REPRODUCTION, AGE AND GROWTH OF THE KELEE SHAD, *HILSA KELEE* (CUVIER, 1829) (PISCES: FAM. CLUPEIDAE) WITH INFORMATIONS ON ITS FISHERY IN MAPUTO BAY, MOZAMBIQUE

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ABSTRACT

Age, growth and reporduction of Hilsa kelee were studied, and a brief description of its fishery in Maputo Bay is given. Most of the material was collected from gillnet fisheries, during 1977-1980, but some material was taken from shrimp trawlers operating in the same area during 1980-1981.

The main spawning seems to take place during October-January with a peak in December. There is also some evidence that spawning takes place during June-July.

The size at first maturity is around 14-15 cm. Ageing was carried out using primary growth rings in the otoliths and length-frequency analysis of fish caught by shrimp trawlers. The results, which are tentative only, suggest that the parameters of the von Bertalanffy's growth equation are about L_∞ = 22 cm, W_∞ = 110 g and K = 1.2. Males and females seem to grow in similar fashion.

There are seasonal trends in the catch composition of the gill net fishery, showing high values during April to September and low ones during October to December.

RESUMO

Foi estudada a idade, crescimento e reproducao de Hilsa kelee e é apresentada uma breve descricao da sua pescaria na báía de Maputo. A maior parte da informacao apresentada foi colhida da pescaria com rede de emalhar, durante o período de 1977-1980, embora uma parte tenha sido retirada dos arrastoes de camarao que operaram na mesma área, durante 1980-1981.

A principal desova deve realizar-se no período de Outobro a Janeiro com o pico em Dezembro. Há também alguma evidência de que a desova se dá durante Junho-Julho. Os peixes tem a sua primeira desova com o tamanho de 14-15 cm.

Foi determinada a idade a partir dos aneis de crescimento diário dos otólitos e da análise de frequências de comprimento dos peixes capturados pelos arrastoes de camarao. Os resultados, que sao ainda preliminares, sugerem que os parâmentros de equacao de crescimento de von Bertalanffy sao approximadamente L_∞ = 22 cm, W_∞ = 110 g e K = 1.2. Os machos e fêmeas parecem ter a mesma taxa de crescimento.

Na pescaria com rede de emalhar os dados de captura foram mais elevados durante o período de Abril a Setembro ê mais bauxos de Outobro a Dezembro.

INTRODUCTION

The Kelee shad, Hilsa kelee (Cuvier, 1829) is a pelagic fish, inhabiting coastal waters and estuaries. It is commercially exploited in Mozambique in Maputo Bay and on Sofala Bank between Savana and Chiloane Island.

In 1971, the collection of biological information of this species was started, but the results were not published. Monteiro (1974) described the fishery and catch and effort data were presented for the period of April 1972 to July 1973. From 1974 to 1976 this study was many times interrupted. In 1977 a program was started with the main purpose of estimating the total amount of Hilsa kelee landed and studying some aspects of the biology of this species, mainly its reporductive cycle and its age and growth.

The present study, based on the catches landed at Doca dos Pescadores (the most important landing site of Maputo Bay) by the gillnetters and on the samples taken aboard the shrimp trawlers operating in Maputo Bay, presents information on the reproduction of H. kelee and some tentative estimates of age and growth. Data on catch and effort and their seasonal variations are also given.

Maputo Bay, including the Espirito Santo Estuary is a large estuarine system protected from the Indian Ocean mainly by Machangulo and Inhaca Island. Five rivers discharge at Maputo Bay. The maximum depth in the bay is 20 m and the bottom is sandy and muddy.

MATERIALS AND METHODS

Collection of samples

From January 1977 to December 1980 a total of 48 000 fish collected from the gillnetters were examined. Weekly a box of 20 kg of H. kelee was taken randomly from a boat. The fork length taken from the tip of the snout to the median rays of

the caudal fin was used and grouped in 0.5 cm length groups. Fortnightly, after the separation by length classes, 5 fish of each length group were randomly chosen and the following parameters recorded for each one: fork length in millimetres, total length in millimetres, total weight in grams, gutted weight in grams, gonad weight in grams, sex and maturity stage.

The macroscopic observations of the development of gonads were based on a maturation scale of 6 stages. The coloration of gonads, presence of superficial blood vessels, size of gonad in the abdominal cavity and presence of visible eggs were taken into account. The description of each stage is given in Appendix 1. A large amount of otoliths were extracted.

From January 1980 to August 1981 a total of 2000 fish collected from the by-catch of the shrimp trawlers were examined. Fortnightly 2 boxes of about 20 kg of fish were taken and the species composition determined. All individuals of H. kelee were measured. The total length was used, taken from the tip of the snout to the end of the upper lobe of the caudal fin and grouped in 0.5 cm length groups. A subsample of 50 individuals taken randomly were examined and the biological parameters mentioned above were recorded for each one. Some otoliths were extracted.

The otoliths were extracted by lateral dissection through the operculum; after being washed and dried they were stored in paper envelopes. The otoliths are small, with a prominent rostrum and a small antirostrum. The opposite edge is rounded.

Two different techniques were used for the preparation of otoliths for readings. Some of them were ground on both sides on a wetted sharpening stone. Grinding was alternated with observation under a microscope until the nucleus was reached. They were then sticked to a glass slide with a drop of transparent cement and covered with a mounting medium (DPX). Others were first sticked on a glass slide with a drop of Mikrokitt and stiffened in an oven at 40°C during about 12 hours. They were then ground with 600 Grit Carborodum wet/dry paper.

alternating grinding with the observation under a microscope. They were cleaned with alcohol and after being dried they were covered with a mounting medium.

Fitting of length-age equations

To fit a growth curve to the length-frequency distributions, the ELEFAN I program was used (Pauly and David, 1981). This program "traces" a von Bertalanffy growth curve through a series of length-frequency samples sequentially arranged in time so that it passes through as many peaks as possible. The program, originally written in BASIC, was run on a Univac 1100 computer. The growth curve based on otolith reading was fitted using a graphical method (Beverton & Holt, 1957, p. 282-284).

The statistical methods used are described by Zar (1974) and by Ricker (1973).

Vessels and fishing gears

The gillnetters are small-sized boats, 8 m long and 48 GRT. A crew of 6 to 8 fishermen work in each boat. The fish is landed at Doca dos Pescadores daily. During the period of study, 12-14 boats were operating.

Besides these ones, artisanal fishing boats propelled by paddles on outboard motors landed their products in other ports of the Bay, normally in Costa do Sol, Catembe and Inhaca. No information is available about the number of these boats. Drift gillnets are the main fishing gear used in this fishery. They can be drifting in the water for 15 to 45 minutes. They are made of nylon, composed by 6 to 8 nets of 60 meters long and 100 mesh height. The mesh size range from 2 to 2 1/4 inches.

H. kelee is also caught by the shrimp trawlers, but represents a very low percentage of the shrimp by-catch.

Information of catch and fishing effort was obtained from the masterfishermen of each gillnetter that land the fish at Doca

dos Pescadores. Twice a week these masterfishermen were asked about the catch landed, fishing areas, number of sets, duration of each set and fishing time. Based on this information the total catch was estimated.

RESULTS

REPRODUCTION

Time of spawning

To estimate the spawning time, the macroscopic appearance of gonads, the gonadosomatic index and the condition factor were analysed. Macroscopic observations of developmental stages were made of 3385 gonads (1911 females and 1474 males) from the catches landed by the gillnetters from January 1977 to December 1978. The results showed that the spawning takes place in the wet season, from October to January, with the peak in December (Fig. 1). A small increase in the percentage of spawning females (stage V) is also evident in June 1977 and in July 1978. Similar results were obtained by the observations of specimens taken from the shrimp trawlers (Table 1).

The gonadosomatic index (GSI), expressed as the percentual relation between the gonad weight (W_G) and the total weight (W_T):

$$GSI = 100 \times \frac{W_G}{W_T}$$

was calculated for 3204 individuals.

The GSI is closely correlated to the maturity stages in both sexes (Fig. 2). The highest mean values were found in the stage IV and represent 7.8% of the total weight in females. The mean monthly values and the confidence limits are presented in Fig. 3. The increase in the GSI coincides with the time of spawning as indicated by stages of maturity. The GSI was also

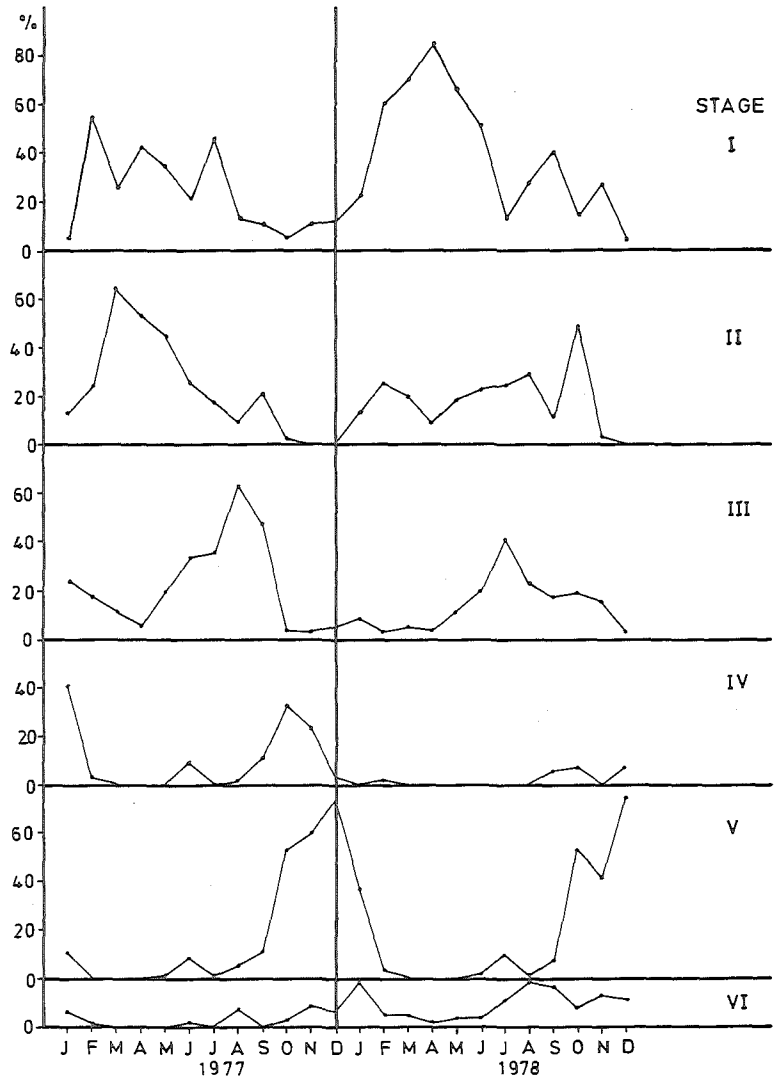

Fig. 1. Distribution of maturity stages of female H. kelee in 1977 and 1978.

estimated for 84 individuals caught by the shrimp trawlers during November 1980 and January 1981 and the values obtained were high:

$\overline{GSI} = 4.43$	$\overline{GSI} = 3.42$
$s = 1.809$	$s = 1.257$
$n = 46$	$n = 38$

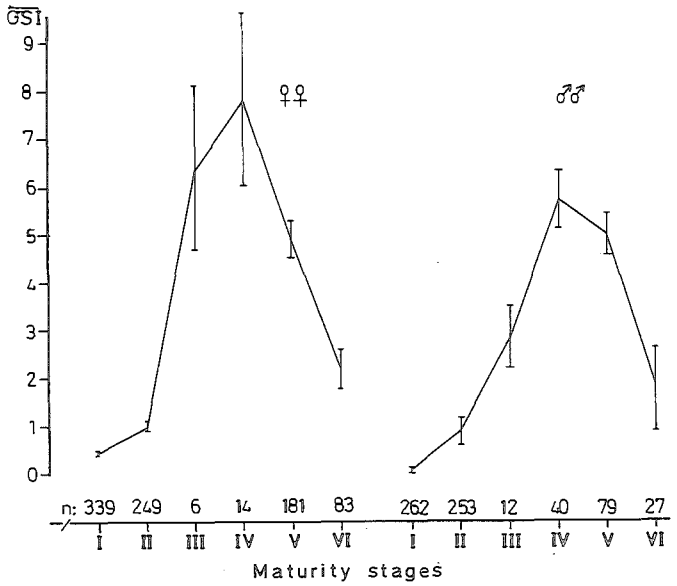

Fig. 2. Mean gonadosomatic index and its confidence limits (vertical bars) for the different stages of maturity of H. kelee. n is number examined.

The variations of Clark's condition factor during the year was also studied. It was expressed as the percentual relation between the gutted weight (W_{GT}) and the cube of the fork length (L_F):

$$K = 100 \times \frac{W_{GT}}{L_F^3}$$

All the individual values were grouped by month and sex (Fig. 4), for the samples taken from the catches landed by the gillnetters during 1977 and 1978. The lower values correspond to the months of October, November, December and January, which coincides with the spawning time. The lowest value of the condition factor coincides with the peak of spawning (December).

Table 1. Percentage distribution of maturity stages of H. kelee caught by shrimp trawlers.

Time of	Females							Males							Juve-
	Maturity stage							Maturity stages							niles
Capture	I	II	III	IV	V	VI	N	I	II	III	IV	V	VI	N	N
May/80						100	18	37.5	12.5			25.0	25.0	8	
Sep/80	94.7					5.3	9	59.1	13.6	4.5		9.1	13.6	22	9
Nov/80	2.9				97.1		34	10.0				90.0		20	3
Jan/81					83.3	16.7	12					94.4	5.6	18	
Mar/81	81.0	4.8		14.3			21	100						4	77
Apr/81	65.5	34.5					29	87.5	12.5					16	39
Jul/81	37.5	50.0				12.5	40	28.2	51.3				20.5	39	4
Aug/81	80.0	10.0				10.0	10	100						2	89

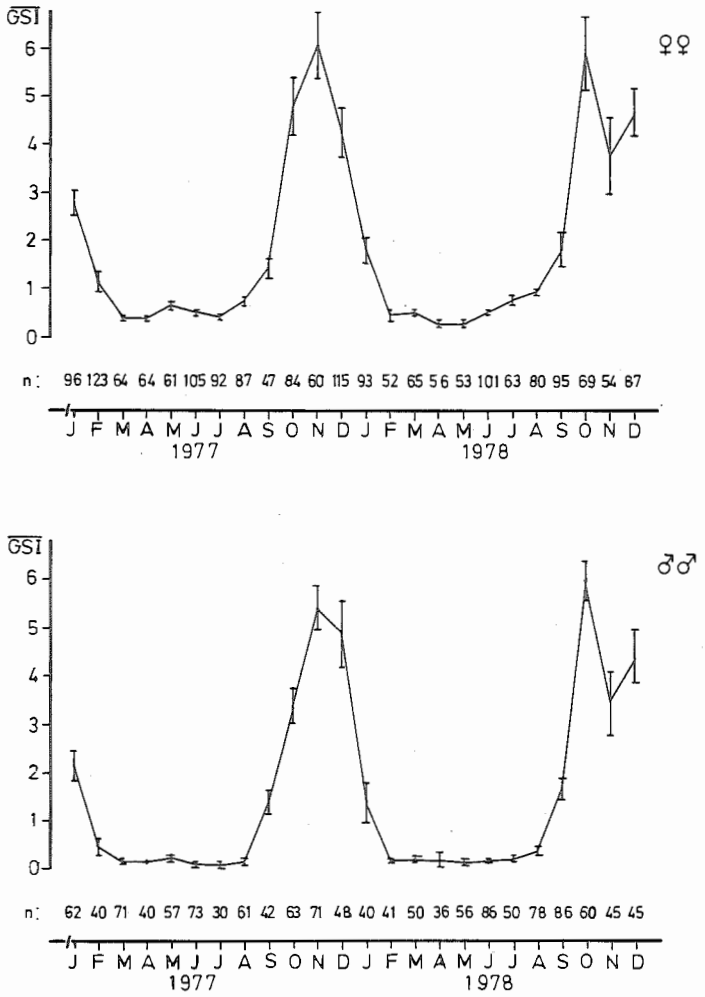

Fig. 3. Monthly variation in gonadosomatic index (mean ± confidence limits) of H. kelee. n is number examined.

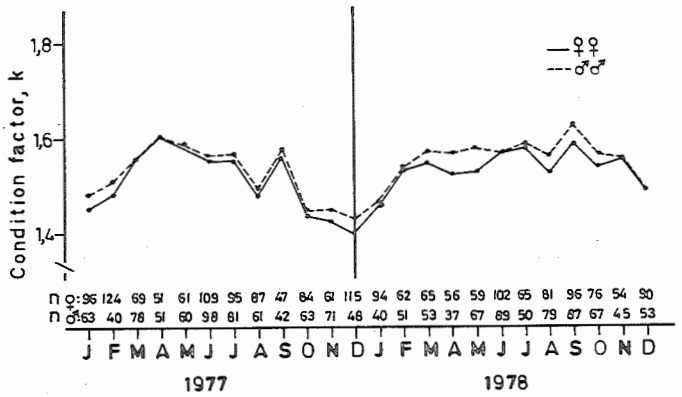

Fig. 4. Monthly variation of Clark's condition factor of H. kelee. n is number examined.

Sex ratio

The ratio of males and females in the samples from 1977 and 1978 is given in Fig. 5. In 20 of the 24 months there were more females than males, and in 9 of these months the ratio was significantly different from 1:1 (5% level). The overall ratio was also different from 1:1 for both years, being 1:0.75 and 1:0.80 for 1977 and 1978, respectively.

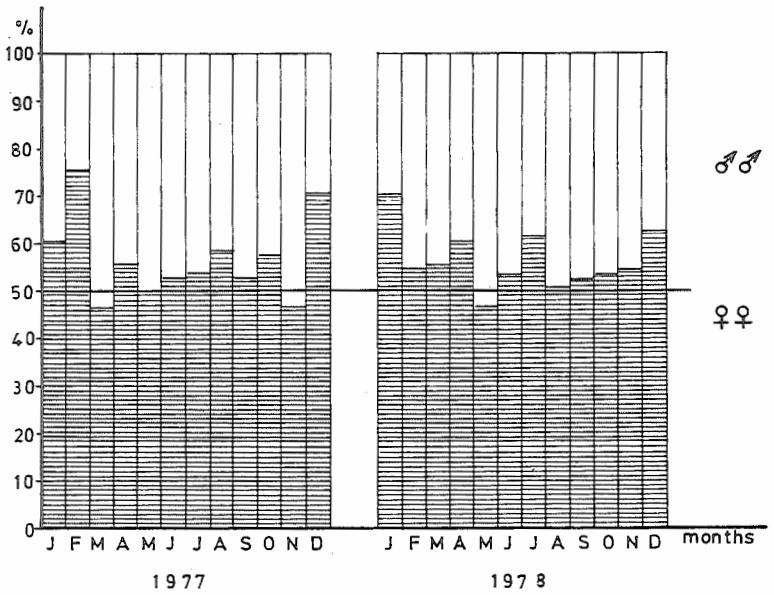

Fig. 5. Sex composition of H. kelee.

When the material is split in length-groups (Table 2) there are more females than males among fish 15.5 cm long or larger, and the ratios were significantly different from 1:1 (x^2-test). For fish ranging from 13.5 - 15.0 cm long the males were more abundant than the females. For smaller fish the difference was either non-significant or the females dominant (Table 2).

There is apparently no difference in growth between males and females. Therefore change in relative mortality of the two sexes after maturation could be a reasonable explanation for the change in sex ratio. However, no further attempts have been made to test this hypothesis.

Table 2. Sex ratio of different length-groups of H. kelee. m>f significantly more males, f>m significantly more females, ns. no significant difference 5% level of significance - not tested.

LENGTH	NUMBER		RESULT OF TEST
	Males	Females	
11	1	6	-
11.5	8	25	f>m
12	24	32	ns
12.5	61	57	ns
13	105	94	ns
13.5	173	114	m>f
14	199	165	m>f
14.5	305	181	m>f
15	240	202	m>f
15.5	145	275	f>m
16	114	310	f>m
16.5	63	247	f>m
17	28	146	f>m
17.5	7	40	f>m
18	1	17	-
18.5		1	-

Size at maturity

To estimate the size at first spawning, the percentage of females classified as spawning (stage V) in October-December 1977 and in November-December 1978 was calculated (Fig. 6). The maturity ogives obtained indices that the average size at first spawning is about 15 cm.

SIZE AND GROWTH

Fork length - total length relationship

To describe the relation between fork length and total length 494 fish was studied and the functional regression

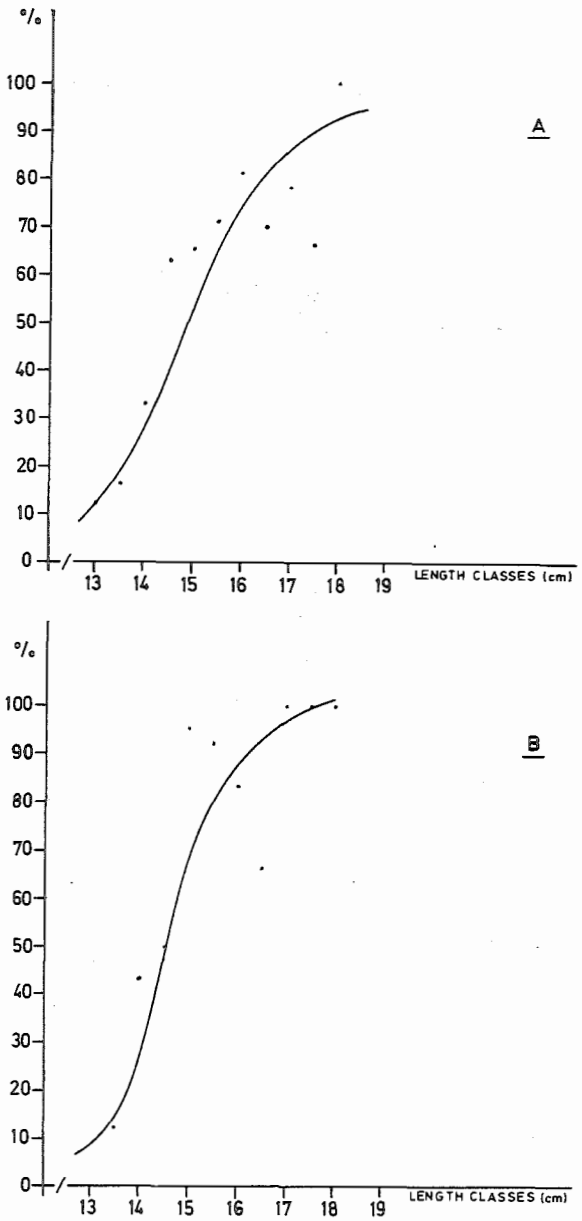

Fig. 6. Maturation ogives for H. kelee. A. October-December, 1977. B. November-December, 1978.

$$L_T = 0.231 + 1.223\ L_F$$

with the coefficient of determination $r^2 = 0.98$ was fitted.

Total weight - gutted weight relationship

The total weight-gutted weight relationship was also estimated. For a total of 489 fish taken as stratified samples with 10

fish from each 0.5 cm length group a functional regression was fitted and the following result was obtained:

$$W_T = 0.549 + 1.124\ W_{GT}$$

with coefficient of determination, $r^2 = 0.98$.

Length-weight relationship

The length-weight relationship was studied based on 550 specimens of H. kelee collected from the bycatch of shrimp trawlers.

Statistical analysis (analysis of covariance) were carried out of logaritmically transformed data fitted to predictive linear regressions:

$$\lg W = a + b \lg l$$

where W is weight in grams and l is length in cm. Following the recommendations of Ricker (1975) these relationships were, however, transformed and presented as functional regressions:

$$\lg W = u + v \lg l.$$

Males, females and juveniles were treated separately. An analysis of covariance and multiple comparisons among the slopes by a Newman-Keules test (Zar, 1974) showed that they were all different.

Although the regressions are significantly different, a common functional regression may be useful for practice purposes:

$$\lg W = 3.268 \lg l - 2.356 \qquad r^2 = 0.981$$

N = 551, Confidence limits of v: 3.230 - 3.307

Some information on length-weight relationship is also available from the gill net fisheries: Based on 494 specimens the equation

$$\lg W = 3.142 \lg l - 1.928$$

was obtained.

Ageing by means of otoliths

The otoliths of H. kelee were difficult to read, because there were several types of rings, and it is not always clear what should be interpreted as daily rings. Usually there is an inner zone consisting of about 25-30 clear primary rings. After that a zone follows, where narrow rings are found, and superimposed on them there are broader but more diffuse rings. In this area, counting the narrow rings will give about 3 times higher values than counting the broad rings. This zone contains an average of 100 or 300 rings, depending of the interpretation. Outside this area the rest of the otolith contains narrow and densely packed rings.

Growth

The length distribution of H. kelee from the gill net fishery is given in Fig. 7. Due to the selectivity of the gear, the variation between months is small. Similar data from the shrimp fishery give a wider size range (Fig. 8) and these data were used for fitting a von Bertalanffy growth curve by means of the ELEFAN I program (Pauly and David 1981). The best fit was obtained for

$$l_t = 23 \ (1 - e^{-1.2(t - t_o)})$$

The value of t_o will depend on how the birth date is set.

Otoliths from 129 specimens in the length range 8-19 cm were studied to count primary growth rings. The rings for males, females and juveniles are given separately in Fig. 9.

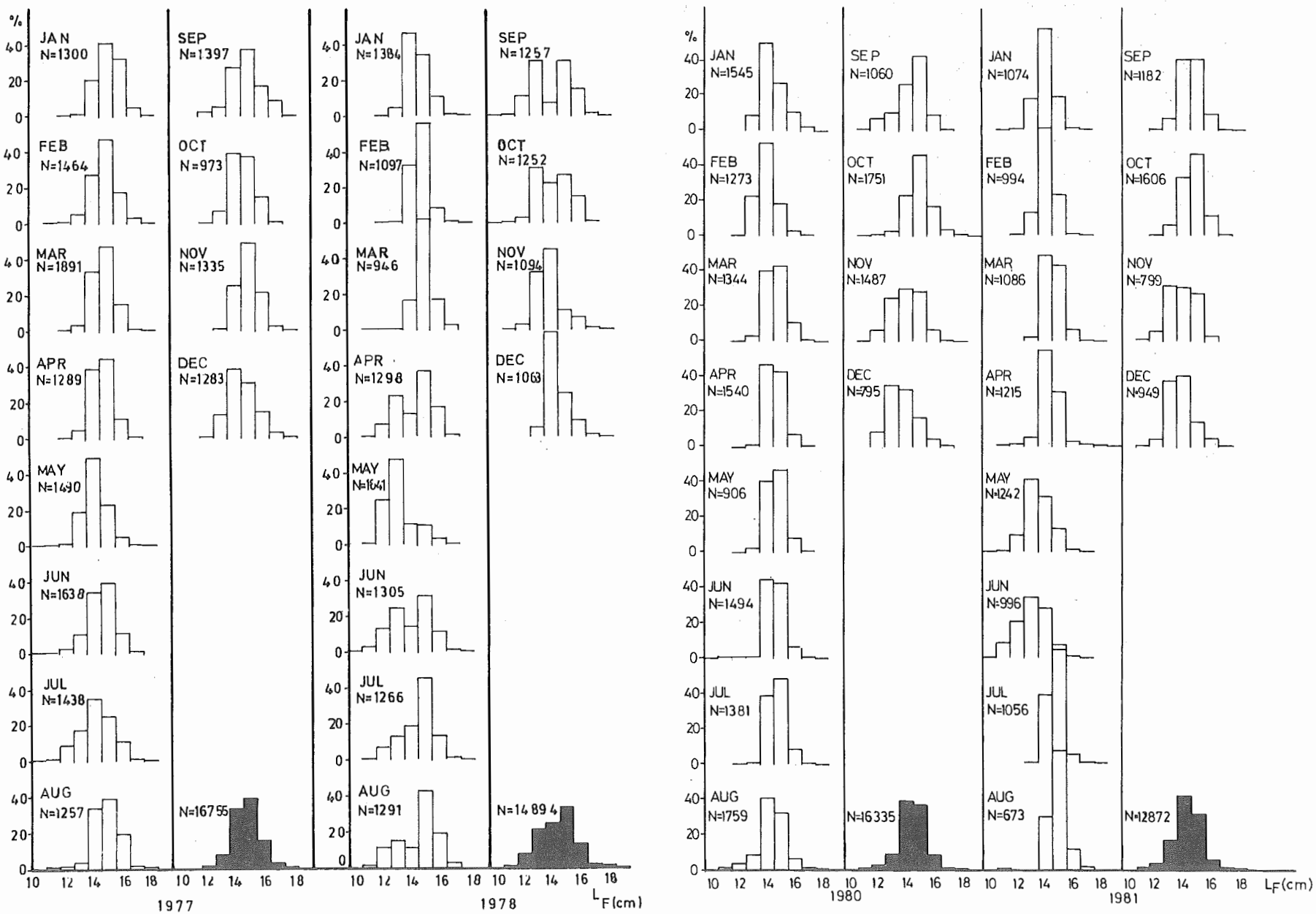

Fig. 7. Length-frequency distributions of H. kelee caught by gill nets.

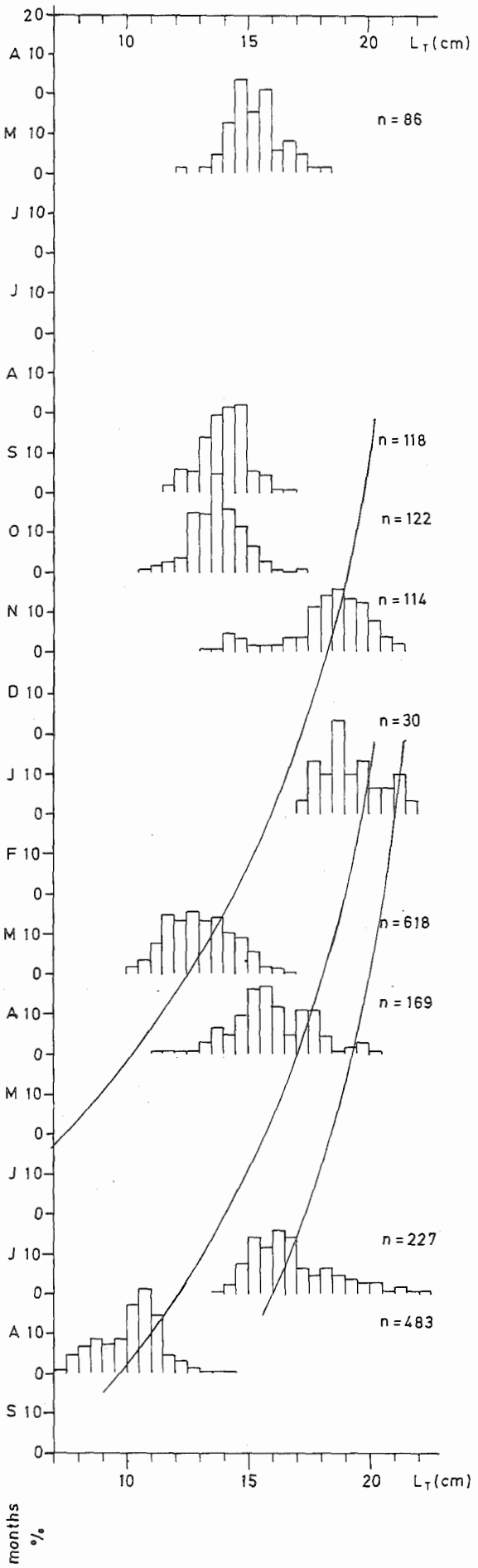

Fig. 8. Length-frequency distribution of H. kelee caught by shrimp trawl.

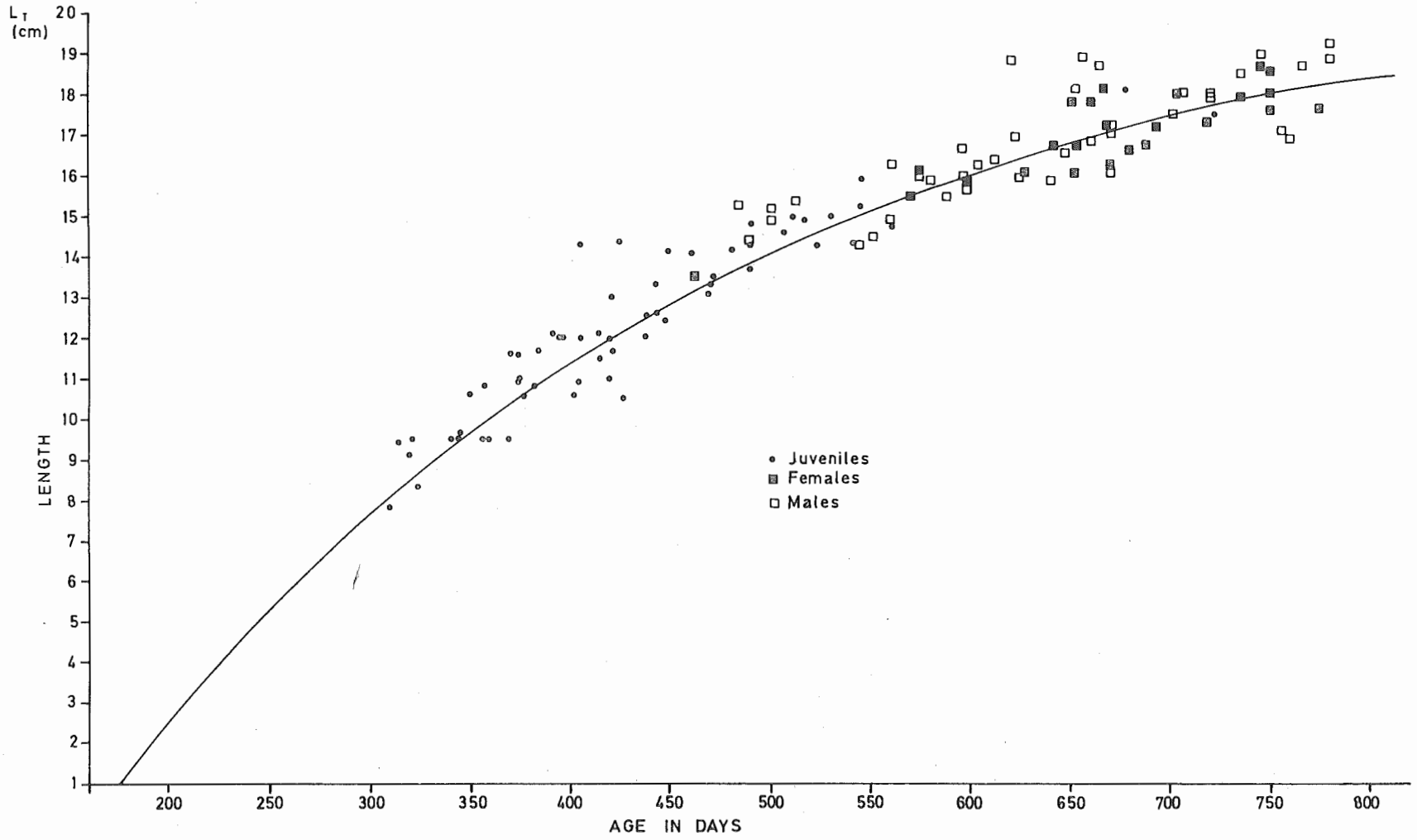

Fig. 9. Age-length distribution of H. kelee aged by means of otoliths. (counting all visible rings).

As there apparently is no difference in growth between the two sexes, one single growth curve was fitted using a graphical method (Beverton and Holt, 1957). The result is

$$l_t = 21.5\ (1 - e^{-1.1\ (t - 0.44)})$$

Otoliths from 64 H. kelee, with size 14-19 cm were also counted under the assumption that the broad bands of the intermediate zone are the daily rings.

The relationship between the two sets of counts is described using a linear regression with

Slope 1.02 ± 0.16 (5% conf.int.),

and intercept 210 ± 8 (5% conf.int.)

The correlation coefficient is 0.858.

As there is an almost linear relation with slope close to one between counts based on the narrow rings in the intermediate zone and those based on the broad rings, the K and L_∞ of the growth equation will remain nearly unchanged. The t_o will change, and will in this case be close to zero. It should be stressed, however, that recounting the otoliths from the young fish too, many change the parameters somewhat.

Based on the ageing presented in Fig. 9, the time of spawning was estimated (Fig. 10). The results suggest that spawning

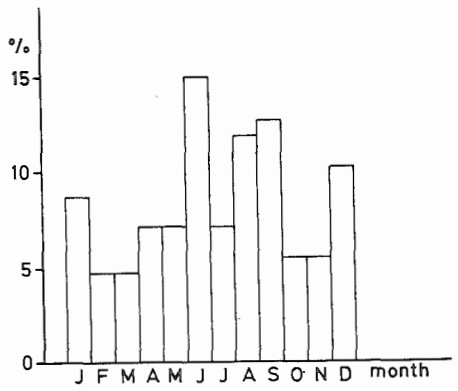

Fig. 10. Date of births of H. kelee back calculated from otolith reading. (counting all visible rings).

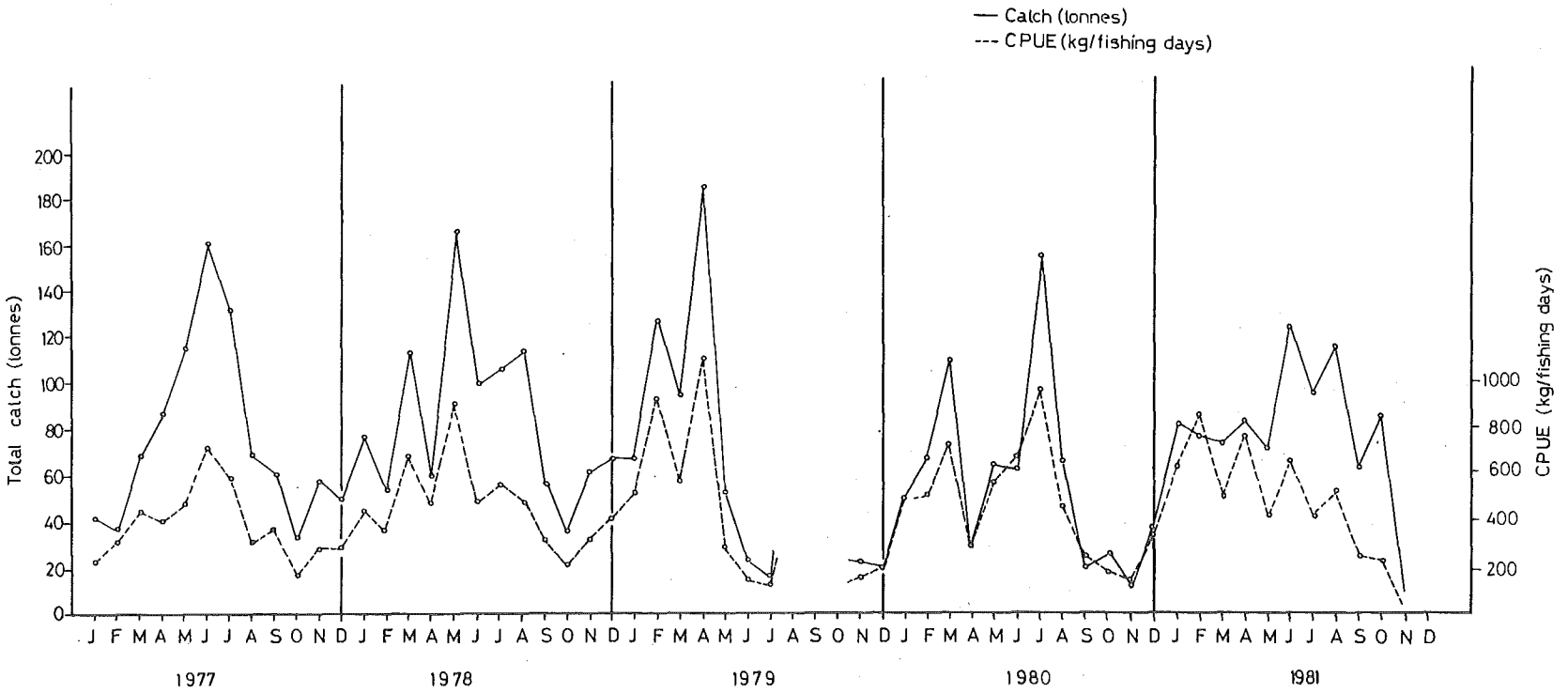

Fig. 11. Catch and catch per unit effort of H. kelee.

takes place all the year, but with maxima in June-September and in December-January.

CATCH RATES

The highest catch rates and also the largest total catches (Fig. 11) were observed during the dry season, from April to September and the lowest in October, November and December. Low values of catches were also found in June and July of 1979 and in April of 1980. This suggests a correlation between

catch rates and spawning activity, with the lowest catch rates coinciding with maxima in the spawning activity.

An analysis of variance was made with the purpose of estimating the variation of catches among fishing days and boats that were operating at the same day. It was found that the variation of catch per fishing day is higher ($F=9$ for 8/54 degrees of freedom) than among boats fishing at the same day ($F=2$ for 10/53 degrees of freedom). This should be expected as the gillnetters are usually fishing close together in a small area while the variations in the weather conditions etc. from day to day can influence the catches very much.

The fishing effort values, in number of days at sea, were calculated by month, from January 1977 to December of 1981 and they are given in Appendix II.

DISCUSSION

The present study is based on material from the gill net fisheries and from commercial bycatches. The gill nets take a very narrow size range of fish, while the shrimp trawlers lose the smallest fish only.

Based on the studies of developmental stages and of gonadosomatic index it is concluded that spawning mainly takes place in October-January. This fits well with observations from the east coast of South Africa (Wallace, 1975). The length compo-

sition in the shrimp trawl bycatches (Fig. 8) and also the date of births calculated from the otolith readings (Fig. 10) suggest that another spawning peak occurs around June-July. If this is true this spawning probably takes place outside Maputo Bay. According to Wallace (1975) H. kelee spawn in inshore marine environments, but no information is available on other spawning sites on the coasts of Mozambique.

The ageing of H. kelee by means of otoliths is difficult because it is not clear what should be interpreted as primary rings. When all visible rings were counted $K = 1.1$ and $t_o = -0.44$ were obtained. Interpretation of the narrowest rings as subdaily in the intermediate zone of the otoliths and counting the broader bands as daily rings will give minor changes in growth rate, but will bring t_o much closer to zero. The growth rate obtained from the length-frequency distribution also corresponds closely to these results.

On the other hand, back calculations of birthdates suggest that there are two spawning seasons and this result is the same for both interpretations of the otolith rings. Counting only the broader rings will however, change the time scale and the highest peak will fall in December. The peak spawning in December-January fits well with that one found by studying the gonads. The other one is also indicated by the length frequency distribution of the bycatches from the shrimp trawlers.

The length at first maturity is, according to the present material about 15 cm (Fig. 6). If the growth estimated by counting the visible rings is correct this corresponds to an age to about 1.5 years. If there are two spawning seasons a year, or if the spawning is acyclic this seems reasonable. If there is only one spawning a year the age at first maturity should be either 1 or 2 years and not a fraction of a year. This discripancy can be resolved - at least in parts - by assuming that the narrow rings in the intermediate part of the otoliths are subdaily, which would bring the estimated age at first maturity down, closer to one year.

As the exact nature of these narrow rings could not be determined, the results presented here should be regarded as preliminary.

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APPENDIX I

Maturity stages of Hilsa kelee.

Size of gonad in the abdominal cavity	General aspect of gonad	Stage
Less than 1/3 of the size of the cavity	Gonads of very small size; Pink ovaries, translucent; The eggs are not visible. Pinkish testis.	I Immature
From 1/3 to ½ of the size of the cavity	Ovaries increase in size and weight and are reddish. The eggs are not visible. Testes present already a triangular section.	II Immature
From ½ to 2/3 of the size of the cavity	Orange to pink ovaries with visible blood vessels; eggs are visible. Testis increase in size and weight and are whitish. The triangular section is evident.	III Maturing
Filling 2/3 or more of the body cavity	Gonads reach their maximum size. The eggs and sperm can come out under a light pressure on the ovaries and testes.	IV Mature
Contracted to about ½ of the size of the cavity; feeble walls	The sexual products are being eliminated; Ovaries with feeble walls; Testis are plain, pinkish with some residual sperm.	V Spawning
Contracted to less than ½ of the length of the cavity	Eggs and sperms are eliminated. Some disintegrated eggs may be left in the ovaries.	VI Post-spawning

APPENDIX II

Catch and effort in the gillnet fishery for H. kelee.

Months	Fishing effort (days at sea)	Number of boats operating	Mean Number of boats H. kelee operating daily	Estimated total catch tonnes	Catch per unit of effort
			Year 1977		
January	188	9	8	42.8	227.7
February	117	10	6	37.4	319.3
March	152	10	6	69.3	455.7
April	212	11	8	86.7	409.0
May	237	12	9	114.9	484.8
June	221	12	9	160.1	724.5
July	223	11	9	132.4	593.7
August	216	11	8	68.8	318.5
September	163	10	7	61.1	374.8
October	193	11	7	32.8	169.8
November	192	10	8	37.5	299.6
December	165	9	6	48.6	294.5
Total	2278	13	8	912.3	400.5
			Year 1978		
January	173	9	8	76.9	444.7
February	150	9	7	54.3	362.2
March	158	8	6	112.8	683.8
April	125	9	5	60.0	480.2
May	177	10	7	161.8	914.0
June	205	9	8	99.1	483.6
July	189	10	8	106.0	560.7
August	230	11	9	113.2	492.2
September	177	10	7	57.2	323.3
October	174	10	7	35.2	202.0
November	189	10	8	61.3	324.3
December	161	10	7	66.8	415.1
Total	2108	12	7	100.5	476.6

APPENDIX II

Year 1979

Months	Fishing effort (days at sea)	Number of boats operating	Mean Number of boats *H. kelee* operating daily	Estimated total catch tonnes	Catch per unit of effort
January	129	8	6	67.4	522.7
February	135	10	6	125.7	931.3
March	167	11	6	95.0	568.6
April	169	9	7	185.3	1096.6
May	175	8	7	52.2	298.3
June	146	9	6	22.7	155.3
July	138	10	5	17.0	123.1
August	*	10	-	-	-
September	*	9	-	-	-
October	*	8	-	-	-
November	137	9	6	22.6	165.0
December	102	7	4	20.3	199.4
Total		13	6		

* No information available.

Year 1980

January	99	9	4	50.7	512.1
February	130	7	6	67.4	518.5
March	146	8	6	108.6	743.5
April	94	9	5	28.8	305.9
May	112	7	5	64.9	579.4
June	92	9	4	63.1	686.4
July	159	9	6	154.8	973.7
August	139	8	5	65.2	468.9
September	76	8	4	18.7	246.5
October	141	8	5	26.1	185.0
November	83	8	4	11.4	137.4
December	110	10	5	37.6	341.7
Total	1381	14	5	697.3	504.9

Appendix II. Catch and effort data, fishing effort and catch per unit of effort for the period of January 1977 to December 1980.

APPENDIX II

Year 1981

Months	Fishing effort (days at sea)	Number of boats operating	Mean Number of boats *H. kelee* operating daily	Estimated total catch tonnes	Catch per unit of effort
January	129	9	6	82.6	640.0
February	89	12	4	76.5	859.8
March	147	11	6	73.9	502.7
April	108	11	5	82.7	765.3
May	172	13	8	71.3	414.4
June	193	17	8	124.8	646.6
July	225	17	9	95.1	422.8
August	223	15	10	115.9	519.6
September	252	20	18	63.0	249.9
October	372	21	15	83.2	229.2
November	293	21	12	9.7	32.9
December	-	-	-	-	-
Total		21	6		