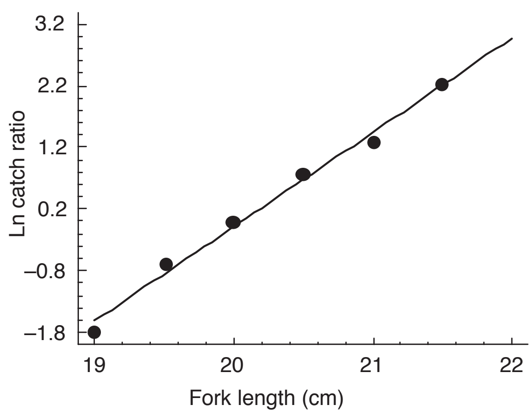

Figure 2. The natural log of the catch ratio (ln C_B/C_A) versus the length-class midpoint.

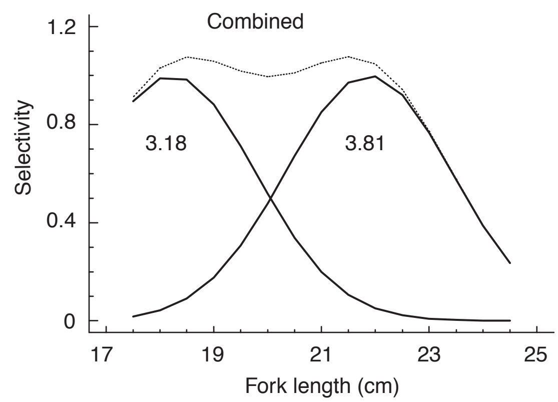

Figure 3. The separate and combined selectivity curves for the 3.18 cm and 3.81 cm mesh nets.

Table 2. The catches (C_A, C_B), catch ratio (ln C_B/C_A), probabilities of capture by each net (P_A, P_B), and adjusted catch (ADJ_{A+B}) of *Hirundichthys affinis* in each length class.

Length-class midpoint (cm)	3.18 cm C_A	3.81 cm C_B	ln C_B/C_A	PA	PB	ADJ_{A+B}	OBS_{A+B}
17.5	1	0		0.	0.02	1	1
18.0	1	0		0.	0.04	1	1
18.5	0	0		0.	0.09	0	0
19.0	6	1	−1.79	0.	0.18	7	7
19.5	12	6	−0.69	0.	0.31	18	18
20.0	14	14	0.00	0.	0.48	28	28
20.5	25	54	0.77	0.	0.67	78	79
21.0	14	50	1.27	0.	0.85	61	64
21.5	7	65	2.23	0.	0.97	66	72
22.0	6	49	2.10	0.	1.00	53	55
22.5	4	32	2.08	0.	0.92	38	36
23.0	1	20	3.00	0.	0.77	27	21
23.5		8		0.	0.57	13	8
24.0		2		0.	0.39	5	2
24.5		1			0.24	4	1

*Used in the regression of catch ratio versus length.

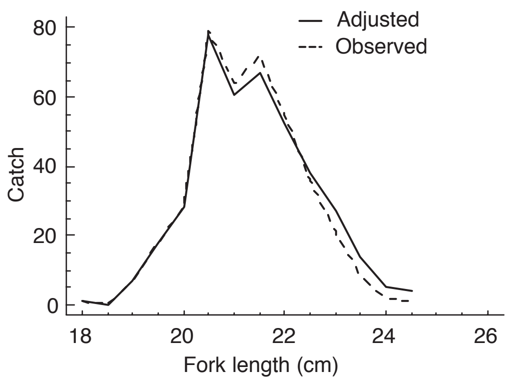

Figure 4. The observed and adjusted combined catch of *Hirundichthys affinis* for the 3.18 cm and 3.81 cm mesh nets.

fishing, as it would lead to unacceptably low catch rates for the flyingfish fishery. This net caught much fewer fish than the 3.81 cm mesh net and most were caught by tangling (at the front of operculum).

Considering that the length frequency distribution of the combined catch of the 3.18 cm and 3.81 cm gillnets does not differ significantly from the actual length frequency estimated by adjusting the catch at length with the combined selectivity values, it appears that the combined catch can be used as a direct estimate of the actual size frequency distribution of the stock.

The close coincidence of the observed and adjusted size structure of the catch from the 3.81 cm mesh net indicates that this net effectively targets the sizes of fish available off Barbados. The 3.81 cm experimental mesh size is very close to the mesh sizes which are used in the commercial fishery (4.06–4.32 cm). The combined fish body compressibility/net twine flexibility is higher for the 3.81 cm experimental net (26%) than for the commercial nets (19%) (Table 2). This probably reflects the thinner twine used in the experimental nets. It will tend to offset any differences in capture probability at size due to the small differences in mesh size between the commercial nets and the 3.81 cm experimental net. Storey (1983) estimated the selectivity curve of the commercial net in the Barbados flyingfish fishery using body girth measurements, and suggested that catch rates might be improved by a slight increase in the commercial mesh size. However, given the compressibility of flyingfish, the body girth method is less appropriate for estimating selectivity of flyingfish gillnets than the method used here.

The present results therefore suggest that the commercial mesh sizes are appropriate for this fishery, and that any slight (e.g. 0.64 cm) increase or decrease in mesh size would result in significant decreases in catch per unit effort. This observation suggests that mesh size regulations would not be an appropriate management tool for the flyingfish fishery. One possible explanation for the observed tendency for catch per unit effort to vary sharply with mesh size is that flyingfish are cylindrical, and relatively narrow for their length, compared to many other pelagic species (e.g. clupeids, scombrids). Therefore the selectivity curves tend to be sharply peaked (leptokurtotic).

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