A CONTRIBUTION TO THE BIOLOGY OF THE HALFBEAK, *HYPORHAMPHUS GEORGII* (CUV. & VAL.) (HEMIRHAMPHIDAE)

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Introduction

The hemirhamphids constitute an important group of the neretic-pelagic fisheries of the Gulf of Mannar and Palk Bay. Although there are eight species of halfbeaks distributed in these waters, *Hyporhamphus georgii* (C.V.) and *Hemirhamphus marginatus* (Forsk.) are the only species which may be considered of sufficient importance to constitute a distinct 'fishery'. With a view to obtaining accurate information on the fishery biology of these common species, a detailed investigation was taken up during 1957–59.

Most of the work so far done on the halfbeaks is more or less of a taxonomic nature and very little precise information is available on their biology. The most significant references on the subject are those of Delsman (1924), Uchida (1930 and 1958), Nakamura (1933), Devanesan (1937), Job and Jones (1938), Hubbs and Kampa (1946), Devanesan and Chidambaram (1948), Ling (1958) and Hattori and Seki (1959). The present paper deals with the results of the investigations on the various aspects of the biology of *Hyporhamphus georgii* (C.V.).

Material and Methods

Material for this investigation was obtained from five centres of observations, *viz.*, Theedai, Pamban and Rameswaram in the Palk Bay, and Kilakarai and Rameswaram Road in the Gulf of Mannar (Fig. 1). Samples were collected at weekly intervals from the various sampling centres except at Theedai where sampling was undertaken on a weekly basis. All samples were collected on the spot from the fishermen's catches. Sex-ratio and length-frequency data were collected in the field in most instances. Length to the caudal fork (L.C.F.) of the fish has been used as the standard linear measurement for all calculations except where otherwise stated.

In the laboratory the following procedure was followed:—

1. The specimens were measured, weighed and sorted into different size-groups.

2. The gonads were dissected out and examined to study the maturity stages. Ovaries in Stages V and VI were fixed in Gilson's fluid for fecundity studies and a count of the ripe ova subsequently made after a wash in 30% alcohol.

3. Scale samples from the region of the dorsals and both the otoliths were also collected.

4. Morphometric measurements and meristic counts were taken of selected samples collected during 1957 from the five sampling stations. The data were analysed by the methods of Analysis of Variance and Covariance.

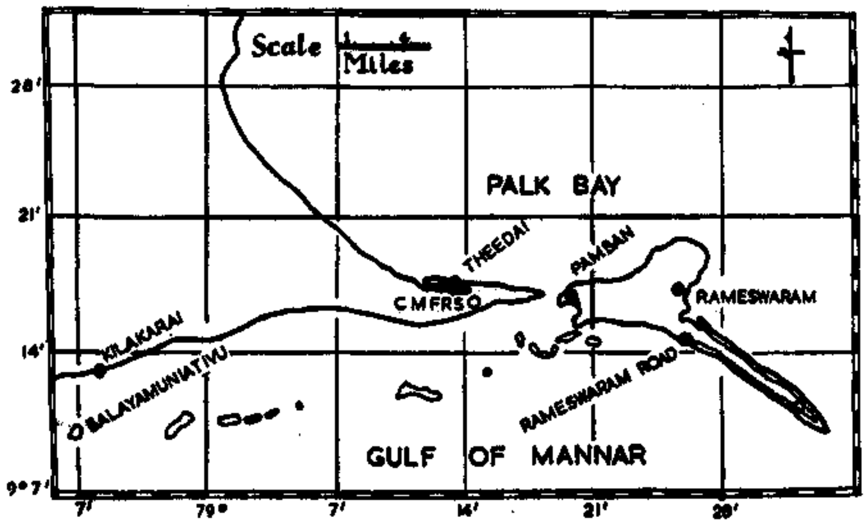

Fig. 1. Map of Mandapam area and Rameswaram Island indicating the five sampling stations.

The details of the methods employed in studying the material and analysing the data on the various aspects of the biology are given in the relevant sections.

SYSTEMATIC STATUS OF THE SPECIES AND ITS DISTRIBUTION

The systematic status of *Hyporhamphus georgii* (C.V.) has been discussed in a separate contribution (Talwar, 1960). On the basis of available ichthyological literature, the geographical distribution of this species is as follows: East Indies, Philippines, north to the Amoy, China and Formosa, east to Micronesian and Polynesian Islands, and across the Indian Ocean to Seychelles and Mauritius Islands.

Racial Analysis

The intraspecific variation in this halfbeak over the area of investigation is potentially an important matter from the standpoint of future management. The researches relating to the taxonomic identity of the intraspecific stocks are generally referred to as 'racial investigations'. These studies are based on the hypothesis that certain morphometric and meristic characters are associated with the various autonomous populations (Williamson, 1900; Schmidt, 1917 *et seq.*; Mottley, 1931 *et seq.*; Tester, 1937 *et seq.*; Hubbs and Perlmutter, 1942; Godsil and Byers, 1944; Taning, 1944 *et seq.*; Clark, 1947; Godsil, 1948; Schaefer, 1950 *et seq.*; Blackburn, 1951; Roedel, 1952; Royce, 1953).

The problem has been approached by comparing five meristic and four morphometric characters of the samples collected from the various sampling stations. The morphometric data have been subjected to the analysis of co-variance and the statistical procedures in comparing the regressions as presented by Snedecor (1946) were followed. The meristic characters were analysed by the technique of Analysis of Variance.

Prior to the ascertainment of significant differences in the regressions of the various body parts from different localities, if any, it was necessary to resolve the possibility of greater differences between the regressions of body parts of males and females in each locality. The compact summary of the findings are given in Tables I–III.

Since the variance ratios to test the significance of the differences in the sample from Rameswaram with regard to the regression coefficients of the four morphometric characters did not reveal any sexual heterogeneity, the data from the different localities were not separated sex-wise but the composite samples were analysed directly.

The following meristic and morphometric characters of the various samples from the different localities were subjected to statistical analysis.

Meristic Counts

(i) Vertebrae,

(ii) Gill rakers,

(iii) Predorsal scales,

(iv) Sum of dorsal and anal rays.

TABLE I

Analysis of covariance of the sexes from Rameswaram

Source of variation	D.F.	Corrected sum of squares and products			Regression coefficient	Errors of estimate	
		Sx^2	Sxy	Sy^2		Sum of squares	D.F.
Entire head length:							
Males ..	11	0·0060	0·0035	0·0033	0·5833	0·0013	10
Females ..	12	0·0043	0·0025	0·0023	0·5814	0·0007	11
Head length:							
Males ..	11	0·0060	0·0053	0·0054	0·8833	0·0007	10
Females ..	12	0·0043	0·0038	0·0047	0·8837	0·0013	11
Distance of ventral from pectoral base:							
Males ..	11	0·0060	0·0067	0·0097	1·1167	0·0022	10
Females ..	12	0·0043	0·0046	0·0065	1·0698	0·0016	11
Pectoral fin length:							
Males ..	11	0·0060	0·0043	0·0082	0·7167	0·0051	10
Females ..	12	0·0043	0·0040	0·0064	0·9302	0·0027	11

Morphometric Characters

X —Standard length,

Y_1—Entire head length,

Y_2—Head length,

Y_3—Distance of ventral insertion from pectoral base,

Y_4—Pectoral fin length.

The statistical details of the analysis of the meristic and morphometric characters are given in Tables IV–XII. The analysis indicates that the samples were derived from a homogeneous population. Hence for the purpose of subsequent studies on the biology of the species, the data collected from the various localities were pooled together.

TABLE II

Analysis of errors of estimate from average regressions within sexes for morphometric characters

Source of variation	D.F.	Errors of estimate: Sum of squares	Errors of estimate: Mean square
Entire head length:			
Deviations from individual sex regressions ..	21	0·0020	0·000095
Differences between regression coefficients ..	1	0·0001	0·0001
Deviation from average regression within sexes ..	22	0·0021	
Head length:			
Deviations from individual sex regressions ..	21	0·0020	0·000095
Differences between regression coefficients ..	1	0·0001	0·0001
Deviations from average regression within sexes	22	0·0021	
Distance of ventral from pectoral base:			
Deviations from individual sex regressions ..	21	0·0038	0·00018
Differences between regression coefficients ..	1	0·0001	0·0001
Deviation from average regression within sexes ..	22	0·0039	
Pectoral fin length:			
Deviations from individual sex regressions ..	21	0·0078	0·00037
Differences between regression coefficients ..	1	0·0002	0·0002
Deviations from average regression within sexes	22	0·0080	

TABLE III

Tests of significance

Character	F	P^5	P^1
Entire head length ..	1·05	3·94	6·90
Head length ..	1·05	3·94	6·90
Distance of ventral from pectoral base	18·5	248	6208
Pectoral fin length ..	1·5	248	6208

SPAWNING AND MATURITY

No valid way has been found to determine the sex of *H. georgii* by the use of morphological characters, the gonads must be examined. The study of the breeding cycle here was resolved into a field and laboratory study of the ovaries of the specimens caught throughout the period of investigation. The testes were not found suitable as no quantitative measure of their sexual products could be found which would provide reasonably accurate estimate of their relative stages of development.

TABLE IV

Frequency distribution of vertebrae

Locality	N	54	55	56
Kilakarai ..	33	8	20	5
Rameswaram Road	30	5	22	3
Theedai ..	42	10	27	5
Pamban ..	39	8	26	5
Rameswaram ..	32	4	26	2

TABLE V

Frequency distribution of gill rakers

Locality	N	60	61	62	63	64	65	66	67
Kilakarai ..	67	..	..	21	21	13	6	4	2
Rameswaram Road ..	18	6	..	13	31	27	..	3	..
Theedai ..	63	..	11	13	16	15	8	..	..
Pamban ..	77	3	8	18	25	16	..	7	..
Rameswaram ..	68	5	7	15	19	19	..	..	3

TABLE VI

Frequency distribution of predorsal scales

Locality	N	35	36	37	38	39	40	41
Kilakarai ..	63	..	3	6	17	23	12	2
Rameswaram Road ..	66	..	2	9	18	19	15	3
Theedai ..	85	..	9	7	15	29	20	5
Pamban ..	69	..	3	16	23	17	7	3
Rameswaram ..	98	3	5	21	29	18	17	5

TABLE VII

Frequency distribution of sum of dorsal and anal fin rays

Locality	N	25	26	27	28
Kilakarai ..	72	3	8	38	23
Rameswaram Road ..	64	3	7	33	21
Theedai ..	75	1	9	44	21
Pamban ..	65	3	8	31	23
Rameswaram ..	97	5	11	48	33

TABLE VIII

Analysis of variance, meristic characters

Count	Source of variation	D.F.	Sum of squares	Mean square
Vertebrae	Between places	4	0·11	0·027
	Within places	164	53·62	0·326
	TOTAL ..	168	53·73	
Gill rakers	Between places	4	11·8	2·95
	Within places	350	650·2	1·85
	TOTAL ..	354	662	
Predorsal scales	Between places	4	15·65	3·91
	Within places	376	615·65	1·64
	TOTAL ..	380	631·30	
Sum of dorsal-anal rays	Between places	4	9·03	2·257
	Within places	268	1617·77	6·036
	TOTAL ..	272	1626·80	

TABLE IX

Tests of significance

Count	F	P^5	P^1
Vertebrae ..	12·07	5·65	13·52
Gill rakers ..	1·5	2·39	3·36
Predorsal scales ..	2·38	2·39	3·36
Sum of dorsal-anal rays ..	2·67	5·65	13·52

TABLE X

Analysis of covariance y_1 to y_4

Locality	Character	D.F.	Corrected sum of squares and products			Regression coefficient	Errors of estimate	
			Sx^2	Sxy	Sy^2		Sum of squares	D.F.
Kilakarai	Y_1	24	0·0837	0·0695	0·0714	0·8303	0·0141	23
	Y_2	24	0·0837	0·0774	0·1077	0·9247	0·0361	23
	Y_3	24	0·0837	0·0839	0·0954	1·0022	0·0113	23
	Y_4	24	0·0837	0·0877	0·0970	1·0478	0·0051	23
Rameswaram Road	Y_1	24	0·0296	0·0175	0·0130	0·5844	0·0029	23
	Y_2	24	0·0296	0·0266	0·0263	0·8986	0·0024	23
	Y_3	24	0·0296	0·0300	0·0330	1·0135	0·0026	23
	Y_4	24	0·0296	0·0263	0·0292	0·8885	0·0058	23
Theedai	Y_1	24	0·0239	0·0162	0·0201	0·6778	0·0076	23
	Y_2	24	0·0239	0·0199	0·0305	0·0326	0·0139	23
	Y_3	24	0·0239	0·0189	0·0218	0·7908	0·0069	23
	Y_4	24	0·0239	0·0145	0·0284	0·6067	0·0196	23
Pamban	Y_1	31	0·0327	0·0206	0·0177	0·6300	0·0055	30
	Y_2	31	0·0327	0·0313	0·0346	0·9572	0·0046	30
	Y_3	31	0·0327	0·0332	0·0357	1·0153	0·0020	30
	Y_4	31	0·0327	0·0235	0·0227	0·7186	0·0058	30
Rameswaram	Y_1	24	0·0106	0·0059	0·0056	0·5566	0·0028	23
	Y_2	24	0·0106	0·0092	0·0102	0·8679	0·0022	23
	Y_3	24	0·0106	0·0117	0·0171	1·1037	0·0040	23
	Y_4	24	0·0106	0·0082	0·0146	0·7736	0·0083	23

TABLE XI

Analysis of errors of estimate from average regressions within localities, morphometric characters

Source of variation	D.F.	Errors of estimate	
		Sum of squares	Mean square
Entire head length (Y_1):			
Deviations from individual regressions within places	122	0·0329	0·00027
Differences among individual regressions ..	4	0·0018	0·00045
Deviations from average regressions within places	126	0·0347	
Head length (Y_2):			
Deviations from individual regressions within places	122	0·0592	0·00049
Differences among individual regressions ..	4	0·0004	0·00010
Deviations from average regressions within places	126	0·0596	
Distance of ventral from pectoral base (Y_3):			
Deviations from individual regressions within places	122	0·0268	0·00022
Differences among individual regressions ..	4	0·0013	0·00032
Deviations from average regressions within places	126	0·0281	
Pectoral fin length (Y_4):			
Deviations from individual regressions within places	122	0·0446	0·00037
Differences among individual regressions	4	0·0051	0·00127
Deviations from average regressions within places	126	0·0497	

TABLE XII

Tests of significance

Character	F	P^5	P^1
Y_1	1·67	2·44	3·47
Y_2	4·9	5·65	13·52
Y_3	1·45	2·44	3·47
Y_4	3·43	2·44	3·47

Macroscopic study of the gonads.—In the present study determination of the maturity stages for females has been based on Hjort's classification with suitable modifications on the lines suggested by Ling (1958). In the males only four stages were recognised namely, Immature, Maturing, Mature and Spent.

By noting the condition of the ovaries over a period extending for a number of years it should be possible to gain a fairly clear insight into the spawning cycle of the fish. The results of the macroscopic studies are expressed quantitatively in Table XIII. These observations indicate that spawning in *H. georgii* commences in mid-March and is continued to mid-April.

Microscopic study of the ovaries.—In order to check the conclusions reached from the macroscopic study of the ovaries that the spawning period in *H. georgii* is short and definite and to ascertain whether the macroscopic study of the maturity stages in this species bears any relation to the microscopic changes which take place in the spawning cycle, a microscopic study of the ovaries was made. Direct observations on the breeding habits of marine teleosts are scanty, usually by indirect methods such as studying the size-distribution of the oocytes in the maturing ovary, evidence about the spawning habits is gathered (Heidrich, 1925; Clark, 1934; Hickling and Rutenberg, 1936; deJong, 1940; Prabhu, 1955; Dharmamba, 1959). From such studies it has been deduced that species which have ova all of the same size spawn together whereas those which have a continuous gradation of ova spawn successively during the season.

TABLE XIII

Percentage frequency of the number of females in the various maturity stages during the years 1957–59

Maturity stage	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Number examined
I	..	..	..	..	..	..	..	..	..	..	..	..	..
II	..	..	..	..	..	..	..	..	91·7	86·3	78·4	46·7	413
III	53·4	50·5	..	..	..	..	..	..	8·3	13·7	21·6	53·3	467
IV	46·6	49·5	7·8	..	..	..	..	..	..	..	..	..	328
V	..	..	59·0	13·6	10·0	..	..	..	..	..	..	..	4,283
VI	..	..	33·1	75·3	17·7	..	..	..	..	..	..	..	4,937
VII	..	..	..	11·1	72·3	..	..	..	..	..	..	..	2,678

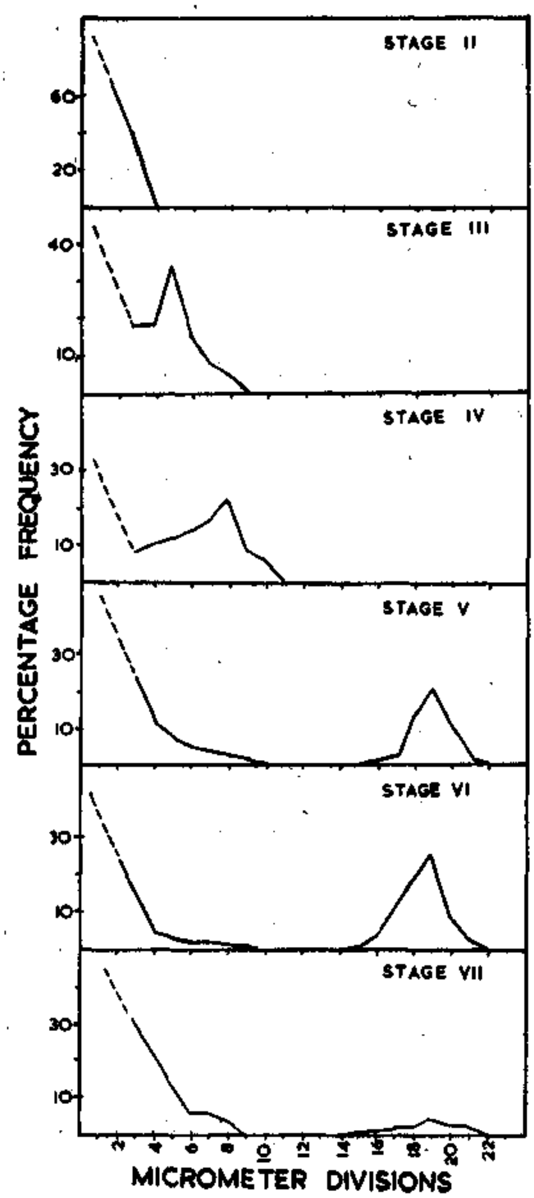

FIG. 2. Ovum diameter frequency polygons showing stages in development of the ova from the immature stage to maturity.

Ova samples were taken after the ovaries had hardened in formalin, 300 ova at random were measured from each ovary by means of an ocular micrometer fitted in a compound microscope at a magnification giving a value of 74·074 μ to each ocular division. Ova less than 3 m.d. were not measured since they were present in large numbers in the ovaries in all stages of maturity. Ovum-diameter frequency polygons were constructed from these data. These stages are shown graphically in Fig. 2 which has no connotation of time, but simply illustrates the development stages from the immature stage to the spawning stage. The polygons are pooled frequencies of several fish of the same maturity classification. Representation of quantitative ovum groupings was not possible because of the occurrence of numerous tiny ova. These formed a distinct modal group throughout the year although they were not so obvious during the spawning season. The degree of formation of yolk in maturing and mature ova was taken as a reliable guide in judging the stages of maturity of the intra-ovarian eggs. The following seven arbitrary stages were defined:—

Stage I.—No data available.

Stage II (Immature).—Mode at 3 m.d., no ova above 4 m.d.

Stage III (Intermediate).—Mode at 5 m.d., no ova above 8 m.d.

Stage IV (Maturing).—Modal value 8 m.d.

Stage V (Ripe).—At this stage the sudden increase in the average diameter is inexplicable. Mode of the most mature group at 19 m.d., some ova are segregated in the lumina of the ovaries.

Stage VI (Spawning).—There is no apparent increase in the size of the ova. They, however, become transparent and are shed at this stage.

Stage VII (Spent).—A sharp drop in the overall size of the ova marks the spent and recovering stages which are followed by a period of quiescence.

In the ripe ovaries (Stages V and VI) two distinct groups of ova are encountered (Fig. 2). Owing to the large size of ripe ova they are well separated from the immature group. The group of mature ova are most abundant during March–April. Spawning is thus at its greatest intensity during these months. A sharp drop in the overall size of the ova during the latter half of April marks the spent and recovering stages which are followed by a period of quiescence. Basing on these observations that spawning commences soon after the eggs are fully ripe, that the remnant egg group begins growth after spawning and the fact that there is a synchronous spawning in all the individuals, it may be concluded that spawning is restricted in this species a definite and short period and that spawning takes place only once a year. This confirms Devanesan's (1937) observation that this species spawns in the Palk Bay during March–April. The periodicity is, of course, shortened or lengthened according to the reproductive function of the individual fish. If, however, individual halfbeaks were to spawn more than once, Fig. 2, Stage V should show a picture similar to that for the California sardine by Clark (1934, Fig. 3). Rather, as the mode representing the larger ova moves to the right, the secondary mode tends to be more or less stationary. Throughout the year there is a residue (Hickling's, 1930, "reserve fund") of tiny ova, which are angular and quite transparent so that the nuclei are visible. The observations of ripe individuals are undoubtedly of value in this direction since the majority have certainly been taken within the localities where the species normally spawns and this indicates correctly the period of principal spawning.

Spawning grounds.—Reference to the spawning ground of *Hyporhamphus georgii* in the Palk Bay was previously made by Devanesan (1937). This spawning ground is in the vicinity of the fishing village Theedai (Lat. 9° 16¾ N., Long. 79° 7 E). In the spawning ground the bottom is rocky and largely composed of dead and decomposed corals, overgrown with seaweeds and nowhere is the depth more than 2–3 fathoms. The sea during the period of spawning is calm, salinity varies between 29·33‰–32·45‰ (Jayaraman, 1954; Prasad, 1956) and the surface temperature between 26 and 28·2° C. (Dr. R. R. Prasad, unpublished data).

Size at First Maturity

Data on the gonad activity of *H. georgii* were examined in relation to size at first maturity for the period 1957–59. Males and females were treated separately in the event of the possibility that male fish did not reach sexual maturity at the same size as females. Data from the period of maximum gonad activity only were analysed so that the results were not biased by the retarded condition of the late spawners or by the recovered gonads of early spawners. Hickling (1930) stated that for the hake, *Merluccius vulgaris*, gonadial development takes place even in fish which are not mature, and that the gonads may enlarge and develop to a kind of pseudomaturity at the same time the adult fish gonads are developing for spawning. These adolescent gonads do not become fully ripe and eventually regress. In this halfbeak however it was evident that such a phenomenon did not occur.

The smallest running male and female of *Hyporhamphus georgii* observed was 153 mm. L.C.F. and 149 mm. L.C.F. respectively. In fact 100% of the fishes were mature above 149 mm. This naturally suggests the size at first maturity. Moreover immature fish were rare in the commercial landings during the spawning period.

SEX-RATIO

The sex-composition data for *H. georgii* (Table XIV) during the spawning period indicates that there is a predominance of males in the commercial catches. Though no conclusive inferences can be drawn from the present observations, it appears possible that the male and female fish congregate into separate schools while moving to the spawning grounds. In the

TABLE XIV

Sex composition of the spawning population of Hyporhamphus georgii

Period of sampling	Sampling locality	Number examined	Sex ratio Male: Female
April 1957 (First fortnight)	Theedai	1,037	62·47 : 37·53
May 1957 (Second fortnight)	Pamban	953	67·68 : 32·32
March 1958 (Second fortnight)	Theedai (i)	1,443	61·47 : 38·53
	(ii)	987	64·13 : 35·57
April 1958 (First fortnight)	Theedai	1,373	58·22 : 41·48
(Second fortnight)	Theedai	1,221	65·77 : 34·23
March 1958 (Second fortnight)	Pamban	659	61·15 : 37·85
April 1958 (First fortnight)	Pamban	807	61·58 : 37·42
March 1958 (Second fortnight)	Rameswaram	913	60·35 : 39·65
April 1958 (First fortnight)	Rameswaram	1,560	59·48 : 39·52
March 1959 (First fortnight)	Theedai	1,147	56·03 : 43·97
March 1959 (First fortnight)	Pamban	423	67·15 : 31·85

Australian garfish, *Reporhamphus melanochir* there was also an indication that the sexes separate into spawning shoals (Ling, 1958). The sex-ratio of *H. georgii* during the maturing phases, however, showed discordant variations which were probably due to the fact that during that phase there was no tendency among the individuals of the population to school together. Such a phenomenon is not uncommon among teleostean fishes (Masterman, 1931; Hoover, 1936; Templeman, 1948).

Fecundity

There has been some difference of opinion as to the relation between fecundity and the size of fish (Franz, 1910 *a* and *b*; Keisselvitch, 1923; Walford, 1932; Raitt, 1933; Simpson, 1951; June, 1953; Lehman, 1953 and Pillay, 1958). The number of eggs per gram body-weight called the 'Fecundity factor' is a suitable parameter for assessment computations and comparative studies.

Very little work has been done on the fecundity of the halfbeaks and the existing knowledge is meagre. Smith (1933) estimated the fecundity of *Hemirhamphus far* and *H. kynsnaensis* at 12,000 and 10,000 eggs per season respectively. Devanesan (1937) gave the ripe egg count of *Hyporhamphus georgii* as 4,000. Ling (1958) estimated the fecundity of 3 specimens of *Reporhamphus melanochir* as ranging from 9,000–10,000 mature ova; there were 1,200 mature ova in the smaller fish, which suggested that size or age may be an influential factor (Ling, personal communication). Scott (1959) gave the number at 10,000 for some of the Malayan halfbeaks.

In the present study of the fecundity of *H. georgii* an attempt was made to find out the statistical relationship between the fecundity and size, weight of the fish, and also with the weight of the ovary.

Fecundity/length relationship.—A relationship of the form $F = AL^n$ in which F = number of ripe ova, L = Length to caudal fork and "A" constant, and "*n*" the exponent expressing the relationship between the number of eggs and the length of the fish. Expressed logarithmically,

$$\text{Log } F = \log A + n \log L,$$

and this is calculated by the method of least squares. The relationship in its logarithmic form is:

$$\text{Log } F = 3 \cdot 8140 \log L - 5 \cdot 5047$$

and is shown with the individual points in Fig. 3. The parabolic equation will therefore be

$$F = 0 \cdot 000003128 \, L^{3 \cdot 8140}$$

This relationship in its curvilinear form is shown in Fig. 4. Hence the fecundity was found to increase with length at a rate substantially greater

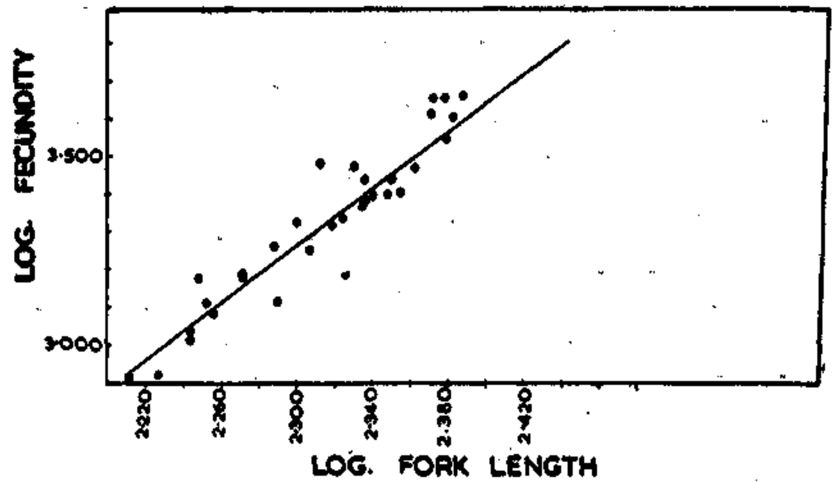

FIG. 3. Logarithmic relationship between length of fish and fecundity in *Hyporhamphus georgii.*

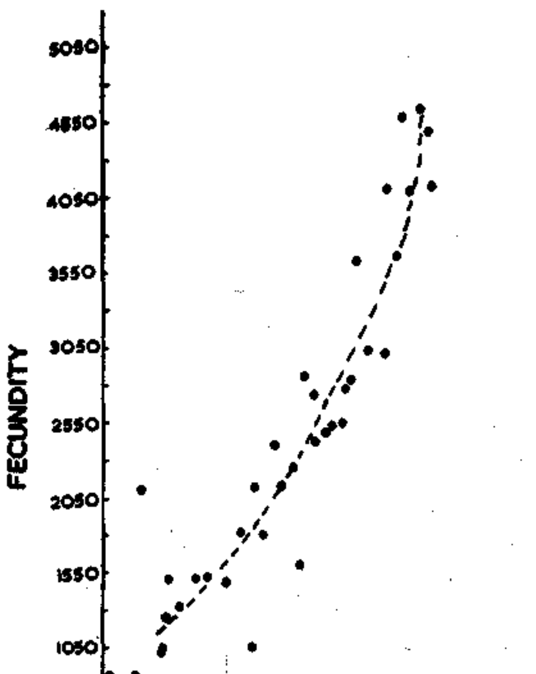

FIG. 4. Parabola describing the relationship between the length of fish and the fecundity of *Hyporhamphus georgii.*

than the third power of the length. Raitt (1933) and Hickling (1940) also found the rate of increase to be greater than the third power of the length. The results of this study support Simpson's argument regarding the relationship between fecundity and length of fish.

Fecundity/Ovary-weight relationship.—As in the previous case, employing the method of least squares the formula which best expressed the relation between fecundity and weight of ovary was calculated to be:—

$$F = 5 \cdot 780\ W^{0 \cdot 6803}$$

where F and W represent fecundity and weight of the ovary respectively. The observed and the theoretical values of fecundity in relation to weight of ovary are shown in Fig. 5. This equation clearly showed that the number of eggs produced has a close correlation to the mean weight of the ovary. Thus the observations are in agreement with that of Hickling (1940) who stated that "Since the production of eggs is the dominant function of the ovary, a close correlation should be expected between the weight of the ovary and the number of eggs produced".

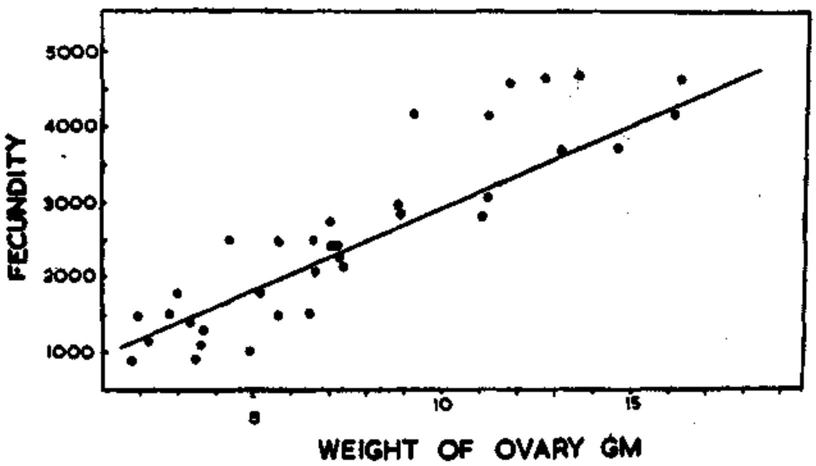

FIG. 5. The relation between the weight of the ovary and fecundity in *Hyporhamphus georgii*.

Fecundity/Whole body-weight relationship.—Having established the relationship between the fecundity and the length of the fish, a straight line relationship obtained graphically for the fecundity data plotted against whole-weight of fish could be accepted as valid. The regression for fecundity on whole-weight of fish was, therefore, calculated by the method of least squares and the resultant equation was:

$$F = 26 \cdot 17\ W^{1 \cdot 4178},$$

where F is the fecundity and W is the whole-weight of the fish (Fig. 6).

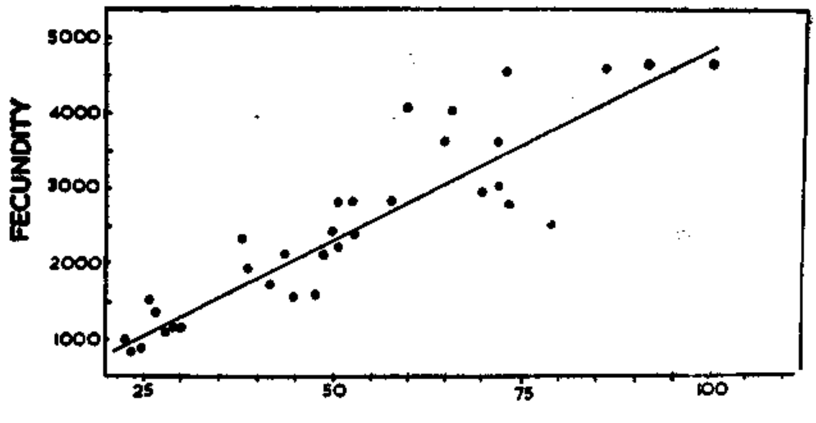

FIG. 6. The relation between body-weight and fecundity of *Hyporhamphus georgii.*

Fecundity factor.—The weight of ripe ova was 2·204 gm. per 1,000 ova in moist condition and the minimum standard weight for the matured ovary was observed as 2·840 gm. at first maturity. The average number of eggs producible by each female of *H. georgii* at the various sizes (or ages) were roughly estimated to be 1110 at 175 mm., 2455 at 215 mm. and 3430 at 235 mm.

AGE DETERMINATION AND RATE OF GROWTH

Methods that have been used in determining the age of the halfbeaks are: (1) study of the length-frequency distributions (Uchida, 1930; Ling, 1958; Hattori and Seki, 1959); (2) Scale analysis (Hattori and Seki, 1959); (3) Study of growth bands on otoliths (Ling, 1958).

The scales are cycloid and deciduous in *H. georgii*, hence most of the samples examined were scaleless except for a small region behind and on either side of the dorsal fin. Examination of the scales from this region gave no indications of growth checks.

515 pairs of otoliths from fish of different sizes were examined for growth checks in an attempt to assess the age of the fish but there were no indications whatsoever of any regular markings. Hence studies on age determination and rate of growth rests mainly on the Petersen's length-frequency method. The samples analysed were mainly from the shore-seine except the catches from Pamban which were from the 'ola-valai'.

The initial step in processing the data was to plot the length of individual fish, grouped into class-intervals, as frequency distributions for monthly periods. Although the number of fish measured each month was not constant, the frequencies were rendered comparable by converting them into percentages of the total for the month. In such studies a series of polygons representing the successive months of some specific year or longer period are generally taken into consideration but during this investigation there were several months in which no fishes were landed and also many in which they were too few to show even one well-defined modal group. However, a series of length-frequency polygons are presented for the months in which samples were adequately available during the years 1957–59 from the different sampling localities separately (Figs. 7 and 8). Since the spawning period of *H. georgii* is of a short duration clearly defined modal-groups should be expected to show up in length-frequency polygons at the approximate mean lengths of each year-class.

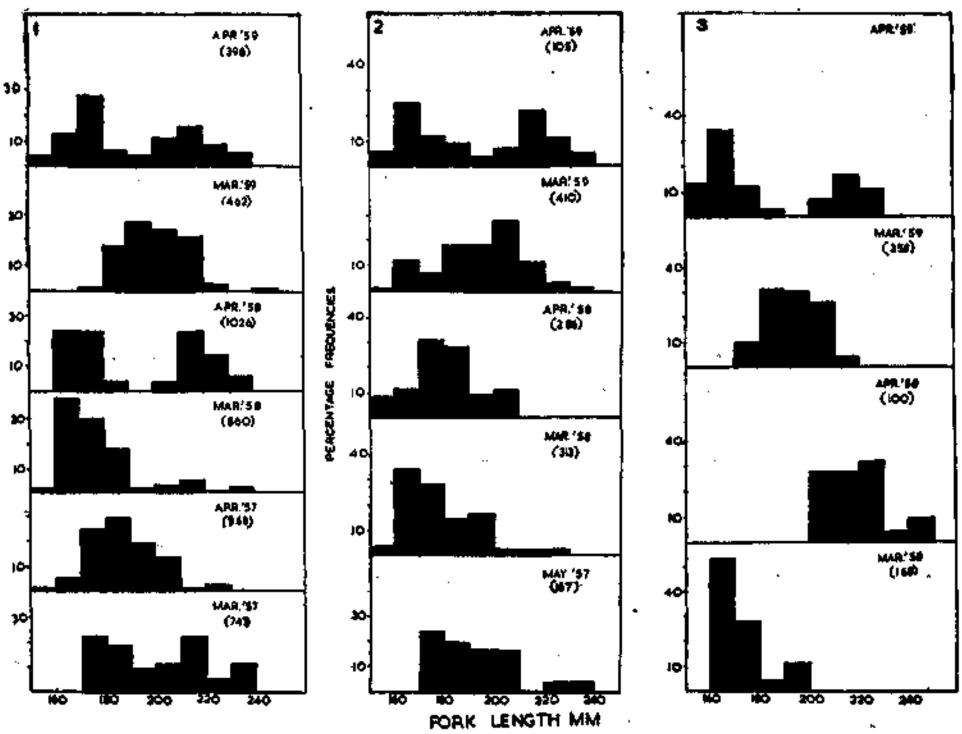

FIG. 7. Length frequency polygons of *Hyporhamphus georgii* from March 1957 to April 1959, (1) Theedai, (2) Pamban and (3) Rameswaram.

Since March-April is the period of the most intensive spawning activity, the March-April polygons may be said to represent the size frequencies at the end of one or more complete year in the life of the fish. Considering the graph at Theedai for March 1957, three modes at 175 mm., 135 mm. and 235 mm. are discernible. These probably represent three year-classes. Regarding the April 1957 frequency polygon, it can be considered more probable that the relatively large size of the broad mode at 185 mm. is due, in part at least,

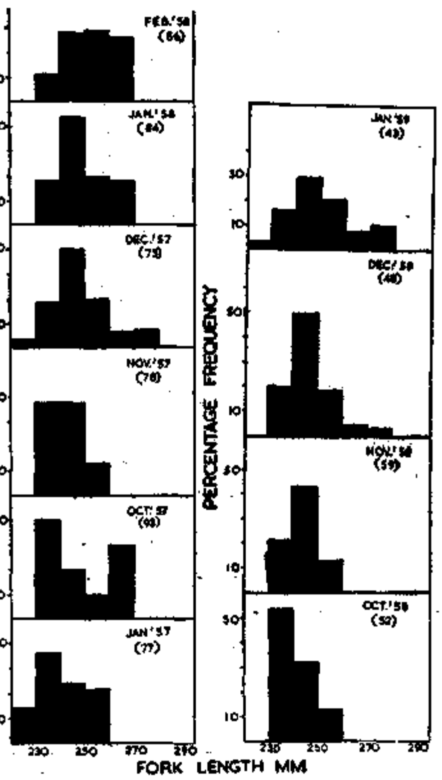

FIG. 8. Showing the size frequency distribution in *H. georgii* at Kilakarai from January 1957 and January 1959.

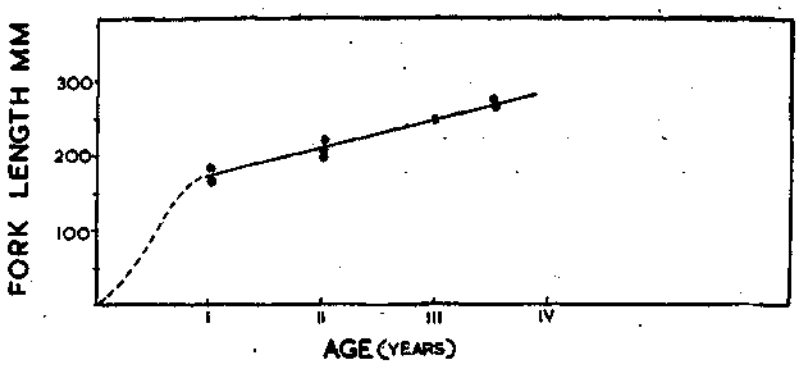

FIG. 9. Growth curve of *Hyporhamphus georgii.*

to the summation of the first two year-classes falling close together in the expected plateau phase of their growth curve. In April 1958 the first year-class was totally absent at Pamban. Absent of the first-year class may imply that insufficient number of fish was sampled so that the true age composition was obscured. The subsequent histograms may be interpreted in exactly the same way.

Summing up, only broad conclusion could be arrived at from the above data. Series of modes were fairly obvious in most of the polygons, but when it came to following the progression of a certain mode in the course of time, the evidence was not very conclusive. It would be possible, however, to make an estimate of the age by fitting the observed modal length to the growth curve and extending the growth curve towards the origin. A growth curve of the type described by Walford (1946) was fitted to the length-frequency data (Fig. 9) in the following manner: the obvious modes representing the year-classes were selected and a line of best fit was computed by the method of least squares for the following paired values: Length at age N and N + 1, at age N + 1 and N + 2, etc. This was produced as a free-hand curve to the age-axis. From this regression curve the length at N + 1, given the length at N, or the length at N + 1, could be computed.

If the age of the year-class entering the fishery during March–April is assumed to be one year, even though the growth attained seems high, it fits the pattern of growth better than the assumption of some other age, such as 2 or 3 years. It would be difficult, however, to obtain any acceptable fit of a growth curve to these modes on any other basis. In this connection it is of interest to mention the findings of Uchida (1930), and Hattori and Seki (1959) on *Hemirhamphus sajori* that the 0-age fish had a growth rate of 150–200 mm. during the first year and 10–50 mm. during the subsequent year. This interpretation of the modal length would imply that the fishery for *H. georgii* depends largely on two adjacent year-classes and entirely to three; the rate of growth being 175 mm. during the first year, 40 mm. during the second year and 20 mm. during the third year.

Length-Weight Relationship

Changes in the weight of the halfbeak as its length increases are a further aspect of the study of the growth-rate (Le Cren, 1951; Martin, 1949). In the present study two samples consisting of 125 males and 128 females of *H. georgii* collected during the year 1957 were analysed. The plot of whole-weight against length to the caudal fork (L.C.F.) of the fish of each sample separately gave a curve that indicated the possibilities of a logarithmic relationship. Hence the weights and lengths for each sex were transformed to logarithms, which plotted graphically, gave a straight line relation (Fig. 10). The lines of best fit, calculated by the method of least squares, are expressed by the following equations:

for Females

$$\log W = 2\cdot8000 \log L - 4\cdot8156$$

for Males

$$\log W = 1\cdot6667 \log L - 2\cdot2437.$$

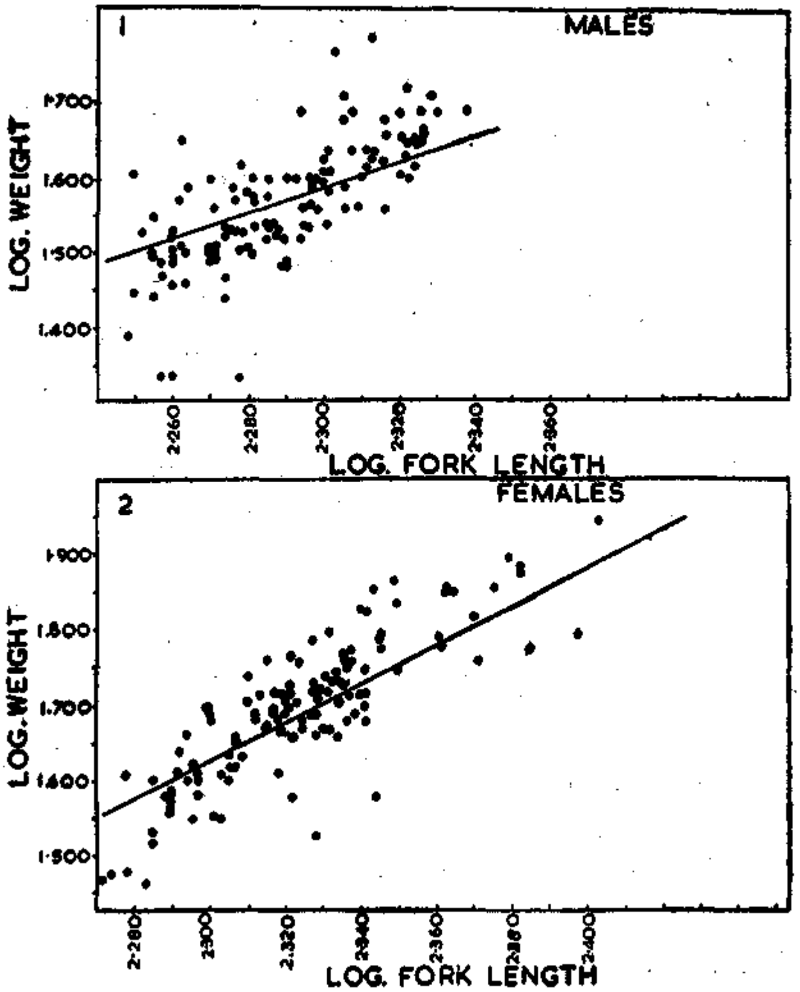

FIG. 10. Logarithmic relation of length and weight of *Hyporhamphus georgii*, (1) Males, (2) Females.

It is remarkable to note that whereas the cubic law is very nearly obeyed in the females, it is not so in the case of males.

Fishery and Fishing Methods

The fishery of *H. georgii* is chiefly confined to the Palk Bay. This fishery has been referred to at some length by Devanesan (1937), Devanesan and Chidambaram (1948) and Krishnamurti (1957). According to Devanesan and Chidambaram (*l.c.*) "This fishery is of the greatest importance in the Palk Bay fisheries; for example, the fishery at Theedai is worth several thousands of rupees annually. In a season on an average about 2–8 millions of fish may be caught. The season of the fishery coincides with the spawning season, March and April".

The nets that are in active operation during the seasons of the appearance of the halfbeaks are the 'karavalai' and the 'ola-valai'. The former is operated from Tuticorin type of boats and the latter from dug-out canoes (Krishnamurti, 1957).

The heavy catches at Theedai are sun-dried on the beach. Theedai being a low-lying area is covered with sea-water from October to February. Subsequently when the water recedes, the sand contains a good proportion of salt which is an additional advantage for drying the fish. These dried fish are warped in palmyra leaf mats and exported. The major catch at this centre is exported to Ceylon, and is also marketed to Paramakudi and Madurai. The catches at Rameswaram and Pamban are mostly sent by rail to interior fish markets packed with ice in baskets.

Summary

The present investigation on the biology of *Hyporhamphus georgii* is based on observations collected at five selected stations in the Gulf of Mannar and Palk Bay during 1957–59. The problems pertaining to racial composition, maturity and spawning, sex-ratio, size and age at first maturity, fecundity, fecundity-factor, age determination and rate of growth, length-weight relationship and fishery of this species, have been investigated in detail. The taxonomic position and its food and feeding habits are, however, discussed in separate contributions.

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