STUDIES ON FISHERY AND BIOLOGY OF *TOR TOR* (HAMILTON) FROM RIVER NARMADA

II. Maturity, Fecundity and Larval Development

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(Communicated by B. S. Bhimachar, F.N.A.)

(*Received 5 October 1971; after revision 11 February 1972*)

The breeding habits of *Tor tor* from the river Narmada were studied for a period of three years on the basis of gross examination of gonads, gonadosomatic index and ova diameter. The breeding commences in July and continues intermittently till February–March. The fish breed in succession at different times exhibiting prolonged breeding. The peak breeding was observed from July to September. The individual fish was found to breed in four acts extending over a period of 2–3 months. The length frequency study of fry also indicated that the breeding period extends from July to March. The condition of fish (*K*) was low during peak breeding period and the spawning strain was comparatively more in males. The fish attained first maturity over 360 mm in total length. The fecundity of mature fish varied from 9,330 to 1,35,470 in the size range of 283–750 mm. The larval development of *Tor tor* based on the connected series of five stages has been described.

Introduction

Studies on breeding habits of mahseer are few and the only specific reference to Tor mahseer, *Tor tor* (Hamilton) is by Hora (1940) who, on the basis of collection of large number of young specimens, concluded that this fish breeds during August and September. The observations recorded by others pertain to the breeding of mahseers in general. From the study of sex organs, Khan (1939) and MacDonald (1948) have observed that mahseer spawns three times in a year, i.e. in January–February, May–June and July–September. On the basis of migration of mature fish, Codrington (1946) has indicated two breeding seasons of mahseer—a minor breeding season in January-February and a major breeding season in August. Except for the brief observations on the breeding season of Tor mahseer by (Hore 1940), no detailed and authentic account is available on the spawning seasons, maturity, breeding periodicity and fecundity of this fish.

The first part of the series of biological studies, on the food and feeding habits of Tor mahseer, was published by the authoi (1970). The observations on maturity, fecundity and breeding peiiodicity along with an account of larval development of *Tor tor* form the second part in the series of its biological studies. The preliminary

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observations on the breeding of Tor mahseer, based on the present study, have been given by Karamchandani *et al* (1967).

MATERIALS AND METHODS

The material for the present study was collected at Hoshangabad fish market from commercial catches brought from the river Narmada. In all, 945 specimens (220–800 mm in total length) were examined from April 1960 to March 1963. In the laboratory the specimens were weighed, measured and dissected to remove the gonads. The gonads were weighed and the gonadosomatic index (GSI)* of individual fish was calculated. The coefficient of condition (*K*)** of the fish was determined by the formula employed by LeCren (1951). The size at first maturity of the female fish was determined from the percentage of the maturing and mature ovaries in various size groups (220–580 mm).

The maturity stages in females were assessed by gross examination of ovaries. The ovaries were classified into 13 categories of maturity (*A* to *M*) which nearly correspond to I to VII stages adopted by the I.C.E.S. (Wood 1930). In order to get a correct picture of the maturity in a particular month, the ovaries of 'virgin' fish were not taken into account and as such the percentage distribution of maturity stages was calculated only for the ovaries of the fish measuring over 360 mm which is the size at first maturity.

The ovaries were preserved in 5 per cent formalin for ova-diameter and fecundity studies. In order to elucidate the breeding season, a method suggested by Orcutt (1950) was adopted by measuring the diameter of twenty-five large-sized ova from each of the ovaries of fish excluding virgins (below size at first maturity). The mean diameter of the large-sized ova and the average value for the month were determined. On the basis of their gonadosomatic index and gross examination, three ovaries were selected from monthly samples for detailed ova-diameter study. In this study the diameters of 1000 ova were measured at random from each ovary adopting the method followed by Clark (1934) and Prabhu (1956). The ova-diameter measurements were taken under microscope with an ocular micrometer at a magnification which gave a value of 0.095 mm to each micrometer division (m. d.).

For fecundity study the number of mature ova from weighed samples of ovaries was counted and the total number of ova in each ovary was estimated (Lagler 1956). The fecundity of fish was determined from 19 ripe ovaries. A good number of ripe ovaries were available mostly from June to August. The sample was dominated by small fish in commercial catches and this factor restricted the data to lower size groups. However, a few specimens of older fish examined from September to November gave some idea of fecundity of the higher, size groups. The relationship of fecundity with length and weight of fish and weight of ovary was determined. The fecundity of a fish measuring 750 mm in total length which was found to be very high (1,01,600) was not considered for determining the above relationships to avoid disproportionate effect.

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*GSI = Weight of gonad (g) $\times$ 100/total weight of fish (g)

**$K = W \times 10^5/L^3$; where W = weight of fish, and L = total length

The breeding periodicity of fish was also studied from length-frequency data of its post-larvae and fry collected from shallow margins of river Narmada by opertaing spawn collection net in monsoon months and a drag net made of mosquito netting cloth during the rest of the period.

OBSERVATIONS

Description of a mature ovary

The mature ovary of *Tor tor* contains large orange coloured eggs measuring from 1.90 to 2.22 mm in diameter. The fully mature ovary occupies nearly the whole of the body cavity when the alimentary canal is very much reduced due to poor feeding. Both the lobes of the mature ovary are generally equal in length but in some specimens they are unequal.

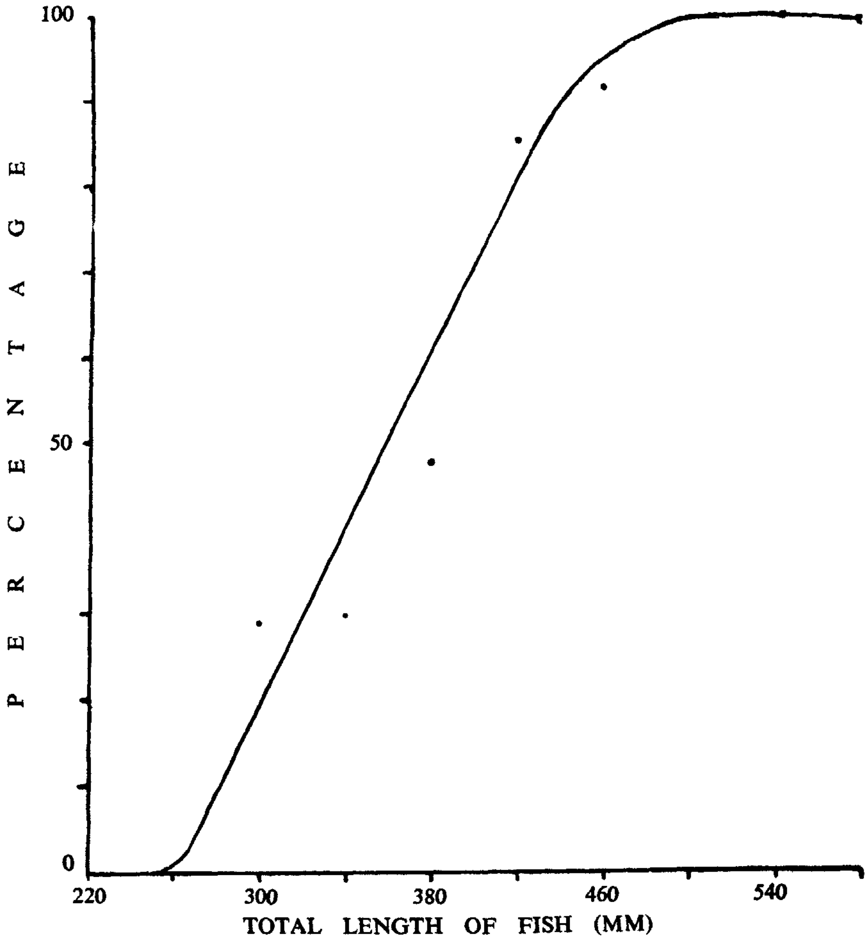

FIG. 1. Size at first maturity of *Tor tor* as indicated by the percentage of maturity of female specimens.

Size at first maturity

For this study the percentage of immature ovaries and that of maturing and mature ovaries was calculated separately. When the percentage of maturing and mature ovaries was plotted against the mid-points of various size groups of fish, a sigmoid curve was obtained (Fig. 1). This curve shows that five per cent of fish are mature at 280 mm, 50 per cent at 360 mm, 90 per cent at 440 mm and practically all the fishes over 500 mm. These observations have indicated that fish attains first maturity in the size range of 340–380 mm (50 per cent mature ovaries).

Microscopic study

(*a*) *Ova-dimeter frequency*—The observation on ova-diameter frequency in various months has shown that the fish has prolonged breeding season and the state of maturity varies greatly among individuals in different months. As such, in a particular month, fishes in all stages of maturity were encountered. Because of this, the data in the present case did not exhibit a definite pattern in the monthly progression of maturity stages as observed in fishes having single restricted breeding season. In a similar situation, Clark (1934) working on the California sardine, *Sardinella caerulea*, grouped the ovaries according to the location of the largest mode in diameter–frequency of the eggs from each fish. Following the above method and in view of fractional spawning of fish, the ovaries of *Tor tor* were classified into thirteen stages of maturity as shown in Fig. 2. Each of these stages has been compared with the stages of I.C.E.S. (Wood 1930) in Table I.

Stage *A* shows the typical immature ovary which has only one group of ova. The fish measuring below 280 mm were in stage *A* and were found all the year round. Stage *B* shows the drawal of one maturing group of ova with a mode *a* from the immature stock. Stage *C* shows that the position of mode *a* has shifted further. In stage *D* there appears further emergence of an intermediate group of ova from the immature stock with a mode *b*. The stages *E, F* and *G* give indication of maturing ovaries where there is gradual withdrawal of intermediate groups of ova from the reserve stock. The stages *E* and *F* show three and four modes of maturing ova respectively. In stage *G* four modes of maturing ova are seen with the advanced position of mode *a*. The stage *H* represents the fully developed and ripe condition of ovary with all its complimenatry four groups of mature and maturing ova without further emergence of maturing group of ova. Though the ripe ovaries in stage *H* were very common from June to September, stray specimens of fully ripe ovaries were encountered in October and November.

The stages *I, J, K* and *L* indicate partly spent condition of ovaries. In stage *I* the insignificant mode *a* shows that one spawning act is over and the intermediate maturing groups of ova standing at the modes *b, c* and *d* suggest that fish will still breed in three acts. In stage *J* the group of maturing ova at mode *b* further advances showing that the fish is on the verge of its second breeding act. The progression of mode *c* in stage *K* shows that the fish is to lay third batch of eggs while the maturation of its fourth batch of eggs further progresses as seen from the movement of mode *d*. In stage *L* the maturing ova under mode *d* increase in size, become fully mature and are ready to be laid as the fourth and the last breeding act of the

TABLE I

Maturity scale of Tor tor *(female)*

I.C.E.S. (Wood 1930)		*Tor tor*
Immature (Stage *A*)	I	Ovary slender, thin, short, whitish and ribbon-like; ova minute, transparent and not visible to naked eye, of which some are devoid of yolk deposition while in some yolk deposition just commenced, frequencies with one mode, maximum ovum diametre=0.57 mm; common all the year round.
Maturing (Stage *B*)	II	Ovary slightly enlarged and becomes translucent; yolk deposition further progresses and ova become yolky, opaque and visible to naked eye, frequencies with two modes, maximum ovum diameter=0.76 mm; common from December to April.
Maturing (Stage *C*, *D*, *E* and *F*)	III	Ovary turns yellow and becomes thickened on all sides, ova have granular appearance and are visible to naked eye, frequencies with two to five modes, maximum ovum diameter=0.95–1.33 mm; common from December to April.
Mature (Stage *G*)	IV	Ovary greatly enlarged with large mature eggs still contained within the ovaries follicle and are not free; frequencies with five modes, maximum ovum diameter=1.90 mm; common from April to June.
Ripe (Stage *H*)	V	Ovary appears like a yellow bag of cellophane paper containing large, yellow, free and mature ova; frequencies with five modes, maximum ovum diameter=2.28 mm; common from June to September.
Partly spent (Stage *I*, *J*, *K* and *L*)	VI	Ovary reduced in size posteriorly, slightly bloodshot and flaccid owing to expulsion of some mature eggs, few mature eggs still present for subsequent spawning); frequencies initially with five modes but subsequently with three modes; common from August to October.
Spent (Stage *M*)	VII	Ovary becomes flabby, further contracted, appears like a wrinkled, collapsed sac with leathery wall in contrast to the parchment–like wall of distended ripe ovary, frequencies with two modes, sometimes showing insignificant modes of mature and degenerating ova common in October–November.

season. The frequency polygon of stage *K* reveals that a small group of maturing ova at mode *e* is seen emerging out from the immature stock. This mode becomes more prominent in stage *L* remaining widely separated from the mature group of ova. The stage *M* represents completely spent ovary which does not show any more group of maturing ova excepting one under mode *e*.

As seen from the stationary position of mode *e* in stages *K*, *L* and *M* which did not grow to the mature size immediately, it is evident that this group of ova prevails during resting stage of the ovary and is carried over to the succeeding season for spawning. This observation shows that in case of *Tor tor* maturation is a

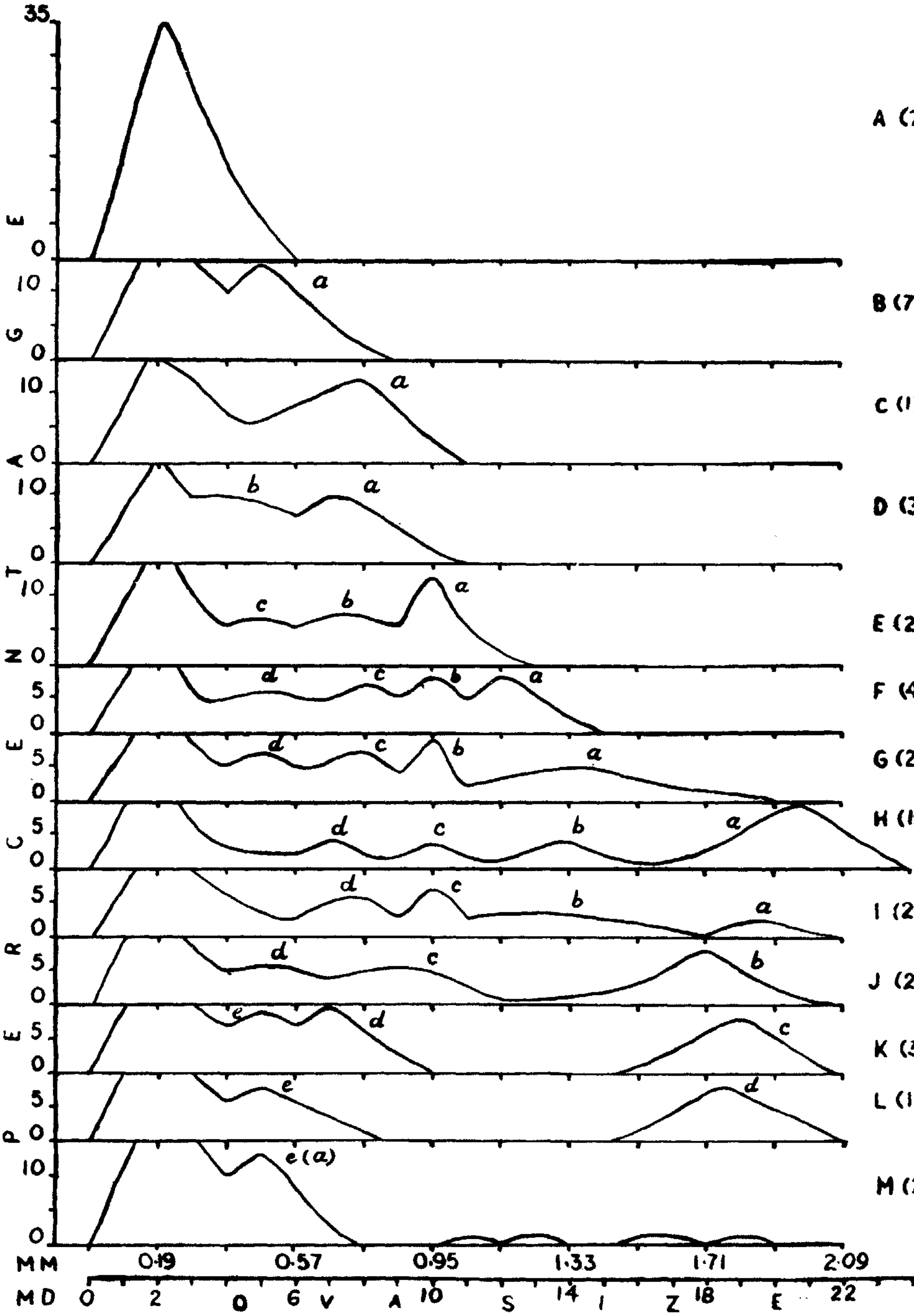

FIG. 2. Ova-diameter frequency polygons of various maturity stages showing the position and progression of modes during maturation (Number of specimens examined in each stage is shown in bracket).

continuous process because the ovary starts maturing as soon as the last batch of ova is laid. This fact was further supported by the observation that during the months from February to April, i.e. after breeding, the female mahseers above 360 mm (growing over size of first maturity) were found to have few maturing yolk, eggs in their ovaries as represented by stage *B* (Fig. 2). These eggs were visible to naked eye and their diameter varied from 0.435 to 0.563 mm during the period February to April and as such they were found unlikely to be resorbed or representing late spawning during the same season. Their retention in maturing state over a period of three months (February–April) clearly indicated that they were to be carried over to ripen during subsequent spawning season.

(*b*) *Mean ova diameter*—With a view to elucidate the breeding season, the monthly average of mean diameter of 25 large-sized ova along with gonadosomatic index for the corresponding months have been given in Fig.3. The ova-diameter was found to increase progressively from April (0.519 mm) to September (1.253 mm) and thereafter decreased gradually up to March (0.435 mm). This trend was found to be in full agreement with that of gonadosomatic index. High values of mean ova-diameter and gonadosomatic index from July to September indicate that the peak breeding takes place during this period.

Gonadosomatic index

The maturing of ovaries was studied by calculating gonadosomatic index (Fig. 3). The gonadosomatic index progressively increased from March (2.85) to August (30.10), declined in September (25.44) indicating the commencement of breeding in July–August. The gonadosomatic index gradually decreased from October (6.56) to February (4.17) giving indication of continuity of breeding till February-March.

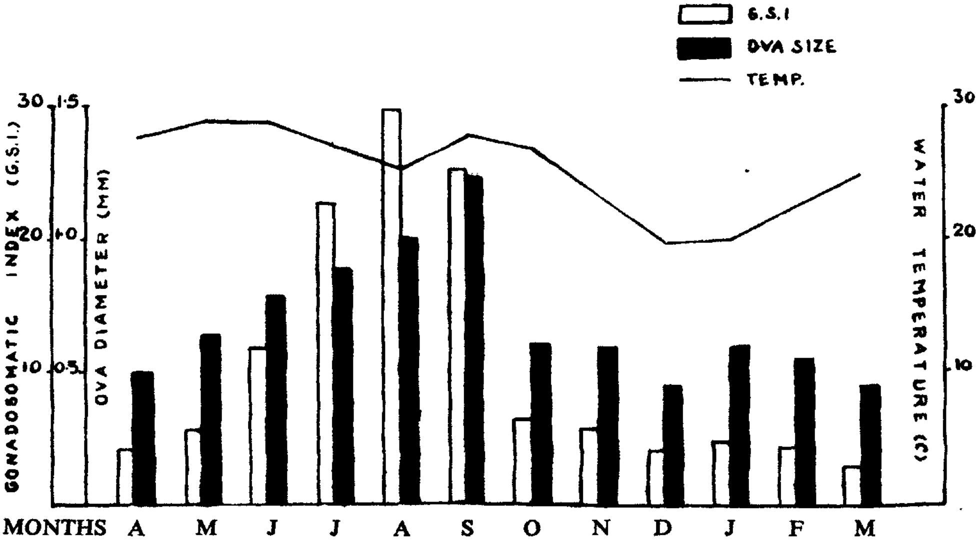

FIG. 3. Breeding periodicity of *Tor tor* as seen from gonadosomatic index and ova-diameter of fish and its correlation with water temperature.

Maturity stages

The monthly percentage distribution of maturity stages is given in Table II which shows that females were mostly maturing (92.7 per cent) in April–June, mature and ripe (57.7 per cent) from July to September and partly spent spent and resting (93.1 per cent) from October to March. These observations have shown that the fish has prolonged breeding season commencing in July–August and continuing up to February–March with the peak from July to September.

TABLE II

Monthly percentage of maturity stages (female) of Tor tor

Months	Maturing	Mature	Ripe	Spent
April	100.00	—	—	—
May	98.0	2.0	—	—
June	80.0	20.0	—	—
July	44.0	56.0	—	—
August	26.0	44.0	12.0	18.0
September	27.0	19.0	42.0	12.0
October	68.0	6.0	16.0	10.0
November	76.0	—	10.0	14.0
December	90.0	—	3.0	7.0
January	91.0	—	3.0	6.0
February	92.0	—	3.0	5.0
March	100.0	—	—	—

Temperature

The data on water-temperature of river Narmada were recorded weekly at 6.00, 13.00 and 22.00 hr. The monthly average temperature curve based on these data has been plotted in Fig. 3 along with gonadosomatic index and ova-diameter with a view to see the correlation between the temperature and breeding periodicity. It is evident from the temperature curve that the temperature fluctuates between 19.9 to 28.4°C during July–March when the breeding is known to take place intermittently. The breeding was not observed during April-June when the temperature progressively increases from 27.8 to 29.4°C.

Spawning frequency

The multiplicity of modes in the frequency curves of ova-diameter from maturing and ripe females strongly suggests that individual fish spawns more than once in each spawning season. It has been stated earlier that as the batch of largest eggs grows to maturity, the smaller eggs increase in size and the succeeding groups also mature in their turn during the same season. In order to substantiate these observations the data on the ova-diameter frequency of 62 ovaries in stages *E–K* have been further analysed and presented in Fig. 4. In this graph all the modes of largest group of ova (y) are plotted against their immediately preceeding modes of next smaller group (x) as suggested by Clark (1934). The straight line relationship as shown by the scatter–diagram clearly indicates that different batches of eggs pass on from one stage to the other with increase in their diameters and are laid as they mature in the same breeding season.

Clark (1934) has observed that the number of eggs in maturing groups bears constant ratio to the number of eggs in the mature group throughout the entire breeding season when in a season the fish lays only one batch out of the several groups of maturing eggs. But the number of maturing eggs in the mature ovary of *Tor tor* was found to increase progressively in proportion to the number of mature eggs as the breeding season advanced from July to November indicating that more than one batch of eggs are spawned in each season. To establish this fact the ratios of maturing eggs (0.47–1.42 mm) to mature eggs (above 1.42 mm) in mature ovaries of stage *H*, commonly encountered during the period July to November, have been calculated and given in Table III. In July and August, the maturing and the mature eggs were found to be nearly of equal ratio (1.03:1). However, during the period September–November, the ratio increased from 1.31:1 to 3.34:1, indicating the gradual increase in the number of maturing eggs. This shows that more eggs are constantly added to the maturing group from the reserve stock as the breeding progresses. Thus the process of matuıation is continuous and the eggs are released in batches.

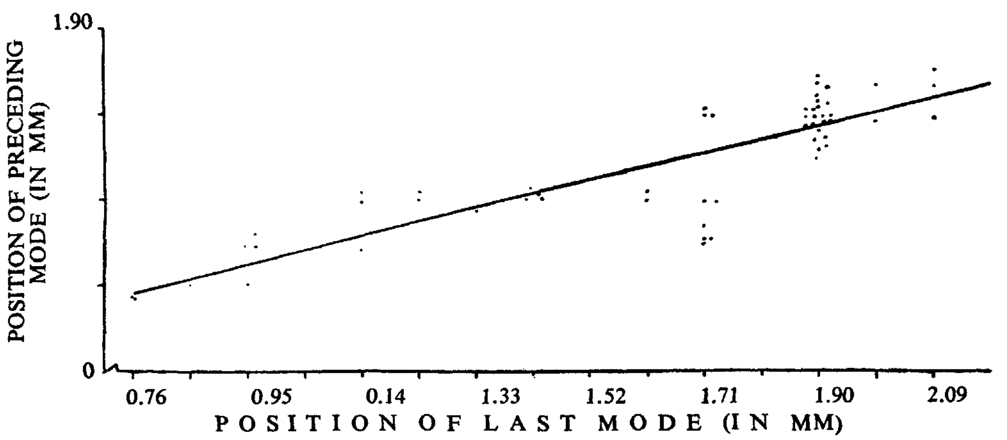

FIG. 4. Diagram showing relationship between modal groups of ova in the ovaries *E* to *K* stages of maturity

The ripe ovaries of *Tor tor* were examined in limited number during breeding season from local fish market of Hoshangabad. Even then it may be seen from Table III that the ripe ovaries of stage *H* were available from July to November and this prolonged-availability of ripe ovaries probably indicates differential spawning of population of this species. The ova-diameter frequency polygon of stage *H* reveals that the distribution of maturing and mature eggs is represented by four modes.

which are far apart from one another. Further, it is clear from the analysis and the results depicted in Fig. 4 that passing of one batch of eggs into the next stage is a continuous process. Thus the individual fish exhibits protracted spawning in three–four acts, probably with an interval of two-three weeks in between two acts (Karamchandani *et al.* 1967). Under these circumstances, if the breeding cycle of individual fish takes an independent course during differential spawning of population in succession, then the species is likely to exhibit prolonged breeding season as observed.

TABLE III

Ratios of ova larger than 1.425 *mm to all ova between* 0.475 *and* 1.425 *mm in the stage H of maturity*

Month	No. of ovaries	Size range of fish (mm)	Ratio	
			Range	Average
July	8	283–615	1:0.72 to 1:1.42	1:1.03
August	6	391–553	1:0.69 to 1:1.56	1:1.03
September	6	330–750	1:0.81 to 1:2.52	1:1.31
October	4	410–659	1:0.78 to 1:3.40	1:1.70
November	7	495–732	1:2.51 to 1:4.85	1:3.34

Length-frequency study of fry and fingerlings

The lengths of 12,243 hatchlings, post-larvae and juveniles of *Tor tor* in the size range 6–60 mm, captured from November 1959 to March 1962, were measured and the data so collected were pooled monthwise and are presented in Fig. 5. The monthly analysis of this data of larval abundance has supported the earlier observations of prolonged spawning of the population. In Fig. 5, the presence of prominent mode *a* at 12 mm in July evidently suggests that the breeding of this species commences in this month. Similar modes at 12 mm in August and September as well show that the breeding continued to be in progress during these months also. The non-availability of smaller larvae in October indicate that there was no breeding during this month. Again the occurrence of larvae in the size range of 6–12 mm in November and December gives indication of slight breeding in these months which continues in January also. No indication of breeding is evident in February. However, a small mode at 12 mm in March tends to show that the breeding continues up to March and no evidence of breeding was observed thereafter. Hora and Nair (1944) have collected very small fry of *Tor tor* in March–April from side pools of the lower section of the Riyang—a belt stream in the Darjeeling Himalayas thereby indicating the breeding of the fish in March–April.

Fecundity

The data on fecundity are presented in Table IV. As seen from this Table, the fecundity of fish varied from 7,000 to 1,01,600 in the size range of 283-750 mm. This fecundity range was found to be associated with only three spawning bursts as the fourth batch of maturing ova (smaller than 0.95 mm) could not be counted.

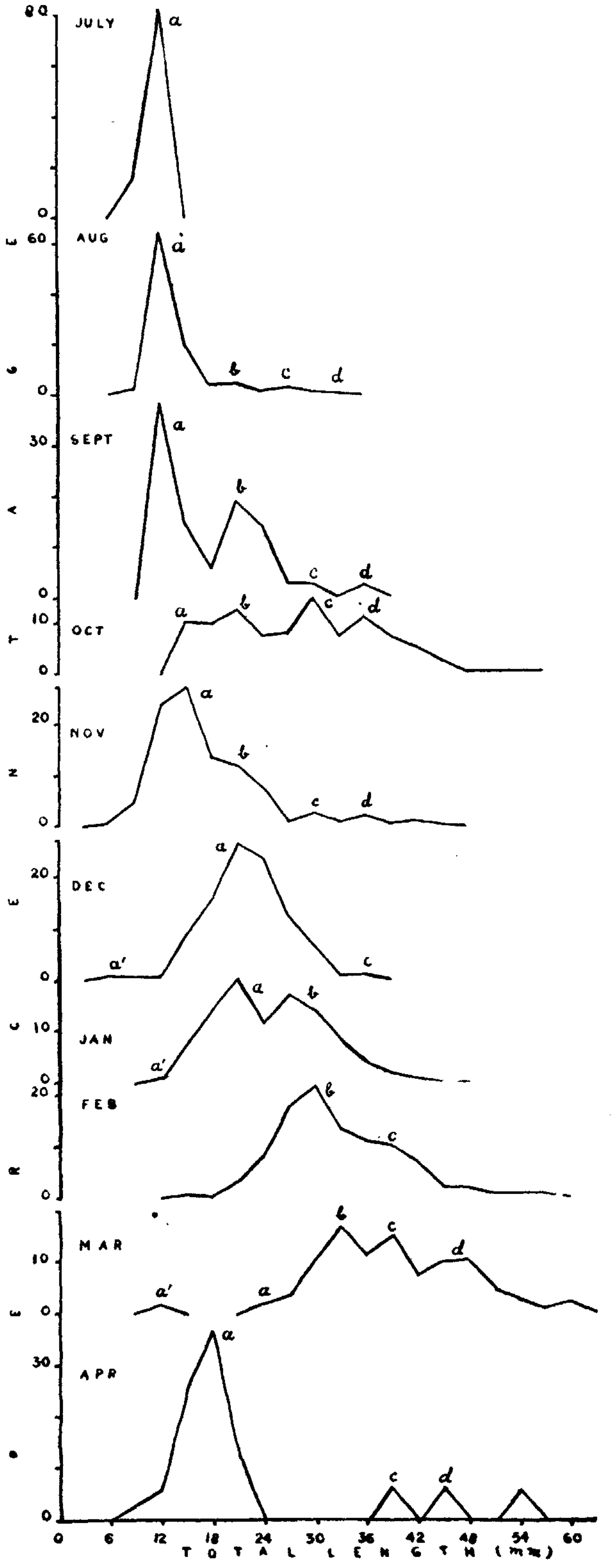

FIG. 5. Length frequency polygons of hatchlings, post larvae and juveniles of *Tor tor* indicating spawning frequency on the basis of their modal distribution.

Therefore, this ova count does not represent total ova production of an individual fish for the entire season. The number of eggs to be shed in four bursts was estimated from the number of ova of three bursts based on the fact that equal number of eggs are laid in each burst as seen from equal number of frequency of mature ova under modes *a*, *b*, *c* and *d* of stages *H*, *J*, *K* and *L* respectively (Fig. 2). By adding the estimated number of ova of fourth burst, the total number of eggs to be laid in one season was estimated to range from 9,330 to 1,35,470.

TABLE IV

Fecundity of Tor tor (Hamilton)

Total length of fish (mm)	No. of ova laid in three bursts	Probable No. of ova maturing in one spawning season
283	7,000	9.330
322	9,800	13.000
377	8,700	11,600
388	8,240	10,990
388	9,200	12,270
390	12,680	16,900
405	16,750	22,330
422	17,550	23,400
453	15,100	20,130
460	17,800	23,730
460	15,000	20,000
465	28,400	37,860
510	28,300	37,730
552	30,400	40,530
582	31,340	41,790
598	53,800	71,730
657	42,600	56,800
727	54,300	72,400
750	1,01,600	1,35,470

The relation between fecundity and total length of mature fish was determined by the method of Least Squares and a parabolic line was fitted to the data. The relationship can be expressed by the equation :

$$Log\ F = 1.9749\ Log\ L - 1.0384;\ r = 0.6838$$

where F is the number of ova in thousands and L is the total length of fish in mm. The relationship shows that with the increase in size the fish lays more number of eggs. The fecundity calculated by regression equation in relation to total length of fish (size range : 290–750 mm) was found to vary from 6,677 to 43,610 (Karamchandani *et al.* 1967).

The data of fecundity when plotted against the weight of mature fish and weight of its ovary the relationship was found to be a straight line as shown in Fig. 6. The regression lines were expressed by the following equations :

$$F = 14.29\ W + 1297$$
$$F = 198.52\ W_0 + 277$$

where F stands for fecundity, W and W_0 for weight of fish and weight of ovary respectively.

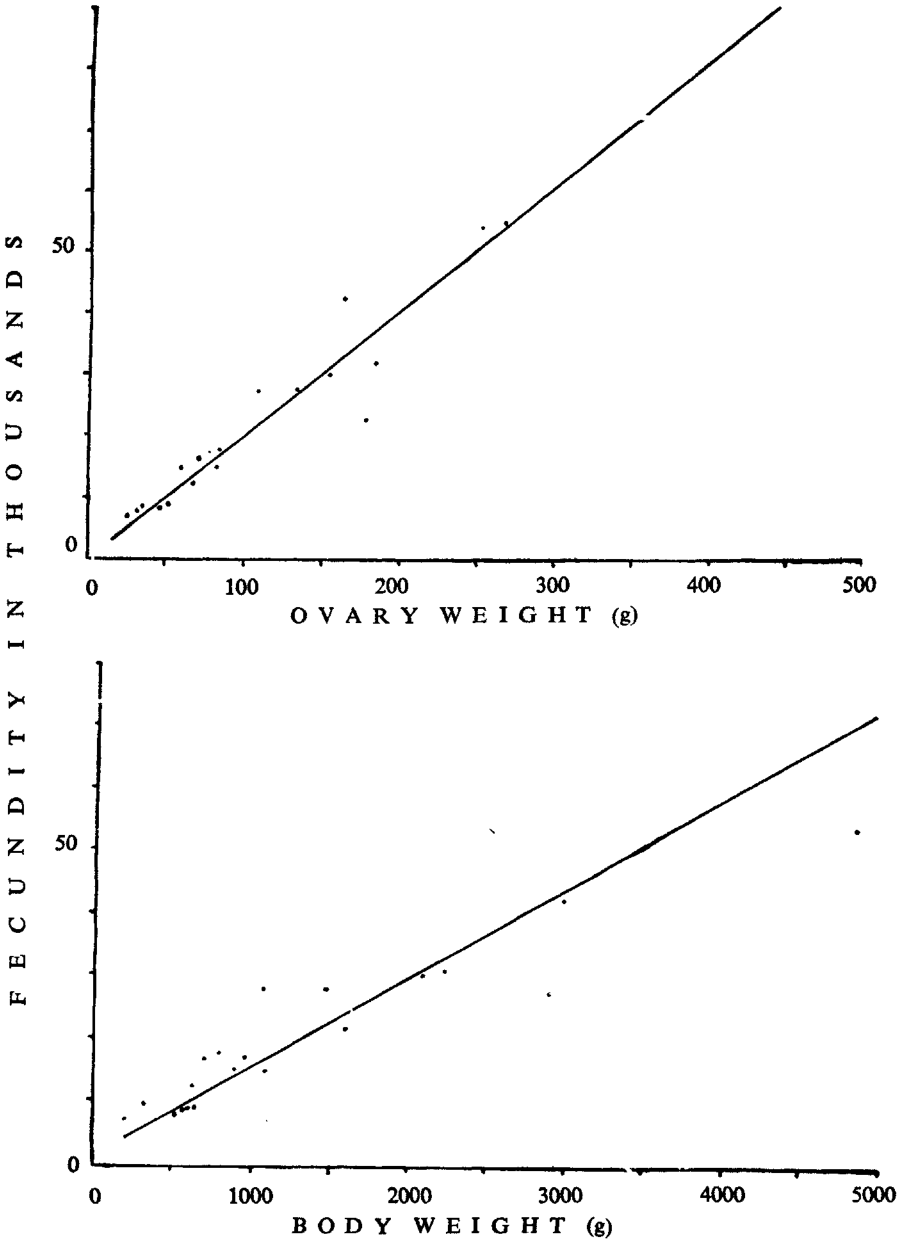

FIG. 6. Diagrams showing fecundity relationships with ovary weight and body weight of mature fish.

Condition factor in relation to breeding

The values of condition factor (*K*) calculated for males and females separately have been shown in Fig. 7. The monthly variations of the condition factor have shown that the general trend of 'condition' of males and females was more or less the same. The 'condition' was found to be poor from July to November and this period coinciding with peak breeding of fish shows its indirect correlation. Contrary to this, Desai (1970) has observed earlier that the 'condition' of *Tor tor* has direct correlation with feeding activity when the poor 'condition' of fish from July to November is attributed to cessation of feeding due to fully developed ovary which leaves limited space for intake of food. Though the high 'condition' of both the sexes synchronised in February, the poor 'condition' of female and male fish was observed in October and November respectively. After the peak breeding the recovery of fish to normal condition was observed earlier in females. The comparatively low 'condition' of males (0.869) as against that of females (0.937) has shown that spawning strain was greater in males.

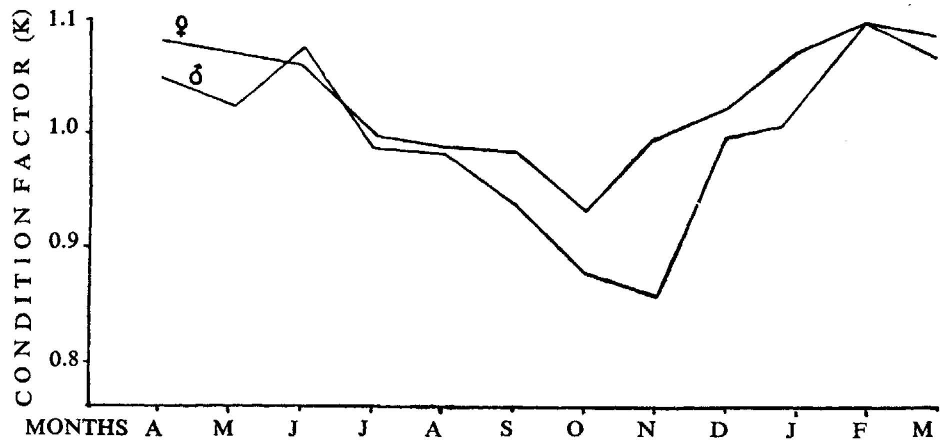

FIG. 7. The seasonal variation in the condition factor (*K*) of fish in relation to spawning.

Larval Development

Regarding the life histories of mahseers, there is no account excepting the early development of *Barbus* (*Lissochilus*) *hexagonolepis*, the copper mahseer, (Nazir Ahmad 1948), larval stages of *Barbus* (*tor*) *mosal mahanadicus*, the Mosal mahseer, (David 1953) and larval stages of *Tor khudree*, Deccan mahseer, (Kulkarni 1971). The larval development of Tor mahseer, comprising of five stages as described below, is based on the collections made from Narmada river from July through March by operating spawn collection and drag net. The larval stages of *Tor tor* were normally collected along with hatchlings, larvae and fry of carps. The hatchlings and larvae of Tor mahseer were easily distinguished from those of carps in the mixed collections on the basis of their large-sized yolk-sac which persisted up to 10 mm size. The post-larvae and fry of both the species of Narmada mahseer have a black caudal spot which subsequently disappears in juvenile stage. This characteristic black caudal spot of mahseer larvae was also noted by earlier workers. Skene Dhu (1918) collected yolked larvae and fry of mahseer with caudal spots. Hora and Misra (1938) found black caudal spot in *Tor khudree*. Hora (1940) has referred to a black spot before the base of the caudal fin in the fry of *Tor tor*.

The advanced stages of fry and juveniles of Narmada mahseer were collected with those of minnow carps like *Barilius bendelisis, B. barila* and *Oxygaster clupeoides* (Desai and Karamchandani 1967). This association seems to suggest that the fry and juveniles of mahseer and minnow carps share the same grazing grounds comprising of rocks, stones and sand layers encrusted with algae and slimy matter. David (1953) also found the fry of mahseer associated with minnow carps like *Barilius bendelisis, B. barila* and *Aspidoparia morar* in Mahanadi river.

Tor Tor (HAMILTON)

(i) 8.74 mm *stage* (Fig. 8 *a*)—This is the smallest stage in the collection. The pro-larva is pale yellow in colour and looks stout because of its big-sized yolk-sac. The yolk-sac which is slightly brownish in colour, is broad anteriorly and gradually tapers to its posterior end. A row of pigmentation is seen on the upper posterior-half of the yolk-sac. The head is broad with pigmented eyes and anterior mouth. The median fold is continuous. The dorsal fin is demarcated but rays are not evident on it. The caudal fin is somewhat truncate in shape. The notochord is slightly upturned. The hypural plates have developed at this stage and seven to eight rudimentary rays are seen in the caudal fin. The anal fin is not yet demarcated. The pelvic fin is not formed. The pectorial fin is seen as a membranous flap without any rays. In all 39 myotomes are discerned. The vent is situated much posteriorly towards the caudal portion below the level of 27th myotome.

(ii) 9.50 *mm* stage (Fig. 8 *b*)—In this stage the yolk sac is slightly reduced. A cluster of chromatophores is seen on the head. The dorsal fin is further demarcated and contains about seven to eight rudimentary rays. Slight depression is seen in caudal fin which comprises 15–16 rays. The anal fin region is slightly demarcated without indication of rays in it. The pectoral fin is still a membranous flap and rays are not evident on it. About 40 myotomes can be seen in this stage. The air-bladder is visible above the yolk sac in between 8th and 16th myotome.

(iii) 10.70 *mm stage* (Fig. 8 *c*)—By this stage the yolk is considerably consumed and only a trace of it is seen. The anterior part of the body looks stout while the posterior part becomes slender in form. The gape of the mouth extends further and is now half way between the tip of the snout and anterior margin of the orbit. The dorsal fin is almost completely formed with all its compliment rays but it is still connected wih caudal fin by a narrow strip of fin-fold. The caudal fin is deeply forked and contains 19 rays. Three rudimentary rays are seen in the anal fin. The rudimentary pelvic fin is visible as a minute bud in front of vent. No rays are evident on pectoral fin. The alimentary canal is seen in a tubular form. A cluster of chromatophores is seen on the head.

(iv) 12.16 *mm stage* (Fig. 9 *a*)—The yolk is completely absorbed in this stage and the larva more or less resembles adult fish. The dorsal fin is detached from the dorsal median fold and a trace of the dorsal median fin fold is still visible near the caudal fin. The anal fin contains seven well-developed rays and still retains its connection with ventral median fold. The pelvic fin is further developed. A trace of pre-anal fin fold is also visible. The pectoral fin is still without rays. A black round spot is seen on the caudal peduncle at this stage. Besides the dense cluster

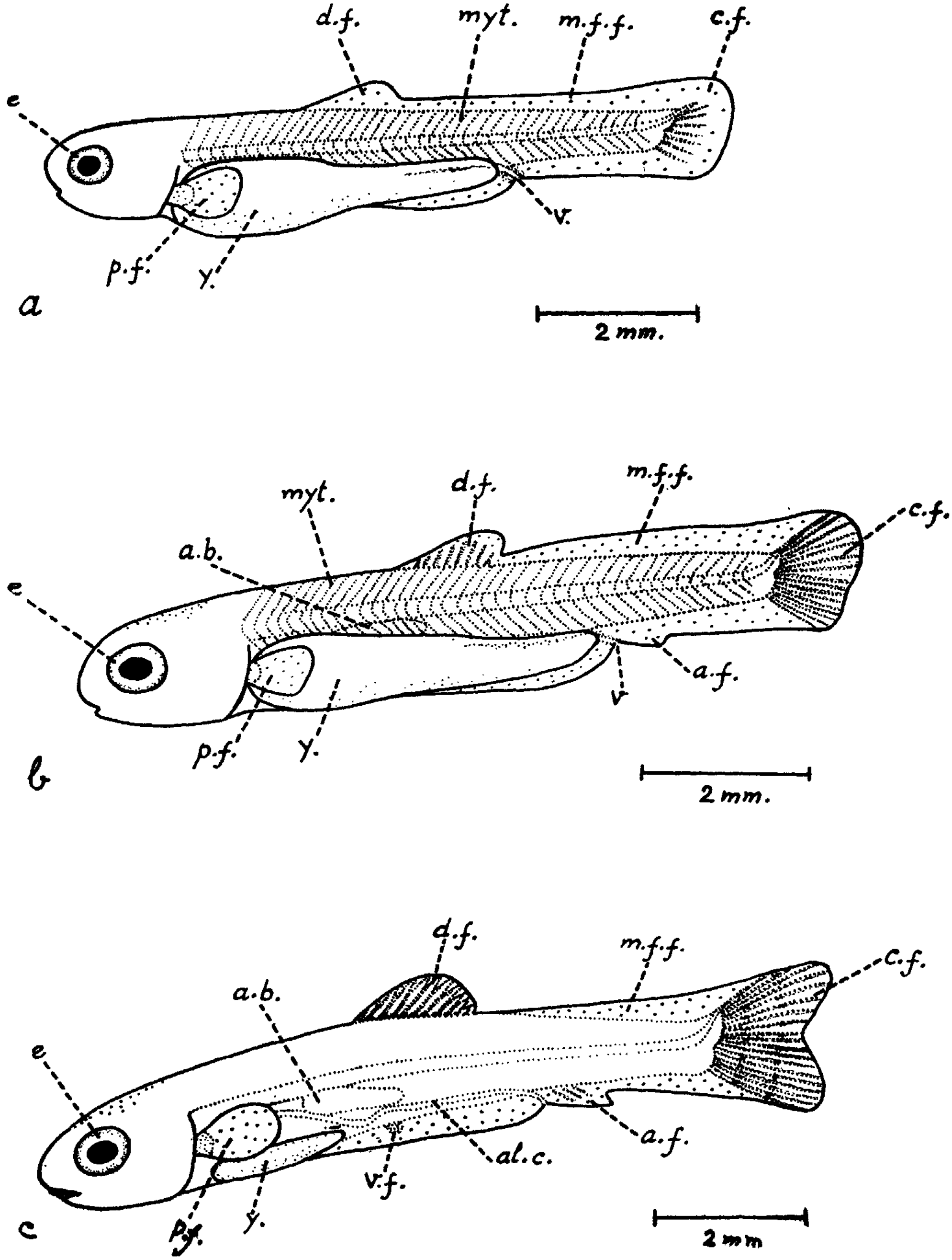

FIG. 8, *a–c*. *Tor tor* (Hamilton)
(*a.b.*, air bladder; *a.f.*, aual fin; *al.c.*, alimentary canal; *c.f.*, caudal fin; *d.f.*, dorsal fin; *e.*, eye; *m.f.f.*, median fin fold; *myt.*, myotome; *p.f.*, pectoral fin; *v.*, vent., *v.f.*, ventral fin; *y.*, yolk).

of chromatophores on head, a few scattered chromatophores are also seen on the snout.

(v) 14.25 *mm stage* (Fig. 9 *b*)—The larva has acquired almost all the characters of an adult fish. All the fins are fully formed. The anal fin which now contains nine rays, is completely separated from the ventral median fin fold. The pelvic fin is well developed and about 9–10 rays are discerned in the pectoral fin at this stage. A few scattered chromatophores are seen on the back of the larva. The spot on the caudal peduncle becomes more prominent.

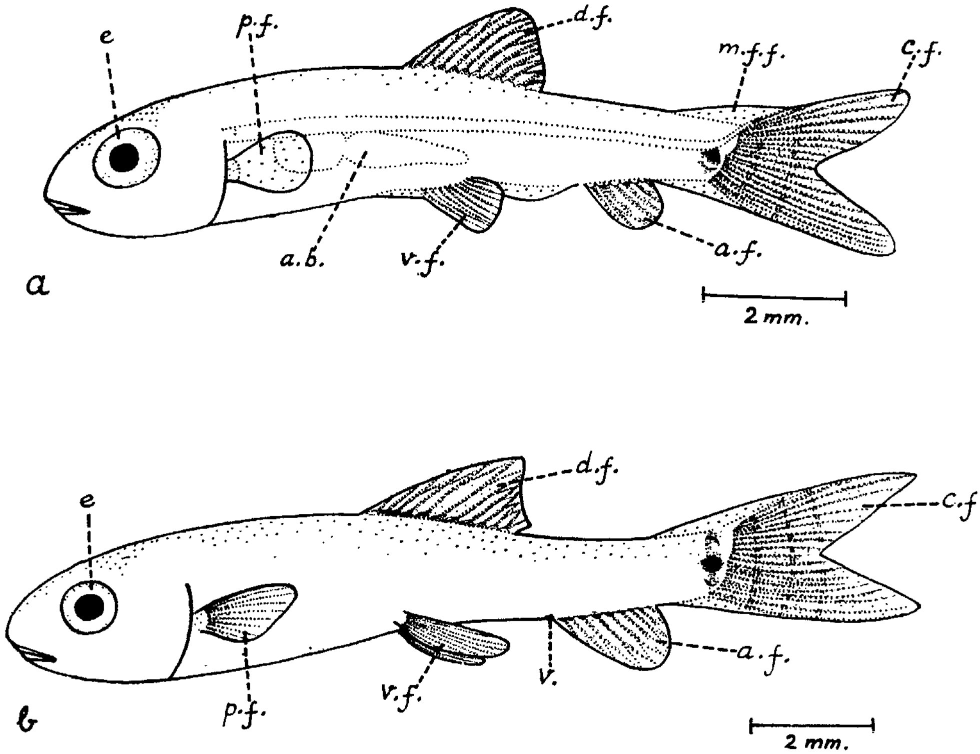

FIG. 9. *a, b. Tor tor* (Hamilton)

The body measurements of the above larval stages of *Tor tor* are presented in Table V.

Migration

Karamchandani *et al.* (1967) have stated that in river Narmada *Tor tor* forms the major fishery of cast net and gill net operations throughout the year except in monsoon period when the operation of these gears is suspended due to high floods in the river. However, the cessation of cast net and gill net operation may not be the only causative factor for the poor fishery of this species during monsoon. The poor catch of Tor mahseer from River Narmada from July to September coincides with its peak breeding. Moreover, the commercial catches from the river during this period comprised mostly smaller specimens of Tor mahseer. The limited availability of adult fish from the river Narmada at Hoshangabad during the peak breeding season points to spawning migration of the fish in the upstream

TABLE V

Body measurements (in mm)	Larval stages				
	I	II	III	IV	V
1. Total length	8.74	9.50	10.74	12.16	14.25
2. Fork length	—	—	10.26	10.93	12.65
3. Standard length	7.79	8.55	9.22	9.69	11.12
4. Distance between snout and vent	5.98	6.36	6.84	7.69	8.27
5. Length of head	1.61	1.90	2.19	2.56	2.95
6. Height of head	1.45	1.63	1.62	1.90	2.10
7. Height of body	—	—	1.62	1.90	2.28
8. Diameter of eye	0.48	0.57	0.67	0.85	0.95

in search of suitable surroundings. The reports of local fishermen and the catch of gravid fish from *nullahs* lend support to these observations. Thus the spawning migration as reported by earlier workers for mahseer in general appears to be true for *Tor tor* of river Narmada also. Beavan (1877) states, "when the rains begin these fish commence moving up the stream for spawning purposes." Thomas (1897) has recorded some adult mahseer gaining the upper reaches earlier in monsoon and subsequently breeding there when floods have receded. Hora and Nair (1944) have referred to migratory habit of mahseer in Riyang where the fish enters small side stream for breeding purposes and descends into the main stream when the waters begin to fall. The migratory habit of mahseer when the fish runs up river to spawn was also observed by Codrington (1946). David (1953) has noticed that *Barbus* (*Tor*) *mosal mahanadicus* is not available in catches from river Mahanadi when the water level in the river rises.

Sexual Dimorphism

In *Tor tor* sexual dimorphism was indicated by the presence of tubercles on the snout of mature male. The examination of males in the commercial catches and the additional check in the laboratory all the year round have shown that the mature male possessed tubercles on either side of the snout only during breeding season (July to January) when this character helped in ascertaining the sex of the fish. The appearance of tubercles on the snout of males during the breeding season and their absence in other months clearly indicates the role of tubercles in sexual play of the fish. It is likely that during courtship the male might be rubbing its rough snout against the body of female inducing excitement and extrusion of eggs. Earlier to this no one has reported presence of tubercles on the snout of mahseer particularly in reference to breeding. David (1953) noted tubercles on the snout in the young specimens (10–17 cm) of Mahanadi mahseer which disappear in larger sizes. Misra (1959) has mentioned about the tuberculated snout of *Tor khudree* and *Tor mussullah* as normal character of both the sexes and not temporary sexual character as seen in males of *Tor tor* of river Narmada.

DISCUSSION

The role of flood water in the spawning of freshwater fishes has been studied by many workers. The intensive flood caused either by rainfall or by artificial means inundating shallow areas, is essential to induce spawning in many carps (Hora 1945). According to Alikunhi and Rao (1951), since the spawning of many freshwater fishes occurred in shallow areas, such grounds could only be made available by flooding. *Tor tor* migrates to upper reaches when the monsoon showers cause flooding in river Narmada and as such the flood water appears to help the fish to reach the shallow breeding grounds. MacDonald (1948) and David (1953) have stated that since mahseers spawn in post-monsoon months it is probable that they move upstream during the monsoon trying to avoid their flooded summer haunts. As *Tor tor* continues to breed in river Narmada even after monsoon till February–March, the flood factor does not seem to be as important in the breeding of Tor mahseer as in the case of major carps.

The temperature as a factor affecting the spawning of mahseer has also been reported by some workers. Earlier records of the breeding of mahseer are mostly from the Himalayan streams where floods are also caused by melting of snow and hence the lowering of temperature by the snow is likely to be a strong factor in determining the breeding season. MacDonald (1948) has attributed the upward migration of mahseers during floods to the changes in temperature seeking more cogenial surroundings for spawning. David (1953) has mentioned that in the Peninsular rivers the optimum conditions for breeding of mahseer are attained during the cold months. According to David (1953), the lowering of water temperature in the river has great influence upon breeding of mahseer as seen by him that in river Mahanadi mahseer breeds during winter when the water temperature in the river ranged between 22 and 28°C. In the present case also the temperature of river Narmada, fluctuating between 19.9 and 28.4°C during July to March, may be considered to provide optimum conditions for breeding. The cessation of breeding during summer months gives indication that higher temperatures are not congenial for the breeding activity of this fish.

The prolonged breeding of this fish may be attributed to the breeding of various size groups in succession during different periods and the peak breeding is exhibited during the first half of the breeding season, i.e. July to September (Karamchandani *et al.* 1967). The presence of four groups of ova in the mature ovary tends to show that the breeding process of individual fish of laying eggs in four acts intermittently extends over a period of about two months. The process of maturation is continuous as seen from the attainment of maturity as soon as the last spawning act is over. In the present study at no time of the year there is preponderance of one stage of maturity excepting in July when the ovaries of stage *H* were exclusively encountered marking the commencement and peak breeding in this month. Due to prolonged nature of breeding season the maturing stages showed considerable overlapping in the population in other months. The fish having attained full maturity in July continued to breed till August–September so as to shed all the four batches of eggs as subsequently evidenced by the occurrence of partly spent and spent ovaries. The occurrence of ripe ovaries of stage *H* from August to September along with their partly spent and spent stages undoubtedly showed that the breeding continued to be in progress during this period. The availability of maturing ovaries of stage *G* in November gave clue that the breeding of mahseer extends further as all the four maturing groups of ova of these ovaries are likely to be laid by January–February. The other possibility of carrying over of stage *G* to the next spawning season is, however, ruled out in the absence of record of ripe ovaries of stage *H* from December to May.

Regarding the mode of releasing eggs of mahseer, Beavan (1877) says, "The mahseers are said not to deposit their spawn all at once like the salmon, but in small batches during a period of several months, say from May to August." Thomas (1897) remarked that mahseer does not spawn all at once but lays an egg a day for many days like a fowl and repeats this process several times in a season. Khan (1939) did not agree with the views of Thomas stating that in mahseer all the eggs contained in the ovaries are laid at the spawning time and the ovaries become empty. At the approach of the next spawning season the ova reappear, increase in size, swell the ovaries and are laid. The ova diameter frequency of partly spent ovaries (Stage *I* to *L*) showing the presence of maturing groups of ova gave no instance of empty ovary in the present study. The number of these maturing groups varied from one to three depending on the number of spawning act of the fish. After the expulsion of mature group of ova the maturing ova further develop to be laid in subsequent spawning acts. Thus the time taken for the development of maturing ova to ripe ova probably amounts to 2–3 weeks (Karamchandani *et al.* 1967) and this interval clearly accounts for the protracted breeding of *Tor tor* in river Narmada. David (1953) has inferred from the several sizes of ova of different developmental stages in the ripe ovary of Mahanadi mahseer that the fish lays eggs in batches. On the basis of several batches of eggs at all stages of maturity in the ripe ovary of *Tor putitora* (Hamilton), Qasim and Qayyum (1961) have observed that the species may spawn several times over a greater part of the year. Bhatnagar (1964) has also noted from the frequency polygons of ova diameter of *Tor putitora* from Bhakra reservoir that the fish releases eggs in several batches during a greater part of the year resulting in prolongation of the spawning season.

Though the mahseer is known to form exclusively a capture fishery, considering its dual importance as food and game it is worthwhile to explore the scope of using this fish for cultural practices. The possibility of growing mahseer in standing waters has been suggested by Hora and Ahmad (1946) and Karamchandani *et al.* (1967). If the utility of Narmada mahseer appears to be promising for culture fishery then steps can be taken to breed the fish in confined water by pituitary hormone administration, for which the presence of tubercles as observed on the snout of male during breeding season will serve a useful character for segregation of sexes.

ACKNOWLEDGEMENTS

I am grateful to Dr. B. S. Bhimachar and Dr. M. P. Motwani for suggesting the problem and showing active interest in the execution of work. I am indebted to Dr. V. G. Jhingran and Dr. Y. R. Tripathi for going through the manuscript critically and offering useful suggestions. My sincere thanks are also due to Shri S. J. Karamchandani under whose supervision and guidance the work was done and to Shri G. K. Bhatnagar for his help in statistical analysis.

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