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Juvenile fishes off Barbados with particular reference to flyingfishes

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Abstract: Seasonal abundance of juvenile fishes off Barbados was investigated by night-lighting and dip netting at a sampling station 6 nm off the northwest coast of Barbados, during 49 nighttime trips from October 1987 to September 1988. Of the 3,020 fishes captured, 89.8% were from the family Exocoetidae, 5.0% from Hemiramphidae, 2.6% from Myctophidae, 1.4% from Coryphaenidae and < 1% from Belonidae and Trichiuridae. Exocoetid juveniles (*Parexocoetus brachypterus*, *Exocoetus volitans* and *Hirundichthys affinis*) and hemiramphid juveniles (*Oxyporhamphus micropterus*) dominated the catch. For *P. brachypterus*, *E. volitans* and *O. micropterus*, recruitment of juveniles began in February/March, and juveniles remained abundant through summer (March-July for *P. brachypterus*, February-August for *E. volitans*, February-July for *O. micropterus*). Juveniles of *H. affinis* appeared in December/January, and abundance increased from February to August. The results suggest that all life-history stages of the commercially exploited flyingfish *H. affinis* are sequentially present year-round near Barbados. This does not support the hypothesis of a large-scale migration of *H. affinis* away from the island in June nor a return migration in November.

INTRODUCTION

Despite the commercial importance of flyingfish (Exocoetidae) and large offshore pelagics (e.g. Coryphaenidae, Scombridae, Istiophoridae) to the fisheries of Barbados and other eastern Caribbean islands (see Mahon *et al.* 1981, Mahon 1993), little is known of their early life-history or population dynamics in this region (Figure 1). Furthermore, both fishing effort and catch-per-unit-effort are markedly seasonal for the offshore pelagic species, the fishing season being primarily between November and June (Mahon *et al.* 1981, Storey 1983, Oxenford and Hunte 1986, Hunte 1987, Khokiattiwong *et al.* 2000). For most species the reason for the seasonality is not known. Possible explanations are: The adult fish, although present, are not susceptible to the fishing gear during the off-season (July-October); adults migrate outside the range of fishing fleets during the off-season; there is an interval between annual cohorts with earlier life-stages, but not adults, being present during the off-season. Distinguishing among these explanations was one of the objectives of the Eastern Caribbean Flyingfish Project, of which this study is a part (Oxenford *et al.* 1993).

A principal constraint to our understanding of the early life-histories of these species is the fact that they are harvested with commercial gear targeting the larger size classes. This is particularly true for flyingfish which are harvested with gillnets of mesh size 38-41 mm, which are not only highly size-selective (taking only adult fish), but also species-specific (taking only *Hirundichthys affinis*) (Storey 1983, Khokiattiwong *et al.* 2000, Mahon *et al.* 2000). There have been few studies of early life-stages of flyingfishes in the eastern Caribbean. Hunte *et al.* (1995) and Oxenford *et al.* (1995) examined larval and juvenile flyingfish abundance, respectively, across the eastern Caribbean in April/May 1988, and concluded that abundance of early life stages varied significantly across the region, and that different life-history stages within species had different geographical distributions. Lao *et al.* (submitted) examined seasonal and spatial variation in abundance of larval fishes off Barbados in 1987/1988 and concluded that flyingfishes were most abundant from February to June, and more abundant at the most offshore station (9 nm from shore) than at the stations 6 and 3 nm from shore. There is no information on seasonal variation in abundance of early life-stages of flyingfishes too large to be taken by neuston tows and too small to be taken by commercial gear, or by the experimental gillnets of mesh sizes down to 24.5 mm used by Khokiattiwong *et al.* (2000). A useful behavioural trait of flyingfishes in this context is that juveniles can be attracted by night-lighting and hence captured by dip net (see Lewis 1959, Oxenford *et al.* 1995).

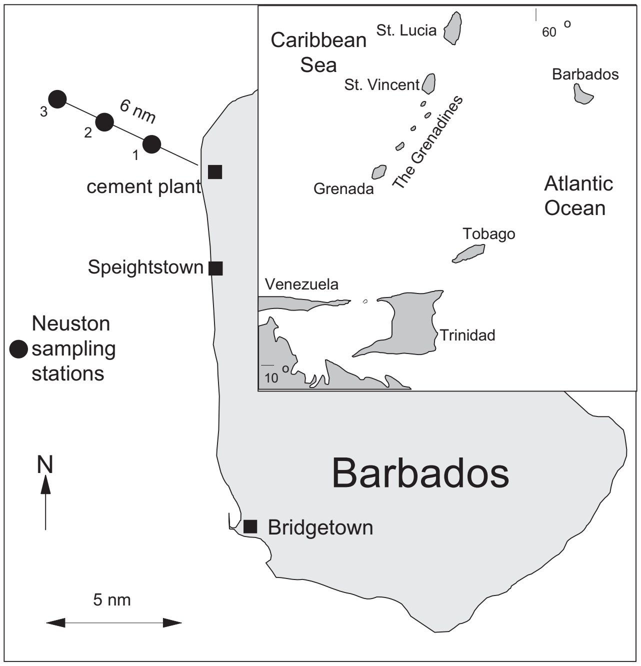

Figure 1. The location of the sampling station with (inset) Barbados and the eastern Caribbean.

The objectives of this study are to investigate seasonal variation in abundance and size of juvenile fishes off Barbados, particularly flyingfish, by night-lighting and dip netting, and to compare the data with those obtained simultaneously off Barbados by Lao *et al.* (2007, Chapter 11*)* for larval fishes collected by neuston tows, and by Khokiattiwong *et al.* (2000) for sub-adult and adult flyingfishes collected by experimental gillnets, to achieve a more comprehensive picture of the population dynamics of the families and/or species common to both sampling methods.

METHODS

Sampling procedure

Night-lighting and dip netting were conducted weekly from October 1987 to September 1988 between 18:00 and 23:00 hr at three different locations (0.5 nm apart), at a station approximately 6 nm off the northwest coast of Barbados (Figure 1). Catches were recorded every 10 min, and sampling was conducted for 1 hr at each of the three locations. Recording catches at 10-min intervals was done to determine if there was local depletion at the sampling location. Locations were changed each hour to minimise the possible effects of depletion due to sampling at the location, and of local patchiness in distribution. A total of 49 sampling trips and 147 hr of night-lighting and dip netting were completed over the 1-yr study period (see also Lao 1989).

The sampling technique was similar to that described by Oxenford *et al.* (1995). Juvenile fishes were attracted to the research vessel using lights comprising two pairs of 50 watt, 12.8 volt car headlamps on a frame suspended over the leeward side of the vessel, where wave action was least, to facilitate catching. An attempt was made to capture all fishes entering the effective fishing area within the illuminated zone, using a long-handled dip net of 5 mm mesh size (with an effective reach of about 2 m), and a short-handled aquarium net of 1 mm mesh size (with an effective reach of about 0.5 m).

Sampling effectiveness was quantified by recording all successful and unsuccessful (missed) dips for flyingfishes every 10 minutes. A successful dip was defined as one in which the target fish was captured, whilst a missed dip was one in which the fish escaped. Only one miss was recorded for each fish regardless of the number of unsuccessful capture attempts.

Treatment of samples

All samples were frozen. Juveniles where identified to family, and for the two common families, Exocoetidae and Hemiramphidae, they were identified to species, wherever possible. Exocoetids were identified using the taxonomic descriptions of Breder (1938), Imai (1959, 1960), Evans (1961), Lewis (1961) and Kovalevskaya (1964). Hemiramphids were identified using the descriptions of Brunn (1935), Breder (1938), Collette (1978) and Fahay (1983). Fork length (FL) of each individual was measured to the nearest mm.

Treatment of data

Data were not normally distributed and could not be normalized by transformations. Non-parametric statistical tests were therefore used. Spearman rank correlation analysis was used to investigate the robustness of the abundance index. Chi-square goodness of fit tests were used to investigate depletion effects between sampling periods. Kruskal-Wallis one-way analysis of variance was used to investigate seasonal variation in abundance of juvenile fish. Modes in length-frequency histograms were clear and could be separated by eye.

RESULTS

Catch as an index of abundance

Since an attempt was made to capture every fish entering the effective fishing area of the illuminated zone, the total number of captures and misses recorded were considered an index of available fish (fish abundance). A comparison of the number of fishes caught with the number of capture attempts therefore allows an assessment of whether catch is an adequate index of available fish. In particular, it is possible that the percentage of fishes caught might decrease with increasing number of fishes present.

During the study, 3,341 attempts to capture fishes were recorded, of which 81% were successful. The proportion of fishes missed in a sampling trip was not correlated with the total abundance of fishes encountered (i.e. the sum of catches and misses) (Spearman Rank correlation: $r_s = -0.167$, $p > 0.05$). This suggests that the efficiency of capture is not a function of the abundance of fishes in the fishing zone, and that the number of fishes caught is an adequate index of fish abundance. Number of fishes caught was therefore used in all subsequent analyses as an abundance index for all species and/or families.

Depletion effects during sampling

Since an attempt was made to capture all fishes that entered the fishing area, it is possible that catch rates at a sampling location (occupied for 1 hr) may decrease with time due to depletion of fishes in the vicinity of the sampling vessel. To investigate this, the number of captures was compared between 10-min sampling intervals of every hour at each of the three sampling locations for each sampling trip. The number of captures did not differ significantly between 10-min intervals for either the first, second or third hour of sampling trips (Chi-square tests: for 1st hr captures, $X^2 = 0.310$, $p = 0.99$; for 2nd hr captures, $X^2 = 0.877$, $p = 0.97$; for 3rd hr captures, $X^2 = 1.011$, $p = 0.96$). This indicates that there was no local depletion at the sampling location during a 1-hr sampling period. Furthermore, the number of captures did not differ significantly between 1-hr sampling periods on a given sampling trip, across all trips (Chi-square test: $X^2 = 0.597$, $p = 0.74$) indicating that there was no depletion at the sampling station over a 3-hr sampling period. Therefore, hourly data were pooled by trip for subsequent analyses of variation in capture rates between taxonomic groups and between months.

Taxonomic composition of catch

A total of 3,020 fishes comprising 6 families were collected by night-lighting and dip netting (Table 1). Exocoetidae accounted for 89.8% of all fishes caught, whilst Hemiramphidae accounted for 5.0%, Myctophidae for 2.6%, Coryphaenidae for 1.4%, Belonidae for 0.9%, and Trichiuridae for < 0.1%.

Table 1. Taxonomic composition and relative abundance of fishes caught by night-lighting and dip netting off Barbados.

Taxonomic category	Number	% of family catch	% of total catch
Exocoetidae	**2711**		**89.8**
Parexocoetus brachypterus	1181	43.6	
Exocoetus volitans	1039	38.3	
Hirundichthys affinis	414	15.3	
Hirundichthys speculiger	43	1.6	
Prognichthys gibbifrons	8	0.3	
Cypselurus cyanopterus	8	0.3	
Exocoetus obtusirostris	6	0.2	
Cypselurus comatus	4	0.1	
Hirundichthys spp.	3	0.1	
Cypselurus furcatus	1	< 0.1	
Cypselurus heterurus	1	< 0.1	
Cypselurus melanurus	1	< 0.1	
Cypselurus exiliens	1	< 0.1	
Cypselurus spp.	1	< 0.1	
Hemiramphidae	**150**		**5.0**
Oxyporhamphus micropterus	123	82.0	
Euleptorhamphus sp.	7	4.7	
Hemiramphus brasiliensis	5	3.3	
Hemiramphus balao	1	0.6	
Unidentified	14	9.3	
Myctophidae	**80**		**2.6**
Coryphaenidae	**48**		**1.4**
Belonidae	**27**		**0.9**
Trichiuridae	**1**		**< 0.1**
Unidentified	10		0.3
Total	3020		

The Exocoetidae comprised 5 genera and at least 12 species, the most common of which were *Parexocoetus brachypterus* (accounting for 43.6% of all flyingfishes caught), *Exocoetus volitans* (38.3%), and *Hirundichthys affinis* (15.3%) (Table 1). The Hemiramphidae comprised at least 3 genera and 4 species, with *Oxyporhamphus micropterus* accounting for 82.0% of all halfbeaks caught (Table 1). Subsequent analyses of seasonal variation in abundance and size structure have been confined to these four species (three flyingfishes and one halfbeak), since all other species occurred in very low numbers.

Size composition of catch

The size structure of the total catch for the four most common species is given in Figure 2. For *P. brachypterus* (October 1987-September 1988) three size modes are evident; the first consists of fish between 20-60 mm fork length (FL), the second between 70 and 90 mm FL, and the third between 100 and 120 mm FL (Figure 2a). Since *P. brachypterus* reaches sexual maturity at about 110-120 mm (Bruun 1935, Lewis 1961), the largest mode was considered adults, whilst all fish smaller than this were considered juveniles. By this criterion, 709 juveniles (60.0%) and 472 adults (40.0%) of *P. brachypterus* were collected.

For *E. volitans* the distribution of length is essentially unimodal, with fish between 20-90 mm FL (Figure 2b). Since estimated size at sexual maturity for *E. volitans* is 140 mm (Bruun 1935), 99.4% of the 1,039 fish collected were considered juveniles.

For *H. affinis* the distribution of length is bimodal; one size-group ranging from around 20-140 mm FL, and the other from around 170-220 mm FL (Figure 2c). Since *H. affinis* reaches sexual maturity at around 190 mm (Bruun 1935, Lewis *et al.* 1962, Storey 1983, Khokiattiwong *et al.* 2000), all fish in the first size-group were considered juvenile, whilst those in the larger size-group were considered adult. By this criterion, 391 juveniles (94.4%) and 23 adults (5.6%) of *H. affinis* were collected.

For *O. micropterus* the distribution of length is essentially bimodal; one size-group ranging from around 30-90 mm FL, and the other from around 110-140 mm FL (Figure 2d). Since *O. micropterus* reaches sexual maturity at about 120 mm (Bruun 1935), the larger mode was considered adult and all fish smaller than this juvenile. By this criterion, 71 juveniles (57.7%) and 52 adults (42.3%) of *O. micropterus* were collected.

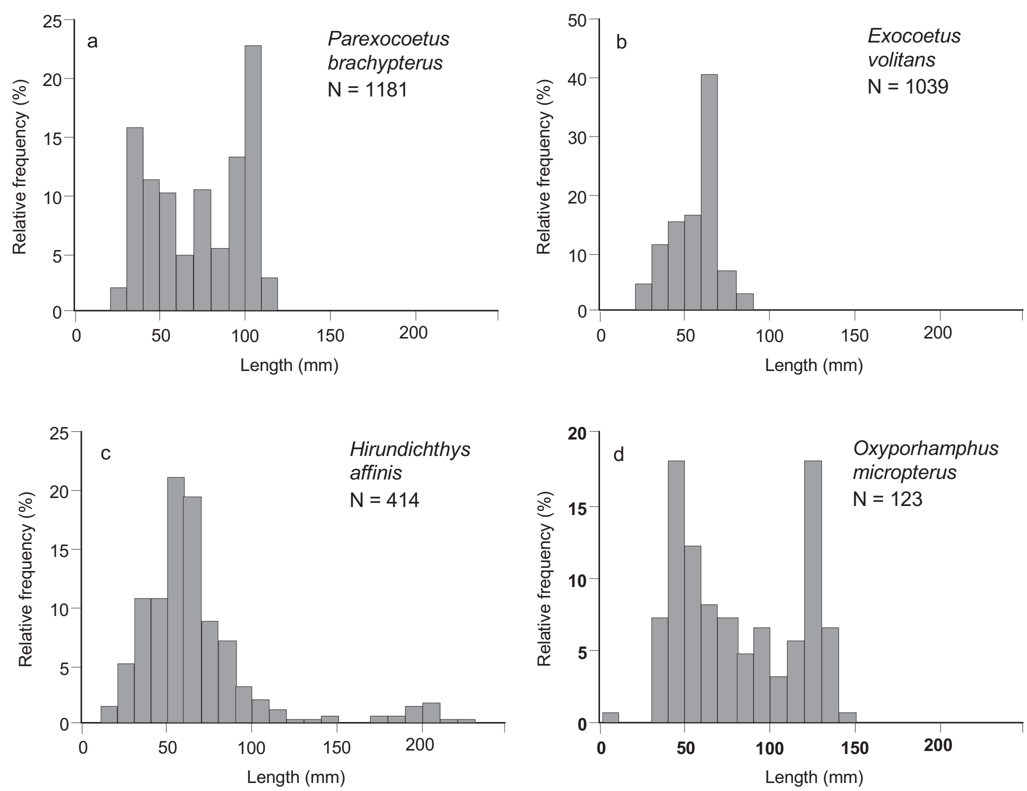

Figure 2. Length frequency distributions (for length mm) for the four most commonly caught species.

Seasonal variation in abundance

The total number of sampling trips and the number of Exocoetidae and Hemiramphidae juveniles and adults caught during the study (October 1987-September 1988) are given in Table 2. Seasonal variation in abundance was examined for all flyingfishes together and separately for the three common flyingfish species and the halfbeak species, *O. micropterus*.

The total number of *P. brachypterus* caught per trip did not differ significantly between months (Table 3), however the numbers of juveniles caught did (Table 3), being greatest between March and July (Table 2). Adults showed no significant seasonal variation in abundance (Table 3).

The number of adults of *E. volitans* caught (N = 6) was insufficient for analysis of seasonal variation in abundance. However, the numbers of juveniles of this species varied significantly between months (Table 3), showing an apparent bimodal distribution, being most common between February and May, and in August/September (Table 2).

The number of adults of *H. affinis* caught (N = 23) was also insufficient for analysis of seasonal variation in abundance. However, juvenile abundance varied significantly among months (Table 3), being most common in February/March and between May and August (Table 2).

The hemiramphid *O. micropterus*, showed no strong seasonal pattern in abundance of juveniles or adults (Table 3), although juveniles appeared to be most abundant between February and July (Table 2).

Table 2. The number of adults and juveniles of the four most common species caught in the one-year night lighting and dip netting study, shown separately by month.

Year	Month	Trips	*Parexocoetus brachypterus*		*Exocoetus volitans*		*Hirundichthys affinis*		Total flyingfish		*Oxyporhamphus micropterus*	
			Juv.	Adult	Juv.	Adult	Juv.	Adult	Juv.	Adult	Juv.	Adult
1987	October	4	0	31	5	0	5	0	10	31	1	1
	November	4	14	9	3	0	0	2	17	11	0	1
	December	5	30	102	3	0	15	1	48	103	2	1
1988	January	4	15	107	2	1	3	1	20	109	2	4
	February	3	6	51	94	0	25	1	125	52	13	1
	March	5	72	19	207	3	18	0	297	22	17	34
	April	4	166	49	149	0	1	1	316	50	5	2
	May	5	201	50	113	1	40	0	354	51	17	4
	June	4	105	15	2	0	38	5	145	20	5	0
	July	4	99	17	2	0	32	12	133	29	6	0
	August	5	1	14	428	0	213	0	642	14	3	0
	September	2	0	8	25	1	1	0	0	22	0	4
Total		49	709	472	1033	6	391	23	2133	501	71	52

Table 3. Results of Kruskal-Wallis tests on variation in the mean number of fishes caught per trip between months (October 1987-September 1988), presented separately for juveniles and adults of the four most common species in the night-light catch. Level of significance: ** p < 0.01, * p < 0.05.

Species	Juveniles		Adults		Total catch	
	H	p	H	P	H	p
Parexocoetus brachypterus	21.03	*	4.84	0.94	9.72	0.56
Exocoetus volitans	28.08	**	-	-	28.00	**
Hirundichthys affinis	24.59	*	-	-	22.94	*
Oxyporhamphus micropterus	18.68	0.07	5.34	0.91	13.92	0.24

In summary, the data suggest that juveniles of the four most common species in the catch are most abundant in a similar period of the year i.e. between February and August. Consequently, seasonal variation in abundance of juveniles is significantly correlated between most species pairs (Table 4).

Table 4. Spearman rank correlation coefficients of the monthly variation in juvenile abundance of the four most common species in the night-light catch. Significant p values are in bold.

Species		***Parexocoetus brachypterus***	***Exocoetus volitans***	***Hirundichthys affinis***
Exocoetus volitans	r_s	0.074	–	
	p	0.610		
Hirundichthys	r_s	0.163	0.313	–
affinis	p	0.258	**0.030**	
Oxyporhamphus	r_s	0.517	0.331	0.299
micropterus	p	**0.003**	**0.022**	**0.038**

Seasonal variation in size

Length frequency distributions for the four most common species in the night-light catch are shown separately at 2-month intervals in Figures 3 to 6.

For *P. brachypterus*, only one cohort was present in December/January (Figure 3). Given the reported size at sexual maturity (110-120 mm), this cohort is best considered young adults. A second cohort of smaller individuals (juveniles) appeared in February/March (Figure 3). The two cohorts remained present and distinct in April/May, but by June/July, the numbers of the older (i.e. >100 mm) cohort were negligible (Figure 3). Monthly median size of the two cohorts increased with each month, presumably reflecting growth (Table 5). The data suggest that the younger cohort grew more rapidly than the older cohort. Given the likely size-selectivity of the sampling procedure, it is inappropriate to use these data to estimate growth rates in this species. Two further points deserve comment. First, the increase in catch (December/January; Figure 3) precedes the appearance of the juvenile cohort, and hence, cannot be the consequence of juvenile recruitment to the population. This suggests that adult fishes become more available to the sampling procedure in December/January. Secondly, if spawning and recruitment of juveniles occur at about the same time each year, the disappearance of the older cohort by July suggests a life-span of about 1.5 years for *P. brachypterus*.

Catches of *E. volitans* were negligible between October and January (Table 2, Figure 4). A distinct juvenile cohort appeared in February/March, remained abundant in April/May, was very scarce in June/July, but was again abundant in August/September (Table 2, Figure 4). There is no obvious explanation for the marked decline in catch in June and July; it may simply indicate a markedly patchy distribution of *E. volitans*. In contrast to *P. brachypterus*, monthly median size in the juvenile cohort did not consistently increase over the period February to September (Figure 4); suggesting continuous recruitment of juveniles and/or size-selectivity of the sampling procedure in this species. The decline in median size in December/January and again in April/May suggests recruitment pulses (Table 5). The increase in median size from April/May to August/September may reflect a reduction in juvenile recruitment, and growth of the juvenile cohort.

Catches of *H. affinis* were negligible in October/November (Table 2, Figure 5). A juvenile cohort appeared in December/January and increased in abundance through to August/September (Figure 5). As with *E. volitans*, median fish size did not consistently increase between December and September. *H. affinis* has a minor spawning peak around December, and a major spawning peak between April and June (Storey 1983, Khokiattiwong *et al.* 2000). The increase in juvenile size from December/January to February/March may reflect growth of juveniles produced in the first spawning peak (Table 5). The reduction in median size from February/March to April/May may result from recruitment following the second spawning peak, the subsequent increase in size through to August/September reflecting growth of these juveniles.

Catches of *O. micropterus* were negligible between October and January (Table 2, Figure 6). Catches increased sharply in February/March, and two distinct cohorts were evident; one with a median size of 49 mm (juveniles) and the second with a median size of 126 mm (adults) (Figure 6). This suggests that the increased catches result both from recruitment of juveniles and increased availability of adults to the sampling procedure. Catches were lower in April/May, particularly of the older cohort, and continued to decline through to August/September, with only the younger cohort being caught between June and September. Median size increased sharply between April and September, presumably reflecting growth of the juvenile cohort (Table 5).

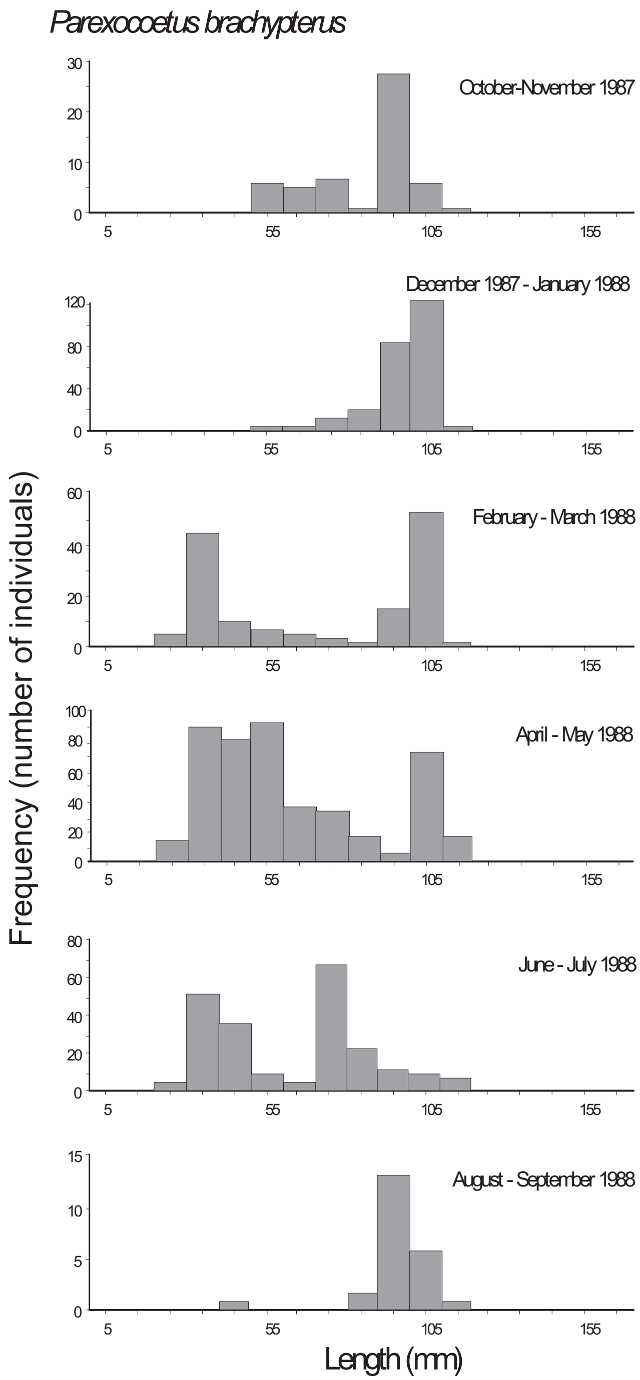

Figure 3. Length frequency distributions (fork length mm) for *Parexocoetus brachypterus* at bimonthly intervals.

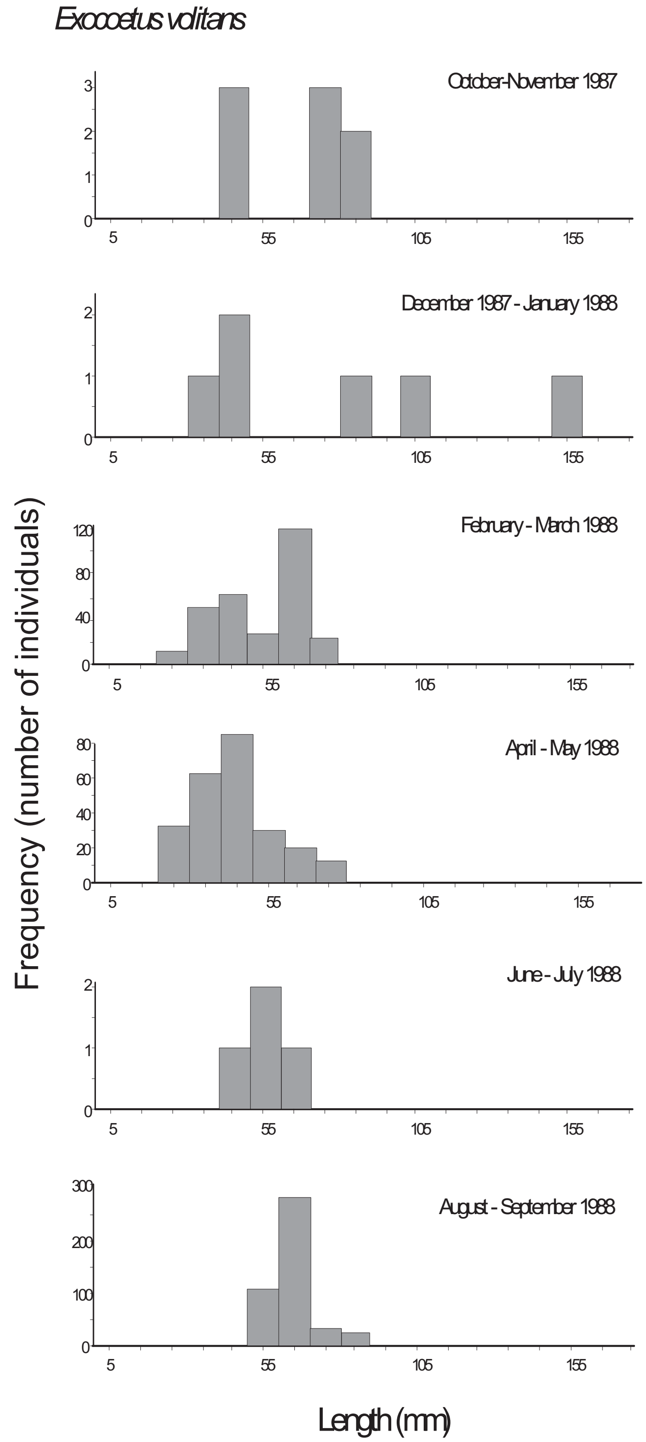

Figure 4. Length frequency distributions (fork length mm) for *Exocoetus volitans* at bimonthly intervals.

Table 5. Median lengths (mm) of the cohorts of the four most abundant species at bi-monthly intervals

Species	Oct -Nov	Dec-Jan	Feb-Mar	Apr-May	June-July	Aug-Sept
Parexocoetus brachypterus - adults	95	100	104	108		
Parexocoetus brachypterus - juveniles			38	50	72	98
Exocoetus volitans			59	43	59	66
Hirundichthys affinis		45	46	33	46	66
Oxyporhamphus micropterus			49	48	62	92

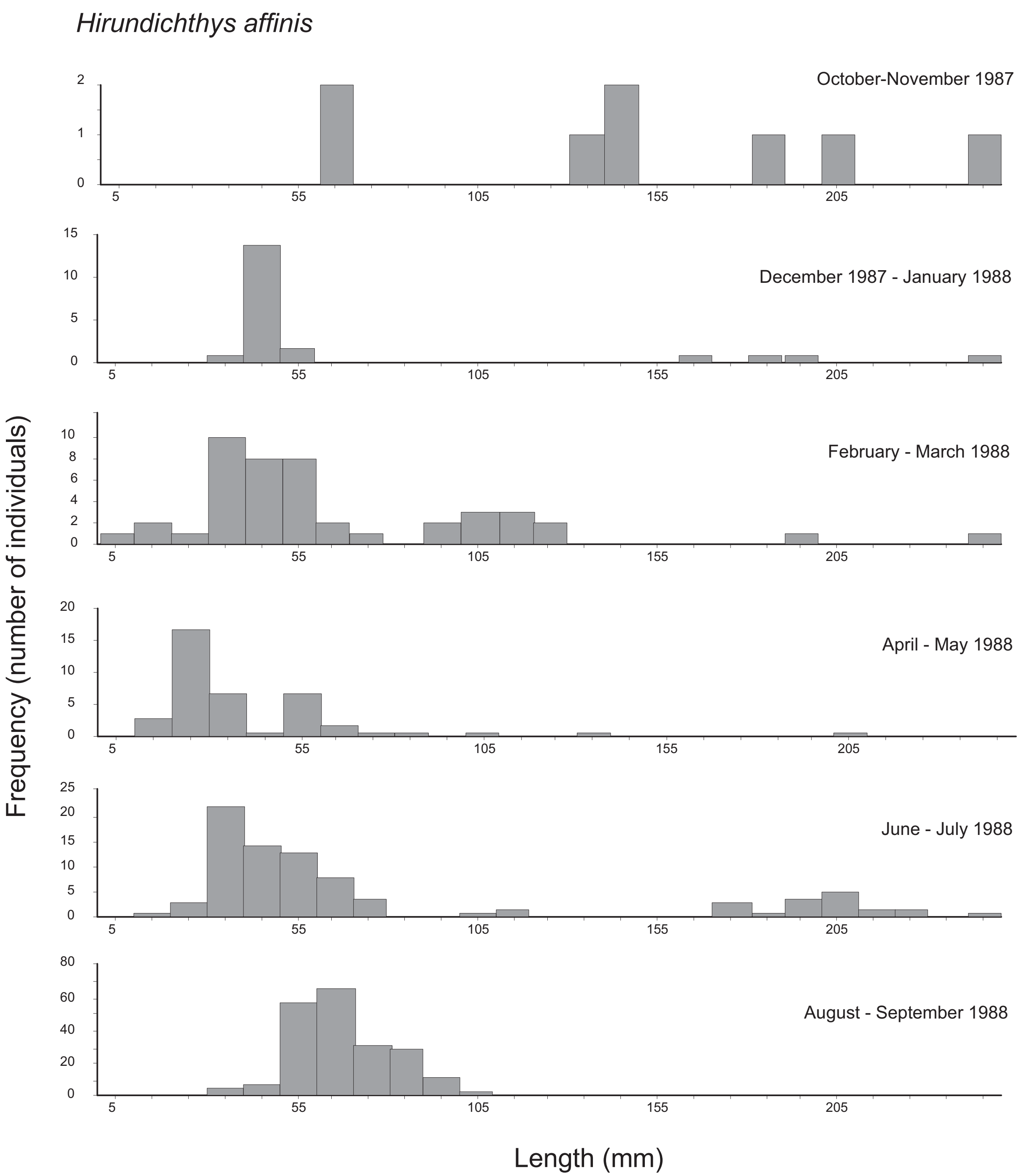

Figure 5. Length frequency distributions (fork length mm) for *Hirundichthys affinis* at bimonthly intervals.

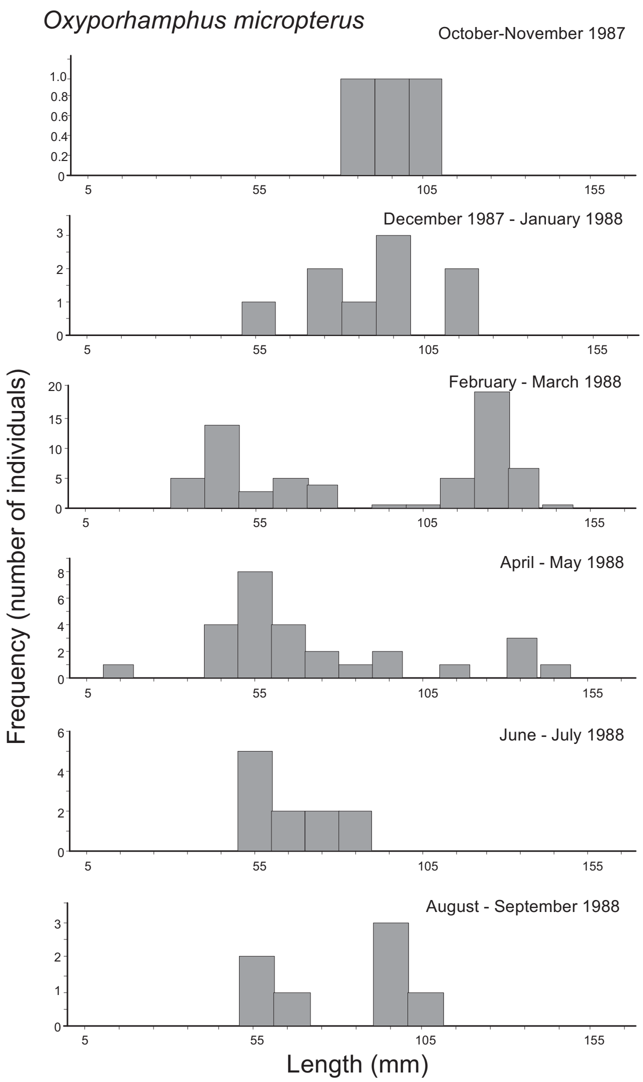

Figure 6. Length frequency distributions (fork length mm) for *Oxyporhamphus micropterus* at bimonthly intervals.

DISCUSSION

Gear selectivity and catch composition

A total of 2,711 flyingfishes were captured in this 1-yr night-lighting study, representing 81% of the flyingfishes observed to enter the effective fishing area of the illuminated zone. The efficiency of capture was not a function of the availability of fishes in the zone. Consequently, the number of fishes caught was considered a valid index of fish availability in the zone.

The sampling procedure, which involved moving between sampling locations every hour and restricting sampling to a maximum of 3 h at the sampling station, appears to have avoided local depletion of fishes at two scales: in the vicinity of the research vessel within 1-h sampling periods; and in the vicinity of the sampling station within a 3-h period. The catch rate was therefore considered to be a valid index of fish abundance.

Although the number of fishes captured may be a valid index of the number of fishes in the illuminated zone, the fishes in the zone are unlikely to be a representative subsample of all fishes present in the vicinity of the vessel. Specifically, the sampling procedure is likely to be selective by species, and within species, by size. Gulland (1983) has emphasized the need to be aware of this aspect of selectivity when sampling fishes by light attraction, since phototactic behavior may vary with species and size.

Six families of fishes were collected during the night-light survey, although 89.8% of the individuals were exocoetids and a further 5.0% were hemiramphids and 2.6% were myctophids. These three families were also reported to be the most common in the night-lighting and dip netting survey across the eastern Caribbean (Oxenford *et al.* 1995a). *Parexocoetus brachypterus, Exocoetus volitans* and *Hirundichthys affinis* dominated the exocoetid catch, whilst *Oxyporhamphus micropterus* dominated the hemiramphid catch. Again, the same three dominant flyingfish species in the same relative proportions were also reported for night-light catches across the eastern Caribbean by Oxenford *et al.* (1995a), although the proportion of *E. volitans* was higher at their sampling station off the northwest coast of Barbados. Interestingly, *E. volitans* was never reported in night-light catches off Barbados by Lewis (1959, 1961) or Lewis *et al.* (1962). Likewise *O. micropterus* has not previously been specifically reported in night-light catches off Barbados (see Lewis 1959, Lewis 1961, Lewis *et al.* 1962), although juvenile hemiramphids were very common in night-light catches over the eastern Caribbean (Oxenford *et al.* 1995a), indicating either that these species were captured but not recorded, or that samples were taken at times of night when these species are not attracted by the sampling procedure. The former may be the more plausible explanation, but the latter emphasises the importance of standardising the time at which sampling occurs, if comparisons of catch abundance and catch composition across months is to be meaningful.

Both juveniles (60% of catch) and adults of *P. brachypterus* were caught. The size-range collected (23-120 mm) was similar to that reported by Lewis (1959, 1961; 30-120 mm) off Barbados, and Oxenford *et al.* (1995a; 10-130 mm) over the eastern Caribbean. Similarly, for *O. micropterus*, both juveniles (58% of catch) and adults were vulnerable to the sampling procedure. By contrast, very few adults of *H. affinis* (< 6%), and almost no adults of *E. volitans* (< 1.0%), were collected. This concurs with the size composition reported in night-light catches over the eastern Caribbean for these two species by Oxenford *et al.* (1995a). Adults of *H. affinis* support a commercial fishery in the eastern Caribbean, and were frequently observed during a 1988 visual survey of flyingfishes conducted in the region (Oxenford *et al.* 1995b). They are therefore known to be present in the area. Their absence from the night-light samples reported by Lewis *et al.* (1962), and the small numbers found in the night-light samples of Oxenford *et al.* (1995a) and the present study, support the suggestion of Nesterov and Bazanov (1986) that adults of this species avoid nightlights. The size range of *H. affinis* collected by Lewis *et al.* (1962; 20-150 mm) and by Oxenford *et al.* (1995a; 20-230 mm) was similar to the size range collected in this study (10-220 mm). In contrast to *H. affinis*, adults of *E. volitans* are extremely rare in commercial catches off Barbados (Storey 1983), were not taken in experimental gillnet catches off Barbados (Khokiattiwong *et al.* 2000), and were not observed during a visual survey of flyingfishes over the eastern Caribbean (Oxenford *et al.* 1995b). Their absence from night-light samples may therefore simply reflect a scarcity of *E. volitans* adults in the area.

Seasonal variation in abundance and size

Length frequency distributions indicate that recruitment of juveniles began in February/March for *P. brachypterus, E. volitans* and *O. micropterus*; and in December/January for *H. affinis*.

The monthly median size of fish in the juvenile cohort did not increase consistently with time for either *H. affinis* or *E. volitans*, suggesting extended recruitment of juveniles and/or size- selectivity of the sampling procedure against larger juveniles in these species. Interestingly, these are the species in which catches of adults are negligible. In the case of *H. affinis*, the pattern of seasonal variation in juvenile size is consistent with the observation of a minor spawning peak around December, and a major peak between April and June (Storey. 1983, Khokiattiwong *et al.* 2000).

By contrast, monthly median size of fish in the juvenile cohort increased more clearly with time for both *P. brachypterus* and *O. micropterus*. This may suggest a shorter recruitment period and/or less size-selectivity of the sampling procedure in these species. The suggestion of less selectivity is consistent with the observation that adults of these species were caught in relatively large numbers by the night-lighting gear.

Juvenile abundance varied significantly between months in all four species. In *P. brachypterus*, *E. volitans* and *O. micropterus*, recruitment of juveniles began at the same time (February/March); and juveniles remained abundant over a similar period (March to July for *P. brachypterus*, February to August for *E. volitans*, and February to July for *O. micropterus*). This suggests a similar pattern of seasonal reproduction in these species. The spawning season of *P. brachypterus* has been suggested to be September to January by Lewis (1961), and March to August by Khokiattiwong *et al.* (2000). The present results suggest that juveniles of *P. brachypterus* grow about 10 mm per month, and that juveniles are nearly 40 mm long at recruitment to the night-light catches in February/March. This suggests that the February\March recruits may have been spawned in the previous October/November. This is more consistent with the September to January spawning period reported by Lewis (1961), than the March to August period reported by Khokiattiwong *et al.* (2000). It is of course possible that the spawning seasonality of *P. brachypterus* varies between years, and it may vary between locations. For example, Erdman (1976) suggested that the spawning of *P. brachypterus* in Puerto Rico occurs between December and April; slightly later than the September to March period proposed by Lewis (1961) for Barbados. Fahay (1975) reported that larval and juvenile *P. brachypterus* were most common in the South Atlantic Bight between July and October; a period which would be more consistent with March to August spawning as proposed by Khokiattiwong *et al.* (2000). There have been fewer studies of spawning seasonality in *E. volitans*. However, Grudtsev *et al.* (1987) reported that spawning occurred in the Atlantic primarily between October and April. This would correspond, with about a 4-month lag, to the occurrence of juveniles between February and August observed in this study.

For *H. affinis*, some recruitment of juveniles began in December/January, but juveniles became increasingly abundant from February through to August. This corresponds well with the December to May spawning season known for *H. affinis* in Barbados (Storey 1983, Khokiattiwong *et al.* 2000), and with the observation that larval exocoetids were most abundant off Barbados between February and June.

Seasonality of *Hirundichthys affinis* adults near Barbados.

The present study provides support for the hypothesis proposed in the introduction, that the seasonality of *H. affinis* in the fishery around Barbados is due to the annual nature of the species resulting in a period during which there are no mature adults to be caught. That all life-stages of *H. affinis* are sequentially present year-round near Barbados, is not consistent with the hypothesis of a large-scale migration away from the island in June and a return migration in November. This is supported by the results of a tagging study for *H. affinis* in the eastern Caribbean, which demonstrated reduced levels of movement towards the end of the season (May/June), and a lack of tag returns in the following fishing season (Oxenford 1994). Peak spawning of *H. affinis* occurs between December and May, peak abundance of larvae is between February and June (Lao *et al. submitted*), juvenile abundance rises from February to a peak near August, and small adults may be taken by experimental gillnets in September/October (Khokiattiwong *et al.* 2000) and begin to be taken by the commercial gillnet fishery in November (Storey 1983, Khokiattiwong *et al.* 2000). This pattern supports the explanation that the period of low abundance of adults (July to October) is primarily caused by an interval between adult cohorts.

This is also consistent with the recently determined short life-span (< 2 yr) of this species (Campana *et al.* 1993). Three other reported observations support the idea of high post-spawning mortality. First, Barroso (1967) suggests that feeding of *H. affinis* decreases during spawning. Second, flyingfish taken by the Barbados commercial fishery in June are typically in poor condition and are often heavily parasitized (Storey 1983). Third, Khokiattiwong *et al.* (2000) found that average size of adults decreased at the end of spawning season, suggesting mortality of larger adults. However, it should be noted that at least some fish of adult size are present in the traditional off-season for the fishery. Twelve of the 23 adults of *H. affinis* captured in this study were collected in July. These fish could either be fast-growing individuals spawned early in the preceding December/May spawning period, or the remnants of the adult population which had spawned in December/May. Given the size of these adults (190-200 mm), the former suggestion seems more likely.

In summary, the most plausible explanation for the seasonality of the commercial fishery for *H. affinis* may therefore be that few adults are present between July and October, and that the few present are not spawning and are not therefore vulnerable to the commercial fishery. The scarcity of adults results from high post-spawning mortality and from the fact that few fish, spawned in the December/May period, attain adult size between July and October.

ACKNOWLEDGEMENTS

This study was funded by a scholarship within the ASEAN-CIDA Cooperative Program for Marine Science to M.R.L., NSERC Operating Grant AO264 to W.H., and IDRC, Canada as a component of the Eastern Caribbean Flyingfish Project. We are especially grateful for sampling assistance from fishermen Emerson Jordan and Vincent Austin.

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