SPAWNING FREQUENCIES AND BREEDING SEASONS OF SOME FRESHWATER FISHES WITH SPECIAL REFERENCE TO THOSE OCCURRING IN THE PLAINS OF NORTHERN INDIA

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Introduction

It is well known that the differences in the spawning behaviour of teleosts can to a certain extent be illustrated on the basis of the condition revealed by the unspawned eggs in the ovary (Heidrich, 1925; Clark, 1925, 1934; Hickling and Rutenberg, 1936). Many studies on the ova diameter frequencies have been undertaken during recent years and in almost all cases it has been accepted that species which have all the ovarian eggs of similar size spawn them together whereas those which have a wide range in oocyte sizes may have several groups of eggs matured and shed periodically during the breeding season (De Jong, 1939; Prabhu, 1956 and Dharmamba, 1959). Qasim (1956 *a* and 1956 *b*) made similar studies on two marine fishes *Blennius pholis* L. and *Centronotus gunnellus* (L.) and confirmed his results on the frequency of spawning by an observation in the aquarium. He showed that the common British blenny, *B. pholis* which has multiple batches of oocytes spawns three times during the breeding season, whereas the other shore fish of the British Isles, *C. gunnellus* has a single stock of eggs and spawns once only. Such differences in the spawning habit of marine teleosts living in temperate regions are correlated with their geographical distributions (Qasim, 1956 *a*). Single stock of oocytes in the maturing ovary is a peculiarity of the arctic-boreal species which spawn only once a year, their spawning seasons being short and occurring during winter and early spring. Multiple batches of eggs, on the other hand, are found among the mediterranean-boreal forms which produce several broods annually, their spawning seasons being long and occurring during spring and summer (Qasim, 1956 *a*).

Among Indian forms, studies on the size frequency distribution of oocytes have been undertaken on marine and estuarine fishes only (Karandikar and Palekar, 1950; Palekar and Karandikar, 1952; Prabhu, 1956; Dharmamba, 1959). There has been no previous account on any of the freshwater fishes,

The present paper deals with the spawning frequencies and breeding seasons of various species in the inland waters of Aligarh and other neighbouring areas.

Material and Methods

Table I gives the various species taken during the present investigation. In all, nineteen different species were studied which include carps, catfishes, murrels, grey mullet and spiny eel. To establish the breeding season of each species, observations were made on its gonad condition according to an arbitrary scheme (*see* below) over a greater part of the year. Ripening or ripe ovaries were then taken from the main breeding months, cut into small portions and fixed in Bouin's fluid. On hardening, they were opened in glass dishes and the oocytes carefully separated from the adhering tissues. All the oocytes thus obtained were measured under a micrometer eye-piece. In making measurements, the small yolkless cells which were much more numerous than the oocytes and apparently belonged to the immature class were omitted. In those species where the ovary was very large, only a portion was taken for the oocyte measurements. Generally three to four average sized individuals of each species were selected for the oocyte study and from these fishes a typical condition was laid down on the basis of its predominance to illustrate the distribution of oocytes in that species. In each individual roughly 500 to 1,000 eggs were measured indiscriminately.

Gonad Condition and Nature of Oocytes in Maturing Ovary

The degree of maturity of gonads in various species was determined according to the arbitrary scheme used for *B. pholis* and *C. gunnellus* (Qasim, 1957 *a* and *b*). In all, five maturity stages were defined as follows:—

(1) Immature virgins	Ovaries thin and ribbon-like, eggs microscopic
(2) Maturing virgins or recovered spents	Ovaries swollen and containing eggs just visible to the naked eye
(3) Ripening	Ovaries enlarged and containing conspicuous opaque eggs
(4) Ripe	Ovaries distended and containing large translucent eggs
(5) Spent	Ovaries collapsed with no eggs seen by the naked eye. In some cases a few residual eggs present

TABLE I

Duration of spawning in various freshwater fishes as deduced by the occurrence of ripe and spent stages in various months, Riverine locality includes the rivers Ganga, Jamuna and Kali. Fishes captured from Naujheel, a large lake about 30 miles away from Aligarh have been kept as riverine, for this lake gets connected with the river Jamuna during monsoon months*

	Species	Locality	Probable duration of breeding	Time of maximum spawning
Carps	*Cirrhina mrigala* (Ham.) ..	Rivers	July-August	August
	Labeo rohita (Ham.) ..	Rivers	July-August	August
	Labeo calbasu (Ham.) ..	Rivers	July-August	August
	Barbus sarana (Ham.)† ..	Rivers	Late June to early September	July and August
	Chela bacaila (Ham.)† ..	Ponds	June-September	August
	Barbus stigma (Cuv. and Val.)	Ponds	June-September	August
	Barbus (*Tor*) *putitora* (Ham.)	Rivers	Non-seasonal	Over a greater part of the year
Cat-fishes	*Wallagonia attu* (Bloch) ..	Rivers	June-September	July and August
	Eutropiichthys vacha (Ham.)	Rivers	June-September	July and August

	Callichrous pabda (Ham.) ..	Rivers	June-September	July and August
	Bagarius bagarius (Ham.)† ..	Rivers	June-September	July and August
	Mystus vittatus (Bloch) ..	Ponds	June-September	July and August
	Mystus cavasius (Ham.)† ..	Ponds	June-September	July and August
	Heteropneustes fossilis (Bloch)	Ponds	Late July-October	August and September
Murrels	*Ophicephalus striatus* Bloch	Rivers	June-October	July and August
	Ophicephalus marulius Ham.	Rivers	June-October	July and August
	Ophicephalus punctatus Bloch	Ponds	June-September	July and August
Grey mullet and	*Mugil corsula* Ham. ..	Rivers	July-September	July and August
Spiny eel	*Rhynchobdella aculeata* Bloch	Ponds	July-September	August

* A small perennial river of the Western U.P.

† Data based on small numbers.

It can be seen from Table I that the material which formed the basis of this study came from two different localities, rivers and ponds. In riverine forms, the occurrence of various stages of maturity was noted in specimens obtained from the local fish market. Depending upon the availability of each species, it became only possible to make observations for a definite period of the year, generally two months before the onset of monsoons (April and May), three months during the monsoons (June to August) and three months after the monsoons (September to November). Pond fishes, on the other hand, were collected by the authors themselves with the help of the technical staff of the department. They were thus made available in large numbers throughout the year and were used for more intensive studies on their biology. Complete data on breeding and its related aspects of various pond fishes will be dealt under separate communications. For the present work, to make comparison more uniform in all the species, the data on the seasonal changes in gonads are given in the form of time and duration of breeding seasons (Table I), as deduced by the occurrence of ripe and spent stages in various months.

Ripening and ripe ovaries of fishes contained oocytes of several different kinds. Those fishes which contained a single group of oocytes, free, large, ripe ova formed the main bulk. The other type present was that of small yolkless cells which were generally embedded in the tissues and probably included follicle cells and oogonia. Other species which possessed multiple groups of eggs, the oocytes were at various stages of development. In addition to the immature yolkless cells, there were also maturing ova which could be distinguished as small opaque eggs provided with little yolk; free mature ova, well supplied with yolk and large translucent ripe ova, full of yolk. Prabhu (1956) made similar observations on the oocytes of maturing ovaries of marine and estuarine fishes.

Spawning Frequencies

Carps.—Size frequency distributions of oocytes in all the species of carps studied are given as histograms in Fig. 1. In each species the month to which the data refer has also been indicated in the figure. As can be seen from the figure, in the four riverine forms, namely, *Labeo rohita*, *Labeo calbasu*, *Cirrhina mrigala* and *Barbus sarana*, conditions shown by the ovaries are very similar. All these species possess a single group of large oocytes evidently destined to be spawned in a single spawning act. The time and duration of spawning in all these species are practically the same, the breeding seasons last for about two months during the monsoons, July and August (Table I). In the Punjab area a large number of riverine carps has been

reported earlier to spawn during the monsoons, main breeding months being July and August (Khan, 1924 and 1942). A short spawning season, as is shown by these fishes, seems a characteristic feature of all those species which possess a single group of oocytes (Qasim, 1956 *a*).

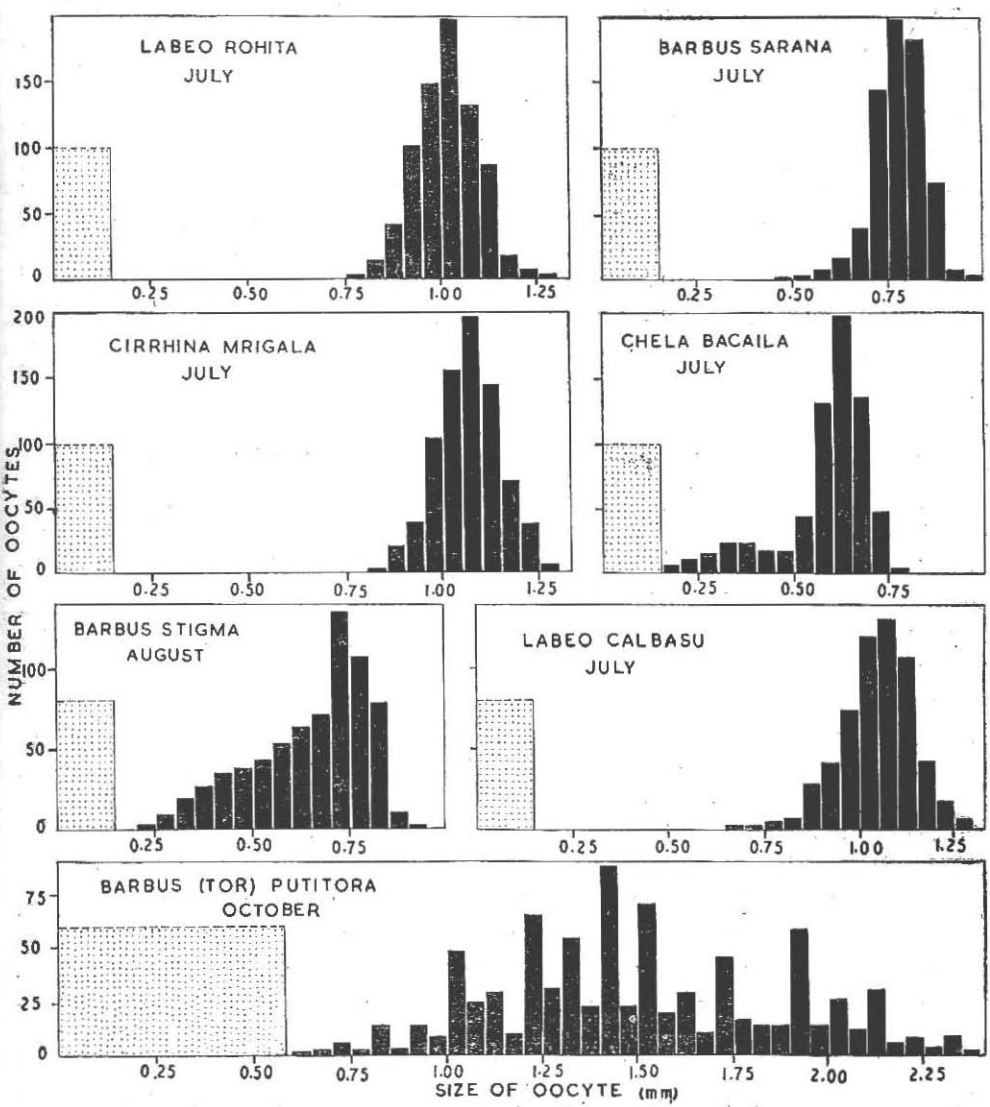

FIG. 1. Histograms showing size frequency distributions of oocytes in maturing ovaries of carps. The various months when typical conditions occur have been indicated with each species. Maturing ova likely to be spawned during the current breeding season are shown as black histograms. The much more numerous yolkless cells which remain in the ovary are marked by stippling. These are either absorbed in the body or form next season's brood.

The conditions shown by the ovaries of other two carps, *Barbus stigma* and *Chela bacaila* collected from ponds are slightly different (Fig. 1). In these species though the size range of the oocytes is large yet there is no clear differentiation of more than one batch of oocytes to be spawned during the same breeding season. Presumably the small oocytes remain in the ovary and are finally absorbed in the body, a feature well known in freshwater fishes. The breeding season in these two carps is comparatively longer and lasts for about four months, June-September. A prolonged breeding in these fishes, as one might infer, is not due to a succession of spawnings in each individual. On the other hand, in ponds, the population of each species is broken up into distinct and separate units; and since the ecological conditions vary from pond to pond, the breeding in all these units does not get synchronised. In some ponds, there may be a continued appearance of gravid fishes whereas in others spent stage may predominate. It is impossible to distinguish these two categories of fishes objectively, so it was thought best to present an overall picture of breeding season from ponds in general.

The ovary of *Barbus* (*Tor*) *putitora* shows an entirely different condition (Fig. 1). In this species the size range is large and there is a continuous gradation from the smallest to the largest size groups indicating several batches of eggs at all stages of maturity. On the basis of this peculiarity it could be generalized that in *Barbus* (*Tor*) *putitora*, the production and withdrawal of eggs from the ovary is a continuous process and that the species may spawn several times over a greater part of the year. The gonads with advanced stages of maturity (Stages III and IV) are seen throughout winter and summer. Earlier authors give three breeding seasons of the mahseer (i) January and February, (ii) May and June, (iii) July to September (Khan, 1940; Macdonald, 1948). These findings fall in close agreement with our deduction on the basis of its ova diameter measurements.

Cat-fishes.—Figure 2 gives the size frequency distributions of the oocytes in all the species of cat-fishes studied. A comparison of various histograms in the figure would reveal that all cat-fishes have spawning frequencies similar to those of the first four species of carps noted above. The entire annual egg production in these cat-fishes seems to have been concentrated into a single spawning act. There are only two types of eggs present in their ovaries, the immature and the ripe and that in most cases, the former is widely separated from the latter. Earlier, studies on *Mystus vittatus* of the brackish-waters (estuarine) have revealed similar conditions of the ovary (Prabhu, 1956).

The five species, namely, *Wallagonia attu, Eutropiichthys vacha, Bagarius bagarius* and *Callichrous pabda* which came from rivers had their ovaries predominantly ripe from May to July. In August gravid fishes became less numerous. It can therefore be inferred that June, July and August are the main spawning months. A single batch of eggs present in the ovary provides

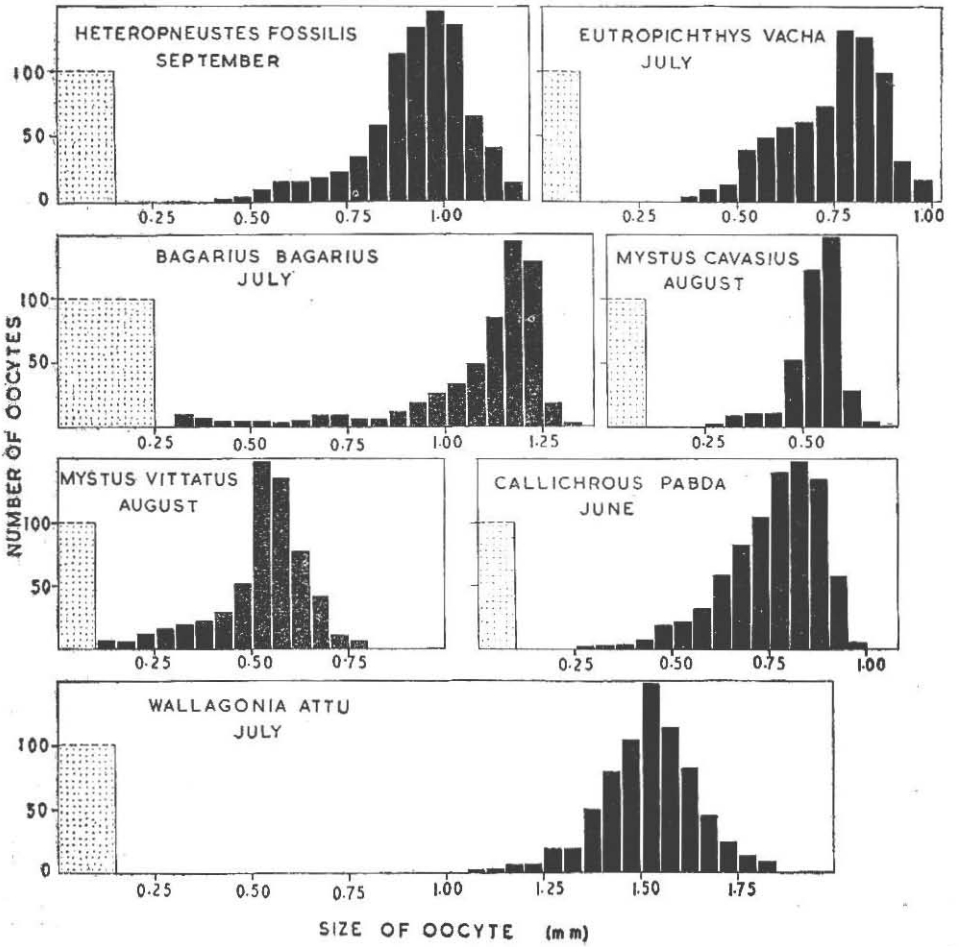

FIG. 2. Histograms showing size frequency distributions of oocytes in maturing ovaries of cat-fishes. Otherwise as in Fig. 1.

a strong evidence that each individual spawns once only during the season. Previous authors have also observed the spawning of *Wallagonia attu* in July (Ahmad, 1944 and Mookerjee *et al.*, 1944).

The other three cat-fishes (*Mystus vittatus, M. cavasius* and *Heteropneustes fossilis*) collected from ponds showed similar conditions of the

oocytes. In all probability there are single batches of eggs in these species. The spawning seasons, however, in these species seem longer than the riverine cat-fishes (Table I). As noted earlier in carps, presumably in cat-fishes too, due to varying conditions of food and shelter prevailing in different ponds, there occurs in some ponds either a delayed spawning or its total inhibition. In the latter case the entire egg mass is absorbed in the body.

In *H. fossilis*, according to Ghosh and Kar (1952) that there is a regular seasonal cycle in the gonads, it appears that each individual spawns once only. A gradual fall in the gonad weight as shown by these authors seems quite suggestive. Perhaps the small-sized eggs are not spawned and are gradually absorbed in the body. At Calcutta the period of maximum gonad activity in female as shown by Ghosh and Kar (1952) lasts from April to July. According to our findings that the individuals at Aligarh with ripe ovaries are not uncommon during the months of August, September and October, it appears that spawning in *H. fossilis* occurs late in the northern India (Table I).

Murrels.—The ova diameter frequencies of the following three species: (i) *Ophicephalus marulius*, (ii) *Ophicephalus striatus*, (iii) *Ophicephalus punctatus* have been shown in Fig. 3. In all these species there is a clear evidence of more than one batch of oocytes in the maturing ovary. Generally the average-sized individuals contain two groups and it is most likely that their withdrawal from the ovary may involve more than one spawning act. This behaviour of producing a succession of broods by each individual is in marked contrast to those of carps and cat-fishes which have a single batch of oocytes and produce a single brood annually. In murrels the breeding season is long and lasts throughout the monsoon and post-monsoon months. All through this period gravid fishes are very common. The cycle of maturation and depletion of gonads in the well-known pond murrel *O. punctatus* has been studied in detail. Its breeding season lasts from June to September. The young fishes guarded by both sexes are of common occurrence throughout the rainy season. At Madras, *O. punctatus* has been reported to have two breeding seasons corresponding to two monsoon rains of the south (Raj, 1916). According to Khan (1924) the breeding season of *O. marulius* in the Punjab lasts from April to July. In *O. striatus*, Raj (1916) gives two breeding seasons at Madras, January to February and June to July. The same species in the extreme south of India has been observed to breed throughout the year (Alikunhi, 1953). It is interesting to note that *O. striatus* which has a definite breeding season in the northern India breeds non-seasonally in the south. Presumably moderate climate and abundant rain-

fall of the south provide favourable conditions for breeding throughout the year. In the north such conditions are only prevalent for a limited period during the monsoon and post-monsoon months. Each individual, therefore, spawns repeatedly during these months.

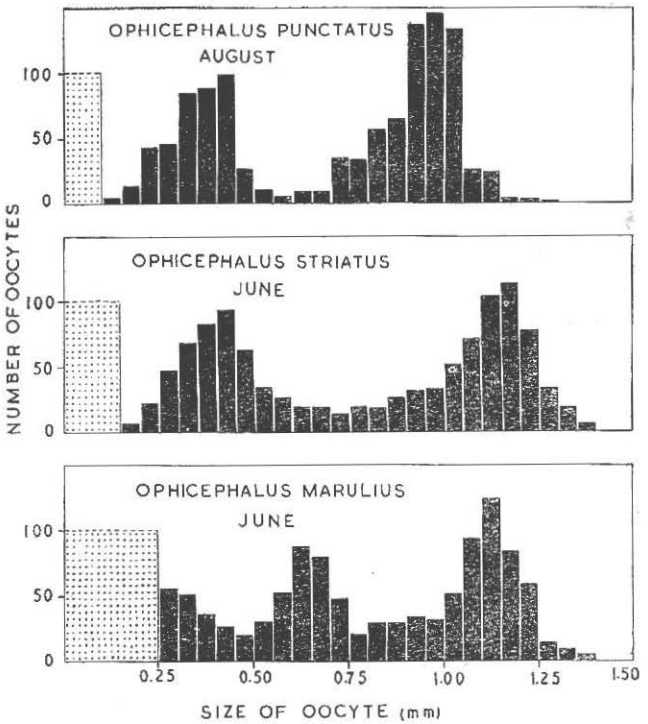

FIG. 3. Histograms showing size frequency distributions of oocytes in maturing ovaries of murrels. Otherwise as in Fig. 1.

Grey Mullet and Spiny Eel.—The conditions revealed by the ovaries of *Mugil corsula* and *Rhyncobdella aculeata* are given in Fig. 4. Both these species contain a single group of oocytes and spawn once a year, their spawning seasons being short and occurring mainly during July and August. Previous authors give the breeding season of *M. corsula* as July and August at the Contai coast, West Bengal (Pillay, 1949), June and July at Barrackpore (Pakrasi and Alikunhi, 1952). In other species of mullets, studies on the ova diameter measurements have revealed interesting conditions. *Mugil cunnesius* Valenciennes, a marine and estuarine form contains a single group of oocytes. It breeds from May to August (Sarojini, 1958). In *M. parsia* H. another marine form, there are two batches of eggs and its

spawning season at Calcutta lasts from December to March (Sarojini, 1957).

Breeding of Fishes in Relation to Seasons

The breeding behaviour of all the species discussed above suggests a principle which may be applicable to all freshwater fishes living in the plains of northern India. On the basis of their ova diameter frequencies, the various species can be divided into the following three categories:—

Category I

In this category are included all those species which possess a single batch of maturing eggs in their ovaries. The spawning in these fishes is adapted to an annual rhythm. The cycle of maturation and depletion of gonads

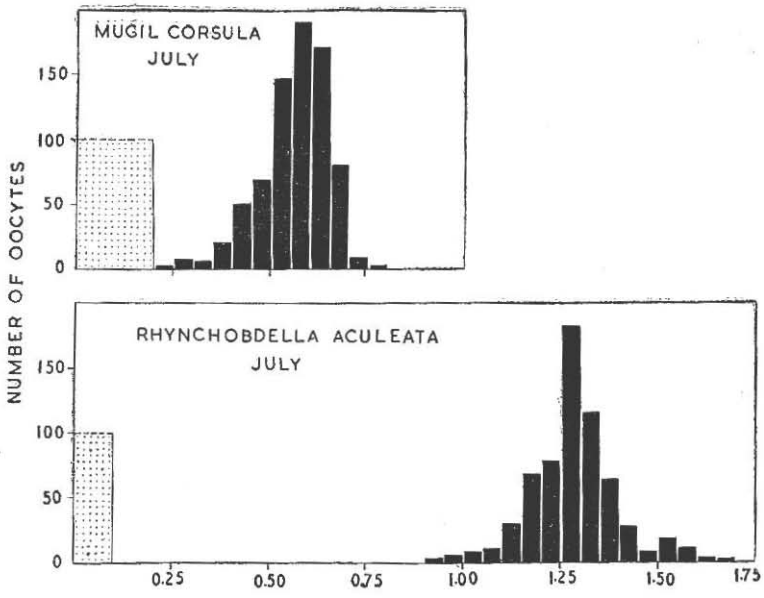

Fig. 4. Histograms showing size frequency distributions of oocytes in maturing ovaries of grey mullet and spiny eel. Otherwise as in Fig. 1.

occurs only once a year and synchronises throughout the population with the onset of monsoon rains. In all such forms, the gonads show a regular seasonal change, and at any given time, the state of maturity is uniform almost in all individuals of the population. An outline of such a regular seasonal change in the gonad condition is presented diagrammatically in Fig. 5 (*a*). The main features of the breeding cycle can be explained as follows:—

From November to January all fishes likely to spawn during the forthcoming breeding season reach the maturing stage. This stage is followed by the ripening stage during February, March and April. In May and June the fishes are predominantly ripe but in July spent fishes begin to appear and their proportions increase rapidly in subsequent months.

In some species, and more particularly among cat-fishes, the breeding cycle showed slight variations from the general picture presented above. This was mainly caused by the adolescent groups. These fishes maturing for the first time are late-spawners and therefore, reach peak ripeness towards the end of the breeding season.

Category II

This category includes fishes which have more than one group of maturing oocytes. In such forms, owing to a succession of spawnings, the breeding cycle of each individual takes an independent course. The breeding season is long and the stages of maturity at any given time show a considerable overlap in the population. A diagrammatic representation of such a breeding cycle is given in Fig. 5 (*b*). As can be seen from the figure, at no time of the year there is an exclusive preponderance of one stage of maturity. In October and November when the majority of fishes are spent, a small portion begins to show maturing condition of the ovary. In December there is a rapid increase in the maturing stage and in January some fishes reach the ripening stage. In February the proportion of ripening stage increases appreciably and in March ripe fishes begin to appear. From then onwards due to repeated spawnings both ripe and ripening stages occur until August. During these months as the gonads do not become spent after early spawnings, there is a general absence of the spent stage. In all these forms the breeding season seems so adjusted that its commencement falls with the onset of pre-monsoon showers. Conditions for breeding seem to remain favourable for a much longer period as the fishes continue to breed in post-monsoon months also. It seems that in the plains of northern India the seasonal rhythm in breeding is imposed on these fishes as a result of extreme and harder weather conditions which prevail during the corresponding winter and summer, for species, like *O. striatus* which breeds seasonally in this part of the country, has a non-seasonal breeding in the south.

Category III

All those species which have oocytes of all sizes ranging from the smallest to the largest with no well-marked batches, *e.g.*, *Barbus* (*Tor*) *putitora*

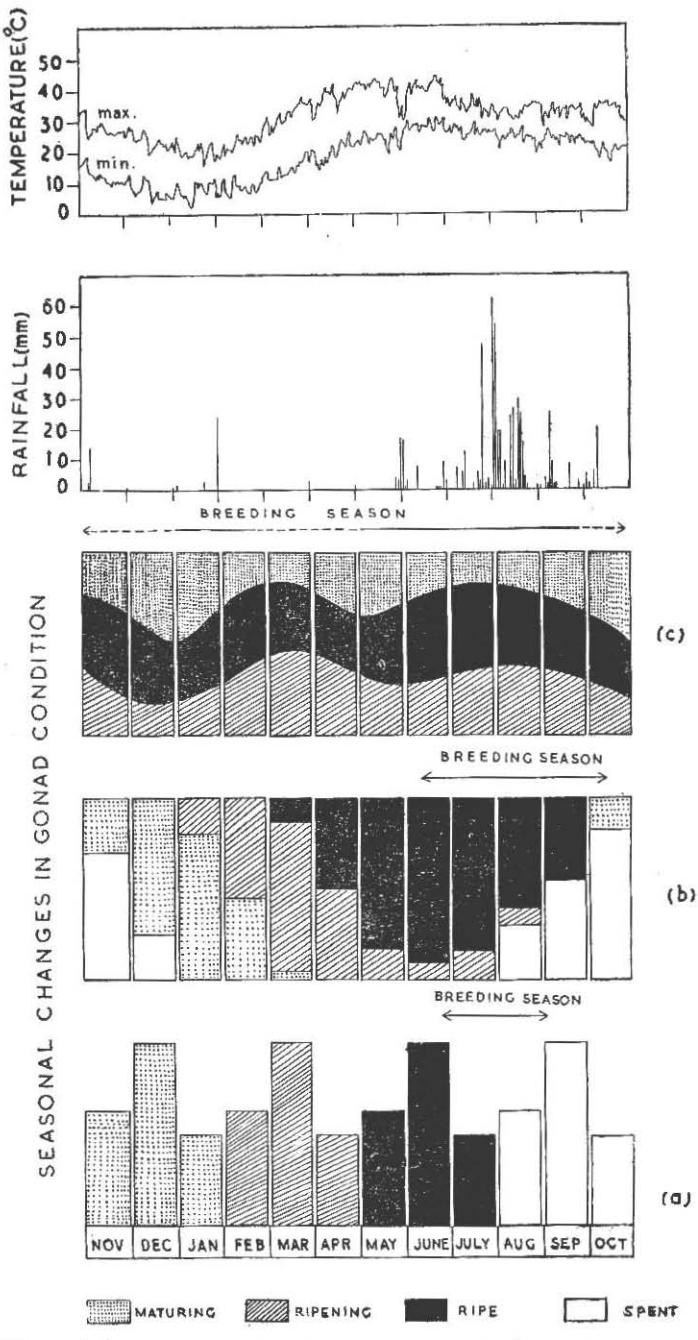

FIG. 5. The relation between breeding seasons, rainfall and atmospheric temperature. (*a*), (*b*) and (*c*) show arbitrary representations of the cycles of maturation and depletion of gonads in the population of various species categorised on the basis of their ova diameter frequencies. (*a*) Regular seasonal cycle when in each individual the withdrawal of all mature ova occurs in a single spawning (category I). (*b*) Overlapping seasonal cycle when each individual has a succession of spawnings (category II). (*c*) Non-seasonal breeding when each individual has an independent breeding rhythm (category III). The rainfall and temperature data refer to Aligarh for the year 1959.

could be included in this category. A general picture of the breeding cycle in such species is given in Fig. 5 (*c*). It is evident from the figure that there is no seasonal rhythm in breeding. Since the cycle of maturation and spawning becomes a continuous process, the population at all times has a random selection of all stages of maturity. The degree of their preponderance may vary according to the frequency of spawning. If conditions of temperature and food supply are favourable, there is no likelihood of coming across spent gonads in the population. On the other hand, if conditions for the building up of reserves are not optimum, there may be a temporary cessation in the gonad activity and this may be reflected by slightly shrunken and quiescent gonads at some stage.

Use of Maturity Stages as an Index of Spawning

It seems important to point out that various arbitrary classifications of gonad conditions or maturity stages devised to establish the time and duration of breeding in fishes can apply successfully only to those forms which show a regular seasonal change (Category I). These classifications with certain modifications and care can also be used to illustrate the spawning seasons of those fishes which produce more than one brood annually provided that their cycles of spawning are extended over one or at the most two definite periods (Category II). In fishes where there is a non-seasonal breeding, all stages of maturity occur practically throughout the year (Category III) and a study of gonads if used to provide an index of spawning is likely to give misleading results. As an example, a fish which has attained peak maturity will be taken as ripe. After it has spawned once, the condition of the gonad instead of moving towards the spent stage to indicate spawning, will go backwards and most probably will be identified as a ripening stage. Perhaps it would be even more difficult to assign a correct maturity stage to those individuals which have spawned more than once.

Breeding Seasons in Relation to Rainfall and Temperature

Many possible factors have been suggested by earlier workers as influencing the spawning of freshwater fishes. In major carps it has been established that intensive flooding either caused by the rainfall or by artificial means, capable of inundating shallow areas, are essential to induce spawning (Hora, 1945). High oxygen content and pH of water are the other factors on which considerable emphasis has been laid (Mookerjee, 1945; Mazumdar, 1945). According to Ganapati, Alikunhi and Thivy (1951), an access to suitable spawning ground was more important to induce spawning than the

physico-chemical condition of water. Since the spawning of many fresh-water fishes occurred in shallow areas, such grounds could only be made available either by flooding or by a general decrease in the water level during a period of drought (Alikunhi and Rao, 1951). Recent observations on the breeding of major carps at a fish farm in the Punjab seem to confirm the view that the chemical composition of water played no role in the spawning and that the spawning was mainly induced by the flood-water having a current of moderate intensity (Khanna, 1958).

The other factor which has been found to affect the spawning of fishes is the temperature. Many instances of optimum temperature conditions as a prerequisite for spawning have been reported earlier (Khan, 1945; Das and Das Gupta, 1945; Smith, 1945) and the temperature range at which the major carps have been observed to breed seems 75 to 86° F. (Hora, 1945).

In the present investigation an approach towards the relationship between physical factors and spawning can be made if the cycles of maturation and depletion of gonads as shown by the various categories of fishes are compared with the seasonal rainfall and temperature (Fig. 5). The evidences can be summarized as follows:—

1. Breeding in most fishes seems directly related to the monsoon cycle; and since in the plains of northern India, the outbreak of monsoon is usually late, the spawning is also delayed accordingly in latitudes further north.

The report of the Meteorological Department based on a ten-year survey of monthly rainfall frequencies throughout India shows that Delhi has on an average 28 inches of rainfall spread over a period of 52 days in a year (*The Statesman*, Monday, June 6, 1960). Roughly the same data apply to Aligarh and other areas of the western U.P. Of the other major cities of India, the report says, "Calcutta with an average rainfall of 63·2 inches has 242 rainless days per year and Bombay whose average rainfall is 75·1 inches has 257 rainless days. The number of rainless days in Madras was 270 while the average rainfall was 44 inches. Except south India, July is easily the wettest month, although in some places there is more rain in June or August than July. For Madras and Kodaikanal, November is the wettest month, while Bangalore, Coimbatore and Vizagapatnam receive the highest rainfall in October, Poona and Sholapur have the maximum rain in September".

By taking the flooded condition as a well-established factor to induce spawning, either directly or indirectly, *i.e.*, by providing an access to suitable shallow areas, from the above data it would appear that breeding seasons

in most fishes will not be the same in different regions. For instance, in the Chittagong Hill tracts where the first monsoon rains of the Indian sub-continent occur, the major carps breed from April to June (Ahmad, 1948). In the Ganga system of North Bihar, depending upon the occurrence of rain and flood from place to place, the breeding seasons in major carps last from April to August (David, 1959). In the western U.P. and further north in the Punjab area the same species breed in July and August (Table I), (*see* Khan, 1924, 1942 and 1943 for Punjab data).

Other riverine forms, such as cat-fishes and murrels commence breeding in many rivers in June (Table I), which is almost two to three weeks before the outbreak of monsoon rains in the western U.P. June is undoubtedly the hottest month in the plains of northern India. Most of the seasonal ponds and streams get totally dried up in this month, but the rivers, nevertheless, begin to swell due to melting snows and heavy rains in the Himalayas. Perhaps a rising level of water in these rivers provides suitable conditions to fishes to commence breeding. Peak spawning, however, follows the outbreak of monsoons.

In perennial ponds, a large number of fishes such as *Barbus stigma*, *Chela bacaila*, *Mystus vittatus* and *Ophicephalus punctatus* begin to breed towards the end of June as soon as the pre-monsoon showers have set in. In July or August after the monsoon season has too far advanced and most of the rivers, streams and seasonal ponds get flooded and low lying areas and fields are fully inundated, gravid fishes in large numbers make an access from rivers and perennial ponds to shallow areas where peak spawning occurs. Young fishes are hatched in these areas. They then begin to move in various directions along with the flood current, and in this way the dispersal of each species is effected over a wide area. This largely explains the consistent occurrence of many riverine fishes in many seasonal and perennial ponds year after year. Indeed, many freshwater fishes have a wide distribution. Some of them are recorded from all parts of India. There seems hardly any other provision to effect their dispersal all over the inland waters except flood conditions that prevail during the monsoons. Soon after the rains are over, all those areas which once became inter-connected are reduced to isolated patches or ponds and there exists a regular fishery of cat-fishes, carps and murrels in many of these ponds. An interesting case of fish dispersal was noticed by one of us (S. Z. Q.) in August 1958 when Aligarh received one of its heaviest rainfalls. The entire Civil Lines area where the University is situated got flooded and on the main highways several broods of *Ophicephalus punctatus* consisting of fry and parents

were noticed in addition to a large number of other species in fields and gardens. Some of these were rather uncommon for Aligarh.

2. Seasonal changes in temperature also seem to regulate the breeding of fishes (Fig. 5). From January onward the atmospheric temperature shows a regular rise reaching its maximum in mid-June. In these months there is also a greater range of variation in the daily maximum and minimum temperatures. Towards the end of June, after the monsoon rains have set in, the temperature falls, and throughout the monsoon months it maintains relatively a uniform range. The daily fluctuations do not exceed more than 5 to 10° C. which are in contrast to the pre-monsoon months when daily variations in temperature may be of 18 to 20° C. Soon after the monsoons are over, and the winter conditions begin to prevail, the temperature decreases. It finally reaches its minimum in January. From October onwards daily variations in temperature also become more and more pronounced.

From these data it is clear that in the plains of northern India where winter and summer seasons are so clearly defined, the only time when temperature conditions remain fairly uniform is that of the monsoons. All fishes, therefore, breed during this season. Due to prevailing flood conditions there is no competition for space. Each species, therefore, gets the best chance of finding suitable grounds to settle. Probably this is the season when most of the physical factors favour natural reproduction.

To sum up, it seems that breeding in freshwater fishes is so adjusted that the larvæ hatch during a season when conditions of temperature and shelter are at their optimum. Considering the significance of such a behaviour in terms of adaptive advantage to the species, the disparity in breeding habits is not so well marked as might be anticipated from the conditions revealed by their ovaries.

SUMMARY

Breeding seasons of 19 different species of freshwater fishes including carps, cat-fishes, murrels, grey mullet and spiny eel were determined by following the cycles of maturation and depletion of gonads over a greater part of the year. Size frequency distributions of oocytes in various species were studied by taking maturing ovaries from the main breeding months. On the basis of the conditions revealed by the unspawned eggs, the freshwater fishes were divided into following three categories:—

(1) Those which possess a well-marked single group of oocytes.

(2) Those which contain more than one clearly defined groups.

(3) Those which have oocytes of all sizes with no well-marked batches,

The breeding season in fishes belonging to the first category is short and lasts for about two to four months. In each individual the cycle of spawning occurs only once a year and the state of maturity at any given time is fairly uniform throughout the population.

Individuals belonging to the second category have a succession of spawnings. Their breeding seasons are relatively longer and last for about four to five months. At no time of the year there is an exclusive preponderance of one maturity stage in these fishes.

Fishes belonging to the third category are characterised by a non-seasonal breeding. Gravid individuals occur over a greater part of the year and it seems that if conditions for spawning are favourable, the cycle can occur at any time of the year. Spawning in each individual is not synchronous with those of other individuals of the population.

In the plains of northern India, most fishes breed during the monsoon months when seasonal temperature remains fairly uniform. Peak spawning occurs after the monsoon rains have properly set in. There is a general delay in spawning in the western U.P. as the outbreak of monsoons is usually late.

It is suggested that the breeding cycles in freshwater fishes are well suited to the conditions that prevail in this part of the country. The breeding seasons are adapted to provide optimum conditions of temperature and shelter for the newly hatched fishes.

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