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Larval fishes off Barbados with particular reference to flyingfishes and their spawning substrata

M. ROMMEL LAO, WAYNE HUNTE AND HAZEL A. OXENFORD

Abstract: Since flyingfish are believed to spawn on floating substrates, the composition and seasonal abundance of flotsam was surveyed by 431 neuston tows at 3 stations offshore between October 1987 and September 1988. Only 38% of tows contained flotsam, and only 1% of tows produced flotsam with flyingfish eggs. Flotsam was most abundant between March and September, when water reaching Barbados is influenced by South American river outflow. Fish larvae of 34 and 24 families were collected in day and night neuston tows respectively, and larval abundance was higher by day than night. The most common families ranged from truly oceanic (myctophids, istiophorids and some scombrids), to offshore (hemiramphids, exocoetids and some scombrids) to coastal (dactylopterids, carangids, mugilids and mullids). Hemiramphids (46% of day catch) and myctophids (51% of night catch) dominated the catches. In both day and night samples, larvae were most abundant between February and June. Larval abundance differed significantly between stations. In most cases larvae were largest and most abundant at the offshore station, and smallest and least abundant at the nearshore station. This is consistent with the suggestion that larvae are being retained in current systems off the northwest coast; larval retention leading to both higher larval abundance and larger size through growth.

INTRODUCTION

The eggs of most Exocoetidae (flyingfish) species (except those of the genus *Exocoetus*) have little or no oil globule for buoyancy, but have filaments for attachment to substrata and are therefore considered demersal (Evans 1961, Collette *et al.* 1984). Since all life history stages of flyingfishes except the eggs are pelagic, it is typically assumed that adults of most species spawn on floating substrata. They apparently spawn on a wide range of floating substrata including *Sargassum* weed (*Hirundichthys* spp.: Breder 1938, Vijayaraghavan 1973; *Hirundichthys affinis*: Brown 1942, Hall 1955, Lewis *et al.* 1962), empty bottles (*Hirundichthys speculiger*: Munro 1954), straw (Gill 1904), driftwood, fragments of algae, pieces of wood, bird feathers, coconuts, drift nets and some pleustonic organisms (*Hirundichthys* spp. and *Cheilopogon* spp.: Kovalevskaya 1982).

The materials used for making fish attraction devices (FADs) in the *H. affinis* fishery in the eastern Caribbean have proven to be good spawning substrata, indicating the flexibility of flyingfish in choice of spawning substratum. Dried coconut branches are used in Grenada (Steele and Oxenford 1986), while banana leaves are used in St. Lucia (Walters and Oxenford 1986). In Barbados, fishermen use either sugar cane trash or coconut branches (Harding 1986). A combination of hibiscus flowers and banana leaves are used in Martinique (Guillou and Oxenford 1986), while either banana leaf trash or coconut branches are used in Dominica (Darroux and Oxenford 1986) and dried leaves are used in Tobago (Fabres 1986). Egg deposition on drifting gill nets is also a common occurrence (Storey 1983, Khokiattiwong 1988).

The tendency of flyingfish, particularly *H. affinis*, to use flotsam as spawning substrata has therefore been known for some time. However, only one study (Hunte *et al*. 1995, conducted in the eastern Caribbean in April/May 1988) has attempted to systematically identify and quantify potential flyingfish spawning substrata, and one study (Hall 1955, conducted off Barbados in February/March 1953) has attempted to determine whether variation in the abundance of floating sargassum weed was correlated with flyingfish catch. No studies have investigated seasonal variation in the availability of spawning substrate. It is therefore not known whether seasonal variation in availability of spawning substrata may influence seasonal variation in

spawning of flyingfish, nor whether the availability of spawning substrata may limit population size. One objective of the present study is therefore to identify flyingfish spawning substrata (flotsam) near Barbados, and investigate seasonal variation in its abundance and use.

There have been few systematic ichthyoplankton surveys in the Caribbean. Powles (1975) conducted a comprehensive plankton survey 4-50 km off Barbados from May 1972 to December 1973 using a bongo net, but found very few flyingfish (N = 13, 0.04% of total catch) probably because the sampling depths (13-60 m below the surface) were too deep. He also used a plankton net nearshore, sampling at a depth of 3 m below the surface, but again no flyingfish were reported. Richards (1984) conducted two extensive fish larval surveys across a wide area of the Caribbean in 1972-1973. Exocoetids occurred more frequently than all other families in the neuston net samples for both surveys, but were relatively rare in the bongo net samples. Hunte *et al.* (1995) conducted a neuston survey across the eastern Caribbean in April/May 1988 and found exocoetids to be the third most common family, comprising 13% of the total catch. Cowen and Castro (1994) examined the vertical (0-140 m depth) and horizontal distribution of ichthyoplankton around Barbados (up to 90 km offshore) using a Multiple Opening-Closing Net in April/May 1990, but only reported the 4 most common families (myctophids, bregmacerotids, nomeids and bothids) in the 140 m deep water column, and analyses were restricted to coral reef-associated fish. Sponaugle and Cowen (1996) examined temporal and spatial patterns of fish larval supply to nearshore coral reefs along the west coast of Barbados using anchored light traps 1 m below the surface from April to May in 1991 and 1992. These collected 31 families of reef-associated species, but no exocoetids. These studies suggest that larval reef-associated fishes are found over a fairly wide depth range below the surface and a broad area of open ocean and coastal waters, whereas exocoetids appear to stay mainly within the 0-0.5 m depth layer sampled by neuston nets (Nesterov and Bazanov 1986) and do not approach the nearshore area.

There has been no seasonal study of neustonic fish larvae in the eastern Caribbean. Consequently, little is known about the seasonal variation in distribution and abundance of flyingfish larvae, since these are primarily neustonic. A second objective of this study is therefore to investigate the composition, distribution and seasonal variation in abundance of fish larvae in the neuston near Barbados, with particular emphasis on flyingfish.

METHODS

Terminology

All flotsam items were considered as potential spawning substrata. Nomenclature of early life history stages of fish (larvae, leptocephali, fry, post-larvae or juveniles) varies with discipline and species, and is often determined by size and behaviour. For ease of description in this study we refer to all fish taken by the neuston sampling gear as larvae.

Sampling stations

Three neuston sampling stations (Stations1, 2 and 3) located 3, 6, and 9 nautical miles (nmi) from shore respectively, were established along a straight-line transect off the northwest coast of Barbados (Figure 1).

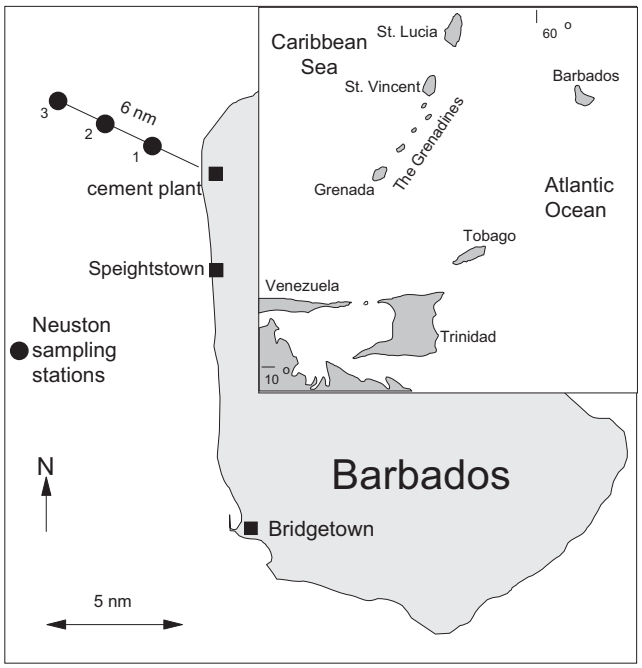

Figure 1. Location of Barbados and of the neuston sampling stations.

Sampling procedure

Flotsam and larvae were collected by day and night using a neuston sampler, which was the same as that used by Hunte *et al.* (1995), being a modified version of the otter sampler used by Sameoto and Jaroszynski (1969) and described in detail by Lao (1989). The 6 m long, 1.27 mm square mesh neuston

net had a 1 × 0.5 m aluminium frame opening and was towed at speeds of up to 3 knots on the windward side of the boat by an adjustable bridle. This ensured that the net tracked away from the wake of the boat, and adjustable elevator fins ensured that the net remained at the surface, sampling to a water depth of approximately 0.25 m. Since it was not possible to maintain consistent towing speeds in the small research boat, tows were standardized by distance (0.5 nmi) as measured to the nearest 0.01 nmi by a trailing log.

Both day and night tows were attempted at least once a week from October 1987 to September 1988 at all three sampling stations. The sequence of tows was always offshore to onshore. Replicate tows were made during day trips, but not during night trips because of the additional difficulties of working from a small boat in the dark. Day tows were conducted in the afternoon between 13:00 and 17:00 hr and night tows were conducted between 23:00 and 03:00 hr. A total of 98 trips (49 day and 49 night trips) were made, and 431 tows (288 day and 143 night tows) were completed (Table 1). Missed trips or missed tows were a result of bad sea conditions, gear failure or lack of time before sunset.

Table 1. Schedule of sampling trips and number of neuston tows completed.

Sampling date		Day		Night	
		Trips	Tows	Trips	Tows
1987	October	5	28	4	10
	November	4	21	4	12
	December	5	30	5	15
1988	January	4	23	4	11
	February	4	24	3	9
	March	4	24	5	15
	April	5	30	4	12
	May	4	24	5	15
	June	4	24	4	12
	July	5	30	4	12
	August	4	24	5	15
	September	1	6	2	5
Total		49	288	49	143

Treatment of samples

All samples were preserved in 5% buffered (sodium tetraborate) formalin solution. All potential flyingfish spawning substrata (flotsam) were sorted into type or species as appropriate, classified as either of terrestrial or marine origin, and weighed to the nearest 0.01 g. All fish larvae were sorted from the plankton and counted. Exocoetidae larvae were identified to genus or species using morphological, and when necessary, meristic characteristics based on the taxonomic descriptions of Bruun (1935), Breder (1938), Imai (1959, 1960), Evans (1961), Staiger (1965), Parin and Gorbunova (1964), Gibbs and Staiger (1970), Gibbs (1978), and Kovalevskaya (1978). Where Exocoetidae larvae could not be reliably identified to species, they were recorded, where possible, by genus (e.g. *Hirundichthys* spp. and *Cypselurus* spp.). Unidentified flyingfish were simply referred to as Exoetidae-unid. Non-flyingfish larvae were identified only to family, using the descriptions of Ahlstrom (1965), Powles (1975), Miller *et al.* (1979), Leis and Rennis (1983), Fahay (1975, 1983), Castle (1984), Moser *et al.* (1984), and Nishikawa and Rimmer (1987). Total length of each identified larva was measured (to the nearest mm) to generate length-frequency distributions.

Treatment of data

Several neuston tows contained no flotsam and/or no larvae of many of the fish families investigated. Consequently, data on flotsam and larvae were not normally distributed and could not be normalized by transformations. Non-parametric statistical tests were therefore used throughout. Chi-square Goodness of Fit tests were used to investigate variation in frequency of occurrence of flotsam. Wilcoxon paired-sample tests were used to investigate variation between replicate tows. Mann Whitney tests were used to compare flotsam and larval abundance between day and night samples, and Kolmogorov-Smirnov two-sample tests to compare length-frequency distributions of day and night samples. Kruskal-Wallis one-way analysis of variance was used to investigate seasonal and spatial variation in abundance of flotsam and larvae; and Mann Whitney tests for paired comparisons between stations. Spearman Rank Correlation analysis was used to investigate correlations between fish larvae from different families.

No significant differences were found between sampling replicates (day tows) for the frequency of occurrence of flotsam (observed occurrence in second tows not different from expected occurrence based on first tows; Chi-square test, $X^2 = 1.58$, $P > 0.05$), the quantity of flotsam collected (Wilcoxon rank test, $T = 0.902$, $P > 0.05$), nor the number of fish larvae collected (Wilcoxon rank test, $T = 0.774$, $N = 137$, $P > 0.05$).

Consequently, data from replicate day tows were pooled for all subsequent analyses of flotsam occurrence, flotsam abundance and larval fish abundance.

RESULTS

Occurrence, composition and abundance of flotsam

The neuston samples contained flotsam in every month of the study. It was collected on 68.4% of all sampling trips, but in only 38.5% of all tows. The median weight of flotsam per tow was less than 0.01 g. Forty-four percent (by weight) of the flotsam collected was of marine origin and 56% of terrestrial origin. The marine flotsam was composed of the seagrasses, *Syringodium filiforme* (25%) and *Thalassia testudinum* (19%). The flotsam of terrestrial origin consisted primarily of tar (4.2%) and pine needles (2.6%); secondarily, of wood, bird feathers, cane trash and plant leaves inter alia (49%).

Variation between day and night tows

The frequency of occurrence of flotsam did not differ significantly between day and night tows (Chi-square test, $X^2 = 0.187$, $P > 0.05$). Consequently, day and night tows were pooled for all subsequent analyses of frequency of occurrence of flotsam. Similarly, the quantity of flotsam collected did not differ significantly between day and night tows (Mann Whitney test, $U = 0.204$, $P > 0.05$). Consequently, day and night tows were pooled for all subsequent analyses of flotsam abundance.

Seasonal variation

The percentage of tows with flotsam differed significantly between months (October 1987 to September 1988; Chi-square test, $X^2 = 79.27$, $P < 0.001$), as did the quantity of flotsam collected (Kruskal-Wallis test, $H = 48.65$, $P < 0.001$). Flotsam tended to be less common between October and February than between March and September (Table 2).

Spatial variation

The frequency of occurrence of flotsam over the full sampling period did not differ significantly between stations, whether the frequency was calculated as percentage of tows with flotsam (Chi-square test, X2 = 0.198, $P > 0.05$) or as percentage of trips with flotsam (X2 = 0.257, $P > 0.05$) (Table 3). Similarly, the quantity of flotsam collected did not differ significantly between stations (Kruskal-Wallis test, $H = 0.463$, $P > 0.05$; Table 3).

Table 2. Frequency of occurrence (as % of trips and tows) and abundance (as wet weight in g) of flotsam shown separately by month over the neuston sampling period.

Sampling date		Trips			Tows			Weight of flotsam (g)
		No. trips	No. trips with flotsam	% Occurrence	No. tows	No. tows with flotsam	% Occurrence	
1987	October	9	4	44.4	38	7	18.4	3.52
	November	8	5	62.5	33	9	27.3	37.38
	December	10	8	80.0	45	14	40.0	8.99
1988	January	7	4	57.1	34	7	20.6	6.41
	February	7	4	57.1	33	8	24.2	3.81
	March	9	8	88.9	39	21	53.8	32.53
	April	9	8	88.9	42	21	50.0	15.89
	May	9	7	77.8	39	19	48.7	30.13
	June	8	8	100.0	36	31	86.0	31.29
	July	9	5	55.6	42	15	35.7	24.99
	August	9	4	44.4	39	10	25.6	21.34
	September	3	2	66.7	11	4	36.4	53.42
Total		98	67	68.4	431	166	38.5	270.11

Table 3. Frequency of occurrence of flotsam (% of tows and % of trips) and quantity of flotsam (wet weight in g) at Stations 1, 2 and 3 over the entire sampling period (October 1987-September 1988).

Parameter	Station 1 (3 nmi)	Station 2 (6 nmi)	Station 3 (9 nmi)
No. of tows	139	144	148
No. of tows with flotsam	54	58	54
% of tows with flotsam	38.8	40.3	36.5
Total weight of flotsam (g)*	121.5	74.95	73.63
% of all flotsam by weight	45.0	27.8	27.2
No. of trips	98	98	98
No. of trips with flotsam	36	39	39
% of trips with flotsam	36.7	39.8	39.8

** Total weight at Station 1 includes 42.67 g (35%) of flotsam collected on one trip in two tows. If these are excluded, Station 1 accounts for 29% of total flotsam.*

Flotsam utilization as spawning substratum

Eggs of *Hirundichthys affinis* were found attached to flotsam at the sampling stations on only 5 occasions during the study (Table 4). These were in December 1987 and between April and June 1988. The flotsam with eggs was found at all three stations, but the eggs could have been spawned elsewhere. The eggs were attached to either *Thalassia testudinum* or cane trash in all cases. The substrata on which the eggs were found were present in small fragments and presumably had been parts of larger clumps. The cane trash fragments were probably remnants of the fish aggregating devices used by fishermen in Barbados. Apart from the above egg samples collected at the standard sampling sites, a clump of *Syringodium filiforme* which was fully laden with *H. affinis* eggs was collected 5 nmi off the north of the island on March 16, 1988.

Composition, abundance and size of neustonic fish larvae

A total of 8,084 fish larvae comprising 39 families were collected during the neuston sampling programme. Numerically, the most abundant families were the Hemiramphidae (accounting for 35.4% of the total catch), Myctophidae (11.8%), Mullidae (9.5%), Dactylopteridae (8.8%) and Exocoetidae (6.9%). The Exocoetidae comprised at least 5 genera and 5 species, the most common of which were *Hirundichthys* spp. (accounting for 21.8% of all flyingfish caught), *Exocoetus volitans* (13.6%) and *Parexocoetus brachypterus* (6.4%) (Table 5). Given the numerical dominance of *H. affinis* over *H. speculiger* in the area (Storey 1983, Khokiattiwong 1988) it is likely that most of the *Hirundichthys* larvae in this study were *H. affinis*.

Table 4. Occasions on which flotsam that had been used as spawning substrate were found at sampling stations.

Sampling date		Station no.	Flotsam type	Weight of flotsam (g)	No. of eggs
1987	Dec 26	3	cane trash	0.7	17
1988	Apr 19	1	*Thalassia testudinum*	1.4	123
	May 3	2	cane trash	17.4	78
	Jun 3	1	*Thalassia testudinum*	0.2	65
	Jun 6	3	*Thalassia testudinum*	<0.1	12

Variation between day and night samples

Day tows collected 6,211 larvae; night tows collected 1,873 larvae. The number of larvae collected per tow during day samples (mean = 22) was significantly greater than that collected per tow during night samples (mean = 13; Mann Whitney test, $U = -3.235$, $P < 0.01$). A difference may be expected since neustonic larval composition typically differs between day and night samples. The consequence is that day and night samples have been treated separately for all subsequent analyses of larval abundance.

The neuston collected during the day comprised 34 families, the most numerically abundant being Hemiramphidae (accounting for 46.0% of the total day catch), Mullidae (12.4%), Dactylopteridae (11.3%), Exocoetidae (7.8%), and Mugilidae (3.5%) (Table 6). The taxonomic composition of the neuston collected at night was markedly different from that in the day (Table 7). It consisted of only 24 families, the numerically dominant ones being the Myctophidae (accounting for 50.7% of the total night catch), Muraenidae (10.1%), Scombridae (6.0%), Exocoetidae (4.1%), and Carangidae (3.7%) (Table 7).

Table 5. Taxonomic composition and relative abundance of Exocoetidae larvae shown as numbers caught separately by month over the neuston sampling programme.

Taxanomic category	Year	1987			1988									Total	%
	Month	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep		
	# tows	38	33	45	34	33	39	42	39	36	42	39	11	431	
Hirundicthys spp.		0	1	2	0	16	5	2	55	30	7	3	1	122	21.8
Exocoetus volitans		1	0	0	0	10	20	20	15	10	0	0	0	76	13.6
Parexocoetus brachypterus		1	0	0	0	2	14	1	11	5	0	0	2	36	6.4
Cypselurus spp.		0	0	0	0	0	2	0	0	1	0	0	0	3	0.5
Prognithys gibbifrons		0	0	0	1	0	0	0	0	1	0	0	0	2	0.4
Exocoetidae-unid.		2	4	3	25	25	75	69	58	11	23	23	2	320	57.4
Total		4	5	5	26	53	116	92	139	58	30	26	5	559	100

The length frequency distributions of larvae caught during day and night sampling differed significantly (Kolmogorov Smirnov two-sample test, $D = 0.562$, $P < 0.001$). The length frequency distribution for larvae caught during the day was unimodal (Figure 2a), and for night larvae was bimodal (Figure 3a). Moreover, larvae caught during the day were smaller than those caught at night (Figures 2a and 3a).

Length frequency distributions for the numerically dominant families collected in the day and night samples are shown in Figures 2b-i and 3b-f respectively. One explanation for the difference in size structure of day and night samples is that species which are numerically dominant at night differ from, and are larger than, the numerically dominant species in the day. For example, myctophid larvae (mean size: 16.12 mm; Figure 3b) are significantly larger than hemiramphid larvae (mean size: 10.16 mm; Figure 2b) (Mann Whitney test, $U = 2.12$, $P < 0.05$); muraenid larvae, which are particularly large (mean size: 88.99 mm; Figure 3c), are common in night samples (Table 7) but virtually absent in the day (Table 6). Note that muraenids are primarily responsible for the larger of the two size modes observed in the night samples (Figure 3a). A second possible cause of the difference in size of day and night larvae is that, for families which are caught both by day and night, the larvae caught at night may be larger than those caught in the day. This is true for the Exocoetidae (night larvae > day larvae; Mann Whitney test, $U = -11.92$, $P < 0.001$; Figures 2e and 3e). However, the size of scombrid larvae does not differ by day and night (Mann Whitney test, $U = 1.42P > 0.05$; Figures 2i and 3d); and the carangid larvae caught by day are larger that those, caught by night (day larvae > night larvae; Mann Whitney test, $U = 3.66$, $P < 0.001$; Figures 2g, 3f).

Seasonal variation in abundance (day samples)

The number of larvae collected per tow in day samples varied significantly between months (Kruskal-Wallis test, $H = 83.49$, $P < 0.001$; Figure 4a). Larvae were most abundant between February and June (Figure 4a). All of the common families considered separately showed significant variation in larval abundance between months (Table 8; Figures 4b-i). Some of the monthly values of larval abundance showed significant positive correlations between families, others showed significant negative correlations, and others were not correlated (Table 9). The common families can be roughly grouped into three categories; those in which sub-adults and adults are largely coastal (Category 1: Mugilidae, Mullidae and most Carangidae), those with sub-adults and adults farther offshore but not fully oceanic (Category 2: Hemiramphidae, Dactylopteridae, and most Exocoetidae; note that dactylopterids have an extended sub-adult phase that is offshore, but adults are coastal) and those with larger, fully oceanic adults (Category 3: Istiophoridae, and most Scombridae). The monthly variation in larval abundance was positively correlated between the Hemiramphidae, Dactylopteridae and Exocoetidae i.e. within category 2 (Table 9); larvae being most abundant between February and June (Figures 4b, d, e). These families, but particularly the Hemiramphidae which constitute 46% of the day catch, are therefore largely responsible for the observation that total larvae in day samples are most abundant between February and June (Figure 4a). Monthly variation in larval abundance was positively

Table 6. Taxonomic composition and relative abundance of fish larvae caught in day tows over the neuston sampling programme, shown as numbers caught separately by month.

Taxonomic category	Year	1987			1988									Total	% (if > 1)
	Month	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep		
	# tows	28	21	30	23	24	24	30	24	24	30	24	6	288	
Hemiramphidae		34	64	88	109	301	483	550	649	306	188	47	36	2855	46.0
Mullidae		79	105	32	35	165	0	6	32	240	25	49	1	769	12.4
Dactylopteridae		2	10	27	34	75	152	180	53	70	89	10	2	704	11.3
Exocoetidae		4	4	4	26	47	93	80	119	54	25	23	23	482	7.8
Mugilidae		2	0	0	2	174	21	16	2	1	0	1	0	219	3.5
Carangidae		12	33	35	13	7	1	18	1	29	8	24	2	183	2.9
Istiophoridae		37	33	24	1	7	3	12	3	13	9	19	4	165	2.7
Scombridae		36	7	7	2	0	1	3	0	6	18	34	2	116	1.9
Coryphaenidae		0	2	1	3	13	19	23	0	5	2	2	3	73	1.2
Serranidae		3	4	11	4	4	3	0	0	1	3	3	0	36	
Gerreidae		0	0	0	6	14	0	0	0	0	0	0	0	20	
Nomeidae		2	0	0	1	0	0	5	0	4	0	8	0	20	
Kyphosidae		0	0	0	2	0	0	0	1	0	1	13	0	18	
Balistidae		1	0	0	0	3	7	2	1	0	0	1	0	15	
Clupeidae		1	4	1	4	1	0	0	0	0	0	3	0	14	
Tetraodontidae		0	0	0	1	2	0	1	2	1	1	1	0	9	
Gempylidae		1	2	1	1	0	1	0	1	0	0	0	0	7	
Chloropthalmidae		0	5	0	1	0	0	0	0	0	0	0	0	6	
Myctophidae		0	1	1	0	0	1	1	0	0	0	0	0	4	
Xiphidae		1	0	1	1	0	0	1	0	0	0	0	0	4	
Pomacentridae		0	0	0	1	0	0	2	0	0	0	0	0	3	
Bregmacerotidae		0	0	0	1	0	0	2	0	0	0	0	0	3	
Sphyraenidae		1	0	0	2	0	0	0	0	0	0	0	0	3	
Holocentridae		0	2	1	0	0	0	0	0	0	0	0	0	3	
Engraulidae		0	0	0	0	2	0	0	0	0	0	0	0	2	
Ostacidae		0	0	0	0	2	0	0	0	0	0	0	0	2	
Scorpaenidae		0	0	0	0	1	1	0	0	0	0	0	0	2	
Syngnathidae		1	0	0	0	1	0	0	0	0	0	0	0	2	
Apogonidae		0	1	0	0	0	0	0	0	0	0	0	0	1	
Bothidae		0	0	0	0	1	0	0	0	0	0	0	0	1	
Echeinidae		0	0	0	0	0	0	0	1	0	0	0	0	1	
Haemulidae		0	0	0	0	0	0	0	0	0	1	0	0	1	
Leptocephali		0	0	0	1	0	0	0	0	0	0	0	0	1	
Ophidiidae		0	0	0	0	1	0	0	0	0	0	0	0	1	
Damaged		19	17	14	12	40	22	67	0	5	10	7	4	217	3.5
Unidentified		16	23	30	32	54	16	9	5	15	22	24	3	249	4.0
Total		252	317	278	297	916	824	976	875	747	402	270	57	6211	
%		4.1	5.1	4.5	4.8	14.7	13.3	15.7	14.1	12.0	6.5	4.3	0.9	100	

correlated between the Istiophoridae and Scombridae (i.e. within category 3; Table 9), with larvae being least abundant between February and June (Figures 4h, i). Consequently, monthly variation in larval abundance of these families is either negatively correlated or not correlated with the families in category 2 (e.g. Scombridae negatively correlated with Dactylopteridae and Hemiramphidae, not correlated with Exocoetidae; Istiophoridae negatively correlated with Dactylopteridae, not correlated with Exocoetidae and Hemiramphidae; Table 9). Seasonal trends in larval abundance of the Mullidae, Mugilidae and Carangidae were less evident (Figures 4c, f, g).

Table 7. Taxonomic composition and relative abundance of fish larvae caught in night tows over the neuston sampling programme, shown as numbers caught separately by month.

Taxonomic category	Year	1987			1988									Total	% (if > 1)
	Month	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep		
	# tows	10	12	15	11	9	15	12	15	12	12	15	5	143	
Myctophidae		17	21	36	32	107	99	197	116	153	51	113	8	950	50.7
Muraenidae		1	4	15	3	12	3	3	37	66	4	22	20	190	10.1
Scombridae		8	6	13	11	9	10	11	8	18	0	16	3	113	6.0
Exocoetidae		0	1	1	0	6	23	12	20	4	5	3	2	77	4.1
Carangidae		2	2	36	12	10	0	1	0	1	1	4	0	69	3.7
Coryphaenidae		1	0	3	3	1	24	11	9	0	0	1	0	53	2.8
Bothidae		0	2	0	1	9	8	0	10	13	0	4	0	47	2.5
Nomeidae		0	0	1	4	10	13	7	6	0	0	0	1	42	2.2
Balistidae		0	2	1	2	0	5	4	14	0	1	1	2	32	1.7
Holocentridae		13	0	0	0	0	0	0	5	3	1	6	3	31	1.6
Gonostomatidae		5	6	2	0	2	0	0	0	1	0	0	3	19	1.0
Serranidae		0	0	4	1	6	2	1	0	0	0	1	1	16	
Priacanthidae		1	1	2	5	2	0	0	0	0	0	0	3	14	
Syngnathidae		0	3	0	2	0	2	0	0	4	0	0	1	12	
Dactylopteridae		0	0	0	0	0	0	1	2	6	0	0	0	9	
Paralepidae		0	0	0	0	4	2	0	0	0	0	0	0	6	
Hemiramphidae		1	0	0	0	0	1	0	2	0	2	0	0	6	
Clupeidae		0	0	3	0	2	0	0	0	0	0	0	0	5	
Tetraodontidae		1	0	1	0	0	0	0	1	0	0	0	0	3	
Acanthuridae		0	0	0	1	0	0	0	0	1	0	0	0	2	
Bercidae		0	0	1	0	0	0	0	0	0	0	0	0	1	
Kyophosidae		0	1	0	0	0	0	0	0	0	0	0	0	1	
Mugilidae		0	0	0	0	0	0	0	0	0	1	0	0	1	
Ostracidae		1	0	0	0	0	0	0	0	0	0	0	0	1	
Damaged		7	5	11	23	12	8	4	9	0	0	1	12	92	4.9
Unidentified		2	4	14	5	16	6	7	5	11	2	4	5	81	4.3
Total		60	58	144	105	208	206	259	244	281	68	176	64	1873	
%		3.2	3.1	7.7	5.6	11.1	11.0	13.8	13.0	15.0	3.6	9.4	3.4	100	

Table 8. Results of Kruskal-Wallis tests for variation in number of fish larvae collected per day tow between months, shown separately for the most common families. Level of significance: *** P < 0.001.

Family	H	P
Carangidae	31.37	***
Dactylopteridae	74.98	***
Exocoetidae	71.89	***
Hemiramphidae	84.25	***
Istiophoridae	57.49	***
Mugilidae	55.46	***
Mullidae	62.19	***
Scombridae	47.84	***
All larvae	83.49	***

Table 9. Spearman rank correlation coefficients of the monthly variation in larval abundance (day samples) between families. The correlation analyses were conducted on a tow by tow basis. Significant P values are underlined.

Family		Carangidae	Dactylopteridae	Exocoetidae	Hemiramphidae	Istiophoridae	Mugilidae	Mullidae
Dactylopteridae	rs	-0.138	—					
	P	0.021						
Exocoetidae	rs	-0.087	0.289	—				
	P	0.145	0.001					
Hemiramphidae	rs	-0.092	0.286	0.513	—			
	P	0.124	0.001	0.001				
Istiophoridae	rs	0.227	-0.131	-0.063	-0.036	—		
	P	0.001	0.038	0.294	0.550			
Mugilidae	rs	0.031	0.215	0.107	0.175	-0.070	—	
	P	0.609	0.001	0.074	0.003	0.245		
Mullidae	rs	0.279	-0.063	-0.031	0.037	0.383	0.064	—
	P	0.001	0.293	0.600	0.540	0.001	0.282	
Scombridae	rs	0.177	-0.191	-0.035	-0.157	0.194	-0.046	0.114
	P	0.003	0.002	0.558	0.009	0.002	0.440	0.057

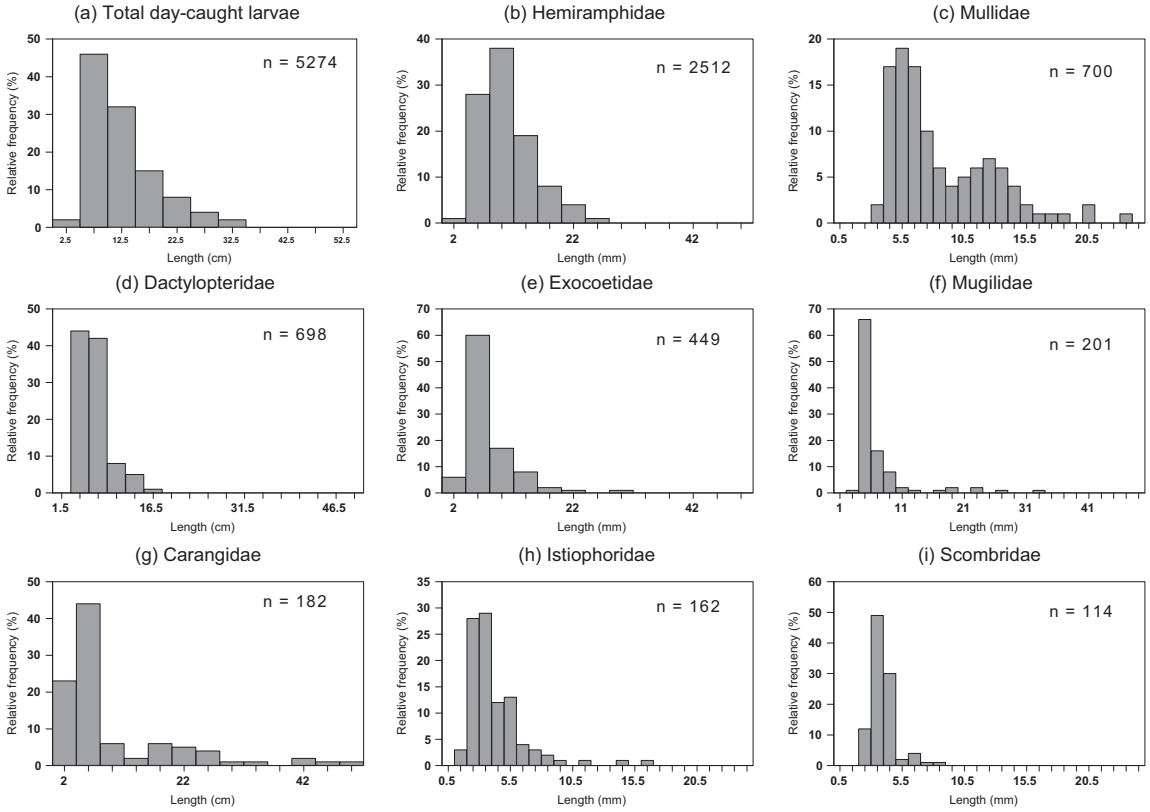

Figure 2. Length frequency distributions for the most common families of fish larvae in the neuston tows (day samples): (a) All larvae, (b) Hemiramphidae, (c) Mullidae, (d) Dactylopteridae, (e) Exocoetidae, (f) Mugilidae, (g) Carangidae, (h) Istiophoridae, (i) Scombridae.

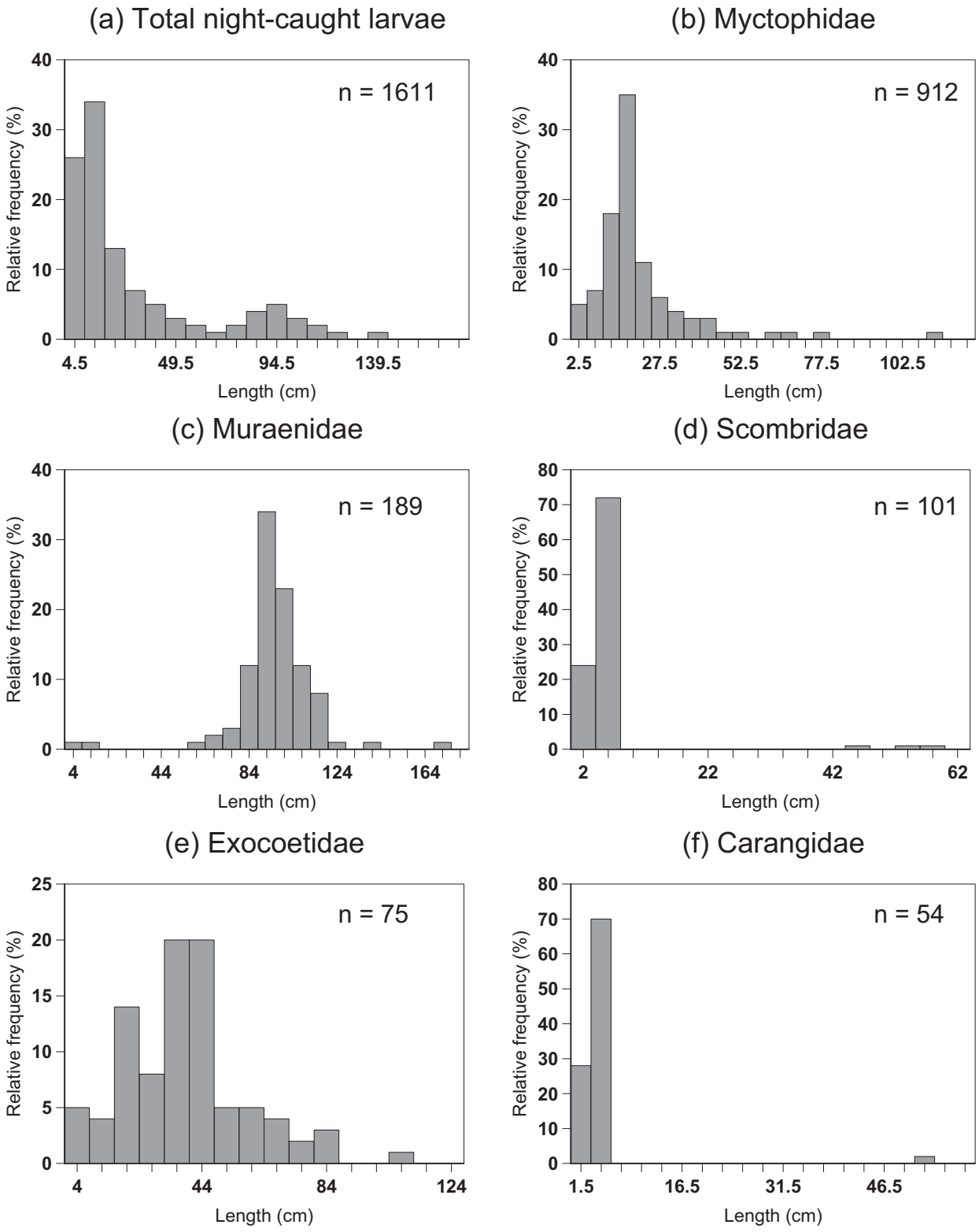

Figure 3. Length frequency distributions for the most common families of fish larvae in the neuston tows (night samples): (a) All larvae, (b) Myctophidae, (c) Muraenidae, (d) Scombridae, (e) Exocoetidae, (f) Carangidae.

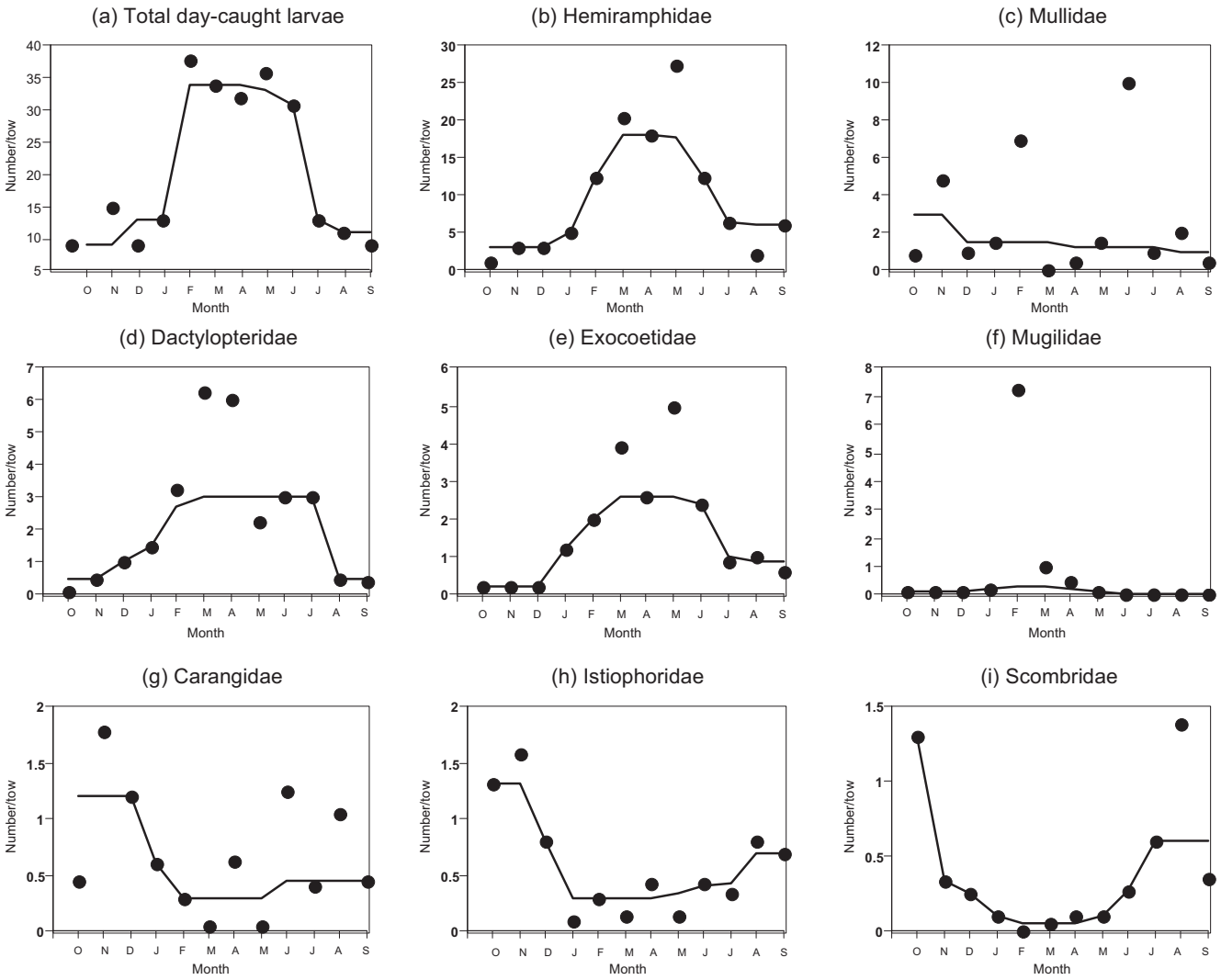

Figure 4. Seasonal variation in abundance of the most common families of fish larvae in the neuston tows (day samples): (A) All larvae, (B) Hemiramphidae, (C) Mullidae, (D) Dactylopteridae, (E) Exocoetidae, (F) Mugilidae, (G) Carangidae, (H) Istiophoridae, (I) Scombridae. The data are expressed as number of larvae per tow, and presented in original form (.) and median smoothed (_._) across 3 month intervals.

Seasonal variation in abundance (night samples)

The number of larvae collected per tow in night samples varied significantly between months (Kruskal-Wallis test, H = 35.69, P < 0.001, Figure 5a). As for day samples, larvae were most abundant between February and June. The consequence is that monthly variation in larval abundance in day samples was significantly correlated with that in night samples (Spearman Rank Correlations for monthly median values, $r_s = 0.72$, P < 0.05). This occurs in spite of the fact that the taxonomic composition of day and night samples differs markedly.

Considered separately, three of the four common families in the night samples showed significant variation in larval abundance between months (Table 10). Variation in larval abundance of the Myctophidae was positively correlated with that in the Exocoetidae (Table 11), both families being most abundant between February and June (Figures 5b, c). Those two families, but particularly the Myctophidae which constitutes 50.7% of the night catch, are therefore responsible for the observation that total larvae in night samples are most abundant between February and June (Figure 5a). Monthly variation in larval abundance of the Carangidae was negatively correlated with that of the Exocoetidae (Table 11), presumably because of the low abundance of carangids between March and June (Figure 5d).

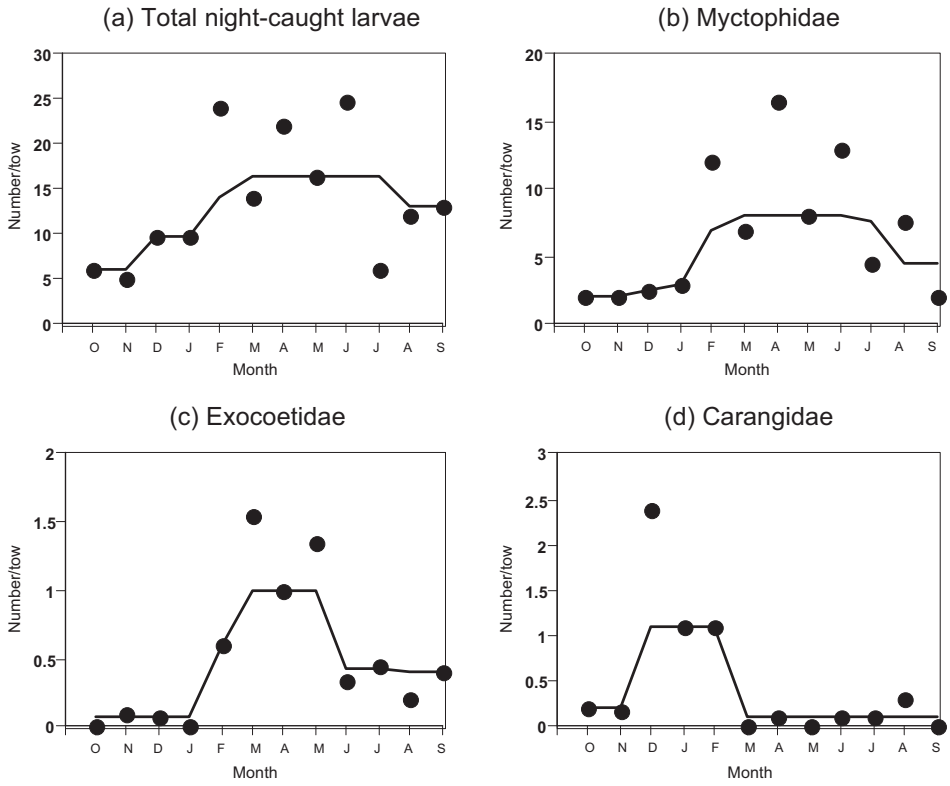

Figure 5. Seasonal variation in abundance of the most common families of fish larvae in the neuston tows (night samples). Only families showing significant seasonal variation in abundance are presented: (A) All larvae, (B) Myctophidae, (C) Exocoetidae, (D) Carangidae. The data are expressed as number of larvae per tow, and presented in original form (.) and median smoothed (_._) across 3 month intervals.

Table 10. Results of Kruskal-Wallis tests for variation in mean number of fish larvae collected per night tow between months, shown separately for the most common families. Level of significance: *** P < 0.001.

Family	H	P
Myctophidae	34.54	***
Muraenidae	10.94	0.45
Scombridae	15.26	0.17
Exocoetidae	40.51	***
Carangidae	33.13	***
All larvae	35.09	***

Table 11. Spearman rank correlation coefficients of the monthly variation in larval abundance (day samples) between families. The correlation analyses were conducted on a tow by tow basis. Significant P values are underlined.

Family		Myctophidae	Exocoetidae
Exocoetidae	rs	0.284	—
	P	0.001	
Carangidae	rs	-0.074	-0.170
	P	0.373	0.042

Three families, the Exocoetidae, the Carangidae and the Scombridae, were relatively common in both day and night samples. Variation in larval abundance of the Exocoetidae and Carangidae in day samples was significantly correlated with their variation in night samples (Spearman Rank Correlations for monthly median values of Exocoetidae, $r_s = 0.78$, $P < 0.01$; Carangidae, $r_s = 0.80$, $P < 0.01$). Both day and night samples therefore support the suggestion that Exocoetidae are most abundant between February and June, and Carangidae least abundant between February and June. This analysis was not performed for Scombridae since they did not show significant seasonal variation in larval abundance in night samples.

Spatial variation in abundance (day samples)

The total number of larvae, and the numbers of larvae in the common families collected in day samples, are presented separately for Stations 1, 2 and 3 in Table 12. The total number of larvae collected per tow differed significantly between stations (Table 13), larval abundance decreasing from Station 3 (9 nmi from shore) to Station 1 (3 nmi from shore) (Table 12). Considered separately, only the hemiramphids, the dactylopterids and the exocoetids, showed significant variation in larval abundance between stations (Table 13). For the hemiramphids and exocoetids, larvae were most abundant at Station 3 and least abundant at Station 1; for the dactylopterids, larvae were most abundant at Station 2 and least abundant at Station 1 (Table 12).

Table 12. Total number of larvae and numbers of larvae in the more common families, presented separately for Stations 1, 2, and 3 (day samples).

Family	Location	Station 1 (3 nmi)	Station 2 (6 nmi)	Station 3 (9 nmi)
	# of tows	94	96	98
Hemiramphidae		535	848	1469
Mullidae		242	335	192
Dactylopteridae		191	308	268
Exocoetidae		99	158	225
Mugilidae		52	144	23
Carangidae		80	50	52
Istiophoridae		48	62	55
Scombridae		46	44	26
All larvae		1550	2156	2505

Spatial variation in abundance (night samples)

The total number of larvae in night samples, and the numbers of larvae in the common families, are presented separately for Stations 1, 2 and 3 in Table 14. As for the day samples, the total number of larvae collected per tow differed significantly between stations (Table 15); total larval abundance decreasing from Station 3 to Station 1 (Table 14). Considered separately, only the Myctophidae and Carangidae showed significant variation in larval abundance between Stations (Table 15). For both myctophids and carangids, larvae were most abundant at Station 3 (Table 14).

Table 13. Results of Kruskal-Wallis tests for variation in mean number of fish larvae collected per day tow between stations, shown separately for the most common families. Level of significance: ** P < 0.01, *** P < 0.001.

Family	H	P
Hemiramphidae	16.73	***
Mullidae	1.64	0.44
Dactylopteridae	11.33	**
Exocoetidae	15.02	***
Mugilidae	0.16	0.92
Carangidae	0.19	0.91
Istiophoridae	3.36	0.18
Scombridae	0.13	0.94
All larvae	12.01	**

Table 14. Total number of larvae and numbers of larvae in the more common families, presented separately for Stations 1, 2, and 3 (night samples).

Family	Location	Station 1 (3 nmi)	Station 2 (6 nmi)	Station 3 (9 nmi)
	# of tows	46	48	49
Myctophidae		144	376	430
Muraenidae		46	50	94
Exocoetidae		15	21	39
Carangidae		13	8	48
Scombridae		36	44	34
All larvae		397	679	805

Spatial variation in size (day samples)

The Hemiramphidae, Mullidae, Dactyolpteridae, Exocoetidae and Mugilidae showed significant variation in larval size between stations (Table 16). When significant differences in larval size occur between pairs of stations, larvae are larger at the offshore than the near-shore station (Table 17). For example, for Mullidae, larvae are larger at Station 2 than 1, at Station 3 than 1, and at Station 3 than 2; for Exocoetidae and Hemiramphidae, larvae are larger at Station 3 than at 1 and 2; and for Dactylopteridae, larvae are larger at Station 2 and 3 than 1. The sole exception is the Mugilidae in which larvae are again largest at Station 3, but are larger at Station 1 than 2 (Table 17).

Table 15. Results of Kruskal-Wallis tests for variation in mean number of fish larvae collected per night tow between stations, shown separately for the most common families. Level of significance: ** P < 0.01, * P < 0.05.

Family	H	P
Myctophidae	10.67	**
Muraenidae	1.29	0.52
Scombridae	1.18	0.55
Exocoetidae	1.97	0.37
Carangidae	7.80	*
All larvae	11.68	**

Table 16. Results of Kruskal-Wallis tests for variation in mean size of fish larvae between stations, shown separately for the most common families (day samples). Level of significance: *** P < 0.001, ** P < 0.01.

Family	H	P
Hemiramphidae	40.31	***
Mullidae	101.64	***
Dactylopteridae	34.52	***
Exocoetidae	25.53	***
Mugilidae	56.68	***
Carangidae	5.17	0.08
Istiophoridae	4.59	0.10
Scombridae	1.55	0.46

Table 17. Median larval size (mm) of the common families in day samples at Stations 1, 2 and 3, and results of Mann Whitney tests for comparing larval sizes between stations. Level of significance: *** P < 0.001, ** P < 0.01, * P < 0.05. (N.B. only those families showing significant differences between all stations were analysed for differences between pairs of stations).

Family	Median larval size						Mann Whitney tests					
	Station 1 (3 nmi)		Station 2 (6 nmi)		Station 3 (9 nmi)		1 vs. 2		1 vs. 3		2 vs. 3	
	No.	Size (mm)	No.	Size (mm)	No.	Size (mm)	U	P	U	P	U	P
Hemiramphidae	488	9.84	744	9.48	1280	10.67	-1.24	0.22	4.12	***	5.89	***
Mullidae	214	5.37	313	6.72	173	7.51	8.89	***	8.42	***	2.13	*
Dactylopteridae	127	6.00	305	7.11	266	7.50	4.70	***	5.86	***	1.32	0.18
Exocoetidae	89	6.32	151	5.93	209	7.90	-1.42	0.16	2.64	**	4.97	***
Mugilidae	47	4.98	131	4.66	23	7.19	-5.33	***	3.53	***	6.33	***
Carangidae	86	6.32	151	5.93	209	7.90						
Istiophoridae	46	4.34	62	5.09	54	5.53						
Scombridae	46	4.23	42	4.50	26	4.11						

Spatial variation in size (night samples)

The Exocoetidae and Muraenidae showed significant variation in larval size between stations, the Myctophidae, Carangidae and Scombridae did not (Table 18). For the Muraenidae, the tendency for larvae to be larger at offshore stations was again observed, larvae being larger at Stations 2 and 3 than Station 1 (Table 19; but note P = 0.07 between Stations 2 and 1). The Exocoetidae were the exception to the day sample pattern, larvae being larger at Station 2 than at 1 and 3 (Table 19).

Table 18. Results of Kruskal-Wallis tests for variation in mean size of fish larvae between stations, shown separately for the most common families (night samples). Significance level: * P < 0.05.

Family	H	P
Myctophidae	0.45	0.79
Muraenidae	6.92	*
Scombridae	0.46	0.78
Exocoetidae	6.38	*
Carangidae	1.58	0.45

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Table 15. Results of Kruskal-Wallis tests for variation in mean number of fish larvae collected per night tow between stations, shown separately for the most common families. Level of significance: ** P < 0.01, * P < 0.05.

Family	H	P
Myctophidae	10.67	**
Muraenidae	1.29	0.52
Scombridae	1.18	0.55
Exocoetidae	1.97	0.37
Carangidae	7.80	*
All larvae	11.68	**

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Dactylopteridae	34.52	***
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Carangidae	5.17	0.08
Istiophoridae	4.59	0.10
Scombridae	1.55	0.46

Table 17. Median larval size (mm) of the common families in day samples at Stations 1, 2 and 3, and results of Mann Whitney tests for comparing larval sizes between stations. Level of significance: *** P < 0.001, ** P < 0.01, * P < 0.05. (N.B. only those families showing significant differences between all stations were analysed for differences between pairs of stations).

Family	Median larval size						Mann Whitney tests					
	Station 1 (3 nmi)		Station 2 (6 nmi)		Station 3 (9 nmi)		1 vs. 2		1 vs. 3		2 vs. 3	
	No.	Size (mm)	No.	Size (mm)	No.	Size (mm)	U	P	U	P	U	P
Hemiramphidae	488	9.84	744	9.48	1280	10.67	-1.24	0.22	4.12	***	5.89	***
Mullidae	214	5.37	313	6.72	173	7.51	8.89	***	8.42	***	2.13	*
Dactylopteridae	127	6.00	305	7.11	266	7.50	4.70	***	5.86	***	1.32	0.18
Exocoetidae	89	6.32	151	5.93	209	7.90	-1.42	0.16	2.64	**	4.97	***
Mugilidae	47	4.98	131	4.66	23	7.19	-5.33	***	3.53	***	6.33	***
Carangidae	86	6.32	151	5.93	209	7.90						
Istiophoridae	46	4.34	62	5.09	54	5.53						
Scombridae	46	4.23	42	4.50	26	4.11						

Spatial variation in size (night samples)

The Exocoetidae and Muraenidae showed significant variation in larval size between stations, the Myctophidae, Carangidae and Scombridae did not (Table 18). For the Muraenidae, the tendency for larvae to be larger at offshore stations was again observed, larvae being larger at Stations 2 and 3 than Station 1 (Table 19; but note P = 0.07 between Stations 2 and 1). The Exocoetidae were the exception to the day sample pattern, larvae being larger at Station 2 than at 1 and 3 (Table 19).

Table 18. Results of Kruskal-Wallis tests for variation in mean size of fish larvae between stations, shown separately for the most common families (night samples). Significance level: * P < 0.05.

Family	H	P
Myctophidae	0.45	0.79
Muraenidae	6.92	*
Scombridae	0.46	0.78
Exocoetidae	6.38	*
Carangidae	1.58	0.45

Table 19. Median larval size (mm) of the common families in night samples at Stations 1, 2 and 3, and results of Mann Whitney test for comparing larval sizes between stations. Level of significance: * P < 0.05. (N.B. only those families showing significant differences between all stations were analysed for differences between pairs of stations).

Family	Median larval size						Mann Whitney tests					
	Station 1 (3 nmi)		Station 2 (6 nmi)		Station 3 (9 nmi)		1 vs. 2		1 vs. 3		2 vs. 3	
	No.	Size (mm)	No.	Size (mm)	No.	Size (mm)	U	P	U	P	U	P
Myctophidae	107	16.98	293	16.00	442	16.00						
Muraenidae	21	80.00	23	94.00	144	89.5	1.83	0.07	2.39	*	-1.16	0.25
Exocoetidae	14	27.50	17	50.00	41	37.00	2.03	*	1.02	0.31	-2.16	*
Carangidae	9	3.31	8	3.91	36	3.75						
Scombridae	27	4.34	34	4.10	36	4.14						

DISCUSSION

Composition and abundance of flotsam

Flotsam components off Barbados have not previously been quantitatively surveyed. The components of the flotsam collected in this study were of coastal marine and terrestrial origin. This suggests that the material originated on or around the island, and/or that it drifted into the area with water from South American rivers (see Borstad 1979, Meade *et al*. 1979, Muller-Karger *et al.* 1989).

The most striking results of the flotsam study are the limited quantities of flotsam collected and the rarity of occasions on which eggs were found attached to it. Only 38% of all tows contained flotsam, and flotsam abundance was < 0.01 g per tow. The fragmented nature of the flotsam suggests considerable disintegration. The low abundance may partly result from rapid sinking, and flotsam could therefore be more abundant at greater depths. Only 1% of tows contained flyingfish eggs. The scarcity of eggs may result from an overall scarcity of spawning substrata near Barbados. Alternatively, the scarcity of eggs and substrata near the surface, and hence vulnerable to the gear, may be because eggs are laid profusely on all available substrata causing both to sink. Whether sinking of substrata commonly occurs during flyingfish spawning is unknown.

To maintain current flyingfish population sizes in the face of the scarcity of surface flotsam observed, either flyingfish are spawning on floating substrata found elsewhere, or spawning success is not dependent on floating material, i.e. spawning may be occurring on submerged substrata or on the bottom, or eggs are remaining viable as substrata sink. The first suggestion is the more orthodox perspective, but a large-scale survey conducted during the breeding season in the eastern Caribbean produced negligible quantities of flotsam and few flyingfish eggs (Hunte *et al.* 1995). Whether flyingfish can utilize submerged substrata or spawn on the bottom, perhaps on seagrasses, in shallower areas, requires further investigation. Interestingly, near-shore spawning flyingfish (e.g. the genus *Fodiator* and *Cypselurus opisthopus*) are known to deposit eggs on coastal algae or sand (Johannes 1981, Gillet and Ianelli 1991). Given the existance off Barbados of a sharp increase in subsurface salinity (and thus density) with depth down to 90-140 m (as measured in April and May 1990, Cowen and Castro 1994), there may be significant quantities of submerged substrata suspended by this high density layer. Furthermore, it is plausible that egg-laden substrata which are no longer bouyant at the surface may only sink a short distance, increasing the likelihood that eggs remain viable.

Seasonal variation in the abundance of flotsam off Barbados has not previously been investigated. Flotsam was present throughout the year, but occurred more frequently and was most abundant between March and September. This corresponds with the period when South Atlantic water mixes with fresh water from the rivers on the north coast of South America and enters the area around Barbados as the Guiana Current (Lewis *et al.* 1962, Froelich *et al.* 1978, Borstad 1982a, 1982b, Muller-Karger *et al.* 1989). The correspondence of high flotsam abundance with the presence of this water mass

near Barbados is consistent with the composition of the flotsam observed, i.e. of terrestrial and coastal rather than oceanic origin. It suggests that a considerable portion of the flotsam may be transported to Barbados from the South American region. The period of high flotsam abundance (March to September) overlaps but is out of phase with the period of availability of flyingfish near Barbados (December to June; Mahon *et al*. 1986), and with the spawning period of flyingfish near Barbados (December to May; Storey 1983, Oxenford *et al*. 1994, Khokiattiwong *et al.* 2000). If spawning on surface substrata is the typical mode of flyingfish reproduction, and if surface substrata are as scarce as indicated by this study, the seasonality of flyingfish reproduction might be expected to coincide with the period of maximum surface substrate availability. The fact that this does not occur emphasizes the need to investigate whether flyingfish can spawn on submerged and/or bottom substrata.

Composition, abundance and size of neustonic fish larvae

Differences between day and night larvae

Larvae of 34 families were identified in day neuston tows and 24 in night neuston tows during the study. They ranged from oceanic families such as myctophids, istiophorids, to offshore but less oceanic families, such as hemiramphids and exocoetids, to coastal families such as mugilids and mullids. Taxonomic composition of the neuston catch was very similar to that reported for the eastern Caribbean by Hunte *et al.* (1995). Hemiramphids (46% of day catch) and myctophids (51% of night catch) dominated day and night samples respectively in both studies. Hemiramphids are surface-dwellers (Collette 1978). They are not commercially important in Barbados, but are one of the main species taken in seine fisheries in many of the eastern Caribbean islands (Mahon 1993), and are used as bait for large pelagic fishes elsewhere in the Caribbean (Collette 1978). Myctophids are primarily oceanic, mesopelagic. They are known to migrate to the upper surface layers at night (Nafpaktitis 1978), which explains their abundance in night samples in this study. Myctophids are not exploited commercially in Barbados or elsewhere in the Caribbean, but the potential of the group as a protein source is being assessed in South Africa and Russia (Nafpaktitis 1978, 1981). Families of considerable commercial importance in Barbados which were collected in the neuston tows include the exocoetids (7% of total catch), carangids (3%), scombrids (3%), istiophorids (2%) and coryphaenids (2%).

Apart from differing markedly in taxonomic composition, day and night samples differed in larval size. Day larvae ranged from 0-20 mm, with a peak around 10 mm. Night larvae were larger, one size group ranging from 0-40 mm and a second group ranging from 80-100 mm. The size differences between day and night larvae result primarily from differences in taxonomic composition of the neuston by day and night. Myctophid and muraenid larvae, which were abundant at night, are larger than the larvae commonly caught by day (e.g. hemiramphids and exocoetids). The size differences may also be influenced by day and night differences in size within taxonomic groups. For example, exocoetid larvae caught in the night were larger than those in the day. This was also reported for exocoetids across the eastern Caribbean by Hunte *et al.* (1995).

Apart from differing in taxonomic composition and larval size, day and night samples differed significantly in larval abundance, in this study and that of Hunte *et al.* (1995), with higher catch rates occurring in the day than in the night. This is expected since many fish larvae, including exocoetids, are known to concentrate at the surface by day and move to slightly deeper water at night (Hempel and Weikert 1975).

Seasonal variation in abundance

Seasonal changes in fish larval abundance may result primarily from seasonal changes in spawning activities of adults (e.g. Robertson *et al.* 1988, Hunte and Côté 1989, Meekan *et al.* 1993). Since many tropical marine fish spawn throughout the year, but with a seasonal peak in activity (e.g. Munro *et al.* 1973, Tupper and Hunte 1994), fish larval abundance may be expected to vary seasonally. However, using plankton nets other than neuston nets, seasonal variation in larval abundance was not detected off Barbados by Lewis *et al.* (1962), Lewis and Fish (1969) nor Sander (1971). By contrast, using bongo nets, Powles (1975) found seasonal variation in larval abundance of several near-shore species (e.g. Labridae, Scaridae, Carangidae, Pomacentridae, Apogonidae and some Serranidae). For these families, there were typically two periods of high abundance, March to May and August to September. However, Powles (1975) found no seasonal variation in abundance of the offshore fish larvae.

The present study is the first investigation of seasonal variation in fish larvae collected by neuston

tows off Barbados. Significant seasonal variation in abundance was observed in both day and night samples for all larvae combined and separately for most of the common families. In both day and night samples, larvae were most abundant between February and June. Two basic patterns emerged when families were considered separately. Larvae were either most abundant between February and June, or least abundant between February and June. This invites the speculation that, in terms of larval release, advantages may accrue from partitioning the environment on a seasonal time scale. Families collected primarily between February and June were the myctophids (51% of the night catch), hemiramphids (46% of the day catch), exocoetids and dactylopterids, which are largely offshore but not fully or exclusively oceanic. Families which were least abundant between February and June were the larger oceanic scombrids and istiophorids, and the coastal carangids. It is of interest that the myctophids and hemiramphids, which together comprise almost 50% of the total larval catch and which are both most abundant between February and June, may be partitioning the upper surface environment by day and night.

The seasonality of spawning for most of the fish families whose larvae were collected in this study is unknown. Consequently, it is not possible to correlate the timing of peak larval abundance with that of adult spawning. The exception is the exocoetids, particularly the most common species, *Hirundichthys affinis*, in which peak spawning activity is known to occur primarily between December and May (Lewis *et al*. 1962, Storey 1983, Oxenford *et al*. 1994, Khokiattiwong *et al.* 2000) and *Parexocoetus brachypterus* for which peak spawning occurs from March to September (Khokiattiwong 1988). The observed seasonal variation in abundance of exocoetid larvae (February to June) therefore corresponds well with the seasonality of spawning reported for adults, particularly *H. affinis*.

Spatial variation in abundance and size

For all larvae combined, and separately for the myctophids, hemiramphids, dactylopterids, exocoetids (in day samples), and carangids (in night samples), there was significant variation in larval abundance between stations. In all cases where significant variation was detected, larvae were less abundant at Station 1 (3 nmi offshore) than at Station 2 and/or Station 3 (6 and 9 nmi offshore respectively). For myctophids and exocoetids, which are found relatively far offshore throughout their life cycle, this pattern of larval distribution may be expected on the basis of adult distribution. However, it is less expected on this basis for hemiramphids and dactylopterids in which adults are found closer to shore, and not expected for carangids, in which adults are often coastal. The high larval abundance of these families offshore may therefore largely result from current patterns, perhaps augmented by larval food distribution. Fish larvae and larval food may be aggregated and retained in eddies created in the downcurrent wake of the island by the east to west transport of water across Barbados (see Powles 1975). Based on island-specific patterns of population recovery in the sea urchin *Diadema antillarum*, Hunte and Younglao (1988) have suggested that larvae are retained downcurrent of islands and primarily recruit back to their natal populations. Moreover, Hunte and Côté (1989), Hunt von Herbing and Hunte (1991), and Tupper and Hunte (1994) suggest that the retention of larvae near Barbados, with subsequent recruitment to natal populations, may explain why reef fish populations in the isolated oceanic island of Barbados are not "recruitment-limited", but limited by space availability on reefs. A more recent synoptic study by Cowen and Castro (1994) strongly supports the existence of surface current retention mechanisms for fish larvae, but suggests that they are driven more strongly by ocean floor topography in the vicinity of Barbados (specifically the 300 m deep Barbados Ridge running to the NW and S of the island) than by island mass alone. This results in a large scale recirculation of water around Barbados, rather than standing or shedding eddies in the lee of the island. This is further supported by spatial patterns in larval abundance of reef fishes reported by Sponaugle and Cowen (1996). They found consistently higher abundance of larvae at the north and south ends of the west coast of Barbados, than in the centre.

For 8 of the 10 common families collected, larval size varied significantly between stations, larvae tending to be larger at offshore than near-shore stations. Interestingly, the pattern of horizontal distribution of larval size closely reflects that of larval abundance. In most cases, larvae are largest and most abundant at Station 3, smallest and least abundant at Station 1; with differences between Stations 3 and 2 being less marked. The horizontal distribution of larval size is therefore consistent with the hypothesis that larvae are being retained by a current system with a strong effect some

6-9 nmi northwest of the island. This coincides with the area of surface water convergence and apparent recirculation reported off the northwestern tip of Barbados in April/May 1990 by Cowen and Castro (1994). Retention of larvae in that vicinity would lead to both higher larval abundance and larger larval size through growth. Retention of larvae downcurrent of islands will tend to lead to island-specific stocks in coastal pelagic and demersal species. However, in offshore pelagic species such as flyingfish, active movement of large juveniles and/or adults between islands may occur, resulting in regional/shared stocks (Oxenford 1994).

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