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AGE AND GROWTH OF THE FISHES OF THE GENUS *CHIROCENTRUS* CUVIER*

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ABSTRACT

Sexual difference in the rate of linear growth, female growing faster than male, was observed in the fishes of the genus *Chirocentrus*, namely, *C. nudus* and *C. dorab*. These two species form a fishery around the Rameswaram Island. The following results relate to *C. nudus* which has been studied in some detail. A close agreement has been found between the average lengths of fish calculated by length frequency method and by back-calculation of the lengths to the successive hyaline zones in the otoliths. The respective lengths to caudal fork (LCF) in cm at completion of 1-13 years of age, as derived from the von Bertalanffy growth equation, those of male being given in parenthesis are : 16.0 (17.5), 26.5 (25.0), 35.5 (31.5), 44.0 (37.0), 51.0 (41.5), 57.0 (46.0), 62.0 (50.0), 66.5 (53.5), 70.5 (56.5), 74.0 (59.5), 77.0 (62.0), 79.5 (64.5) and 82.0 (66.0). Fish of 4-6 years of age, which are well past the size at first maturity in both sexes, form bulk of the catches in the drift net fishery around the Island. Consistent and significant difference in the size at first maturity between sexes as well as in the sex ratios in the broad length groups, or between juveniles and adults have been found to serve as a good indication for the existence of sexual difference in the rate of linear growth.

INTRODUCTION

THE FISHES of the genus *Chirocentrus*, the wolf herrings, support a fishery of considerable importance around the Rameswaram Island (09° 17′ N, 79° 17′E). Drift nets which are operated at night from Tuticorin type boats land bulk of the wolf herring catches. Though two species, namely *C. dorab* (Forskal) and *C. nudus* Swainson occur in the fishery the latter accounts for about 80% of the wolf herring catches (Luther, 1968). The only information available in literature on the growth of the species of *Chirocentrus* is that given by Prabhu (1953) under *C. dorab*. But he did not point out the significant difference that exists in the growth rates between the two sexes. This account gives estimates of age and rate of growth in length from examination of otoliths and length frequency analysis for *C. nudus*, with remarks on the differential growth rates of the two sexes of *C. dorab*.

Grateful thanks are due to Dr. S. Jones, former Director of CMFRI for guidance during the course of this study. Sincere thanks are due to Dr. P. S. B. R. James, Director of CMFRI and to Dr. E. G. Silas, former Director for the kind encouragement received and to Shri K. V. Narayana Rao for critically reviewing the manuscript.

MATERIAL AND METHODS

The material for this study was mainly drawn from samples of fresh fish at weekly intervals from the catches of drift nets from April 1964 to July 1967 and from July 1968 to June 1969, and supplemented by those from shore seines collected during July 1967-June 1968, from the fish landing centres around the Rameswaram

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Island. The unusual manner in which the wolf herrings are caught in drift net is that most fish do not get entangled by a mesh of the net passing round its nape or body as is usual with other fishes, but do so by their sharp fang-like teeth caught in the net-strings presumably in their struggle to escape. Devanesen and Chidambaram (1953) have also made similar observations. Thus, fish of a wide size range were available in the drift net catches. On account of this, samples from drift net were considered useful for this study.

Fork length or length to the caudal fork (LCF), measured from tip of lower jaw, after closing the mouth, to the fork of the caudal fin was used as a routine measurement of the length of fish. The measurements were grouped into 2 cm class intervals. For example, fish measuring between 20.0 cm and 21.9 cm were assigned to the class interval of 20-21 cm and are referred as belonging to 21 cm size group. In view of the greater difference in the growth rate of fish between sexes in larger fish, and as fish could be measured with reference to sex from only drift net, length frequency analysis of data from shore seine was limited to fish below 25 cm length.

Although both scales and otoliths showed growth zones or checks, much reliance could not be placed on these caducous scales for this purpose as the scales of one fish tend to adhere to the body of another when the fish was handled at the landing centre. For this study, therefore, the scatter diagram technique of modal progression analysis of length frequency data, which gives the average sizes of fish at different ages, and counting the number of periodic rings or zones on otoliths (sagittae) have been employed to determine the age and growth.

As dry otoliths do not show the hyaline and opaque zones straight away, attempts were made to ascertain the methods by which the zones could be made clear and readable by employing several techniques as proposed by Sato and Kaga (1952), Chugunova (1963) and Christensen (1964). In liquid media such as rectified spirit, xylol, creosote oil and cedar-wood oil the otoliths showed alternating wide opaque and narrow hyaline zones besides a hyaline centre, the nucleus, the number of zones present being dependent on the size of the fish specimen in each sex. The translucent (hyaline) zones, when present, were easily distinguishable over the longer ventral limb than over the dorsal limb and the posterior end of otolith. Creosote oil, which was found to be more practicable during the study, was used for clearing the otoliths. The terminology adopted for otoliths was that proposed by Jensen (1965). Criteria for identification of the annulus in the otolith were those proposed by Walford and Mosher (1943) and adopted by later workers.

Otolith measurements were made on the outer somewhat flat surface of the left saccular otolith using the monocular microscope fitted with an ocular micrometer. Measurements recorded in micrometer divisions (1 md = 0.06 mm) were used as computations were facilitated by expressing the otolith radius in ocular micrometer units rather than the metric equivalents. For back-calculating length at age, radial length measurements of otoliths were taken along the longer (ventral) limb up to end of each successive hyaline zone (r_n) and to the tip of otolith (R_t) along the same axis. Since the length of the otolith is about twice the breadth, the accuracy of the radial length along the former axis has been considered twice as greater as that calculated along the latter axis. Further, as stated earlier, the hyaline zones are easily discernible over the ventral limb.

AGE AND GROWTH OF *C. NUDUS*

Age determination from otolith readings (Plate IA)

A total of 507 otoliths were examined during the present study. The readability of these otoliths could be classified as 'Fair' following the terminology proposed by Jensen (1965) as the hyaline zones, although visible, are not well defined. Further, the first zone in all otoliths, the next one or two zones in a few otoliths, one or two intermediate zones in a few others, and the last few zones in yet few others were found to be missing or not formed. In a few cases false or multiple zones were noticed, and these otoliths were rejected together with those wherein the intermediate zones were suspected to be missing. The first three conditions were recognised to be so after the intermediate lengths of fish were determined for each completed hyaline zone by back-calculation and compared with normal ones, and from the results of the length frequency analysis.

As emphasized by Graham (1929), Van Oosten (1929) and many other later workers, before attempting to interpret the hyaline zones on the otoliths as evidence of age of the fish, it is necessary to provide corroborative evidence that the zones are annual in their formation. This is done in the present study by the length frequency analysis as described later, and from the seasonal formation of the zones on the otoliths. As the growing outer edge as well as the formation of the hyaline zone resemble each other it was difficult to recognise the outermost hyaline zone until formation of the next opaque zone has commenced and progressed to some extent. The opaque margin of the otolith was found to be narrow generally during January-March period; and growing wider thereafter it was found to attain maximum width during September - October. Therefore, October-December is the main period of formation of the hyaline zone in the otoliths. Thus only one hyaline zone is formed in a year, and the number of these hyaline zones indicate the age in years.

Since the growth of any structure, such as the otolith, to be used in ageing has to be proportional to the growth of the fish, the relationship between otolith radius and fish length was estimated separately for female and male from a total of 289 and 218 observations respectively. Scatter diagrams of total radius of otolith (R_t) in micrometer divisions (md) on the corresponding fork length of fish (L_t) taken in millimetres indicated that the fish length-otolith radius relation is exponential in the original form. The regression equations estimated together with the co-efficients of correlation are as follows :

Female : $\log R_t = 0.0730+0.5784 \log L_t$; $r = 0.9601$

Male : $\log R_t = 0.1074+0.6564 \log L_t$; $r = 0.9745$

The foregoing values of the coefficients of correlation indicate a high level of significance in the respective correlations. In deriving a formula for back-calculation, however, it is necessary to take into consideration the regression of length of fish (L) on otolith radius (R_t) as the object of the study is to predict intermediate values of fish length for known intermediate values of otolith radius (Smith, 1955, Pantulu 1961 and others). Such regression equations for female and male were found to be as follows :

Female : $\log L_t=0.0847+1.5936 \log R_t$

Male : $\log L_t=0.2828+1.4462 \log R_t$

Based on these relationships, the following formula was used for back-calculation of lengths, at completion of various hyaline zones in the otoliths :

$\log L_n=\log L_t+ b\ (\log r_n-\log R_t)$

where L_n=length of fish at age 'n'; L_t = length of fish at the time of capture; r_n=radius of the otolith at the time of capture; and b=slope of the regression line.

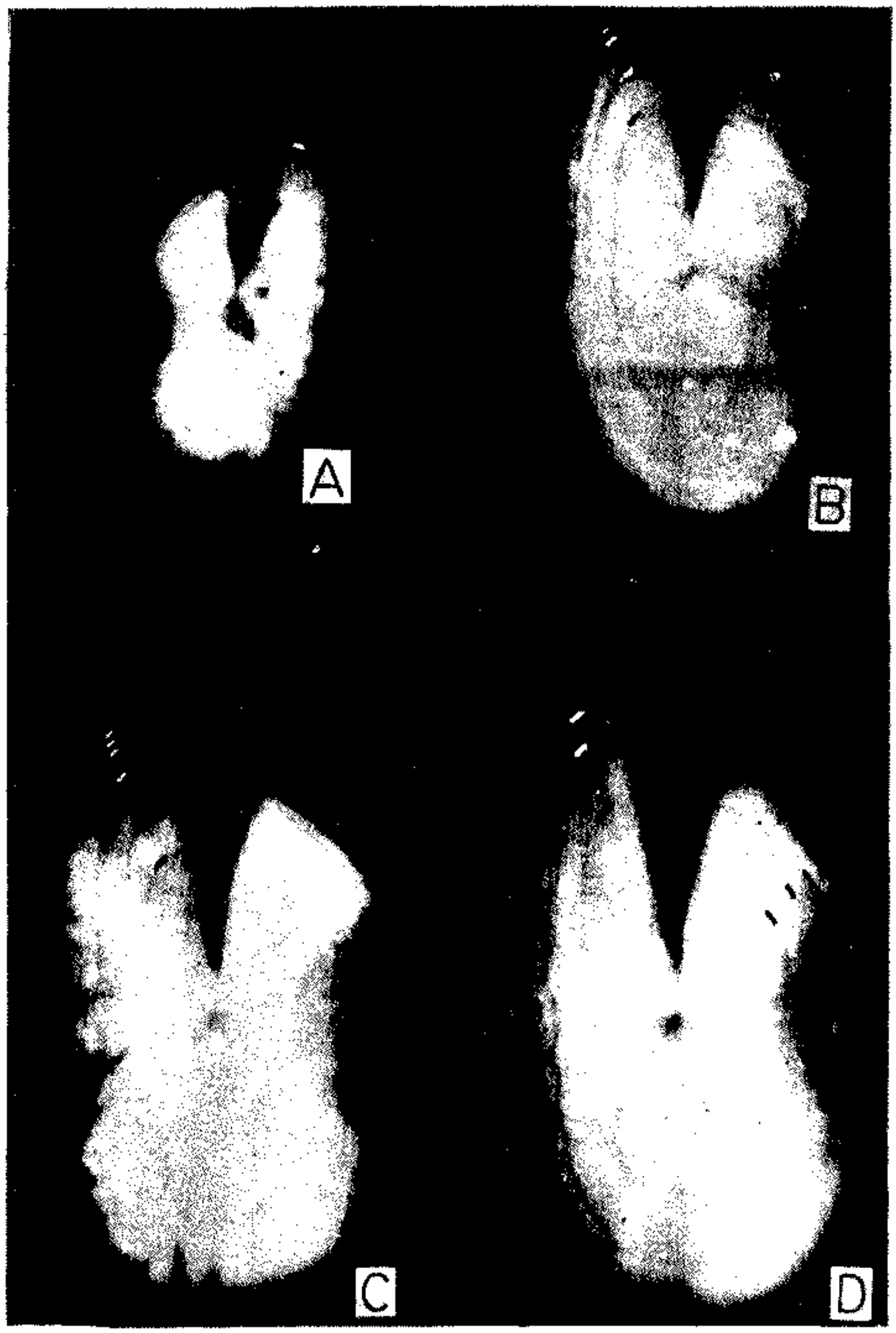

PLATE I. Otoliths of *C. nudus* photographed against a black background under reflected light : A. Female, 238 mm length, with one hyaline zone, B. Male, 378 mm length, with four hyaline zones. C. Female, 546 mm length, with six hyaline zones and D. Female, 614 mm length, with the first hyaline zone missing on dorsal (shorter) limb, and the first and third hyaline zones missing on ventral (longer) limb.

The merit of using this equation lies in the fact that the estimates of length at a given age depend on the ratio of the total radius of the otolith to the radius at age 'n', and back-calculations are made based on a calculated slope 'b' of the regression line (Smith, 1955; Pantulu 1961, 1963; Singh and Rage, 1968; and others.).

Results of back-calculations

Estimated lengths of fish (Ln) at completion of the various hyaline zones by back-calculation of the otoliths for female and male using the aforementioned formulae are given in Tables 1 and 2 respectively. The back-calculated lengths in cm to the successive hyaline zones 1-8 for female were found to be 21.49, 31.57, 39.54, 47.09, 53.55, 58.43, 64.75 and 68.50 respectively. Similarly, the lengths in cm for male were found to be 20.24, 27.62, 33.57, 37.62, 42.07, 46.60 and 51.30 at completion of 1-7 successive hyaline zones respectively. That males attain a lesser length than females at completion of the different hyaline zones is evident from the foregoing results.

The wide range of length that fish of both sexes attain at completion of the successive hyaline zones may also be noted from examination of the tables mentioned above. Thus for female the size ranges were : 16.6—27.4 cm at zone 1 with 28 observations; 25.4-38.0 cm at zone 2 with 27 observations; 34.3-45.8 cm at zone 3 with 31 observations; 39.2-53.0 cm at zone 4 with 28 observations; 48.2-59.3 cm at zone 5 with 21 observations: 52.8-63.3 cm at zone 6 with 15 observations; and 64.2-65.4 cm at zone 7 with 4 observations. Similarly, for males the size ranges were 16.3-24.6 cm at completion of zone 1 with 12 observations; 25.0-31.8 cm at zone 2 with 33 observations; 30.2-36.9 cm at zone 3 with 32 observations 34.0-40.6 cm at zone 4 with 28 observations; 39.5-44.3 cm at zone 5 with 15 observations; and 45.5-48.8 cm at zone 6 with 3 observations. A considerable overlap in the size of fish of both sexes at completion of different hyaline zones is evident from the foregoing results. Age determination of fish from length frequency analysis indicates that the formation of the hyaline zone-1 takes place when the fish is about a year and a half old.

Age Determination from analysis of the length frequency distribution

It may be mentioned here that the spawning season of *C. nudus* extends from February to July/August with the peak period during April-June (Luther, 1985).

Length frequency analysis of small fish

The monthly length frequency polygons for the period from July '67 to June '68 are given in Fig. 1. Adequate length frequency data, however, were available for only six months. Yet, the data do indicate a good picture of the growth pattern of the smaller size groups.

The polygon in July 1967 shows three modal sizes, namely, a, b & c at 7 cm 15 cm and 23 cm respectively. Considering the period of peak spawning, it is reasonable to assume that the smallest modal size (at 7 cm) represents the progeny of the current spawning season with its peak during April-June. This gives a monthly growth rate of about 3.5 cm. This mode seems to have progressed to 17 cm in March '68 registering a length increment of about 10 cm during the course of 8 months, and this gives an average monthly growth increment of about 1.25 cm for the '0' year class fish.

The mode 'b' at 15 cm in July '67 shifted to 23 cm in September '67 showing a monthly increment of 4 cm. The 15 cm group, however, is poorly represented in the July samples. However, this gives an indication that the July-August period could be favourable for faster growth of the juvenile fish. But the more

TABLE 1. *Measurements of fish length* (L_t), *otolith radius* (R_t) *and estimated length of fish* (l_n) *at completion of* 1-8 *hyaline zones by back-calculation of the otolith data of female* C. nudus

Fish length LCF (mm)	Otolith radius (md)	Back calculated lengths (mm)							
		l_{n_1}	l_{n_2}	l_{n_3}	l_{n_4}	l_{n_5}	l_{n_6}	l_{n_7}	l_{n_8}
271	30.0	236	..	..	..	..	..	..	..
213	26.0	187	..	..	..	..	..	..	..
222	27.0	209	..	..	..	..	..	..	..
202	25.0	189	..	..	..	..	..	..	..
238	28.0	211	..	..	..	..	..	..	..
235	30.0	211	..	..	..	..	..	..	..
235	28.5	209	..	..	..	..	..	..	..
220	29.0	208	..	..	..	..	..	..	..
196	25.5	166	..	..	..	..	..	..	..
203	25.0	178	..	..	..	..	..	..	..
246	29.0	194	..	..	..	..	..	..	..
282	30.0	211	..	..	..	..	..	..	..
566	44.5	226	302	..	..	..	..	..	..
452	42.0	237	323	..	..	..	..	..	..
567	42.0	202	264	444	..	..	..	..	..
450	41.0	245	318	390	..	..	..	..	..
595	48.0	238	312	376	481	..	..	..	..
456	44.0	222	275	361	392	..	..	..	..
550	46.0	182	324	423	512	..	..	..	..
503	41.0	274	347	391	465	..	..	..	..
517	42.0	226	319	422	517	..	..	..	..
492	43.0	248	338	421	474	..	..	..	..
660	51.0	199	254	346	484	560	609	..	..
534	46.0	215	270	361	445	516	..	..	..
566	52.0	199	261	343	403	482	532	..	..
546	48.0	206	301	408	458	501	528	..	..
675	51.0	245	354	458	514	593	633	..	..
660	58.0	243	322	410	488	555	624	..	..
700	50.0	..	294	379	452	551	613	..	..
652	49.0	..	373	417	530	590	..	..	..
584	47.5	..	359	392	480	..	..	..	..
646	53.0	..	289	364	463	533	608	..	..
600	51.0	..	271	360	457	527	563	..	..
523	44.0	..	380	405	449	495	..	..	..
475	45.0	..	348	418	..	..	..	..	..
470	44.0	..	357	420	..	..	..	..	..
750	54.0	..	326	428	493	541	571	642	685
620	45.0	..	308	415	474	..	..	..	..
460	39.0	..	336	423	..	..	..	..	..
576	51.0	..	..	370	464	524	..	..	..
493	42.0	..	..	402	447	..	..	..	..
575	50.0	..	..	356	469	521	557	..	..
515	43.0	..	..	371	441	..	..	..	..
592	52.0	..	..	374	470	556	..	..	..
630	45.0	..	..	403	522	564	..	..	..
695	53.0	..	..	..	480	526	584	654	..
614	45.5	..	..	..	461	540	582	..	..
690	50.0	..	..	..	..	513	573	647	..
634	52.0	..	..	..	..	540	596	..	..
705	57.0	..	..	..	..	518	591	647	..
Mean		214.9	315.7	395.4	470.9	535.5	584.3	647.5	655

TABLE 2. *Measurements of fish length* (L_t), *otolith radius* (R_t) *and estimated length of fish* (L_n) *at completion of 1-7 hyaline zones by back-calculation of the otolith data of male* C. nudus

Fish length LCF, (mm)	Otolith radius (md)	Back-calculated lengths (mm)						
		l_{n_1}	l_{n_2}	l_{n_3}	l_{n_4}	l_{n_5}	l_{n_6}	l_{n_7}
251	30.5	210	..	..	..	..	..	..
212	28.0	201	..	..	..	..	..	..
328	34.0	163	254	..	..	..	..	..
383	41.0	171	256	343	..	..	..	..
354	36.0	246	285	319	340	..	..	..
378	39.0	199	252	297	350	..	..	..
387	39.0	227	265	317	345	..	..	..
378	42.0	179	255	315	352	..	..	..
433	43.0	186	257	315	376	419	..	..
444	47.0	210	266	302	352	417	..	..
410	39.0	234	294	336	365	395	..	..
407	41.0	188	284	..	..	..	..	..
680	53.5	..	267	316	..	..	..	..
505	44.0	..	249	333	378	..	..	..
415	40.0	..	248	335	378	400	..	..
424	41.5	..	265	331	373	..	..	..
430	43.5	..	288	334	367	409	..	..
455	42.0	..	266	350	394	424	..	..
406	39.0	..	251	333	391	..	..	..
290	33.0	..	265	..	..	..	..	..
465	46.0	..	275	353	394	436	..	..
417	37.0	..	293	369	401	..	..	..
420	43.0	..	250	312	378	..	..	..
458	44.0	..	289	363	406	443	..	..
477	46.0	..	282	341	390	433	455	..
505	44.0	..	249	333	363	424	..	..
358	38.0	..	292	344	..	..	..	..
471	43.5	..	289	316	373	417	455	..
401	42.0	..	295	334	374	..	..	..
422	45.0	..	281	350	..	..	..	..
404	40.0	..	..	333	368	..	..	..
555	47.0	..	318	362	400	440	488	518
432	40.0	..	299	356	386	416	..	..
405	44.0	..	315	340	379	..	..	..
437	45.0	..	304	394	389	416	..	..
421	44.0	..	315	367	394	..	..	..
450	44.0	..	..	343	378	421	..	..
Mean		202.4	276.2	335.7	376.2	420.7	466.0	513.0

or less stationary position of mode 'b' as well as of mode 'a' in October indicates very little or no growth during this month. This supports the observation that formation of the hyaline zones on the otoliths begins from about October. In view of this and the modal size distribution of fish during September-October,

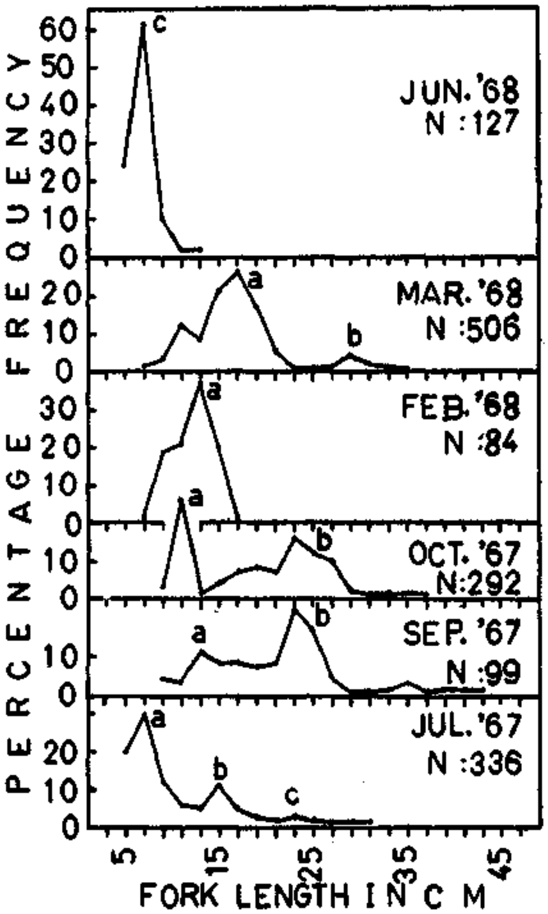

FIG. 1. Length frequency distribution of small sized *C. nudus* for the period July 1967—June 1968.

it is reasonable to expect the formation of the first hyaline zone on otoliths in fish of 11-13 cm length and about 6 months of age ; and the second zone in fish of about 23 cm size when it is about 1½ years old. But back-calculation of the otoliths have shown that the first hyaline zone is formed at about 20-21 cm thus indicating that formation of the hyaline zone due in fish of 11-13 cm length does not take place in this species. From the length frequency polygon for March '68, it is reasonable to consider the modal size of 17 cm to represent fish of about one year in age. But the group of fish representing the mode 'b' at 15 cm in July '67 should also be considered to have already completed one year of life. Thus the modal size of one year old fish may vary between 15 and 17 cm length. This observation is supported by the results of the growth equation presented in a later section (Table 6).

Length frequency analysis from drift net catches

Fish over a wide size range of 16-83 cm length (LCF) occurred in the drift net catches. The largest female measured 83 cm and male 68 cm length during the period of observations. As growth rate was found to differ between the sexes, only those measurements of fish for which the sex was determined had to be made use of in the final analysis of length frequency data. Thus the size of the samples available for each sex in the different months became inadequate. In view of these, and to avoid taking cognizance of false modes arising out of sampling defects, it was considered desirable to pool the length frequency data in quarterly periods, each of three months, January-March being taken as one quarter, and so on. The length frequency data and the polygons for the different quarterly periods from April 1964 to July 1967 and from July 1968 to June 1969 are given in figures 2 and 3. Noteworthy features of these length frequency distributions are that the dominant modal size and the maximum size of male, compared with those of female, are smaller. Further, male is predominant among the smaller length groups and female among larger length groups. The modal locations for female and male for the different quarterly periods are depicted in fig. 4

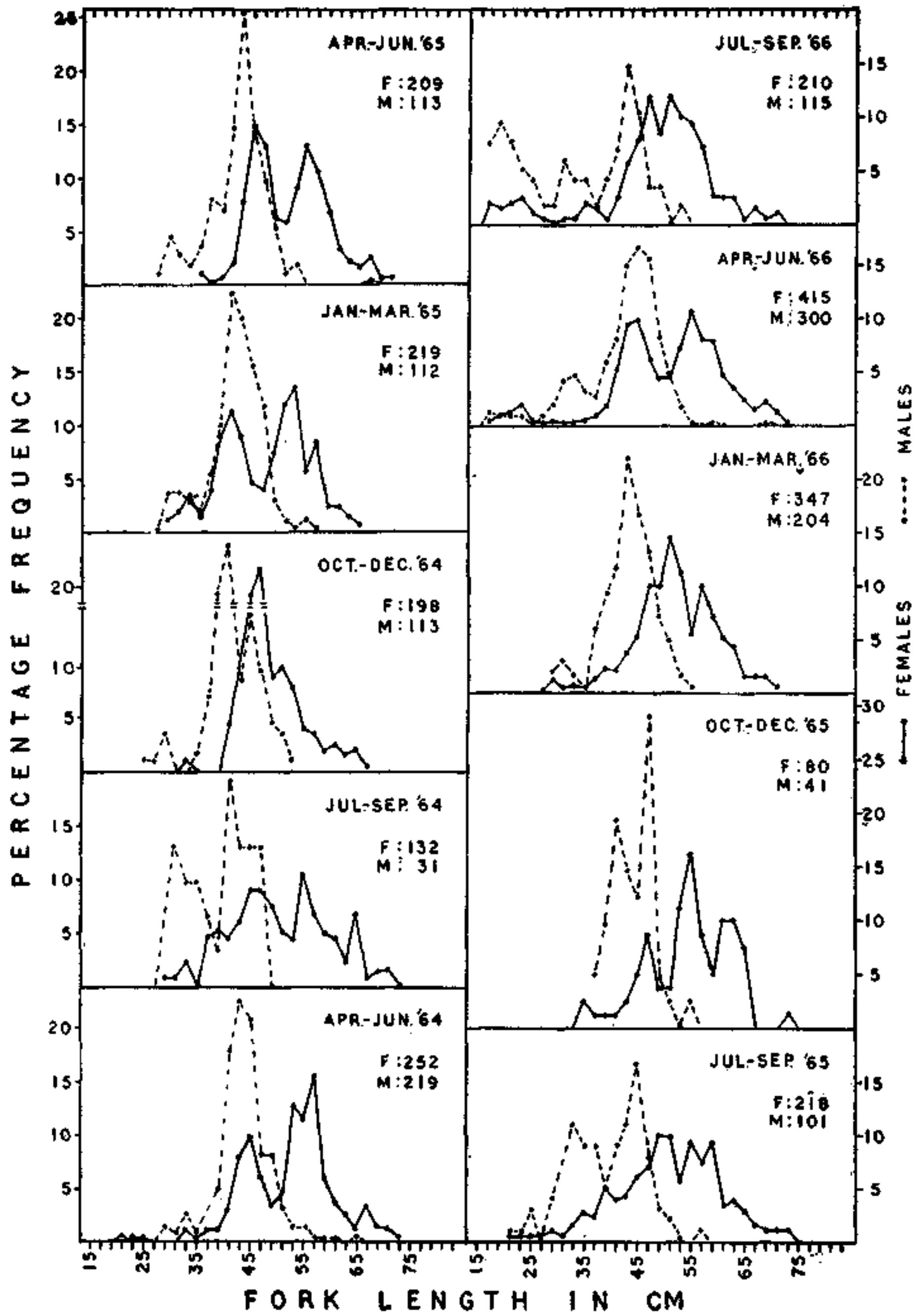

FIG. 2. Length frequency distribution for female and male *C. nudus* from April-June 1964 to July-September 1966. Number of females (F) and males (M) measured for length in each period is indicated.

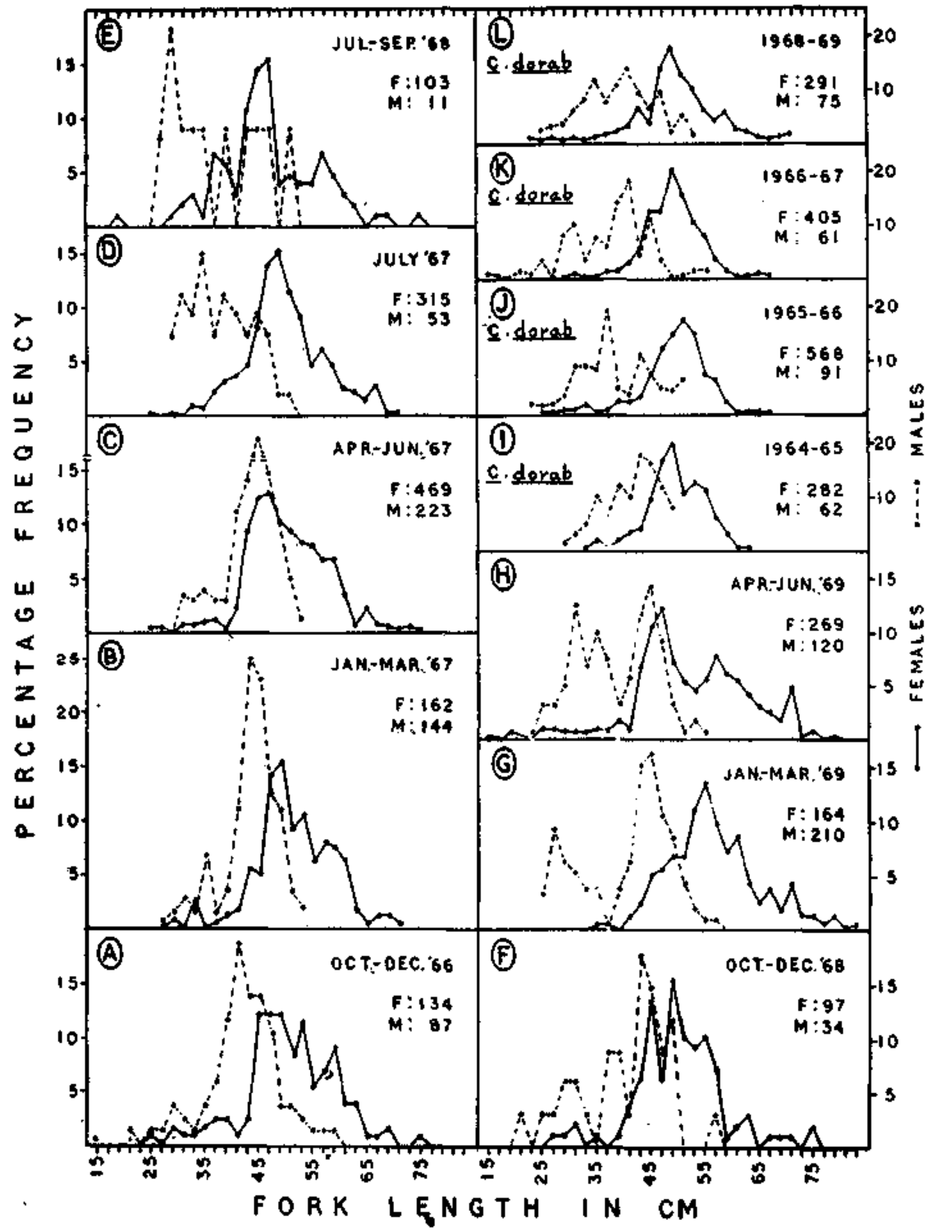

FIG. 3. a to h represent length frequency distributions of *C. nudus* from October-December 1966 to July 1967 and from July-September 1968 to April-June 1969. i to l represent annual length frequency distributions of *C. dorab* from 1964-65, 1966-67 and 1968-69. The other details are same as in the previous figure.

and 5. For plotting the quarterly modal points, the modal sizes were classified into three categories and denoted by different symbols in order to present a picture of the dominant and other size groups of fish in the catches. The most dominant mode is represented by a square; the smaller modes, each representing about 5% or less of the number in the frequency distribution by circles; and the modes that range in between the above two categories by triangles.

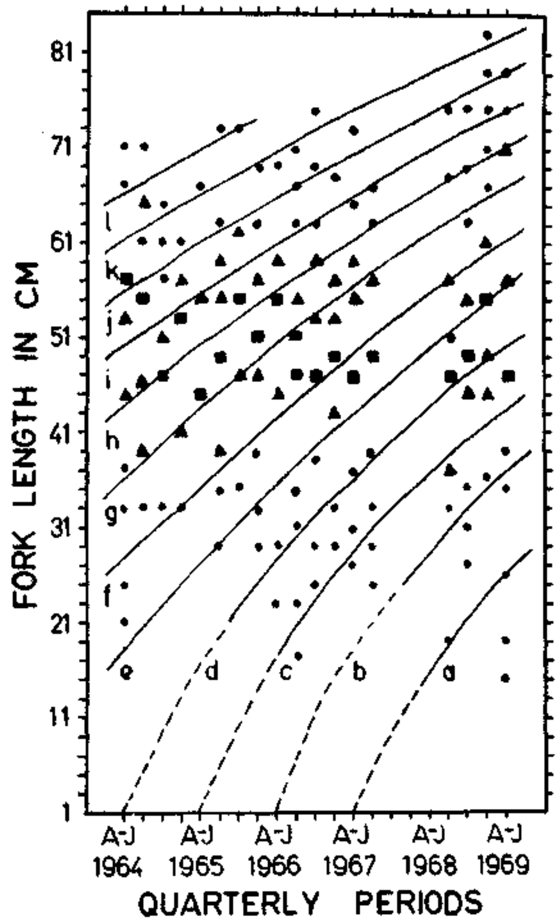

FIG. 4. Approximate growth curves drawn to the modal points in the length-frequency distribution of female *C. nudus* presented in Figs. 2 and 3.

The diffused nature of the distribution of the modal points is understandable in view of the wide size range of each age group of the fish, as inferred from otolith studies. On account of this and, perhaps also, the inherent nature of the size distribution of fish in the drift net samples, a single age group is seen to be represented by more than one modal size group in the samples analysed. This has placed a certain amount of restriction to discuss the progression of the modal lengths during the successive periods, as is usually done for estimating the age and growth rate from length frequency analysis. Hence in order to obtain a picture of the general trends of growth in the two

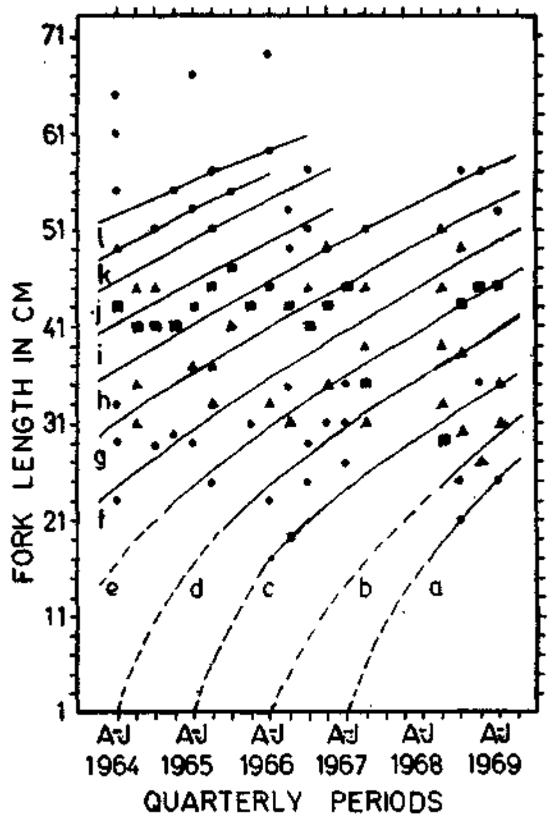

FIG. 5. Approximate growth curves drawn to the modal points in the length-frequency distribution of male *C. nudus* presented in Figs. 2 and 3.

sexes, growth curves have been drawn approximately through the middle of the modal locations representing each annual brood for the two sexes separately (Figs. 4 and 5). The following considerations have been applied in drawing these approximate growth curves. April-June quarter, which is the peak spawning season for the species has been taken as the period of birth of each annual brood, and fish of both sexes of each brood have been considered to have attained approximately lengths of 11-13 cm, 15-17 cm and about 23 cm at completion of 6 months, 1 year and 1½ years respectively as inferred from the length frequency distribution of small sized fish. The remaining portion of the curve was drawn depending on the distribution of the modal points.

As the length frequency analysis is being examined here in order to obtain supporting evidence for the results obtained from otolith study, the average size of each brood is read off from the curves during the quarter October-December, when the hyaline zone is formed each year (Tables 3 and 4).

The average lengths in cm for female at completion of 1½ to 11½ years of age, with yearly intervals, were found to be as 22.67, 32.30, 39.70, 46.70, 53.20, 58.60, 63.90, 68.50, 72.87, 77.00 and 81.00 respectively. Similarly for male the average lengths in cm at completion of 1½ to 9½ years of life, with yearly intervals, were found to be 21.00, 27.20, 33.00, 38.30, 43.20, 47.80, 51.80, 55.38 and 58.00 respectively. These results also clearly demonstrate a difference in the growth rates of female and male from very early age, and this difference becomes greater in larger sizes.

Growth Equation

The von Bertalanffy growth equation (Beverton and Holt, 1957) has been adopted here as it is most widely accepted in fishery biological work (Taylor, 1958; Southward and Chapman, 1965; and Dickie, 1971). For fitting the curve the estimates of length at age as obtained from back-calculation of otoliths were used. The estimates of various parameters of von Bertalanffy equation separately for the female and male are :

	Female	Male
t_o	-0.3066	-1.0848
k	0.1370	0.1109
$L\infty$	97.67 cm	83.92 cm

Hence the von Bertalanffy growth equation of female and male of *C. nudus* can be written as :

Females : $L_t = 97.67\ (1 - e^{-0.1370\,(t + 0.3066)})$

Males : $L_t = 83.92\ (1 - e^{-0.1109\,(t + 1.0848)})$

Fig. 6 gives the growth curves for the two sexes based on the theoretical growth equations. The theoretical lengths at different ages as calculated by the von Bertalanffy growth equation show a very high degree of agreement with

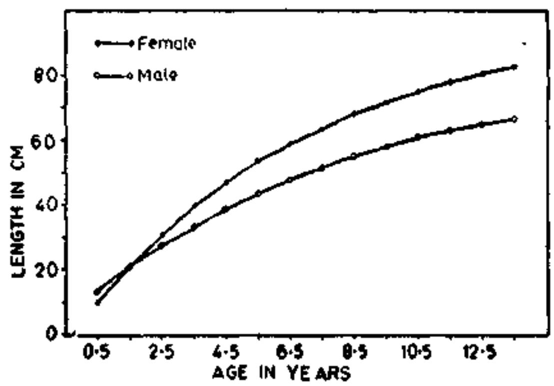

Fig. 6. Growth curves for female and male *C. nudus* obtained from von Bertalanffy growth equation.

the lengths at ages derived from length frequency studies, and from back-calculation of otoliths (Table 5). As the lengths of fish at different ages given in the foregoing table relate to ½, 1½, 2½, 3½ years etc., of ages, the approximate lengths of fish at ages

TABLE 3. *The sizes (in cm) attained by the progeny of each spawning season at completion of 1.5 to 11.5 years of age for female* C. nudus *as derived from the growth curves in Fig.* 4

Growth curve	Age (years)										
	1.5	2.5	3.5	4.5	5.5	6.5	7.5	8.5	9.5	10.5	11.5
a	21.5										
b	..	33.0									
c	23.5	33.0	40.0								
d	..	32.0	40.0	47.0							
e	23.0	31.5	39.5	46.5	53.5						
f	..	32.0	39.0	46.0	52.5	58.5					
g	..	..	40.0	47.0	53.5	59.5	64.5				
h	..	..	..	47.0	53.5	59.0	64.0	69.0			
i	..	..	..	..	53.0	58.0	63.5	68.5	73.0		
j	..	..	..	..	..	58.0	63.5	68.0	72.5	77.0	
k	..	..	..	..	..	..	64.0	68.5	73.0	77.0	8.10
l	..	..	..	..	..	..	..	68.5	73.0	..	..
Mean	22.67	32.30	39.70	46.70	53.20	58.60	63.90	68.50	72.87	77.0	81.0

TABLE 4. *The sizes (in cm) attained by the progeny of each spawning season at completion of 1.5 to 9.5 years of life for male of* C. nudus *as derived from the growth curves in Fig.* 5

Growth curve	Age (Years)								
	1.5	2.5	3.5	4.5	5.5	6.5	7.5	8.5	9.5
a	21.0								
b	..	26.5							
c	21.0	27.0	32.0						
d	..	27.5	33.0	38.0					
e	..	27.5	33.0	38.0	43.0				
f	..	27.5	33.0	38.0	43.0	47.5			
g	..	..	34.0	38.5	43.0	47.5	52.0		
h	..	..	..	39.0	43.5	48.0	52.0	56.0	
i	..	..	..	..	43.5	48.0	52.0		
j	..	..	..	..	..	48.0	52.0	56.0	
k	..	..	..	..	..	..	51.0	55.0	
l	..	..	..	..	..	..	..	54.5	58.0
Mean	21.0	27.20	33.00	38.30	43.20	47.80	51.80	55.38	58.0

TABLE 5. *Comparison of estimates of lengths (in cm) at different ages by different methods in* C. nudus

Age (years)	Otolith		Length frequency		von Bertalanffy growth equation	
	Female	Male	Female	Male	Female	Male
0.5	..	..	12.00*	12.00*	10.27	13.55
1.5	21.49	20.24	22.67	21.00	21.45	21.14
2.5	31.57	27.62	32.30	27.20	31.22	27.57
3.5	39.54	33.57	39.70	33.00	39.72	33.46
4.5	47.09	37.62	46.70	38.30	47.15	38.71
5.5	53.55	42.07	53.20	43.20	53.62	43.48
6.5	58.43	46.60	58.60	47.80	59.25	47.73
7.5	64.75	51.30	63.90	51.80	64.17	51.54
8.5	68.50	..	68.50	55.38	68.45	54.93
9.5	..	..	72.87	58.00	72.20	58.00
10.5	..	..	77.00	..	75.46	60.71
11.5	..	..	81.00	..	78.29	63.15
12.5	..	..	..	..	80.78	65.32
13.5	..	..	..	..	82.94	67.27

* Average of the length range of 11-13 cm obtained for unsexed fish of about 6 months of age from length frequency analysis.

1, 2, 3 etc., for female and male as obtained from the respective growth curves are given in Table 6 together with the corresponding total length of fish (in cm) in parenthesis. The formula for converting fork length (X) into total length (Y) has been found to be as follows :

$$Y=1.946778+1.158560\ X (r=0.9998)$$

As mentioned earlier the largest female observed in the catches measured 83 cm, and male 68 cm in length. From Table 5 it is seen that these lengths are attained by the fish at about 13 years of age.

GROWTH OF *C. DORAB*

Otoliths, scales and length frequency data were collected for estimating the growth of *C. dorab*. A very large number of the otoliths were unreadable in this species as the opaque and hyaline zones are poorly defined. So they could not be employed for age and growth estimation. Scales, owing to their caducous nature, also could not be used with confidence for the purpose. On account of the protracted spawning season of this species, extending almost throughout the year (Luther, 1985) length frequency studies also have been found not quite useful. Hence, no attempt has been made to study the age and growth rate of this species for the present.

The differential growth rate between the two sexes as inferred from observations on size at first maturity of male and female and on sex ratios at different length groups (Table 7) has, however, been investigated. For this purpose, length frequency data from drift net catches were pooled on a yearly basis from July to June, for the periods from July 1964 to June 1967 and from July 1968 to June 1969. The polygons of the two sexes for the four

TABLE 6. *Average length (LCF, cm) at different ages as derived from the growth equation and the corresponding total length (cm) in parenthesis for females and males of* C. nudus

Sex	Age (years)												
	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	XIII
Females	16.0	26.5	35.5	44.0	51.0	57.0	62.0	66.5	70.5	74.0	77.0	79.5	82.0
	(18.7)	(30.9)	(41.3)	(51.2)	(59.3)	(66.2)	(72.0)	(77.2)	(81.9)	(85.9)	(89.4)	(92.3)	(95.2)
Males	17.5	25.0	31.5	37.0	41.5	46.0	50.0	53.5	56.5	59.5	62.0	64.5	66.0
	(20.5)	(29.2)	(36.7)	(43.1)	(48.3)	(53.5)	(58.1)	(62.2)	(65.7)	(69.1)	(72.0)	(74.9)	(76.7)

years are presented in Fig. 3, I-L. The limits of the class interval of each size group and the mid point considered, are similar to that mentioned for *C. nudus*.

The polygons reveal that 49 cm size group was most dominant in the commercial catches for female. For male, however, the dominant size group was at 41 cm for two years, during 1966-'67 and 1968-69. But it was smaller at 37 cm, during 1965-66 and greater, at 43 cm, during 1964-65. The maximum size of male varied between 49 and 55 cm and of female between 63 and 71 cm during the course of four years. Similarly, male was predominant among the lesser length groups and female among the higher length groups. Assuming that fish of comparable age groups school together and thus occur in the catches, and taking into consideration the differential size frequency distribution of the two sexes, as well as the results obtained for *C. nudus* under similar size distribution pattern, it is reasonable to assume a differential growth rate for the two sexes of *C. dorab* also.

DISCUSSION

The present study has shown that the wolf herring *C. nudus*, has a much longer life-span, of at least 13 years, than many of the marine fishes of India whose age and growth have been investigated (Qasim, 1973). The close agreement between the average lengths calculated by the length-frequency method and the back-calculation of lengths to the successive, periodic hyaline zones present on the otoliths indicates that these estimates of age and growth of *C. nudus* are reliable and that the hyaline zones on the otoliths are valid annular marks for age determination. Further, von Bertalanffy growth equation, 'which gives a curve for growth in length that fits well to the growth rates of many species of fish' (Berverton and Holt, 1957) was also found to describe adequately the growth of the female and male of *C. nudus*.

TABLE 7. *Sex ratio in the various length groups of the two species of* Chirocentrus

Length group (LCF, cm)	*C. nudus*		*C. dorab*	
	N	Sex ratio (F : M)	N	Sex ratio (F : M)
16—19	40	40.0 : 60.0	..	.. ..
20—23	51	49.0 : 51.0	6	33.3 : 66.7
24—27	78	23.1 : 76.9	15	40.0 : 60.0
28—31	183	20.2 : 79.8	40	22.5 : 77.5
32—35	209	46.2 : 53.8	65	32.2 : 67.7
36—39	345	36.5 : 63.5	110	46.4 : 53.6
40—43	893	38.5 : 61.5	182	67.6 : 32.4
44—47	1250	55.6 : 44.4	385	87.5 : 12.5
48—51	779	75.1 : 24.9	532	96.4 : 3.6
52—55	613	94.3 : 5.7	329	99.1 : 0.9
56—59	483	98.6 : 1.4	131	100.0 : ..
60—63	250	100.0 : ..	19	94.7 : 5.3
64—67	115	99.1 : 0.9	7	100.0 : ..
68—71	73	98.6 : 1.4	2	100.0 : ..
72—75	17	100.0 : ..		
76—79	4	100.0 : ..		
80—83	1	100.0 : ..		
Over the whole period	5384	63.6 : 36.4	1823	84.8 : 15.2
16—23	91	45.1 : 54.9		
24—43	1708	34.6 : 65.4		
44 & above	3585	77.9 : 22.1		
20—39	..	.. ..	236	37.7 : 62.3
40 & above	..	.. ..	1587	91.8 : 8.2

The significant difference in the growth rates between sexes of higher age groups, female having a faster rate of linear growth than male, as also the unequal sex ratios at different size groups (Table 7), as observed in the present study for *C. nudus* could be a characteristic of long-lived species. The largest female and male encountered in this study were 83 cm and 68 cm LCF respectively. Commenting on short-lived species, Qasim (1973) states, 'As a rule it might be indicated that in most of the short-lived species, a significant sexual difference in growth rate seems unlikely. Probably, this may be one of the reasons why their sex-ratios do not differ markedly'. Luther (1985) has shown that though the overall sex ratio in both the species of *Chirocentrus* is unequal, female predominating over male, both sexes are nearly equally distributed in the smaller length groups male dominates in the intermediate length groups and female in the larger sizes. This situation could have arisen due to the more rapid reduction in the rate of linear growth which has been found to set in from about the size at first maturity in both sexes (see next para) and the reduction in numerical strength of the higher age groups in the exploited stock, even if equal numbers of them were to be born and to survive. Qasim (1956) and Raja (1972) have shown that the preponderance of one sex in the population of fish is because of the sexual difference in growth rate. Nikolsky (1963) states that males are larger than females in only a few species, implying that in the vast majority the females grow larger in size as observed in the present study. However, for the same length of fish, male has been found to weigh more than female in *C. nudus* (Luther, 1985).

A fall in the growth rate of *C. nudus* as could be observed from the growth curve (Fig. 6), around 40 cm for female and about 30 cm for male which lengths respectively are close to the size at first maturity, is therefore, associated with attainment of sexual maturity by the fish. The author (Luther, 1985) has observed that females of both the species of *Chirocentrus* mature at a large size than males, the difference being about 10 cm. For *C. nudus* the sizes at 50% level of maturity for female and male were found to be 42.2 cm and 31.0 cm respectively. Thus the marked differences in size at first maturity between male and female could be indicative of the sexual difference in growth rate as well as the longevity of the species. It is therefore, imperative to make a prior examination of the difference in the size at first maturity between the sexes, as well as the sex ratios in different length groups so that adequate data could be collected separately for each sex for studies on age and growth in fishes.

The non-formation of the first hyaline zone in all otoliths, the next one or two zones in a few, one or two intermediate zones in a few others and of the last few zones in yet a few others as observed in *C. nudus* may be the result of the condition of the fish being above the threshold value in that period (De Bont, 1967). Holden (1955) as cited by De Bont (1967) has expressed the causes for ring formation in the scales of two species of *Tilapia* thus: ' Ring formation is dependent upon the condition of the fish and there is a threshold level of condition above which no ring formation will occur, but below which ring formation is continuous...'. Immature *T. esculenta* which did not show a ring, according to him (De Bont, 1967), could have had a fall in their condition which fall was not below the threshold value and the term ' condition ' used here being not necessarily synonymous with the term ' condition factor '.

As mentioned earlier, spawning season for *C. nudus* extends from February to July/August with the peak period during April-June and the main period of formation of the hyaline zone in the otolith is October-December. This rules out the possibility of the spawning stress influencing the formation of a hyaline zone. Further, these zones are formed even in fish below the minimum size at first maturity.

Possible factors for zone formation according to De Bont (1967) are changes in quality and quantity of food, in hydrological conditions and temperature. The changes taking place in the hydrological conditions around Rameswaram Island during the period of hyaline zone formation (October-December) are associated with the northeast monsoon. The November-January period is characterized by low salinity and low temperature around the Island. The fall in salinity starts from October/November and reaches a minimum (24.8%) during December-January and the fall in temperature starts by about September and reaches a minimum (23.5° C) during December-January (Jayaraman, 1954; Bapat, 1965; Prasad, 1958). These periods coincide with the period of low catch per unit effort for *Chirocentrus* around Rameswaram Island, namely, August-December (Luther, 1973). Thus there appears to be some physiological stress on the wolf herring population resulting in their moving away from their normal fishing grounds around the Rameswaram Island and this could be one of the factors inducing the formation of the hyaline zone in the otoliths.

The general trend of the age composition of the commercial catches of *C. nudus* based on the present estimates of length at age and with reference to the quarterly length frequency polygons (Figs. 2 and 3) reveals that recruitment to the fishery takes place when the fish are about two years old. The common sizes of fish of both sexes in the drift net catches being 4-6 years of age, are past their size at first maturity and fish upto 13 years of age are met with in drift net fishery.

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