# BEHAVIOUR AND BREEDING BIOLOGY OF THE FISH *TOR PUTITORA* (MAHASEER)

A THESIS

SU[illegible] PARTIAL FULFILMENT OF THE REQUIREMENTS FOR T[illegible]REE OF DOCTOR OF PHILOSOPHY

BY

FAZLI SUBHAN

DEPARTMENT OF BIOLOGICAL SCIENCES

QUAID-I-AZAM UNIVERSITY ISLAMABAD

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DEDICATED TO MY MOTHER AND DAUGHTER

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# ABSTRACT

Breeding biology and behaviour of the putitora mahaseer (*Tor putitora*) inhabiting Rawal lake and its tributaries in Islamabad were studied with focus on (1) gonadal maturation, seasonal rhythm and spawning, size and age at first maturity, (2) fecundity, (3) breeding behaviour, (4) schooling behaviour of juveniles, and (5) food and feeding behaviour.

Morphological details of ovaries and testes and gonadosomatic index determined over a 2-year period reveal that the breeding season of the putitora mahaseer lasts from late July to early October with peaks in August-September. The maturation of the gonads coincides with the onset of monsoon season when the water temperature also declines from a peak value of 28°C in the summer. There is evidence that spermatozoa occur in the testes of some males as early as May. The above observations have been supported by details of histocytological changes in the ovaries and testes as well as compartmentation of the seasonal ovarian and testicular rhythm into distinct stages. It is noteworthy that oocyte development in the ovaries is asynchronous and presence of more than one advanced stage of oocytes

indicates that the mahaseer spawns more than once in the breeding season. The mean GSI values for the two sexes show peaks in August and September.

The female putitora mahaseer become mature first at a size of 326 mm total length and 551 g body weight when they are in the 3rd year of life or have completed 3 years of age. The males become mature first at a size of 170 mm total length and 104 g body weight when they are in the 2nd year of life.

The fecundity of the species determined gravimetrically ranges from 7,570 to 30,295 ova for fish measuring 470-667 mm total length and 757-2997 g body weight. The relationship of fecundity with total body length, body weight, ovarian weight and age has been described on the basis of Least Squares estimates and analysis of regression: The equations yielding the best fit to the data reveal a strong correlation of fecundity with the above parameters.

The breeding behaviour of the mahaseer involves upstream migration. The fish breeds in shallow pebbly

and rocky sites in the Ramli and the Kurang streams between sunset and dawn. The behaviour comprises courtship and spawning act. During courtship several males follow a single female with display of nudging and tail-flapping. The spawning act occurs in currents of swift water where the female is joined by a male (rarely more than one), the bodies of the individuals arch as they make jerky quivering movements apparently signifying release of eggs and milt. This behaviour is repeated periodically involving the same female and other males.

Schooling behaviour is shown here to emerge only gradually in the juvenile stage. During November when the fry have a mean size of 9.5 mm, they generally occur as solitary individuals. With increase in size during December and January there is a tendency toward formation of loose groups (non-polarized) as well as polarized schools comprising 2-5 individuals. In February (70 mm mean size) a polarized state becomes pronounced with most individuals occurring in schools ranging from 2-20 individuals. The features of the polarized schools and maintenance of this state in subsequent months are described and discussed.

It is shown here that the putitora species feeds in marginal areas of the lake and the streams during the morning and the afternoon but may also feed at night. Gut analysis revealed presence of macrovegetation, algae, animal food and detritus. Macrovegetation and algae together constitute the most abundant food items. Seasonal variations in the composition of the diet have been examined. The animal food component increases noticeably in the summer (June). Food preferences have been determined on the basis of numerical analysis and frequency method. The former shows that *Spirogyra* and *Vallisnaria* interchange during the year as the dominant items. The latter revealed the following order of preference; waterboatman and waterbug (insects), *Hydrilla*, *Spirogyra*, *Vallisnaria* and *Ulothrix* (decreasing order of the first five items). The study collectively shows that the mahaseer is an omnivore with a primarily herbivorous habit. The value of the relative length of the gut (RLG) also supports the above conclusion. The absence of a true stomach, presence of pharyngeal teeth and small gill rakers have been noted and discussed in relation to the feeding habits of the putitora mahaseer.

# CHAPTER - 1

## INTRODUCTION

The putitora mahaseer, *Tor putitora*, is a large scaled carp belonging to the family Cyprinidae, sub-family Barbinae (Mirza, 1975). Members of the Genus *Tor*, commonly known as mahaseer, are distributed in Asia and Africa. Only 4 species of mahaseers occur in Pakistan, namely, *Tor putitora*, *Tot tor*, *Tor mosal* and *Tor zhobensis* (Mirza, 1975). *Tor putitora* is found in the montain and submontane areas of Pakistan and extends into northern plains of the Punjab. *Tor tor*(tor mahaseer) has been reported from the Punjab in Pakistan by Misra (1962) but is considered to be uncommon. The taxonomic status of mahaseers at the generic level had remained uncertain for quite some time. The members of this group have been formerly grouped in the genus *Cyprinus* (Hamilton), and until recently in the genus *Barbus* (Day). Currently, however, the various species of the mahaseers are now listed in the Genus Tor.

The mahaseers are generally large-sized fishes and the putitora mahaseer has been claimed to attain a length of 180 cm (Qureshi, 1965). During the course of the present study one specimen collected from the Rawal Lake weighed 8 Kg. On account of their palatability and large size the mahaseers form a commercially important group of carps. Apparently, owing to the fight these fishes put up during angling, they are much sought for by anglers and the name "mahaseer" has been argued to have gained its origin from Mahi-Sher meaning fish and "sher" (lion), although other origins of the name have also been attempted (Hora, 1939).

Compared with such commercially important carps as *Labeo* spp., *Cirrhinus* spp., and *Catla* sp., much less has been known regarding the biology of the mahaseers of the Indo-Pakistan subcontinent. The earliest descriptions (Beavan, 1877; Nevill, 1915; Khan, 1924, 1939; Hora, 1939, 1945; Codrington, 1946; McDonald, 1948) of the biology of the mahaseers have at best been cursory. More recently, however, several reports mainly from the Indian region (Qasim and Qayyum, 1961; Bhatnagar, 1964; Desai and Karamchandani, 1968; Rai, 1967; Desai, 1973; Malhotra, 1982; Nautiyal, 1984) have given very useful details of the biology of the putitora and tor mahaseers (*Tor putitora*, *Tor tor*). The main aspects covered in these reports are gonadal maturation, spawning habits, fecundity, food and general ecological considerations. With the exception of some brief works by Khan (1924), Ali and Hussain (1968) and a note by Butt and Hayat (1978) no noteworthy study of the mahaseers in Pakistan has been extended. The biology and behaviour of organisms in general tend to vary according to their geographical distribution, attendant climatological and ecological conditions. It, therefore, becomes imperative that systematic studies be conducted on the putitora mahaseer thriving in Pakistan's water systems. The available literature on the putitora mahaseer contains conflicting reports pertaining to the breeding biology and food and feeding habits (Qasim and Qayyum, 1961; Bhatnager, 1964; Ali and Hussain, 1968; Butt and Hayat, 1978; Pethani, 1983). Although it may be argued that discordance in these studies may some times stem from weaknesses and differences in methodology, a probable reason is likely to be regional ecological variations to which the respective populations of the putitora mahaseer have adapted. The observations of Khan (1943; mrigal), Qasim and Qayyum (1961; carps, catfishes and murrels), Swee and McCrimmon (1966; *Cyprinus carpio*) and Crivelli (1981; *Cyprinus carpio*) illustrate and support this contention strongly.

From the point of view of fisheries biologists extensive information on all aspects of biology of species of commercial value are essential to enable them to exploit the resources economically, effectively and on a sustainable basis. Some of the main areas which have traditionally attracted attention in this context encompass taxonomy, zoogeography, morphology, physiology and endocrinology, gonads and breeding, fecundity, food and feeding, age, growth, metabolism and nutrition, diseases, behaviour and population dynamics. The increasing demand for animal protein as a result of human population pressures has further necessitated, in recent years, an intensification of aquacultural and fish farming programs. In order to achieve success in these latter commitments it is necessary to have the requisite body of scientific information on the biology and behaviour of natural populations of species contemplated to be used either in a monoculture or a polyculture program. For an appreciation of the status, problems and requirements of freshwater fishery development in Pakistan reference should be made to reports by Mirza (1975), Javaid (1977), Ahmad (1980a, 1980b, 1980c, 1983) and Lone (1983). In the context of development of fishery resources, reservior fisheries demands equal attention not only from the stand point of utilization of these impoundments for maximizing fisheries potential but also in reference to the adverse effects, improperly planned development of these may have on the biology, behaviour and movements of species thriving in natural waters.

In Islamabad Rawal Lake is a man-made lake where a variety of fishes occur including the putitora mahaseer, rohu, mrigal, thaila and recently the common carp has also been introduced here. The lake is located at latitude $33^{O}$N, longitude $73^{O}$E and at an altitude of 503 meters. It spreads over a 3 sq. mile area. The lake and the dam have been built on the Kurang river. It receives inflow from the Kurang and the Ramli streams (Fig. 1 Chapter 2) each originating in the Murree and Margala hills respectively.

The present work on the putitora mahaseer (*Tor putitora*) was undertaken keeping in view the paucity of available information on the biology of this species thriving in Pakistan as well as in the light of relevance of the anticipated information to fishery resources of the lake, management planning and application in aquacultural programs. The areas emphasized in the study are (1) gonadal maturation, spawning seasonality and frequency, (2) fecundity, (3) spawning behaviour, (4) schooling behaviour, and (5) food and feeding behaviour.

# CHAPTER - 2

## GONADAL MATURATION AND BREEDING CYCLE

### Aims and Rationale

The mahaseer constitute an important group of carps from the stand point of commercial exploitation and sport fishing. In this context examination of gonadal cycles and breeding biology of this group of fish is of considerable value. Most of the investigations conducted in the Indo-Pakistan subcontinent prior to 1948 have been of a preliminary nature based on general field observations and gross examination of the gonads of various species of mahaseers. The descriptions provided by Beavan (1877), Hora (1939, 1940), Khan (1939), Codrington (1946), Smith (1947) and McDonald (1948) are notable in this regard. Hora (1939, 1940) has provided evidence in favour of a restricted breeding season (July - September) for the putitora mahaseer, *Tor putitora*. In contrast, Qasim and Qayyum (1961) have reported that this species in the Gangetic plains breeds several times during a greater part of the year. According to Bhatnagar (1964) also, the putitora mahaseer thriving in a lake off Sutlej river in

Himachal Pradesh, India, breeds continuously over a greater part of the year. These observations are in general agreement with some of the preliminary comments of Day (for citation see Hora, 1939), Beavan (1877), Nevill (1915), Codrington (1946) and McDonald (1948). More recent observations of Pathani (1981, 1983) on this species indicate that the breeding season of a population residing in Bhimtal of Naini Tal falls between May - September. It is thus evident that conflicting opinions exist in the literature regarding seasonality and spawning frequency of the putitora mahaseer from different regions or even in the same region of the Indo-Pakistan subcontinent. Similar disparities exist regarding the breeding periodicity of the related tor mahaseer, *Tor tor* (Beavan 1877; Nevill, 1915; Codrington, 1946; McDonald, 1948; Desai, 1973; Chaturvedi, 1976; Pathani, 1983). Khan (1939) has described continuous breeding of *Barbus tor* in the Punjab waters (January - February, May - June, July - September) but it is difficult to judge whether he examined a single species or several species of the mahaseers.

The present investigation was undertaken in view of lack of a clear understanding of the breeding habits of the putitora mahaseer. It is also noteworthy in this regard that hardly any recent systematic investigations have been carried out to describe the pattern of gonadal maturation and breeding cycle of this species in the Pakistani part of the subcontinent in the context of local ecological peculiarities. It was, therefore, proposed to study gonadal histology, seasonal changes in the gonads, and length, weight and age in relation to the time of first maturity in the putitora mahaseer thriving in the Rawal lake and its tributaries. Morphological and gonosomatic indices were used as criteria to define the maturational and breeding rhythm.

## Materials and Methods

Monthly samples of putitora mahaseer (*Tor putitora*) were collected from Rawal Lake (latitude 33$^{O}$N, longitude 73$^{O}$E, Fig. 1) and the adjoining streams over a 2 year period (1983, 1984) with the assistance of local fisherman as well as independently by the staff of the Fish Biology research unit of the Department. The fish were usually collected with gill nets but cast nets were also used especially during the breeding season in shallow spawning areas. All specimens were transported to the laboratory as soon as possible.

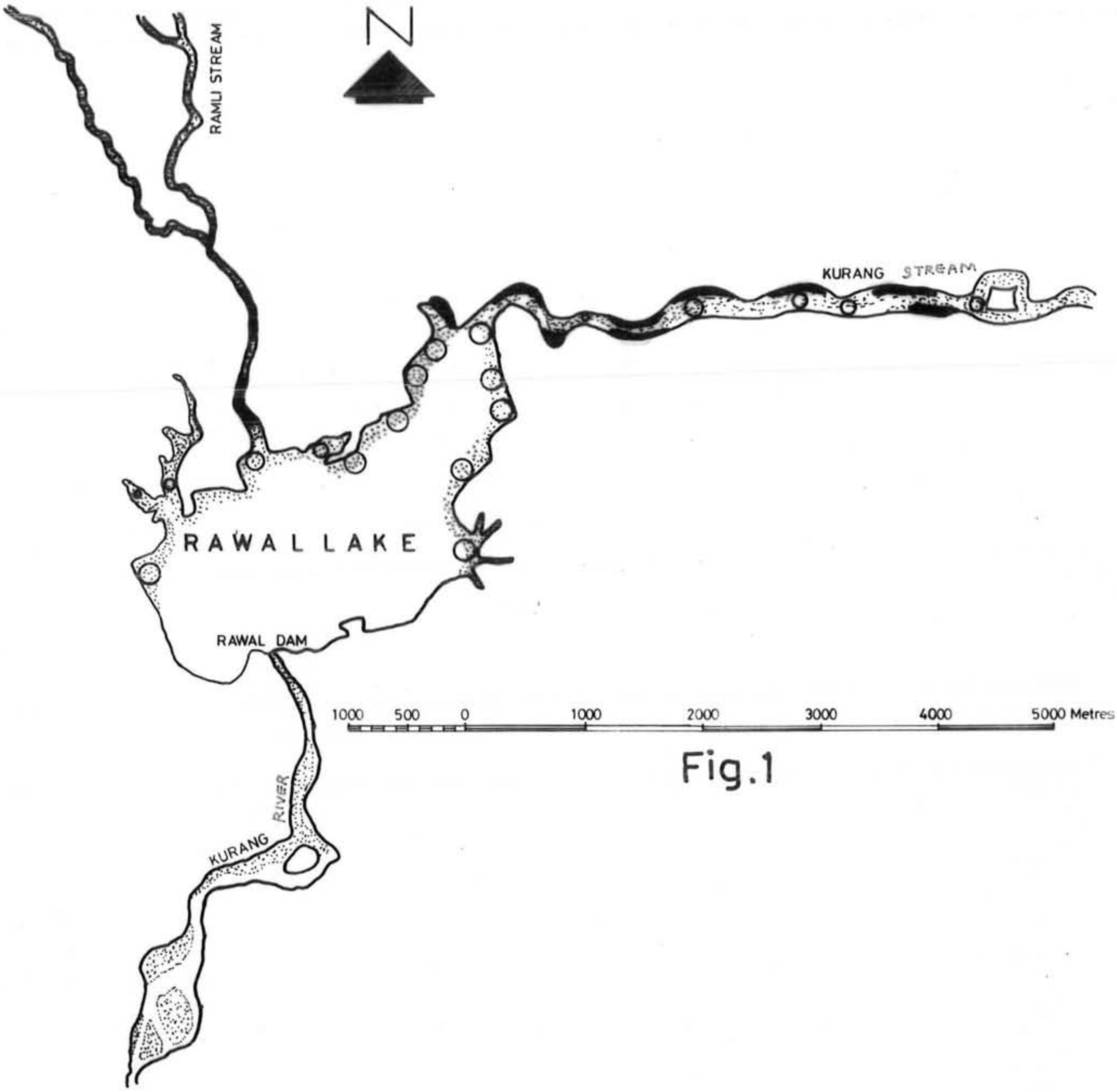

RAMLI STREAM
KURANG STREAM
RAWAL LAKE
RAWAL DAM
KURANG RIVER
1000 500 0 1000 2000 3000 4000 5000 Metres

Fig.1

Body weight, standard and total lengths (S.L. and T.L.) of fish were routinely recorded. Samples of scales were removed from an area of the body between the dorsal fin and the lateral line (sub-dorsal area) and saved for age determination. The fish were dissected for examination of gonadal anatomy. The gonads were removed carefully to avoid damage, blotted on paper towels and weighed to the nearest mg on a Mettler balance. These were preserved in 10% formalin or in aqueous Bouins.

Morphological (gross and microscopic) details of the gonads were examined and seasonal changes in gonadal maturation cycle were determined by the Gonosomatic Index (GSI: Gonadal weight as percent of body weight) as well as according to morphological (histological and cytological) criteria. For histological examination the gonads were removed from the fixatives, washed briefly in running water, dehydrated in ascending ethanol series cleared in cedar wood oil-Xylene and embedded in paraffin wax. Blocks of the tissues were sectioned with a rotary microtome (American optical company) at a thickness of 6-10 μ . The sections were affixed to albuminized glass slides and stained with hematoxylin-eosin.

Histological details of the gonads were studied in representative monthly samples. For the ovaries, diameters of oocytes were measured using a calibrated ocular micrometer at appropriate magnifications and oocyte development was partitioned into stages according to the classification of Yamamoto (1956) and Yamamoto and Yamazaki (1961). The morphological details encompassing size, color, vascularity of ovaries and histologically discernible changes in oocyte development as well as shifts in diameter of oocytes were classified on monthly basis to generate a classification into 6 stages (I-VI) reflecting seasonal maturational rhythm. Similarly, testicular development was assessed by examining histological details and spermatogenetic stages to determine relative preponderance of spermatogonia, spermatocytes, spermatids and spermatozoa. These stages of ovarian and testicular development based on morphology were further compared with mean monthly gonosomatic index (GSI) derived by using gonadal weight as a percent of body weight. These criteria served as the basis of assessment of seasonal maturity rhythm of the fish.

The monthly GSI data were plotted separately for all females and males regardless of weight and length of individuals in each sex category. In order to assess the timing of first maturity, the monthly GSI data were also plotted separately according to weight and length for each sex. First maturity was also determined according to age. For this purpose, age of individual fish was determined by examination of scales. The scales were washed with ethanol, mounted between clean glass slides and examined under a dissecting microscope (Bausch and Lomb) for counting annual checks. Age - maturity relationship was determined for samples of fish collected during the breeding season. The relationship was based on percent of the sample appearing mature during the breeding season. All fish with a mean GSI of 3.0 were considered to be mature for purposes of assessing age at first maturity.

## Results

### GONADAL MORPHOLOGY AND RHYTHM

#### Macroscopic structure of gonads:

The ovaries of putitora mahaseer are paired and elongate organs held from the dorsal body wall by a mesovarium. Each ovary continues posteriorly into a short oviduct. The oviducts unite posteriorly forming a common chamber leading into a urogenital sinus with its opening located dorsal to the anus. The two ovaries are usually of equal size but some variation is encountered especially as maturation progresses. In such situations the left ovary tends to be slightly larger. The ovaries vary in size and appearance seasonally and contain oocytes in different stages of development. As the females develop to maturity, the ovaries change in color from pinkish in the immature to a yellow shade in the gravid fish, increase in both length and girth and become turgid. Fully ripe and ready to spawn ovaries occupy the entire abdominal cavity and the yellowish oocytes are visible through the ovarian wall. The ovaries of spent fish appear dirty brown and collapsed.

The testes are also paired and elongate organs attached to the dorsal body wall by a mesorchium. The two testes are strap shaped. The vas deferentia run along the dorsomedial side of the testes and unite to form a common duct which runs through the genital papilla to open to the outside. The size of the testes varies according to season and size of the fish. During the breeding season these become enlarged, milky white and appear laterally compressed. In fully ripe males, milt flows freely even with gentle pressure on the abdomen.

Histological changes in the ovary:

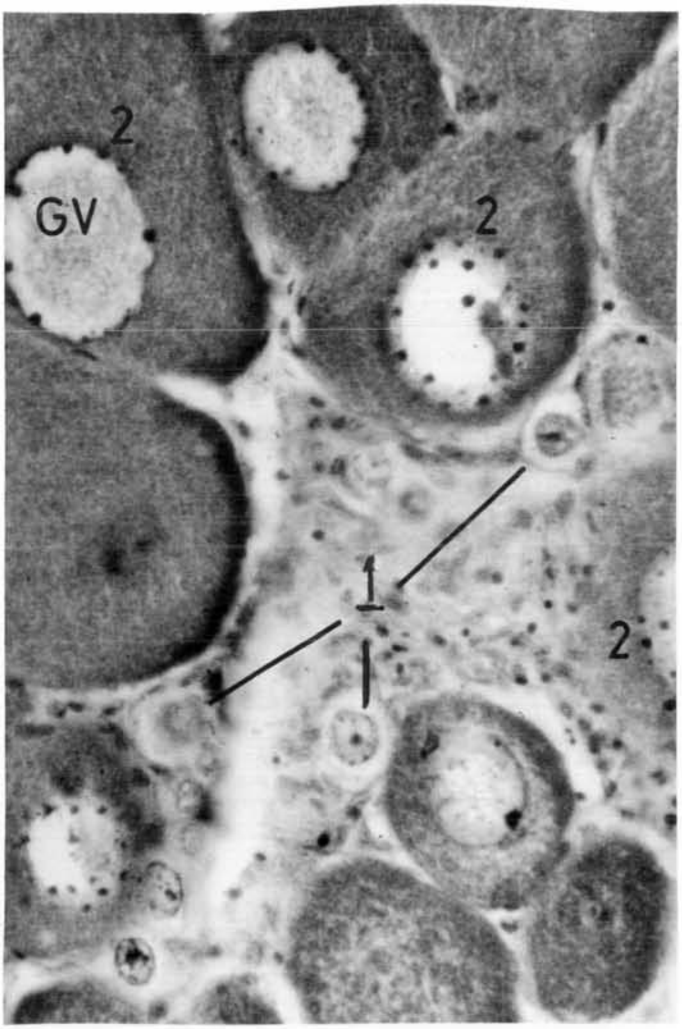
The ovary in the mahaseer is saccular and consists of an outer peritoneal layer which encloses an inner layer, the tunica albuginea. The latter comprises connective tissue, muscle fibers and blood vessels. The thickness of the layer varies seasonally. It is thick in immature and thin in ripe ovaries owing to distension resulting from increasing size of oocytes. The innermost layer of the ovary is epithelial consisting of cuboidal cells. This layer is thrown into numerous folds or lamellae projecting into the ovarian cavity and is the germinal epithelium. It consists of ovigerous tissue where nests of oogonia are lodged. The ovarian cavity is large and conspicuous in immature and spent ovaries but becomes attenuated and sinuous in ripe ovaries. The oogonial nests occur throughout the year but are most prominent in immature and recovering-spent ovaries. Blood vessels penetrate the lamellae from the outer connective tissue layer.

In conformity with available descriptions of maturational changes in the ovary of fishes (Yamamoto, 1956; Yamamoto and Yamazaki, 1961), the following stages have been recognized depicting a progressive shift from oogonial to the ripe ova stage.

The oogonia lie in nests (Fig. 2) in the ovigerous epithelium and contain a large pale nucleus. One to several nucleoli occur in the nucleus depending on the stage of meiotic division. The cytoplasm of the oogonia is clear to lightly basophilic. These cells are in the chromatin nucleolus stage and are in the process of passing through the usual presynaptic, bouquet and post synaptic phases of meiosis leading to formation of oocytes. The oogonia range in diameter upto 0.03 mm.

The next phase is characterized by oocytes where the nucleoli increase in number and occupy a peripheral position next to the nuclear membrane (Fig. 2). The central nucleus (germinal vesicle) is large with nucleoli showing strong basophilia. This is the perinucleolus stage. The cytoplasm has increased in amount over the previous stage and is strongly basophilic in smaller oocytes but in the larger oocytes of this stage it is less basophilic more peripherally imparting a

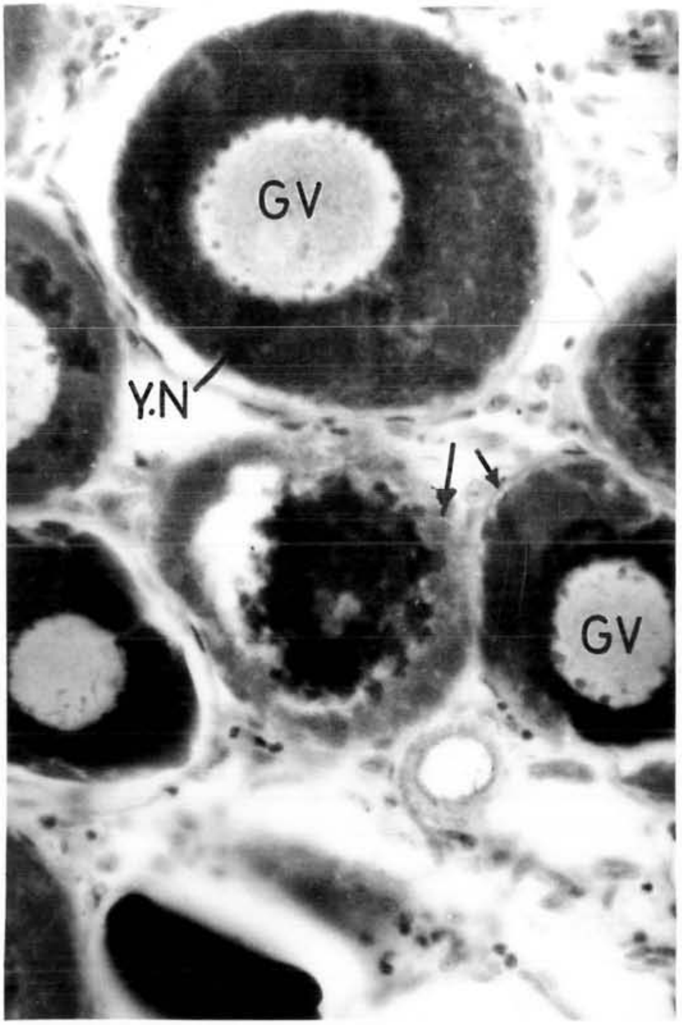
Fig.2



zonation to it (Fig. 3 ). A yolk nucleus (Fig. 3) has appeared which lies inside the nucleus or close to the outer side of the nuclear membrane in younger oocytes but migrates peripherally in the advanced phase of this stage. The yolk nucleus seems to have a nuclear origin. A follicular layer is visible but distinction between theca and granulosa cells is not yet possible. The oocytes range in size to as much as 0.25 mm in diameter.

In the yolk vesicle stage (Figs.8,9,10) the oocytes have increased to a larger size and possess a distinctly eosinophilic ooplasm. A characteristic feature of this stage is formation of yolk vesicles which arise as small vacuoles first peripherally and later centrally. The germinal vesicle is nearly central in position and contains many nucleoli peripherally but their position becomes variable as size of the oocytes increases. The nuclear membrane also becomes increasingly irregular and wavy in the larger oocytes. A distinction between theca and granulosa is possible and a zona radiata is present next to the plasma membrane of the oocytes. The oocytes now measure upto 0.9 mm in diameter.

Fig. 3



The next phase of development is characterized by appearance of yolk granules in the extra and intravesicular ooplasm and the oocytes pass through primary, secondary and tertiary yolk stages. This is a period of rapid vitellogenesis. In the primary yolk stage (Fig. 4) the central germinal vesicle contains many irregularly distributed nucleoli and the nuclear membrane is wavy. The yolk globules (Fig. 5) arise as tiny particles in the peripheral cytoplasm and become increasingly prominent more centrally as time progresses. The follicular layer and the zona radiata become thick and the theca is prominent (Fig. 5). In the secondary yolk stage, the germinal vesicle becomes small in size and contains only few nucleoli. The yolk globules are larger in size and density and push the yolk vesicles toward the periphery of the ooplasm. In the tertiary yolk stage the yolk granules have coalesced further to form larger grains and push the yolk vesicles toward the immediate vicinity of the plasma membrane adjacent to the zona radiata and the entire ooplasm becomes studded with the globules. The oocytes measure as much as 1.7 mm in diameter.

In the migratory nucleus stage (Fig. 6) the yolk spherules have coalesced completely filling the ooplasm.

Fig.4

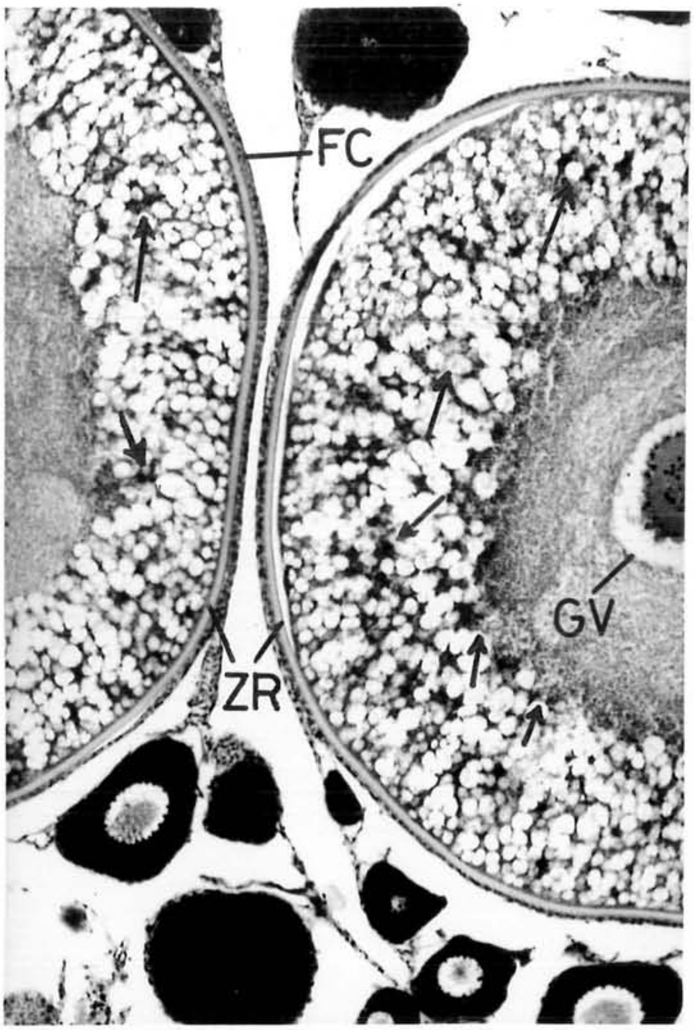


Fig.5

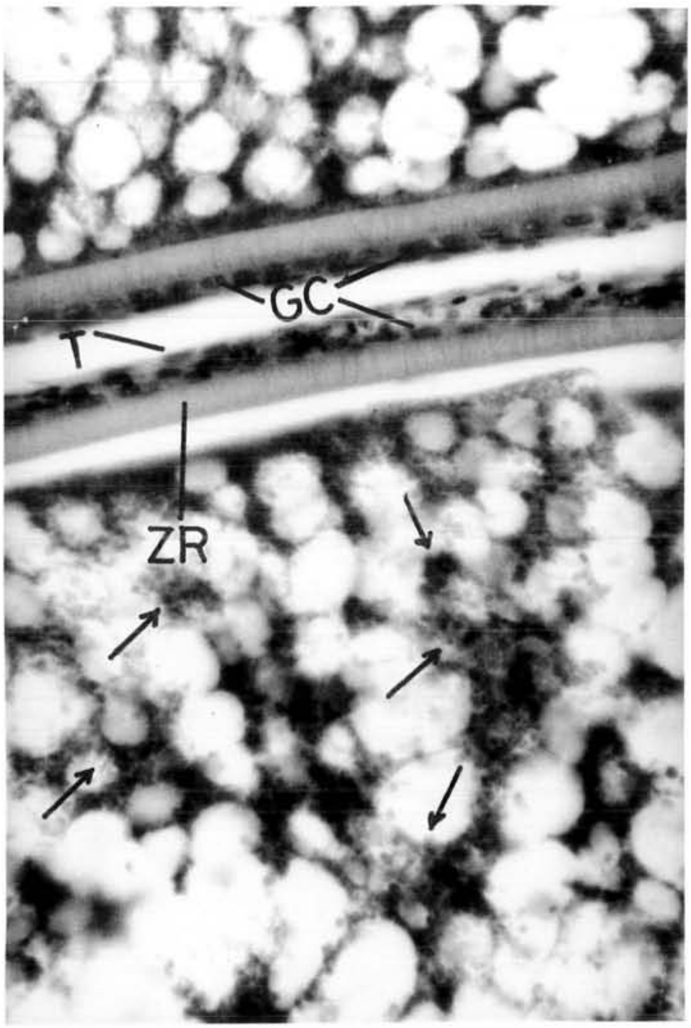
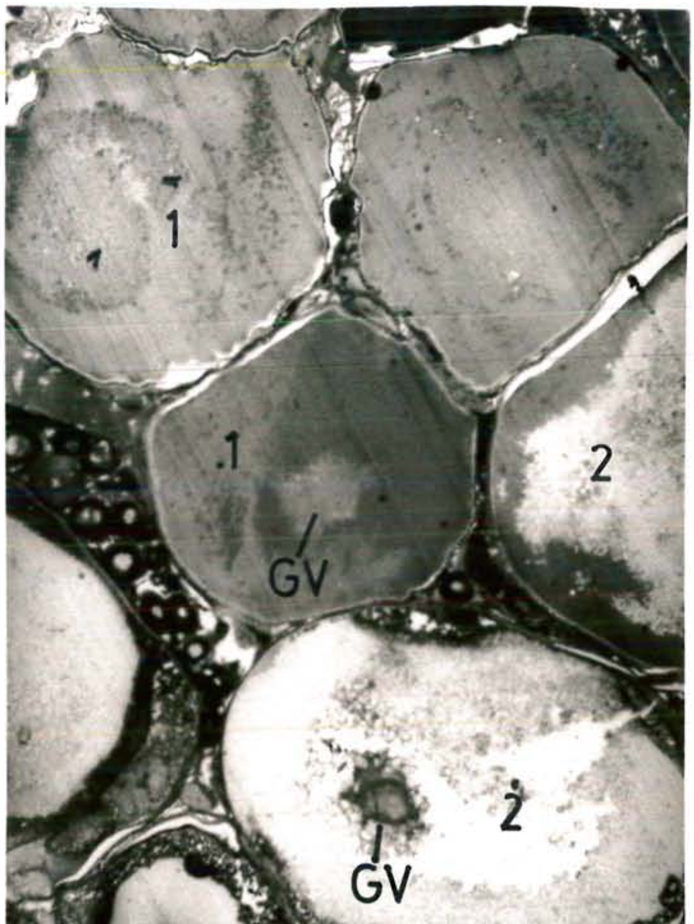


Fig.6



The germinal vesicle has migrated assuming an eccentric position. The nucleoli are scattered in the nucleus. The size of the oocytes increases to as much as 2.3 mm in diameter.

In the pre-ripening stage the germinal vesicle, when seen, lies next to the plasma membrane. In most cases the germinal vesicle cannot be seen presumably owing to loss of the nuclear membrane. The yolk vesicles lie in the immediate vicinity of the plasma membrane.

The final stage is the ripe ova stage. The ova are characterized by a distinct but thin layer of theca, granulosa cells and a thick zona radiata. The ooplasm is rich in yolk spherules. The ova appear yellow in color and are translucent. The largest oocytes measure 3.0 mm in diameter. The ova are often present loosely in the ovarian and oviducal cavity.

Seasonal ovarian rhythm:

When the histological and cytological classification of changes in the oocytes are assessed according to months and seasons it is possible to discern six stages of ovarian cycle.

Immature ovaries, stage I. The ovaries appear as slender and elongate structures with a pinkish tinge and characterize fish which occur all year round. The ovarian wall in thin and the lumen of the ovary is pronounced. It contains numerous oogonial nests and oocytes which have not yet advanced beyond the yolk vesicle stage. Most oocytes are in the perincleolus stage (Fig. 7).

Immature virgins and recovering spent, stage II. This stage comprises ovaries of virgin fish as well as of those which had spawned in the previous breeding season and are in the process of recovery. The spent ovaries are particularly distinguishable in late October and November on the basis of their collapsed state, dirty brown appearance, numerous postovulatory follicles and internal hemorrhage. The recovery process continues in the following months of December, January and February but in these months a clear distinction from the immature virgin ovaries is sometimes difficult to make. In the

Fig.7

virgin immature ovaries developmental progress beyond January the size increases and blood vessels are notable giving them a reddish color. Oogonial nests are predominant in December and January. The recovering fish contain oocytes (Figs. 8,9) in all stages upto tertiary yolk stage depending on the month. Ovaries with such oocytes occur as late as June.

Maturing: stage III. This stage is marked by considerable increase in size of the ovaries which now appear creamy yellow in color with the oocytes showing through the thin vascular ovarian wall. The ovarian cavity is reduced. The oogonia are proportionately few. The large oocytes (Fig. 10) fall in three main categories, namely, yolk vesicle stage, yolk stage and migratory stage. The most predominant of these are in the yolk vesicle and yolk stages. This condition prevails in early July.

Prespawning: stage IV. The ovaries now occupy almost 3/4 of the body cavity and are distended with ova imparting the ovaries a yellow color. The ovaries appear very vascular. Oocytes in the tertiary yolk and migratory

Fig.8

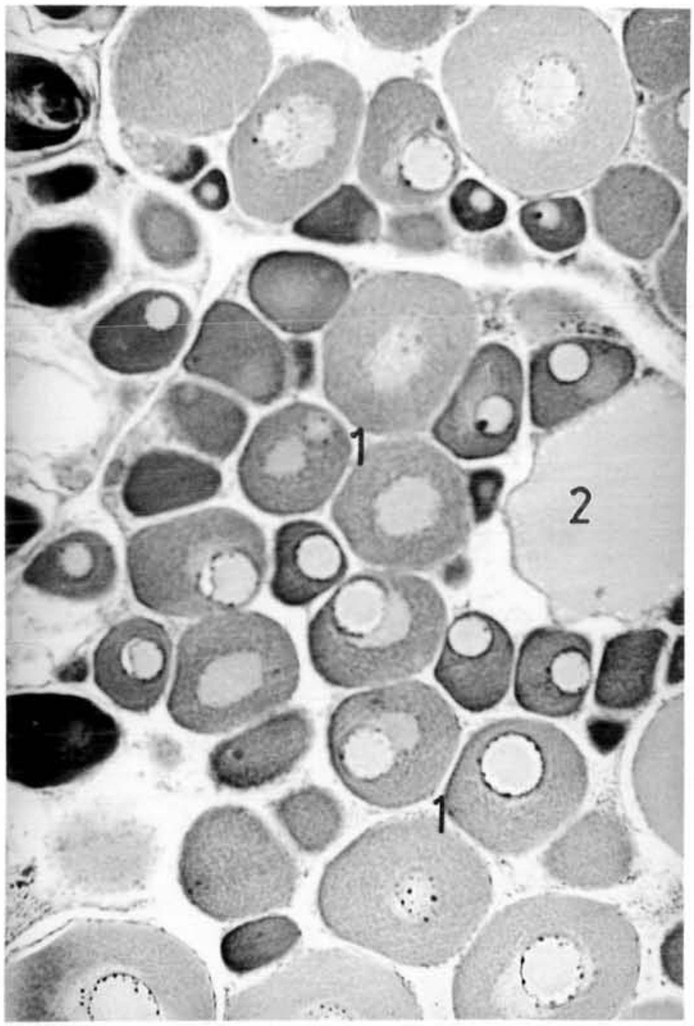
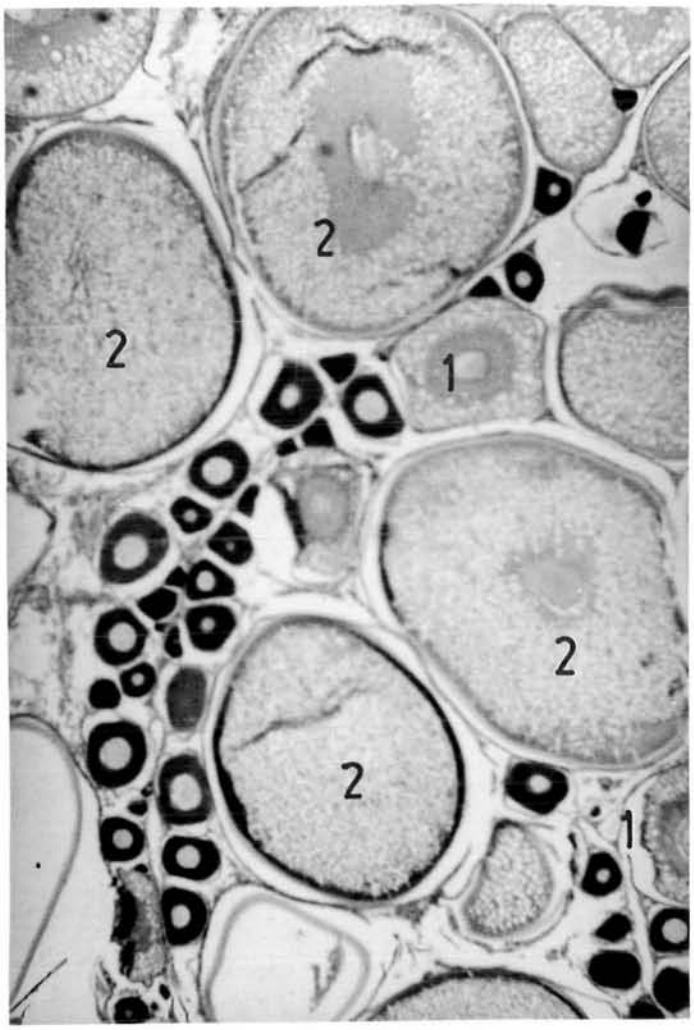


Fig.9

Fig.10



stages are preponderant (Fig. 6) although oogonia, and various earlier stages of oocytes are also present. This stage is quite common in late July and early August. Postovulatory follicles are not encountered at this time but few ripe ova are present. The oviduct is free of ova.

Spawning: stage V. The ovaries in the spawning stage with ripe ova fill much of the body cavity, the ovaries are turgid, yellow in color with a highly vascular and thin wall through which ova are readily seen. The oocytes are preponderantly in the ripe stage, appear translucent and are also often present loosely in the ovarian cavity. The oogonia are few. Oocytes in the perinucleolus, and in yolk stages are also present but are few. Atretic and discharged follicles start showing up in late August and become preponderant in late October. The first appearance of the spawning stage occurs in late July or early August and continues through September.

Spent: stage VI. This stage is encountered from mid September onward. The incidence of spent ovaries increases in October substantially when the ovaries appear collapsed and dirty brown in color. Histologically, the ovarian wall is still thin, there is evidence of dirup-tion of ovarian lamellae, (Fig. 11) considerable internal hemorrhage and invasion of follicles by phagocytes. The oogonia and the early stages of oocytes are prominent, and atretic follicles are seen frequently. Figure 12 shows part of a partially spent ovary collected in September.

Histological changes in the testis:

The testes are enveloped in coelomic epithelium surrounding the tunica albuginea (Fig. 13). Each testis consists of numerous seminiferous tubules (Lobules) which empty into the vas deferens through a network of spermatic ducts (vasa efferentia). The tubules are very conspicuous in maturing and ripe testes where these are enlarged and branch extensively but can be discriminated with difficulty in the immature individuals. Blood vessels and fibroblasts lie in the lobular interstices (Fig. 13) where interstitial cells (Leydig) are also interspersed. The seminiferous lobules consist of nests or cysts containing spermatogenetic and sertoli cells (Figs. 13, 14, 15). All cells in a cyst divide synchro-nously and are in the same stage of development. The

Fig.11

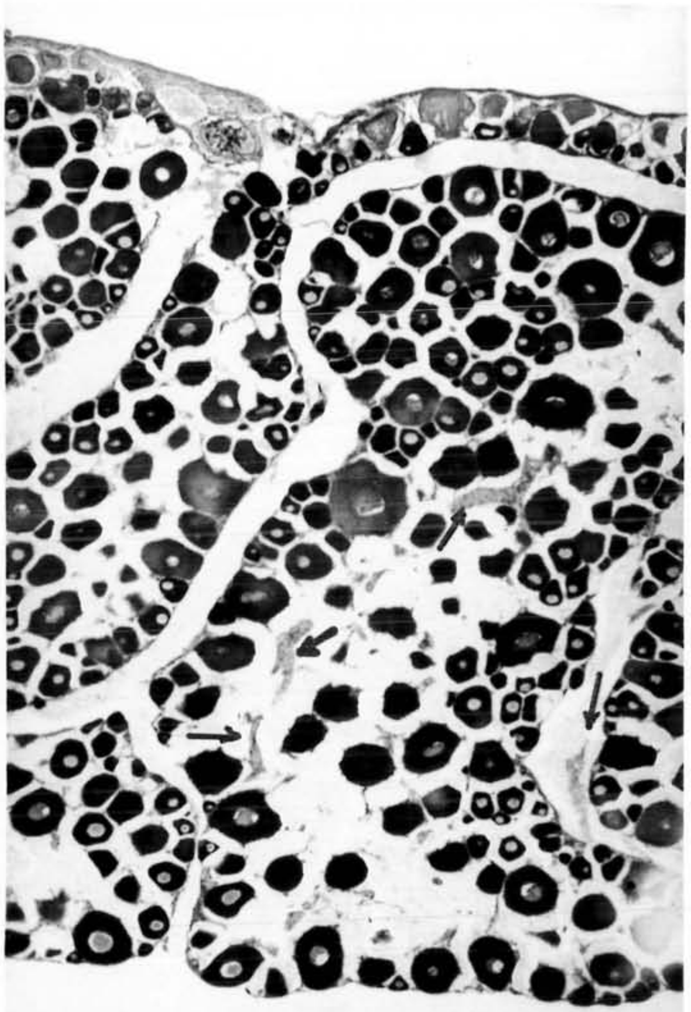


Fig.12

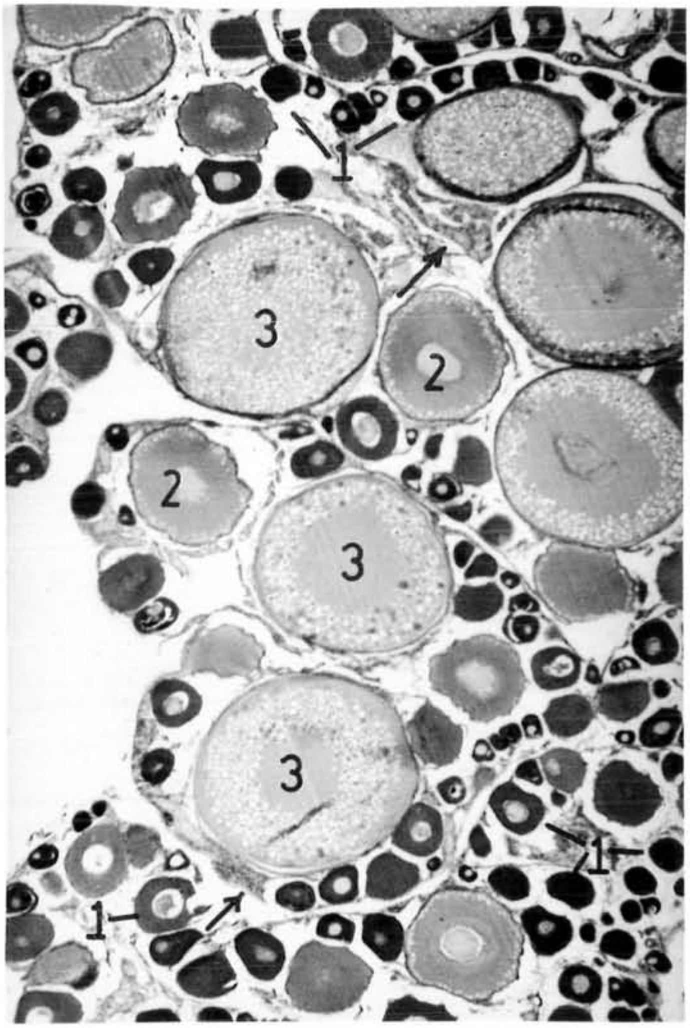


Fig.13

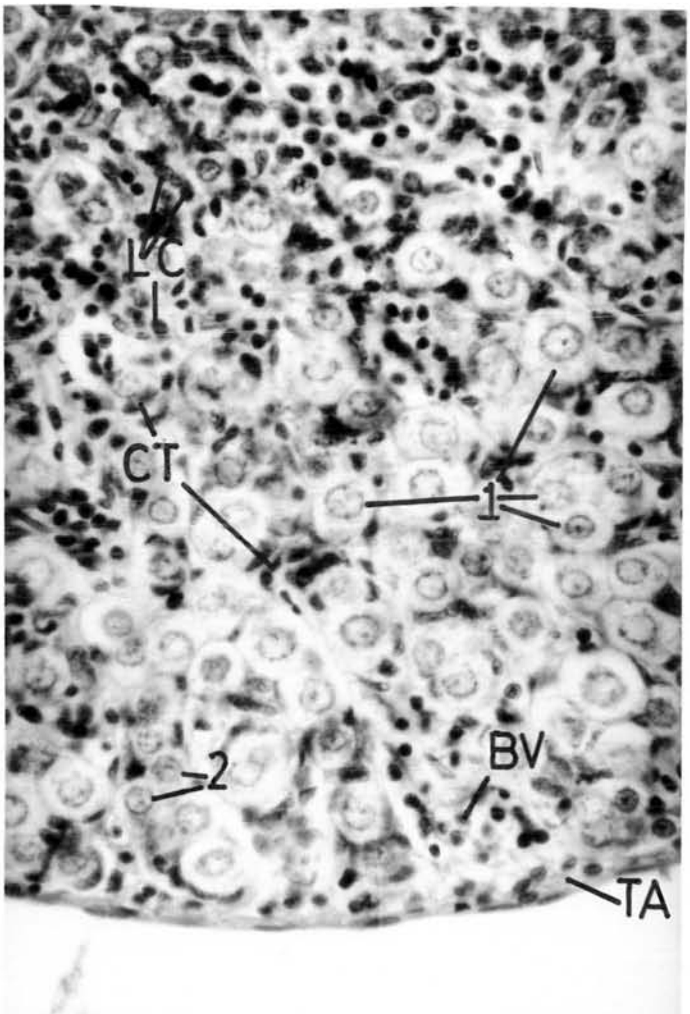


Fig. 14

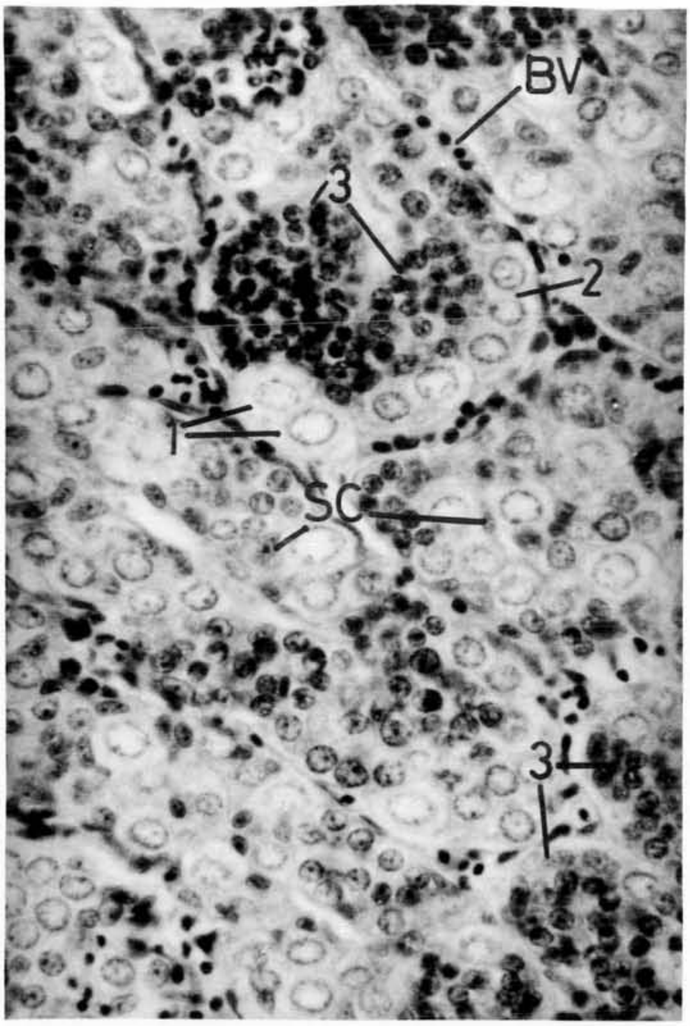
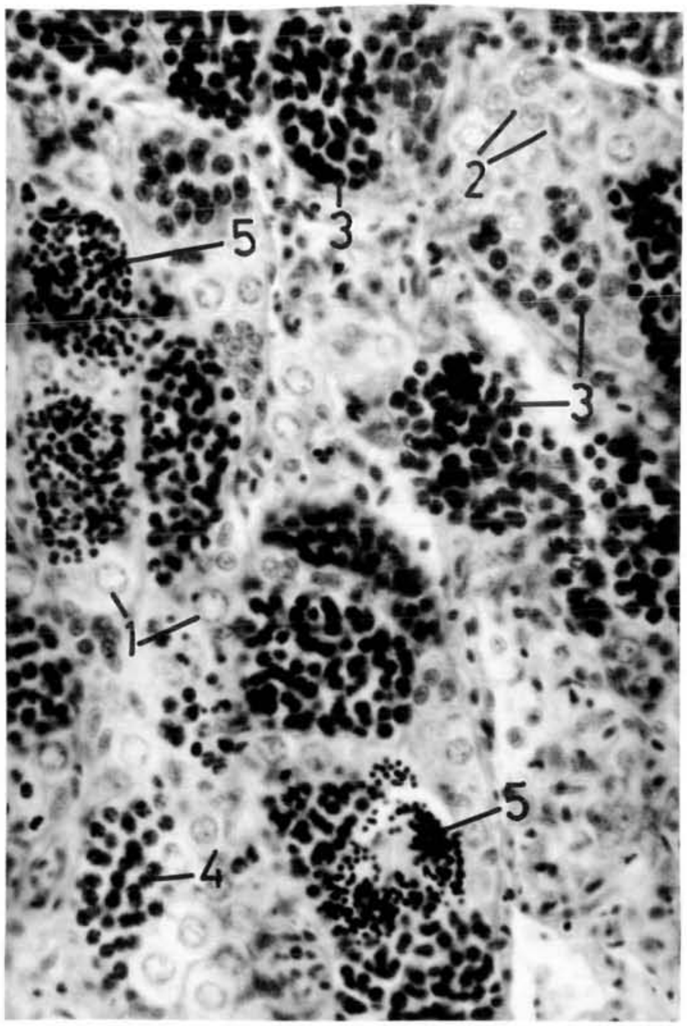


Fig.15



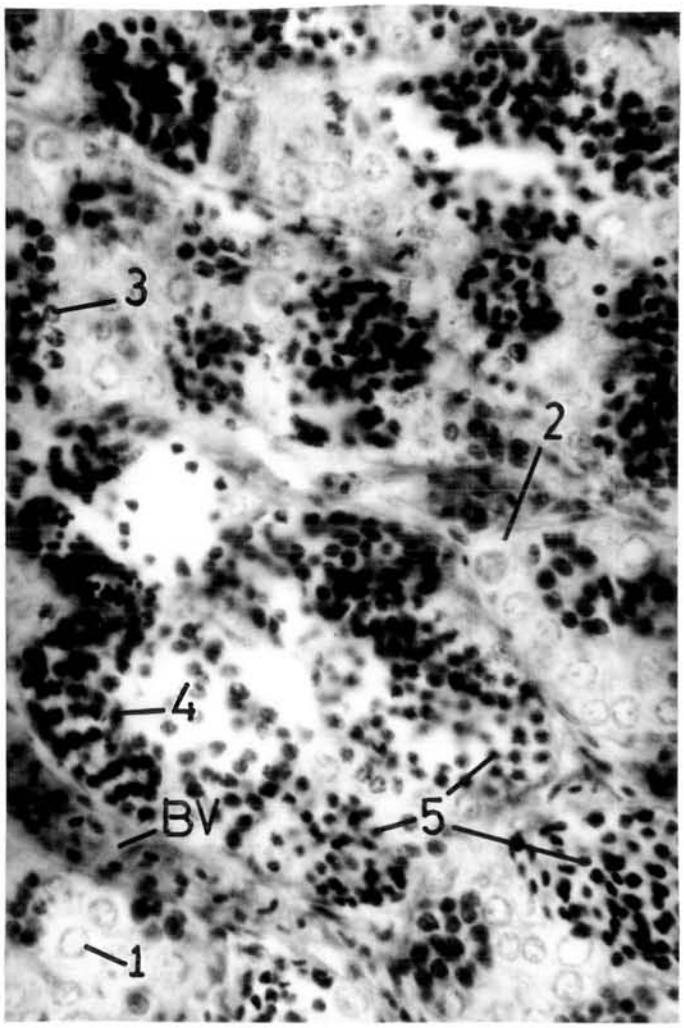
following details of spermatogenetic development are discernible.

The largest cells are the spermatogonia or mother cells. The primary spermatogonia divide mitotically and form secondary spermatogonia. The former are large clear cells with a large nucleus containing an acentric nucleolus (Figs. 13, 14). The chromatin material occurs near the nuclear membrane. The nuclei of these cells have a mean size of 10 μ . The secondary spermatogonia (Figs. 13, 14, 15) possess noticeably smaller nuclei (mean size = 7.5 μ ), containing a central nucleolus and denser chromatin imparting the nuclei a basophilic character.

The primary spermatocytes (Figs. 14, 15, 16) which arise from the secondary spermatogonia possess smaller nuclei (mean size = 5.25 μ ) which are very chromatic and show considerable variation in the distribution of chromatin material. Dividing cells in various stages of meiotic phases are also detected.

The secondary spermatocytes (Figs. 15,16) are

Fig.16



seldom detectable. Their nuclei are considerably smaller with deeply stained chromatin material forming a clumpy mass in the nucleus.

The spermatids (Figs. 15, 16, 17, 18) possess small, round, extremely hematoxyphilic nuclei with a mean diameter of 2.25 μ . The chromatin material varies in degree of condensation and often appears U-shaped. These cells transform into spermatozoa (Figs. 17, 18) which are easily distinguishable forming massive clumps in the lobules, spermatic ducts and the vas deferens. Their nuclei are very small (mean size = 1.3 μ ).

Seasonal testicular rhythm:

The rhythmic development of the testis occurs in 4 seasonally definable stages. The first is the resting stage (Fig. 13) extending from November to January. Histologically, the testes appear very stromal (infiltrated with interlobular septa containing connective tissue cells and interstital cells) and possess small lobules rich in primary and secondary spermatogonia (Fig. 13). The spermatocytes are rare or are entirely absent. The cysts are small, each containing a single

Fig.17

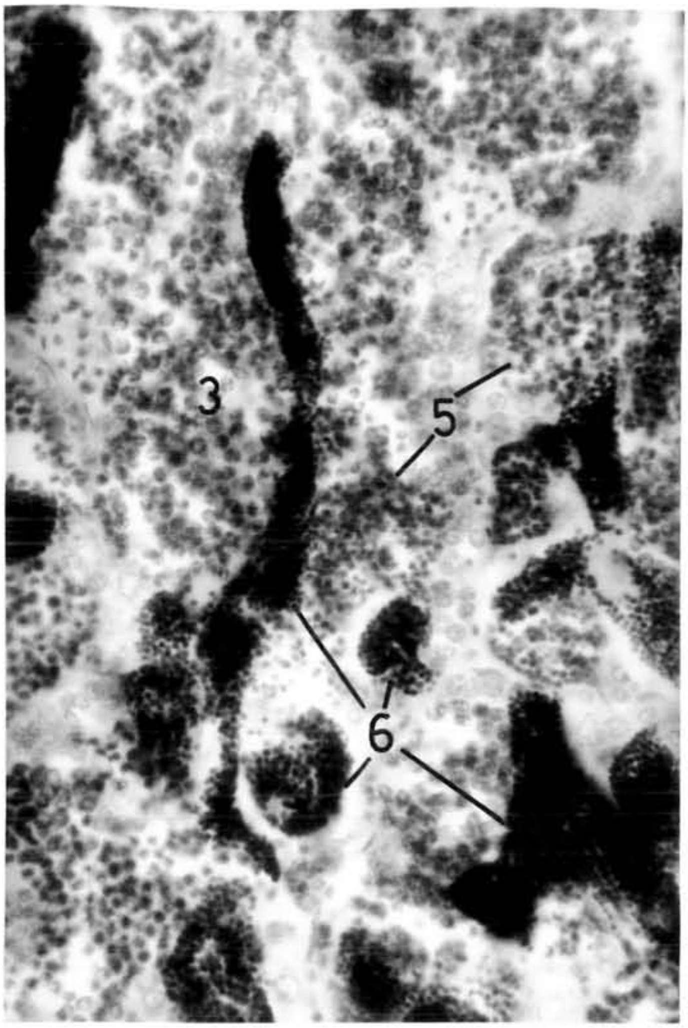
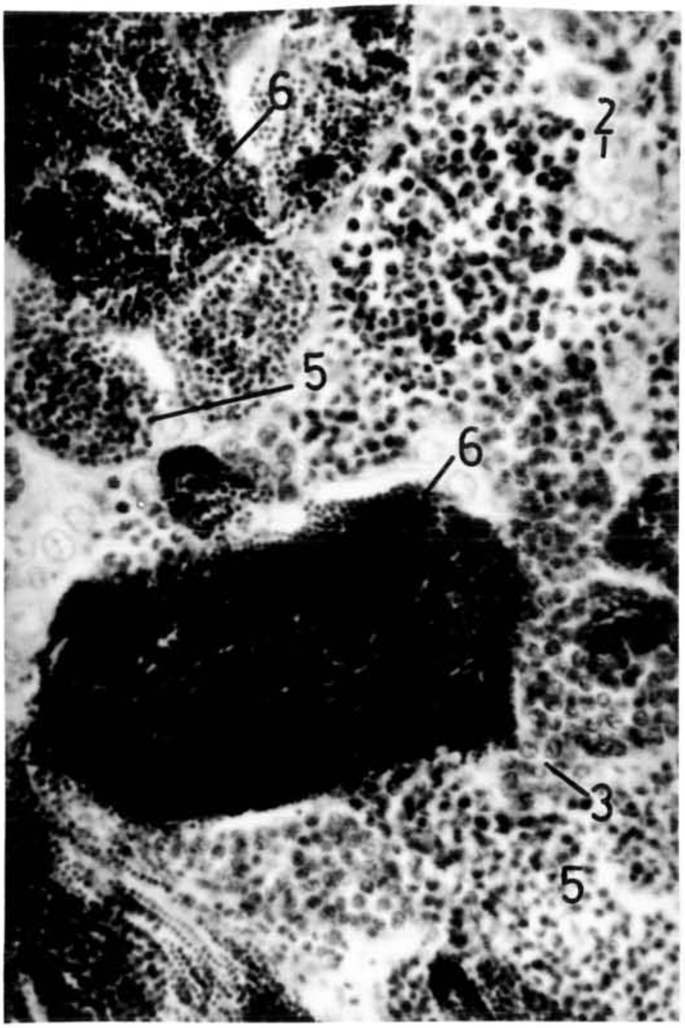
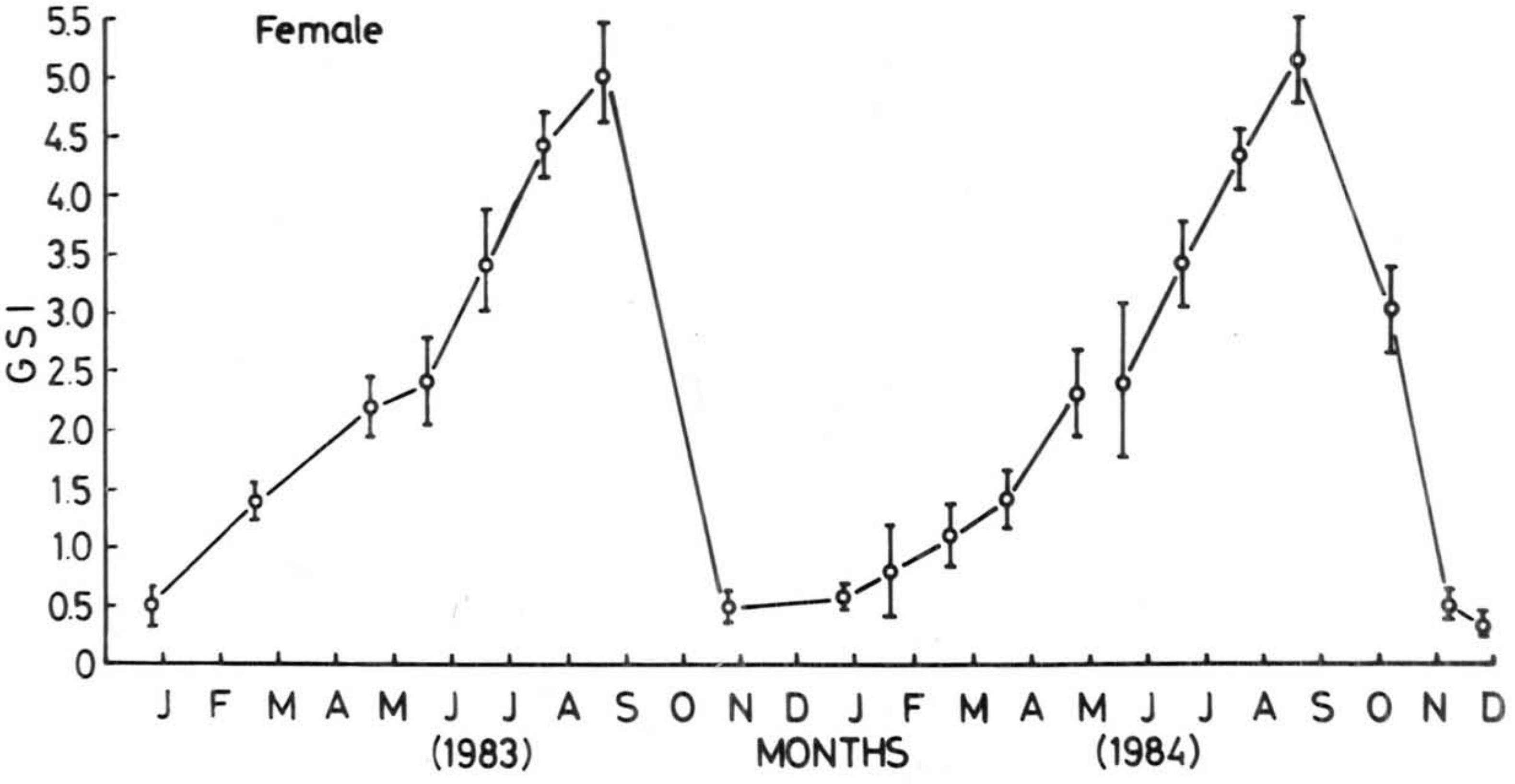


Fig.18



spermatogonium. In the second stage (Fig. 14), the testes appear in the process of maturation with a progressive shift in relative abundance of advanced spermatogenic cells. Already in February, the secondary spermatogonia and the primary spermatocytes increase in volume and there is a corresponding increase in the lobular size and their branching. The number of cells in the cysts has increased. In April, the primary spermatocytes are the most preponderant cells but often secondary spermatocytes and spermatids are also encountered (Fig. 15). In May, June and July the spermatids predominate (Figs. 16, 17). Most cysts are studded with them. The size of the lobules has increased and spermatozoa frequently occur in the cysts and in the spermatic ducts not only in July but sometimes also in May and June. In the next stage which represents the period of ripening testes, the lobules appear distended, the cysts are studded with spermatids and spermatozoa (Fig. 18) which also fill the cavity of the lobules, the spermatic ducts and the vas deferens. Spermatogonia are present but are relatively sparse, the interlobular septa are thin, blood vessels are prominent and the Leydig cells are conspicuous. This period lasts from late July to end of September and early



Female
GSI
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0
J F M A M J J A S O N D J F M A M J J A S O N D
(1983)
MONTHS
(1984)


Fig.19

corresponds with the period of rapid vitellogenesis as is evident from histological criteria. The ovary appears in the process of maturation. The fish having reached this GSI value are bound to become ripe and spawn in the current spawning season. The GSI values of less than 3% correlate with ovaries containing earlier stages of the oocytes.

Length and weight at first maturity: Females.

Figure 20 shows GSI changes in the female according to length classes for the years 1983 and 1984. In both years the pattern turned out to be quite comparable. Only females measuring 326 mm ( S.L. ) or greater reach values of nearly 5%. Smaller fish fail to mature. Similarly, fish with body weights greater than 550 g achieve values of 4% or greater (Fig. 21) during the years 1983 and 1984. It again appears that once a GSI value of 3% or greater is achieved the fish are destined to become ripe and spawn in the current breeding season. The data reveal that the females reach first maturity at a mean size of 326 mm (S.L.) and 551 g.

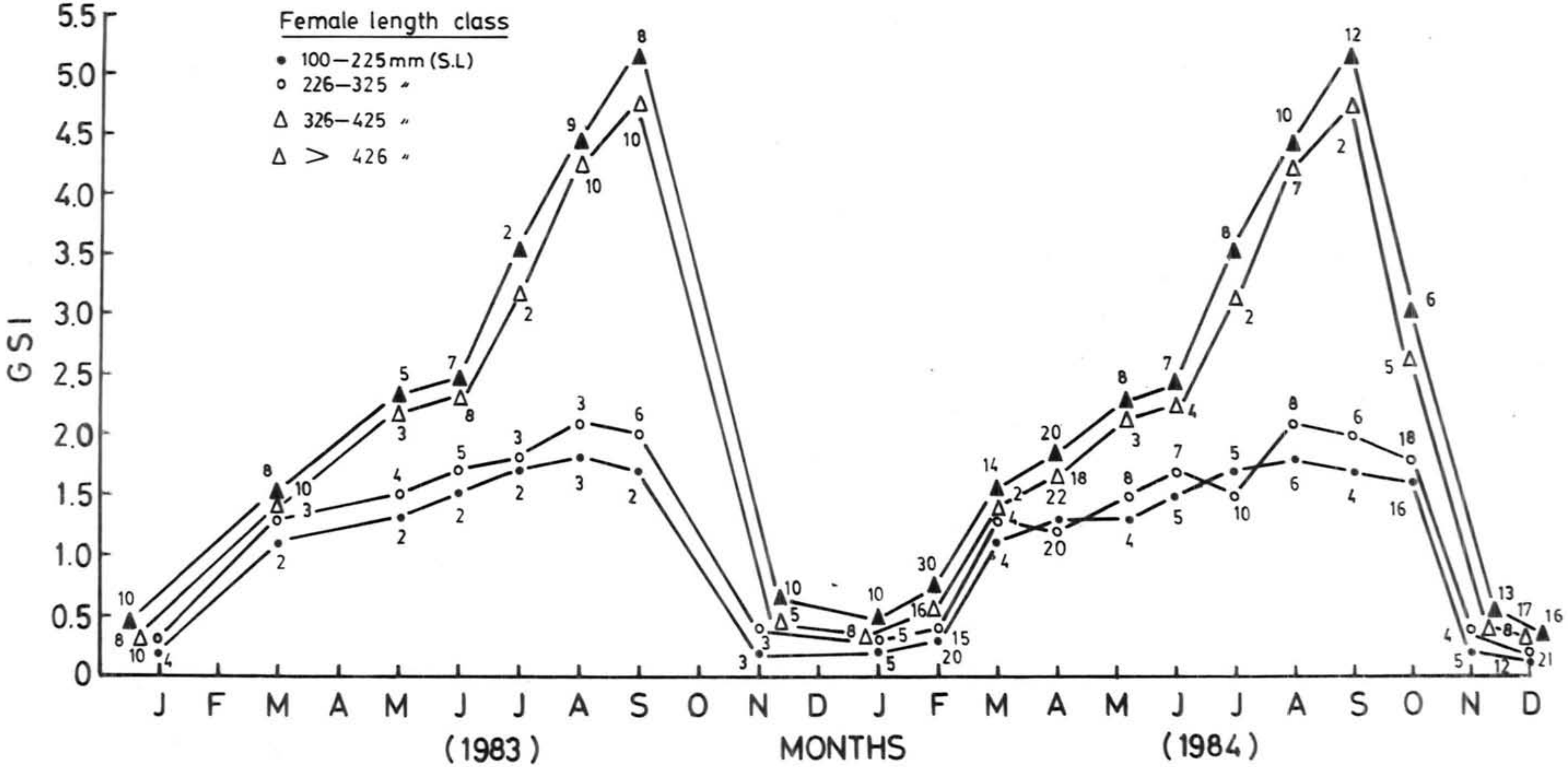

GSI
Female length class
• 100–225mm (S.L)
o 226–325 "
Δ 326–425 "
Δ > 426 "
MONTHS
(1983)
(1984)
J F M A M J J A S O N D J F M A M J J A S O N D

Fig.20

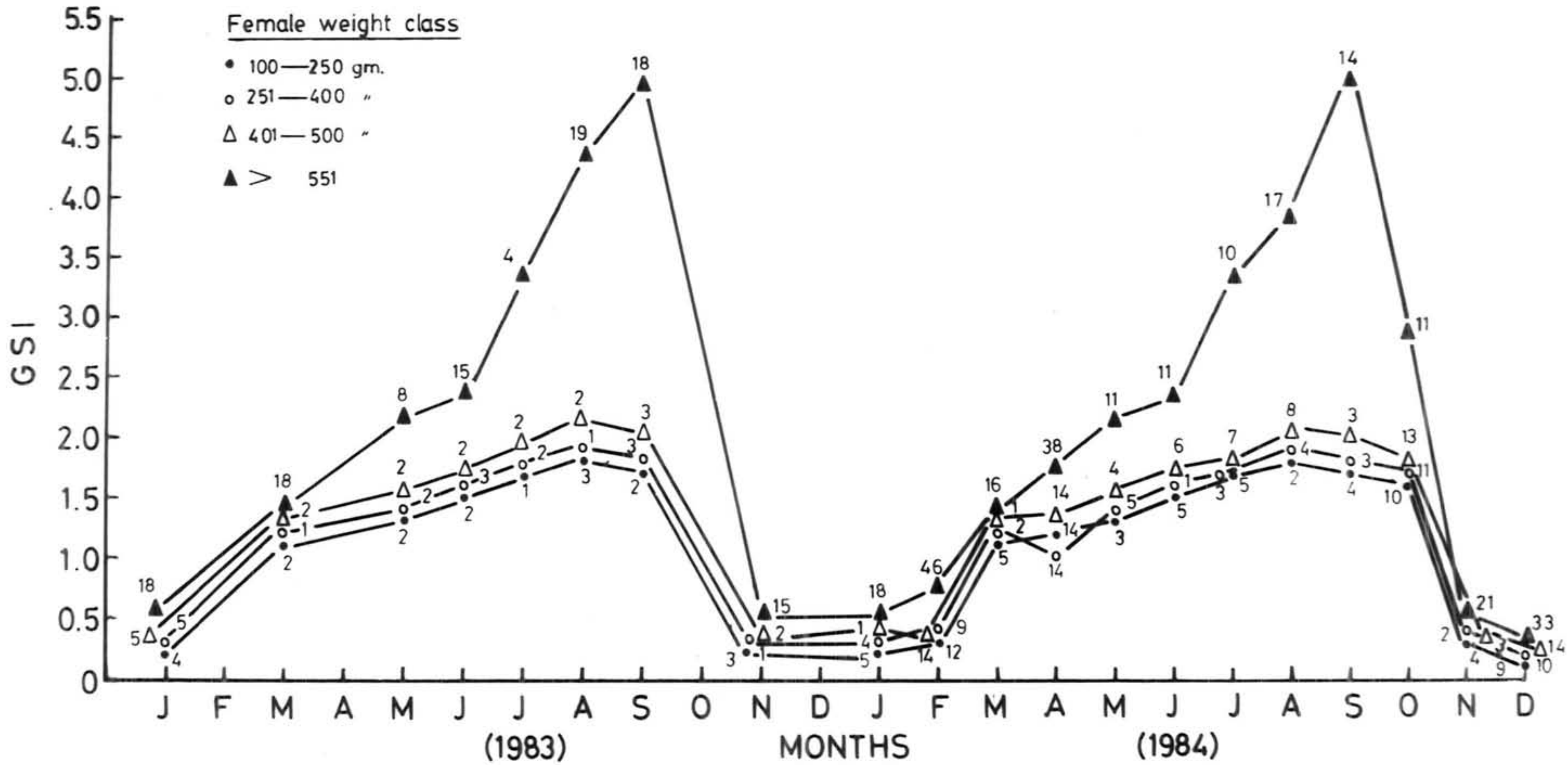

Female weight class
100—250 gm.
251—400 "
401—500 "
> 551
GSI
MONTHS
(1983)
(1984)
J F M A M J J A S O N D J F M A M J J A S O N D

Fig. 21

Age at first maturity: Females.

In order to establish a correlation between age and maturity all individuals having attained a mean GSI of 3% or greater were taken to be mature. Accordingly, percent of the samples showing mature ovaries have been plotted against age and shown in Fig. 22. Almost 90% of the sample showed first maturity at the age of 3 years. The percentage of mature females in the older age groups varied but the maximum value was recorded for age groups 7 and 8 (Fig. 22). None of the samples containing female fish younger than 3 years showed maturity (Fig . 22).

Male GSI:

Seasonal changes in the mean GSI for the males during the years 1983 and 1984 are shown in Fig. 23. The values rise from 0.3% and 0.2% in January to 0.9% and 0.8% in March in 1983 and 1984 respectively. Between May and July the values change to 3%. The highest GSI values occur in August and September (range 4.0 - 4.8%, 1983-1984) followed by a decrease to 0.4% and 0.3% in November.

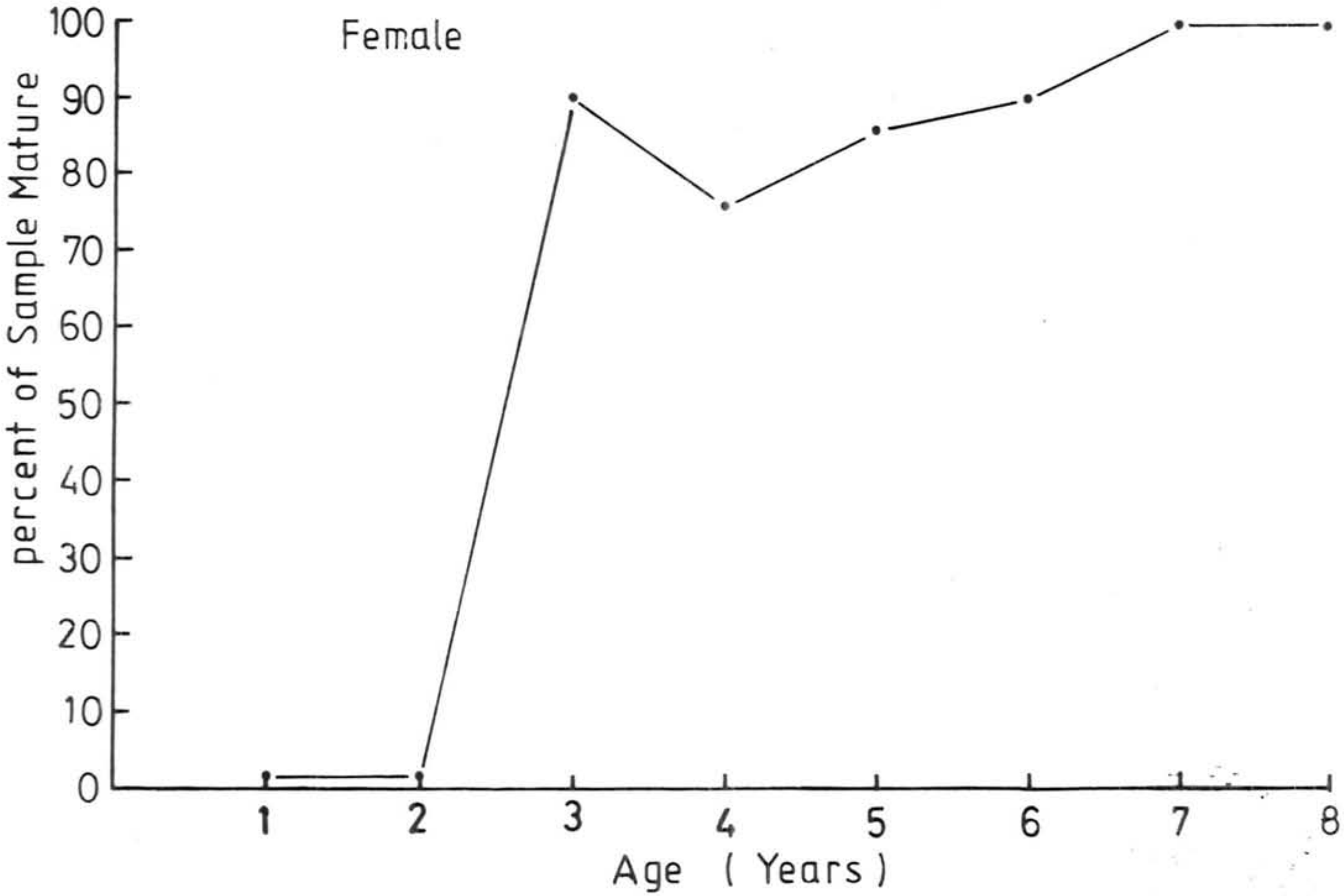

Female
percent of Sample Mature
100
90
80
70
60
50
40
30
20
10
0
1
2
3
4
5
6
7
8
Age ( Years )

Fig. 22

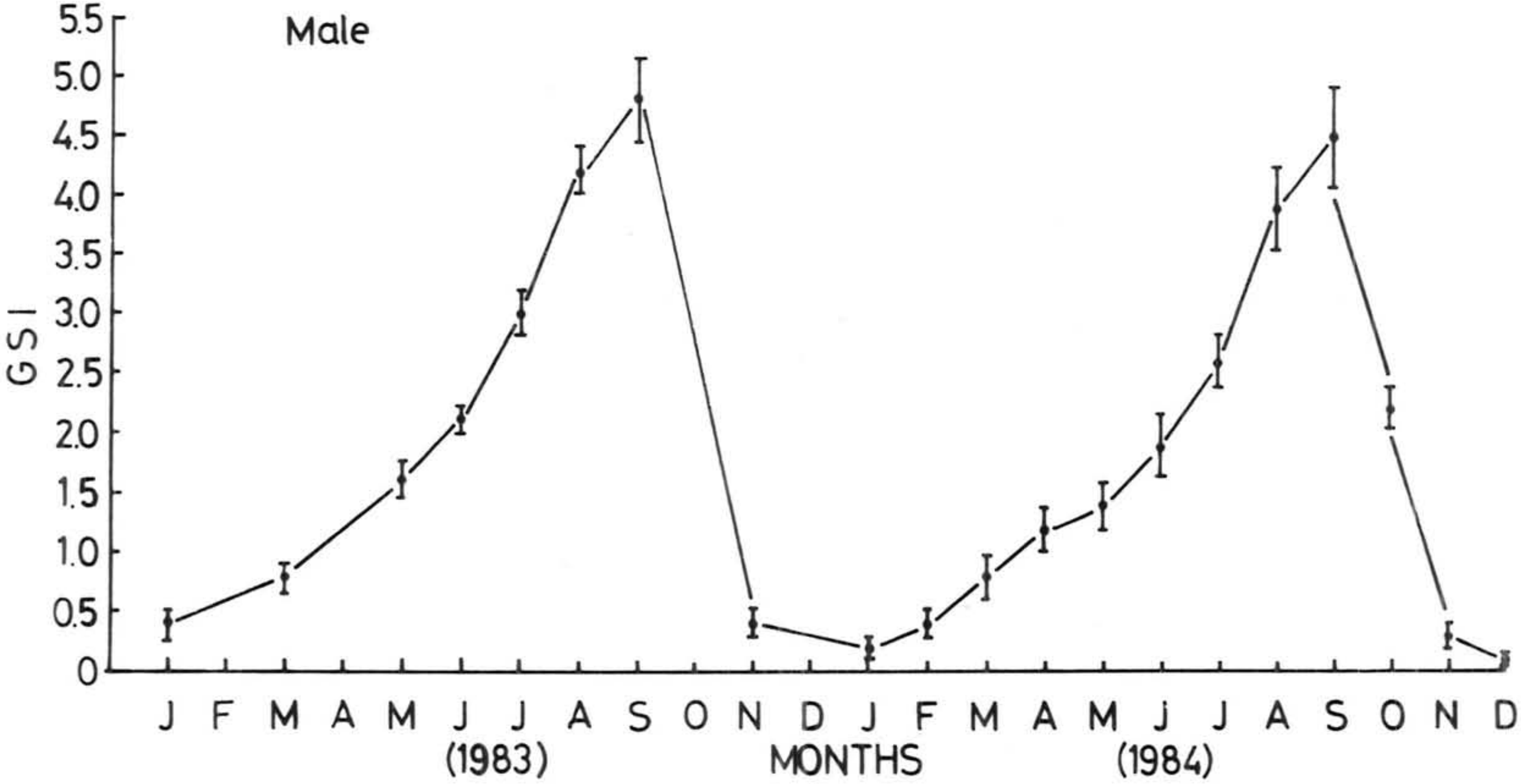

Male
GSI
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0
J F M A M J J A S O N D J F M A M J J A S O N D
(1983)
MONTHS
(1984)

Fig. 23

## Length and weight at first maturity: Males.

When the GSI is compared with fish length, the pattern is similar for the years 1983 and 1984 (Fig. 24 ). All male fish above 170 mm ( S.L. ) reach maturity and maintain a high mean GSI in August and September. The change is progressive with a gradual rise to peak values. Males smaller than 170 mm were not available during the year 1983. However, in 1984 this length class occurred in the samples and the data show that such males fail to achieve maturity (Fig. 24 ). Similarly males weighing less than 104 g fail to reach maturity (Fig. 25). All males above 104 g in weight become ripe ( Fig. 25 ). The data for the year 1984 indicate that the average size of males at first maturity is 171 mm ( S.L. ) and 104 g.

## Age at first maturity: Males.

According to the criterion described in the earlier section, first maturity in the males occurs in the 2nd year and later since over 90% of the sample appears to be mature ( Fig. 26 ). This percentage varies for older males but the difference is only slight. It

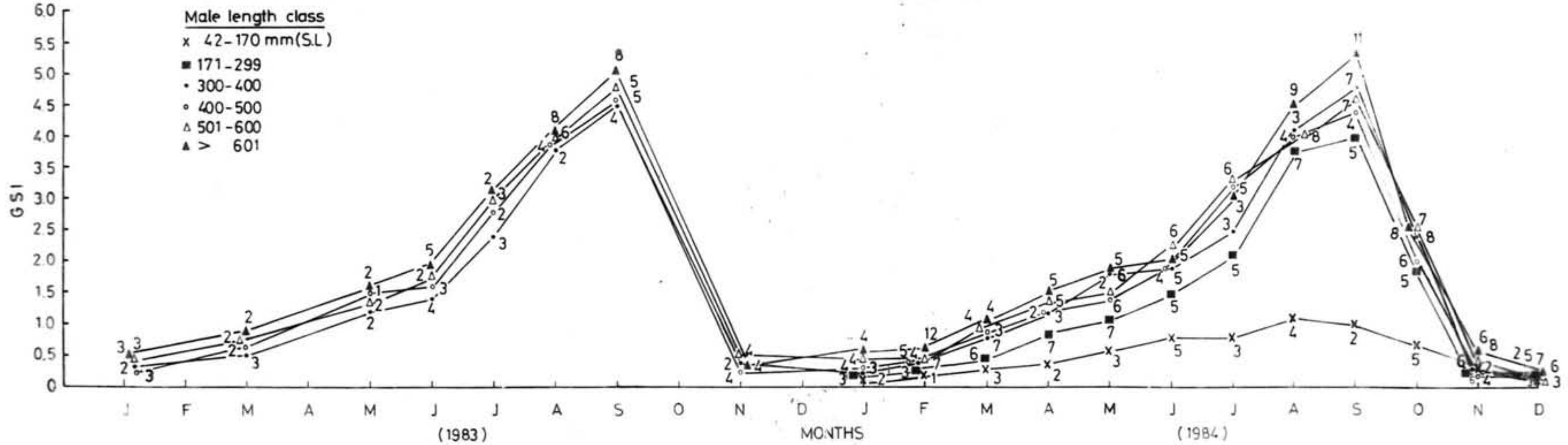
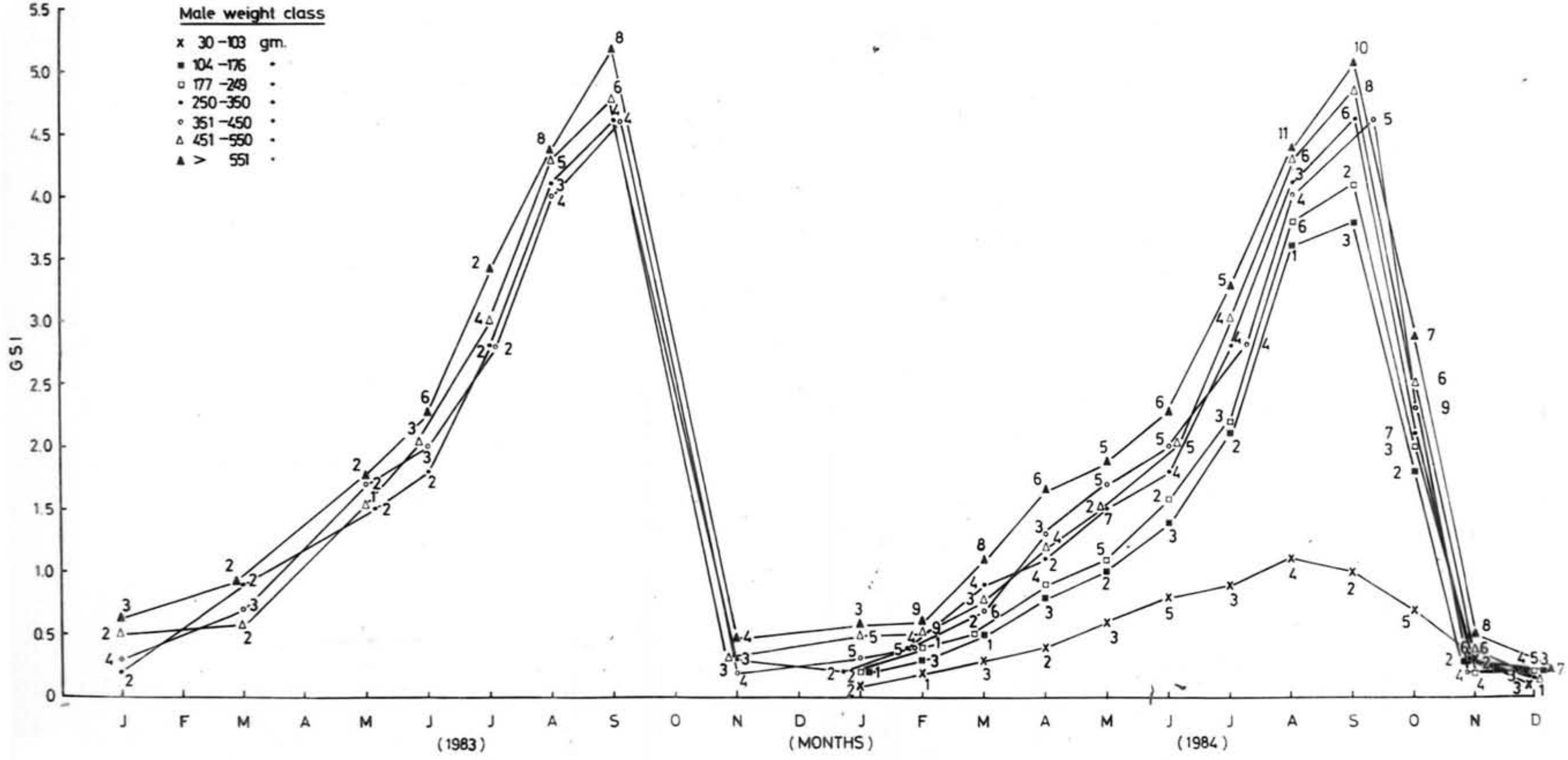
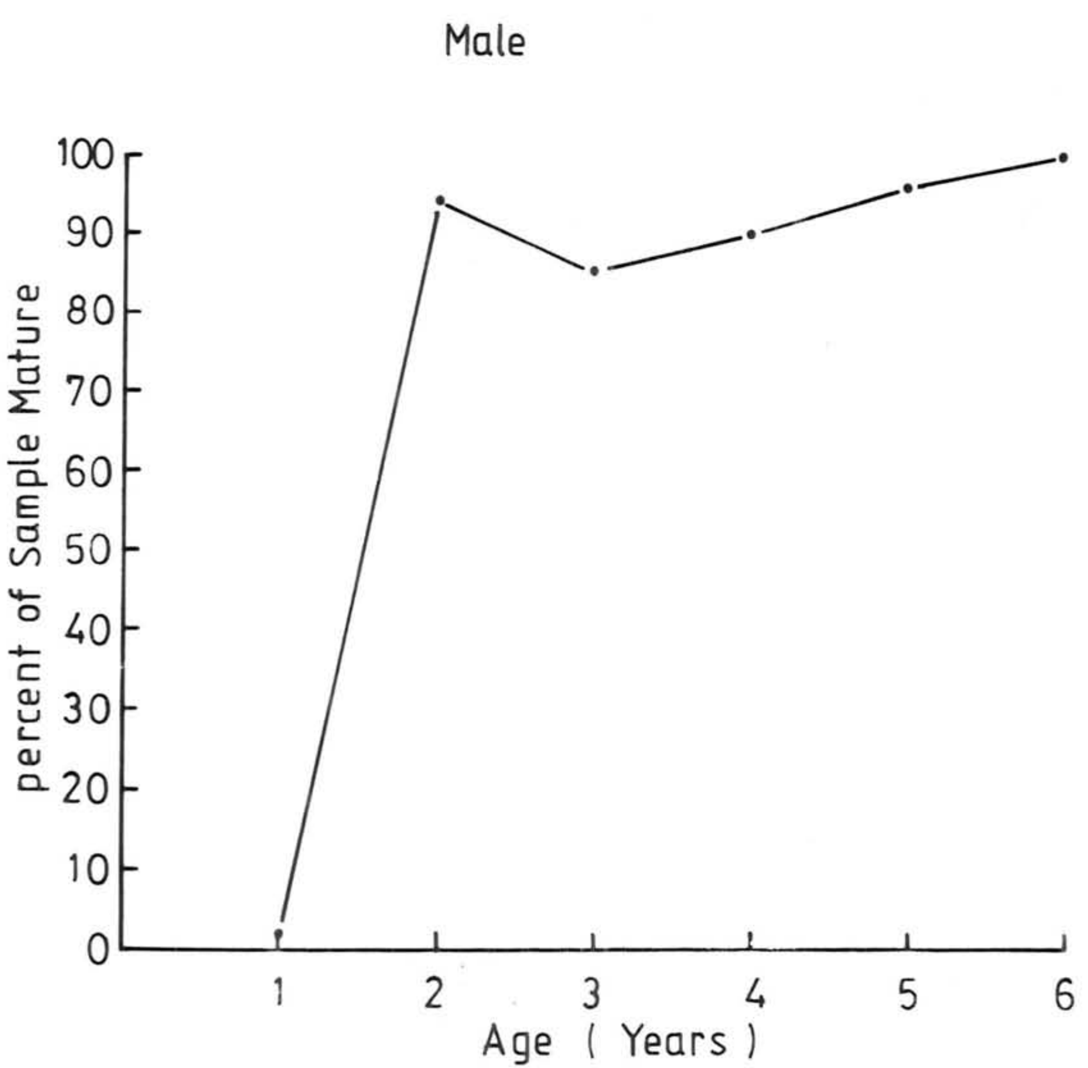

Male length class
x 42-170 mm (S.L)
■ 171-299
• 300-400
∘ 400-500
△ 501-600
▲ > 601
GSI
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0
J F M A M J J A S O N D J F M A M J J A S O N D
(1983)
MONTHS
(1984)

Fig.24



Male weight class
x 30-103 gm.
■ 104-176 "
□ 177-249 "
• 250-350 "
○ 351-450 "
△ 451-550 "
▲ > 551 "
GSI
J F M A M J J A S O N D J F M A M J J A S O N D
(1983)
(MONTHS)
(1984)


Fig.25

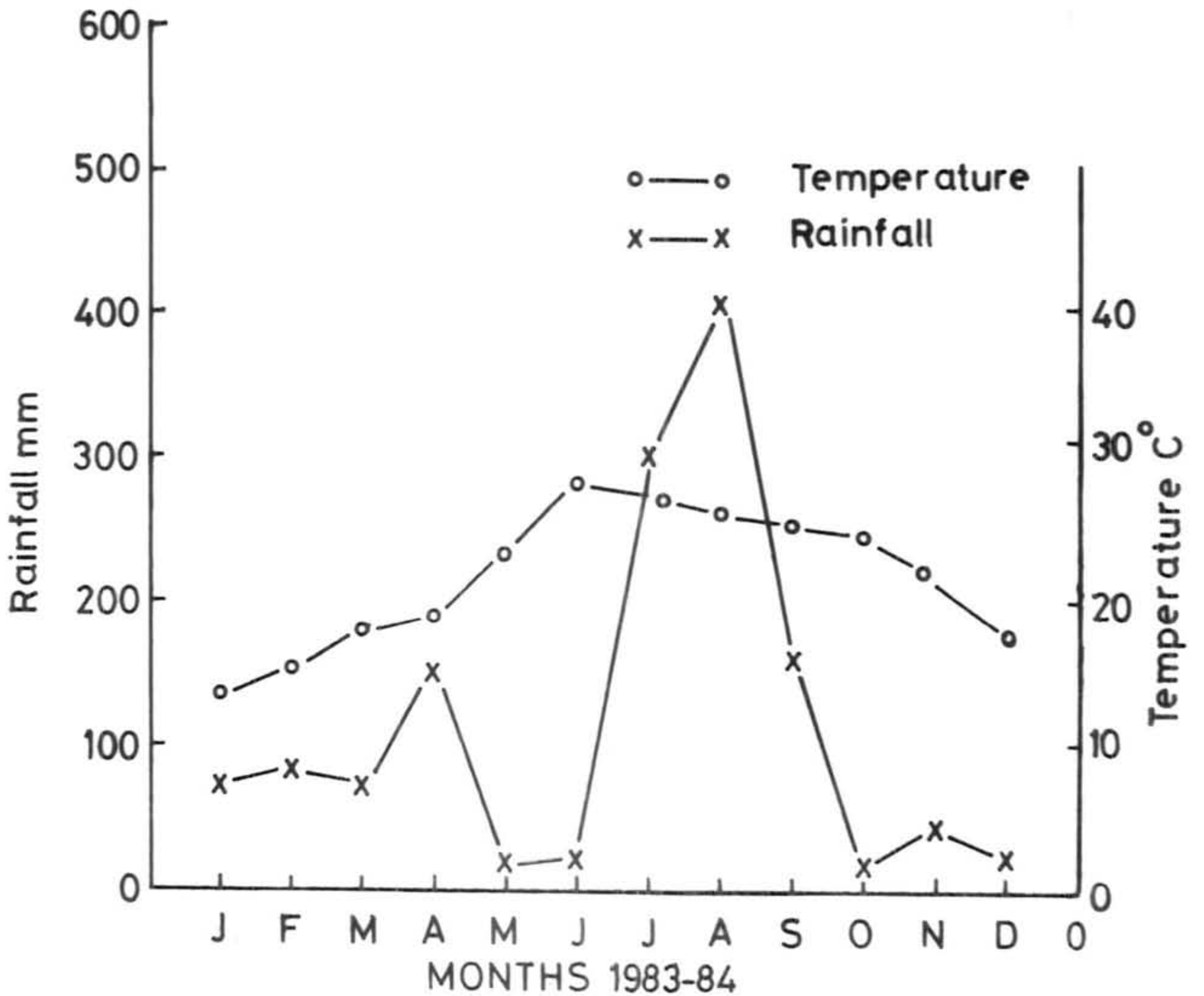

Male
100
90
80
70
60
50
40
30
20
10
0
percent of Sample Mature
1
2
3
4
5
6
Age ( Years )
Fig. 26

should, however, be noted that rarely specimens of 1-year old males (180 mm and 110 g) have been collected during this study which possess running testes (ripe and spawning condition).

RAINFALL AND TEMPERATURE DATA.

Figure 27 shows seasonal variations in rainfall in the Islamabad area (data for the years 1983 and 1984 averaged: Department of Meteorology, Government of Pakistan) and surface water temperature ( $^{o}C$ ) of the Rawal Lake. The period July to September represents the monsoon season with a high incidence of rainfall. A small peak occurs in April. The water temperature (Fig. 27 ) gradually rises from a January low of $12^{o}C$ to a peak in June ($28.5^{o}C$). A gradual drop in temperature coincides with the onset of monsoon rains. The temperature drops to $17^{o}C$ in December.

The beginning of rainfall and a decline in temperature show a strong correlation with the onset of breeding in July - early August. During the breeding season, July to early October, the prevailing water temperatures range from $27^{o}C$ to $24.8^{o}C$.


Temperature
Rainfall
Rainfall mm
600
500
400
300
200
100
0
Temperature C°
40
30
20
10
0
J F M A M J J A S O N D 0
MONTHS 1983-84
Fig. 27

## Discussion

A number of different approaches have been commonly utilized in the study of seasonal gonadal rhythm and spawning habits of fishes. Of these histological and gonadosomatic indices have been considered of particular value especially when the two methods are combined. The histological method has the advantage of revealing directly the rhythmic development of the ovaries and the testes and the changes through which the germ cells pass during the year. Yamamoto and Yamazaki (1961) have shown that the histological criterion for defining the spawning rhythm is substantially more reliable than the egg frequency curve method. In the present study on the putitora mahaseer the histological and gonadosomatic criteria show that this species achieves breeding condition in late July with peak spawning occurring in August and September.

The details of histologically discernible changes in the ovaries of the putitora mahaseer are nearly comparable to those presented by Rai (1967) for the tor mahaseer (*Tor tor*). In the resting state the ovary is rich in oogonial nests from which oocytes arise and which subsequently undergo progressive development forming ripe and ready to spawn ova. During this progressive shift, it is possible to delineate a series of cytologically definable stages, namely, (1) chromatin nucleolus, (2) perinucleolus, (3) Yolk vesicle, (4) early to late Yolk, (5) migratory nucleus, and (6) early to late ripe (ripening and ripe) stages in oocyte development. This pattern is not unique to the putitora mahaseer but characterizes the oogenetic cycle in oviparous fish in general (see Yamamoto, 1956; Yamamoto *et al.*, 1959; Yamamoto and Yamazaki, 1961; Rai, 1967; Htun-Han, 1978, Takahashi, 1981) with minor cytological variations. One of the noteworthy features of the ovary of the putitora mahaseer is that all oocytes do not develop synchronously. Instead several stages of developing oocytes occur in the ovary suggesting that spawning takes place more than once in the breeding season. Marza (1938) has provided useful information on this subject showing that oocyte development is either synchronous or asynchronous depending on species. Species with asynchronous development have an extended breeding season with spawning occurring more than once in the same breeding season (see also, Yamamoto, 1956, Yamamoto *et al.*, 1959; Vladykov, 1956; Ishida *et al.*, 1959; Yamamoto and Yamazaki, 1961; Rai, 1967). Rai (1967) and Desai (1973) have also found that the tor mahaseer breeds more than once during the breeding season as evidenced by asynchronous development of the oocytes (several modes of ova in the ovary). In the putitora mahaseer, at least two advanced stages of oocytes, Yolk stages and ripe ova occur in the ovary between July and October. The Yolk stage is the period of rapid vitellogenesis reflecting active maturational progress and as the ripe ova are shed the other advanced stages follow in succession during the same spawning season.

The seasonal rhythm in ovarian development in fishes has usually been classified into seven stages (stages 1-7, Wood, 1930) and although numerous variations in staging have been practiced, most conform to the classification proposed by Wood (1930). Noteworthy reports in this respect are those given by Marza (1938), Clark (1934), Hickling and Rutenberg (1936), Andreu and Pinto (1957), Gokhale (1957), Bhatnagar (1964), Rai (1967), Desai (1973), Chaturvedi (1976) and Takahashi (1981). In the present work on the putitora mahaseer the histocytological changes in the developing ovaries, shifts in the size of oocytes, vascularity and color of the ovary have been used collectively to evolve a final classification of the seasonal ovarian rhythm into six stages (stages I-VI). Accordingly, there appears to be a progressive development of the ovary and oocytes from January onward with vitellogenesis in the oocytes occurring actively in July. Fully ripe oocytes predominate in the enlarged ovaries (histological stages IV-V) in August and September. In early to middle October ripe oocytes persist but the ovaries contain numerous post-ovulatory and atretic follicles along with Stage I-III oocytes. By November, the ovaries are entirely spent (Stage VI) and collapsed with only occasional residual ova, numerous post-ovulatory follicles, Yolk vesicle, earlier stages of oocytes, and abundant evidence of internal hemorrhage. The immature oocytes and the oogonial nests represent a source of recruitment of oocytes for spawning in the succeeding year.

The fact that the putitora mahaseer breeds between late July and September or as late as early

October is not only reflected in the gonadal morphology but is also corroborated in this study by the seasonal pattern of the gonadosomatic index (GSI). The mean GSI rises to nearly 3% in July. This is also the time when vitellogenesis is occurring actively and there is a substantial increase in the size of the oocytes. Such oocytes have been taken, in this study and by other workers as well working on other species of fish (Rai, 1967; Martinez and Houde, 1975; Pathani, 1983), to be well on their way toward the ripe spawning state. There is also close correspondence between the mean GSI values in August and September and the preponderance of ripening and ready to spawn ova in these months. Such a close correspondence in GSI and histologically discernible maturation of the ovary has been noted in the tor mahaseer by Rai (1967), Desai (1973) and Chaturvedi (1976), in the queen fish (*Seriphus politus*) by De Martini and Fountain (1981) and in other species as well (Martinez and Houde, 1975; Pathak and Jhingran, 1977).

In contrast to the ovarian changes, those in the testes appear less dramatic. With the exception of the work by Rai (1965) on the testes of the tor mahaseer none of the past studies on the spawning habits and gonadal maturation of the mahaseers has described the seasonal rhythm in the testes. Whereas Pathani (1981; 1983) has described the breeding biology of the putitora mahaseer, no published information is available on the testicular rhythm in this species. Although excellent accounts of spermatogenetic rhythm in the testes of fishes are available in the literature (Turner, 1919; Foley, 1926; Hoar, 1957; Hendersen, 1962; Ahsan and Hoar, 1963; Belsare, 1966; Hyder, 1969; Bisht, 1974; Shreshtha and Khanna, 1978; Swarup and Srivastava, 1978; Panday and Misra, 1981; Andrade and Godinho, 1983), the results of the present study on testicular maturation can hardly be fully assessed in the absence of detailed histocytological descriptions of the testes for the various mahaseers. The rhythmic pattern of the spermatogenetic changes in the testes of the tor mahaseer (Rai, 1965) shows good conformity with the morphocytological changes in the testes of the putitora mahaseer with the exception that differences exist in respect to the seasonal period during which maturational progress occurs in the two species. The testes of the putitora mahaseer are shown here to display progressive maturation from a quiescent stage in the winter. Spermatogenetic events start occurring in late February and March when primary spermatocytes are noticeable for the first time.

However, there is a predominance of primary and secondary spermatogonia, the testes are small, poorly vascularized and appear highly stromal. It is interesting that whereas the ripening of the ovary becomes evident in late July or early August, the spermatogenetic events are already evident in May when spermatozoa are detectable in the lobular lumen, spermatic duct and the vas deference in some males. Seldom, males with running testes are also encountered in this month. In August and September the testes are studded with spermatozoa; the primary spermatocytes, though present, are few and spermatogonia are extremely reduced. The mean monthly GSI of the testes corresponds closely with the histological evidence of testicular maturational rhythm. However, the somewhat earlier maturation of the testes in some of the males is difficult to explain. That the putitora mahaseer may indeed achieve breeding state in May (as shown by Pathani, 1983) or even an earlier maturational start by the male are points which deserve notice. The former possibility should not be entirely ruled out but evidence for this is lacking at the present time. It is also noteworthy that in many fish species the males are known to become mature and active ahead of the females (Swee and McCrimmon, 1966; Crivelli, 1981; Gibson and Ezzi, 1981).

The available literature on the frequency of spawning of the mahaseers is full of conflicting reports. The reasons for discordant descriptions may be ascribed to (1) some confusion regarding the correct taxonomic identity of the species being described, (2) uncritical and rather cursory observations forming the basis of given conclusions, and (3) regional differences in ecological surroundings of the species studied and hence the different descriptions. Khan (1939) has described that *Barbus tor* (presumably *Tor tor*) breeds 3 times in a year ( January-February, May to June, July-September ). His observations are based on gross examination of isolated ovaries sent to him for examination from various localities of the Punjab. Since he has himself pointed out that the taxonomic status of *Barbus tor* remains uncertain it is possible that the samples examined by him belonged to any of the several species of *Barbus* (*Barbus tor*, *Barbus putitora*, *Barbus hexatictus*, Khan, 1939). Khan's observation have received support from the work of Qasim and Qayyum (1961) on *Barbus* (*Tor*) *Putitora* collected from rivers of the Gangetic plains of India. According to these authors the putitora mahaseer contains all stages of developing oocytes throughout and that breeding occurs over a greater part of the year. Whether the above two groups of workers are dealing with the same species remains unclear. Furthermore, the data on annual temperature and rainfall cycle presented by Qasim and Qayyum bear no strict correlation with either of the two parameters. The species has been stated to breed when the air temperature is $20^{o}C$ and hardly any rainfall (winter) as well as when the air temperature rises to nearly $40^{o}C$ followed by increasing incidence of monsoon rains and a concomitant drop in temperature. In contrast, Hora (1939) reports that the putitora mahaseer in the Punjab breeds during August to September. This report and the more recent work of Pathani (1983) on *Tor putitora* and *Tor tor* are in near accord with the observations presented here. Pathani's results (1983) for the high altitude populations (1530 meters) of these species in Naini Tal ($24^{o}N$, $29^{o}E$), India, show that the two species breed respectively during May to September and April to September and that breeding is intermittent during the season. The latitude at which these populations occur is quite different from that of Islamabad and this may explain the somewhat extended seasonality in the above situation. The population of mahaseer in and around Rawal lake shows spawning activity during July to early October according to the GSI and oocyte developmental changes. Vitellogenesis becomes first evident in July and the fish containing ovaries in this stage are destined to breed during the current season. Although some males with running testes are encountered in May and June suggesting maturation ahead of the females, there is no evidence at present that the females ripen in these months. Whereas Pathani (1983) argues for a relatively restricted breeding season (May to September) for *Tor putitora* differing from the present results only in respect to timing of onset, Bhatnagar (1964) supports the observations of Qasim and Qayyum (1961) on the basis of frequency polygons of diameters of ova derived from only two ovaries of this species collected from Bhakara resrvoir off Sutlej river in Himachal Pradesh, India. Bhatnagar (1964) has observed all stages of developing eggs (4-5 batches) with fully mature ( ripe ) eggs occurring in June just prior to floods in the Sutlej river. His work indicates that the species breeds over a greater part of the year. Interestingly, Butt and Hayat (1978) have reported that the putitora mahaseer breeds in the winter as well since they collected a female specimen from Mardan in North West Frontier Province with ripe ovaries. Basing his conclusions on frequency polygons of ova diameters, Chaturvedi (1976) has described only two batches of eggs ( immature and mature ) and hence suggested a relatively short breeding season during the year for the related *Tor tor* in lakes of the Udaipur district in India. According to this worker, spawning activity in this species coincides with onset of the monsoons (i.e. late June to early July ( when the water temperature also drops ) and continues until the end of September -- a time when the monsoon season ends. Since the onset of monsoons seems to vary not only regionally ( hills versus plains ) but also from year to year within a given geographical locale, the onset of breeding activity may be expected to vary in accordance in species of fish primarily dependent on monsoon rains and floods ( Hora, 1945; Alikunhi and Rao, 1951; David, 1953; Desai, 1973; Pathani, 1983). Thus, the onset of gonadal ( particularly ovarian ) maturation would show a corresponding shift in timing. Crivelli (1981) has summarized wide variations in the breeding season of the common carp, *Cyprinus carpio*.

These range from a short 2-month season to a long season extending over 5-6 months depending on geographical localities in Europe and North America.

The information pertaining to first maturity in relation to body length and age of putitora mahaseer from the Islamabad area is in accord with that presented by Pathani (1981, 1983) for this species thriving in Naini Tal, India. The slight difference in regard to the length of the fish in the two studies is negligible and reflects measurements in terms of standard (present study) and total length ( see Pathani, 1983 ). It is evident from both studies that the males first become mature at a smaller size and when they are 2 year old or are in their second year of life while the females first become mature at a larger size when these are in the 3rd year or have completed 3 years. During the present investigation small males in their first year of life have been collected in running condition (180 mm, S.L., 110 g) but this has been noted very rarely. Pathani (1983) has also reported a similar observation for the male. The observations of Chaturvedi (1976) on the tor mahaseer (*Tor tor*) from the Udaipur district of India are interesting. In this population the smallest mature males measure 254 mm (TL) and all males 310 mm in size show mature testes. The females show first maturity at a length of 322 mm and maturity in the two sexes occurs within one year of age. In contrast, the data of Pathani (1983) for this species in Naini Tal are quite comparable to those for the putitora mahaseer. It appears that the population of *Tor tor* in the Udaipur district appears to grow much faster than the populations of *Tor putitora* and *Tor tor* thriving at the altitudes of Islamabad and Naini Tal. However, one has to be certain whether the age determination in the Udaipur *Tor tor* was based on reliable methods.

# CHAPTER - 3

## FECUNDITY

### Aims and Rationale

The number of eggs produced by fish has been of interest from the point of view of population dynamics, productivity (weight of eggs in proportion to total weight of fish) and mortality estimates (Bagenal, 1967, 1973). The number of eggs laid in a spawning season sets the starting point of potential recruitment of youngs to the existing population of a species. Studies on fecundity of fish, therefore, are of particular value especially in respect to species of commercial importance.

A considerable volume of information is currently available on the fecundity of diverse fish species and much work has been done on this aspect of carps (Alikunhi, 1956; Peters, 1963; Pope *et al.*, 1961, Mathur, 1964; Das, 1964; 1967; McFadden *et al.*, 1965; Swee and McCrimmon, 1966; Jhingran, 1968; Sheri and Power, 1969; Bhargava, 1970; Lear, 1970; Gorbach, 1972; Jayoti and Malhotra, 1972; Parmeswaran *et al.*, 1972; Desai, 1973;

Varghese, 1973, 1976; Martinez and Houde, 1975; Chaturvedi, 1976; Pathak and Jhingran, 1977; Shackley and King, 1977; Panek and Cofield, 1978; Bruton, 1979; Rao *et al.*, 1979; Hunter and Goldberg, 1980; Crivelli, 1981; DeMartini and Fountain, 1981; Pathani, 1981.

Whereas several descriptions of fecundity of major carps are available, very little work has been done on the fecundity of the mahaseers and none on populations resident in rivers and streams in Pakistan. Desai (1973) and Chaturvedi (1976) have reported data on the fecundity of the tor mahaseer, *Tor tor*, from waters in the Indian subcontinent. On the other hand, only Pathani (1981) has studied fecundity of the putitora mahaseer, *Tor putitora*, resident in the Bhimtal Lake in Naini Tal, India. Since no work has been done on this aspect of the biology of this species in Pakistan, assessment of fecundity was planned as part of the present work on the breeding biology of the putitora mahaseer.

## Materials and Methods

The specimens of the putitora mahaseer for study of fecundity were collected (as previously described) from the Rawal Lake and adjoining streams in July - August 1983. Total length (T.L.) and body weight were recorded as per routine. On the assumption that all maturing and mature ova would be expected to be spawned during the current spawning season, only fish which were judged to be maturing or contained ripe ovaries were selected for the study. A total of 38 females were selected. The size of fish ranged from 470 to 667 mm T.L. and 757 to 2997 g body weight.

The fish were dissected, the ovaries removed and weighed to the nearest mg on a Mettler balance. Fecundity was determined by gravimetric method. A 1.0 g sample of ovary from the mid part of the preweighed ovaries was taken and preserved in 10% formalin for at least 48 hours. Subsequently all samples from individual fish were transferred to a solution of 10% NaCl for 48 hours to soften the connective tissue. The counts of oocytes in each gram sample of ovary were made under a dissecting microscope. Each sample of ovary was blotted dry on paper towels and teased with glass needles to separate the oocytes from the ovarian tissue. The oocytes thus separated were placed on a mm grid on the glass microscope stage. All oocytes measuring nearly 1 mm and larger in the ovarian sample were counted. The oocytes measuring close to 1 mm have been determined histologically to be in the yolk stage and undergoing vitellogenesis (see previous section). All such oocytes are expected to become ripe and would be spawned, barring any preovulatory atresia, during the current spawning season. It was this assumption on the basis of which the 1.0 mm cut off was used in counting the oocytes for determination of fecundity. Fecundity was calculated as the product of count per gram ovary times the combined weight of the two ovaries.

Four relationships of fecundity were determined, namely, fecundity and total length, fecundity and total body weight, fecundity and ovarian weight, and fecundity and age. Determination of age of fish was based on the scale method as described earlier in the previous chapter. Estimates of fecundity were made by the Least Squares method and analysis of multiple regression.

## Results

Table 1 shows length, body weight, ovarian weight, age and fecundity data collected for 38 maturing/mature mahaseer. Fecundity (total number of ova/fish) varied between individual fish. The length of the fish varied between 470 to 667 mm T.L. and the weight between 757 to 2997 g. The individual fecundity ranged between 7570 to 30295 ova.

### Body Relationships with Fecundity.

When fecundity was correlated with the size of the fish the following relationships emerged.

<u>Total length and fecundity</u>. Least squares estimates of fecundity in relation to body length are shown in Table 1. A consistent increase in fecundity in relation to body length is observed. When fecundity was regressed on total length, the following relationship provided the best fit to the data ( $r = 0.97$, $P < 0.001$ ).

$$F = -38616 + 104\ TL, \quad r = 0.97$$

Table-1. Total length, body weight, ovarian weight and age data used to estimate fecundity of the putitora mahaseer (*Tor putitora*) on the basis of gravimetric method and counts of maturing and ripe ova.

| Specimen No. | Total Length (mm) | Total body weight (g) | Ovarian weight (g) | Age (Yr.) | Actual fecundity | Estimated fecundity and length | Estimated fecundity and weight | Estimated fecundity and ova. weight | Estimated fecundity and age |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| 1 | 470 | 757 | 19.5 | 4 | 7570 | 10282 | 9128 | 7087 | 9140 |
| 2 | 470 | 763 | 25.0 | 4 | 9808 | 10282 | 9181 | 7981 | 9140 |
| 3 | 473 | 767 | 22.8 | 4 | 7680 | 10594 | 9216 | 7624 | 9140 |
| 4 | 478 | 810 | 39.0 | 4 | 10598 | 11114 | 9595 | 10257 | 9140 |
| 5 | 476 | 846 | 38.5 | 5 | 10460 | 10906 | 9911 | 10176 | 14447 |
| 6 | 476 | 880 | 40.5 | 4 | 10820 | 10906 | 10211 | 10501 | 9140 |
| 7 | 478 | 885 | 41.0 | 5 | 8885 | 11114 | 10255 | 10582 | 14447 |
| 8 | 480 | 899 | 44.6 | 4 | 10888 | 11722 | 10378 | 11167 | 9140 |
| 9 | 483 | 937 | 43.0 | 5 | 9370 | 11634 | 10712 | 10907 | 14447 |
| 10 | 483 | 948 | 47.4 | 4 | 11205 | 11634 | 10809 | 11622 | 9140 |

Contd...

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|
| 11 | 484 | 959 | 46.5 | 5 | 11500 | 11738 | 10906 | 11476 | 14447 |
| 12 | 484 | 965 | 48.4 | 5 | 11910 | 11842 | 10959 | 11785 | 14447 |
| 13 | 488 | 1010 | 50.8 | 5 | 19010 | 12155 | 11355 | 12175 | 14447 |
| 14 | 492 | 1210 | 58.5 | 5 | 12700 | 12571 | 13115 | 13427 | 14447 |
| 15 | 493 | 1293 | 60.2 | 5 | 12930 | 12675 | 12845 | 13703 | 14447 |
| 16 | 490 | 1331 | 67.8 | 5 | 13810 | 12363 | 14179 | 14938 | 14447 |
| 17 | 494 | 1345 | 65.8 | 5 | 13550 | 12779 | 14303 | 14613 | 14447 |
| 18 | 496 | 1400 | 69.8 | 5 | 14900 | 12987 | 14787 | 15264 | 14447 |
| 19 | 498 | 1446 | 66.5 | 5 | 16050 | 13195 | 15191 | 14727 | 14447 |
| 20 | 511 | 1605 | 80.3 | 5 | 16050 | 14547 | 16591 | 16970 | 14447 |
| 21 | 528 | 1765 | 88.5 | 6 | 17650 | 16316 | 17999 | 18303 | 19754 |
| 22 | 536 | 1805 | 85.9 | 5 | 16962 | 17148 | 18351 | 17881 | 14447 |
| 23 | 540 | 1840 | 95.5 | 6 | 17395 | 17565 | 18659 | 19441 | 19754 |
| 24 | 548 | 1875 | 96.8 | 5 | 18760 | 18397 | 18967 | 19652 | 14447 |
| 25 | 551 | 1891 | 100.0 | 6 | 18941 | 18709 | 19107 | 20173 | 19754 |

Contd...

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|
| 26 | 558 | 1915 | 104.3 | 6 | 19348 | 19437 | 19319 | 20872 | 19754 |
| 27 | 563 | 1985 | 103.5 | 6 | 19890 | 19957 | 19935 | 20742 | 19754 |
| 28 | 570 | 2155 | 105.2 | 6 | 20550 | 20686 | 21431 | 21018 | 19754 |
| 29 | 575 | 2195 | 108.9 | 6 | 20988 | 21206 | 21783 | 21619 | 19754 |
| 30 | 586 | 2331 | 110.5 | 7 | 22210 | 22350 | 22979 | 21879 | 25061 |
| 31 | 590 | 2375 | 120.0 | 6 | 23700 | 22767 | 23367 | 23424 | 19754 |
| 32 | 596 | 2420 | 118.8 | 6 | 23200 | 23391 | 23763 | 23229 | 19754 |
| 33 | 605 | 2490 | 123.5 | 7 | 24800 | 24327 | 24379 | 23993 | 25061 |
| 34 | 612 | 2550 | 125.2 | 7 | 25500 | 25055 | 24907 | 24269 | 25061 |
| 35 | 628 | 2695 | 130.7 | 7 | 26050 | 26720 | 26183 | 25163 | 25061 |
| 36 | 657 | 2920 | 145.5 | 7 | 30295 | 29737 | 28163 | 27569 | 25061 |
| 37 | 661 | 2968 | 152.0 | 8 | 29400 | 30153 | 28585 | 28625 | 30368 |
| 38 | 667 | 2997 | 158.5 | 8 | 29210 | 30778 | 28840 | 29682 | 30368 |

When Log 10 Fecundity was regressed on Log 10 total length, the following exponential equation gave equally good fit to the data.

$$F = 0.0000113\ (L)^{3.356}\ ,\ r = 0.94$$

Although the correlation coefficient is slightly lower than that obtained with untransformed data, it is still quite high. The relationship though curvilinear has a pronounced linear component (Fig. 1).

The minimum and maximum estimates (see Table 1) of fecundity based on simple regression are 10282 (0.95 CL: $7597 \leqslant F \leqslant 12967$) at 470 mm TL and 30778 (0.95 CL: $28092 \leqslant F \leqslant 33463$) at 667 mm TL.

Weight and fecundity. Least squares estimates of fecundity in relation to body weight are shown in Table 1. Again a consistent increase in fecundity occurred with increase in body weight. When fecundity is regressed on body weight a linear relationship occurs (Fig. 2) with the following equation yielding the best fit ( $r = 0.97$, $P < 0.001$ ) to the data.

$$F = 2466.716 + 8.8\ W, \quad r = 0.97,$$

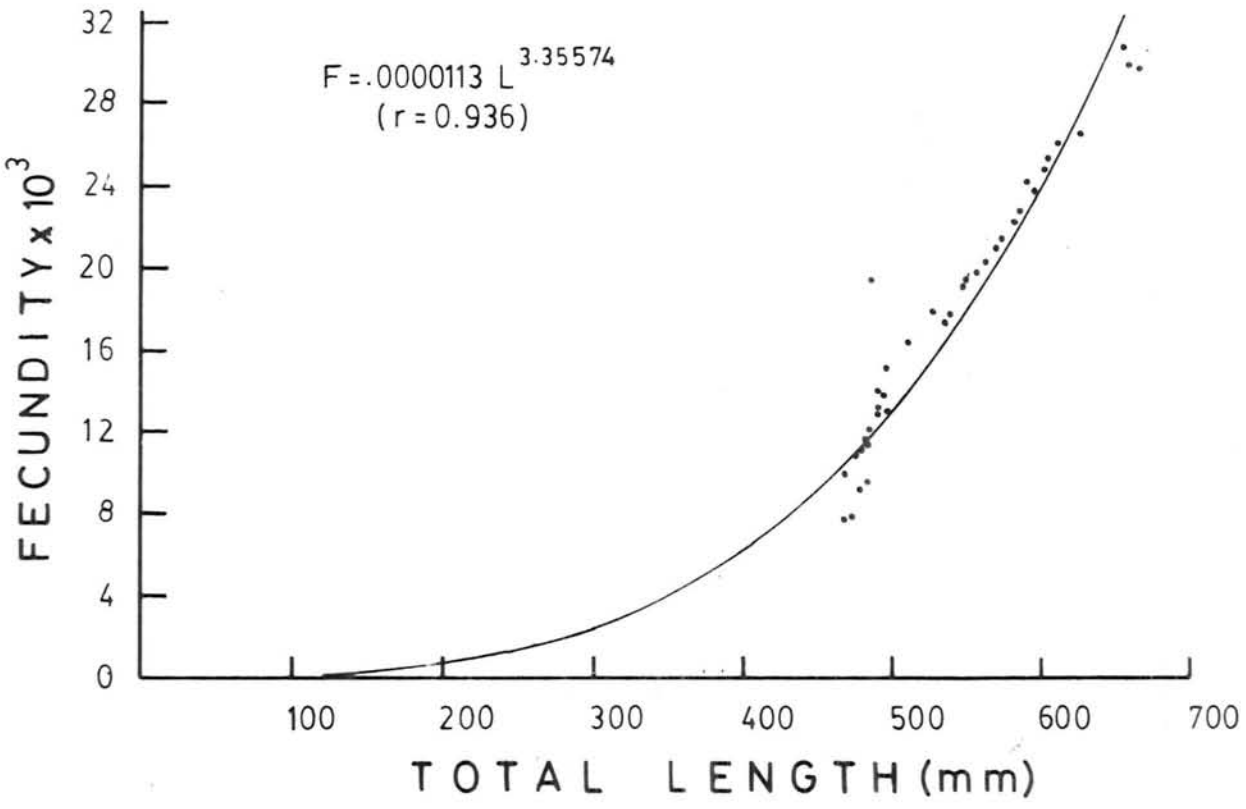

F = .0000113 L 3.35574
(r = 0.936)
FECUNDITY x 10 3
32
28
24
20
16
12
8
4
0
100
200
300
400
500
600
700
TOTAL LENGTH (mm)

Fig.1

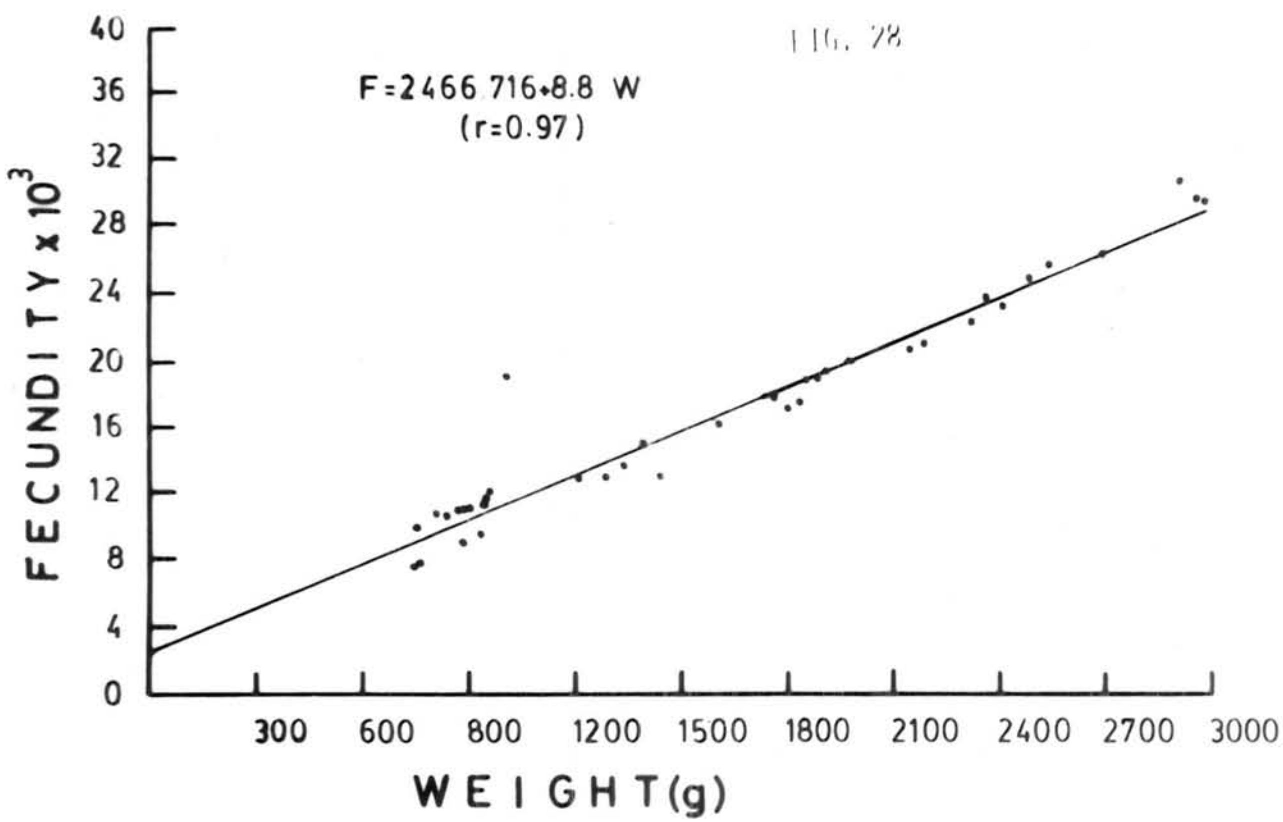


FIG. 28
F=2466.716+8.8 W
(r=0.97)
FECUNDITY x 10^3
0
4
8
12
16
20
24
28
32
36
40
300
600
800
1200
1500
1800
2100
2400
2700
3000
WEIGHT(g)

Fig.2

There is a direct proportionality between fecundity and weight. It increases as 8.8 ova per unit body weight (slope b = 8.8). The correlation coefficient ( r = 0.97 ) is again significantly very high. The minimum and maximum fecundities estimated from regression are 9,128 (0.95 CL: $7{,}375 \leq F \leq 10{,}897$) at 757 g and 28,840 (0.95 CL: $23{,}077 \leq F \leq 34{,}100$) at 2997 g.

Fecundity and ovary weight. Least squares estimates of fecundity in relation to ovarian weight (OW) are shown in Table 1. When fecundity is regressed on ovarian weight the following equation describes the relationship best ($r = 0.97$, $P < 0.001$).

$$F = 3918 + 162.5\ OW, \quad r = 0.97$$

The relationship is linear (Fig. 3) revealing a direct proportionality between fecundity and ovarian weight.

Fecundity and Age.

Least squares estimates of fecundity in relation to age are shown in Table 1. When fecundity is regressed on age, the following equation gives the best fit to the data ($r = 0.92$, $P < 0.001$).

$$F = -12087 + 5307\ Age, \quad r = 0.92$$

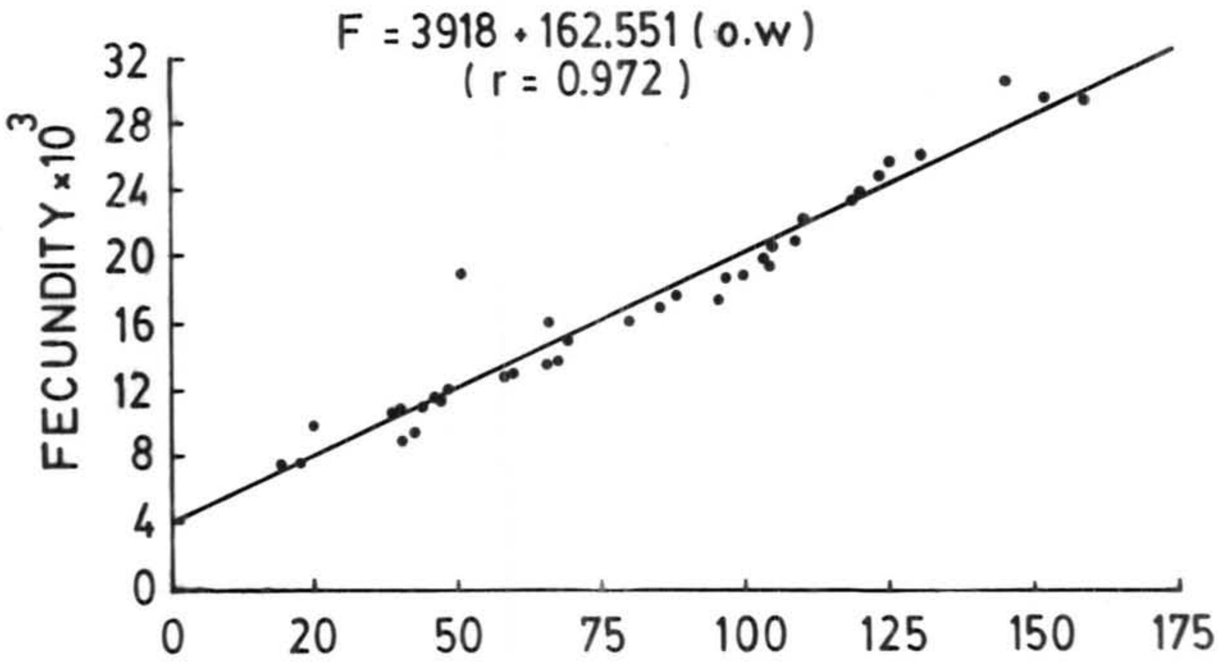

F = 3918 + 162.551 ( o.w )
( r = 0.972 )
FECUNDITY × 10^3
32
28
24
20
16
12
8
4
0
0
20
50
75
100
125
150
175
OVARIAN WEIGHT ( g )

Fig.3

The number of ova increases with increasing age. Fish younger than 3 years do not mature as shown in the previous section (Chapter 2). The youngest fish utilized in the present study were 4 year old and fecundity estimates were obtained for 5 year-classes (Table 1). Although the actual fecundity of individuals of a particular age showed some inconsistency (4 yr = 7570 - 11205; 5 yr = 8885 - 19010; 6 yr = 17395 - 23700; 7 yr = 22210 - 30295; 8 yr = 29210 - 29400), the fecundity estimates revealed a consistent increase with age. The correlation coefficient (r = 0.92) for the fecundity-age relationship is lower than that for the other relationship but still significantly high.

## Discussion

In the past a variety of methods have been used for determination of fecundity of fishes. One of the common approaches is to count number of ripening and ripe eggs present in a female prior to the spawning season and which are expected to be spawned in that season. Bagenal (1967, 1973) has reviewed the various methodologies in detail and enumerated such approaches as (i) count of number of youngs produced during the lifetime of an individual (e.g. population dynamics studies), (ii) measurement of weight of eggs produced by a female (e.g. productivity studies), and (iii) count of ripening and/or ripe ova present in a fish (absolute fecundity).

In the present study it has been shown that the putitora mahaseer breeds during the period July - September or early October and presumably sheds the eggs in more than a single spawning act during this period (see Chapter 2) as is evident from presence of 2-3 batches of developing oocytes in a mature ovary (yolked stage, migrating stage, ripe stage). This observation has also received support from other descriptions of ovarian maturation cycle in the mahaseers (*Tor putitora*: Bhatnagar, 1964; Pathani, 1983; *Tor tor*: Desai, 1973; Chaturvedi, 1976; Pathani, 1983). In view of this, determination of fecundity in the work reported here has been based on counts of all oocytes which were histologically determined to be in an advanced state of development. All oocytes measuring approximately 1.0 mm and larger show active vitellogenesis and are deemed to be well on their way toward maturation and would be recruited in the ready to spawn population of ova. Determination of fecundity by counting maturing and ripe oocytes has been practiced by other workers as well (Martinez and Houde, 1975; Bruton, 1979; Pathani, 1981). Martinez and Houde (1975) have made a comparative estimation of fecundities of the scaled sardine (*Harengula jaguana*) using in one case collective counts of developing and ripe oocytes and in the other counts of only the ripe (i.e. the most advanced) oocytes. They concluded that the latter method gives a low estimation of annual egg production by the scaled sardine. They have argued in favour of the former basis as a more realistic criterion for determination of fecundity as a means of avoiding underestimations.

Four relationships of fecundity, namely, those with total body length, body weight, ovarian weight and age of the mahaseer were examined. The actual fecundity ranges between 7,570 to 30,295 eggs for fish ranging in total length and weight between 470-667 mm and 757-2997 g respectively. These data differ from those of Pathani (1981) in respect to the upper limit only and that too because of differences in the upper limit of length and weight of fish used in the two species. The specimens used by Pathani measured 339-517 mm T.L. and 302 - 1280 g with actual fecundity ranging between 7076 - 18,525. The data on fecundity of the putitora mahaseer presented here also differ in comparison with those presented by Desai (1973) for the tor mahaseer in India. For fish measuring 465 mm T.L. the reported fecundity is 28,400 eggs and for fish measuring 750 mm T.L. it is 1,01,600 eggs. Even higher values of fecundity for the tor mahaseer have been reported by Chaturvedi (1976). Besides the species difference, the ecological conditions particularly in regard to seasonal fluctuations in water temperature and available food may also be different in various regions (e.g. Naini Tal, Himachal Pradesh and Islamabad). Compared with species of carps which thrive in the plains, growth is considered to be slower and fecundity lower in species which reside at high altitudes (Pathani, 1981) Limnological information providing data on the productivity and food resources in the Rawal Lake and the adjoining streams is restricted to a brief note by Ahmad *et al.*, (1985). The productivity in general appears low and surface water temperature drops down to 13°C in the winter months but rises to as high a value as 28°C in the summer. In contrast, water temperature in the Narmada river (Desai, 1973, *Tor tor*) ranges between 19°C to 29°C and in the Gangetic plains the air temperature varies between 5°C (winter) to almost 40°C (summer) (Qasim and Qayyum, 1961). The published differences in respect to maturation, frequency of spawning and fecundity in the mahaseer species from these regions are likely to be related to differences in these factors.

According to the present data, there is a positive relationship between fecundity and total length, total body weight and ovarian weight. The correlation coefficients for all relationships are significantly high ($r = 0.94$, 0.97 and 0.97 respectively). Pathani (1981) obtained a linear relationship with both length and weight of the putitora mahaseer but the correlation coefficients were considerably lower ($r = 0.58$, $r = 0.50$ respectively). Lower correlation coefficients have also been reported for these parameters for other carp species (Islam and Talbot, 1963 for hilsa; Parmeswaran *et al.*, 1972 for common carp; Desai, 1973, for tor mahaseer; Varghese, 1973, 1976 for *Labeo* spp. ; Rao, 1974 for *Labeo fimbriatus*).

A linear relationship also exists between fecundity and age of the putitora mahaseer (see also Pathani, 1981). Although positive effects of body length, body weight and ovarian weight on fecundity have been noted generally, the data on age effect have been discordant (Simpson, 1951; Gerking, 1959; Bridger, 1961; Bagenal, 1967). A positive correlation with a significantly high correlation coefficient has been reported for the mahaseers (Desai, 1973, Chaturvedi, 1976; Pathani, 1981).

# CHAPTER - 4

## BREEDING BEHAVIOUR AND SCHOOLING

### Aims and Rationale

Whereas data concerning the biology and ecology of the two common species of mahaseers, *Tor putitora* and *Tor tor*, thriving in Indian waters have been made available periodically by various workers (Qasim and Qayyum, 1961; Bhatnagar, 1964; Rai, 1967; Desai, 1973; Chaturvedi, 1976; Pathani, 1981, 1983; Malhotra, 1982; Tandon and Johal, 1983), spawning behaviour has hardly been studied. Only some brief comments of largely incidental nature on the spawning habits and breeding sites have been made by Kulkarni (1970) and Jhingran and Sehgal (1977). Earlier observations of Thomas (see Hora, 1939) and Nevill (1915) and those of Pathani in recent years (1983) collectively provide some insight into the spawning behavioural aspect of the putitora and the tor mahaseers. In contrast, the spawning behaviour and its analysis for a variety of fish species has attracted considerable attention in other parts of the world (Needham and

Taft, 1934; Royce, 1951; Lowe, 1956; Mortimer, 1960; Ikowitz, 1969; McInerney, 1969; Bagenal, 1971; Kramer and Liley, 1971; Baldaccini, 1973; Constanz, 1975; Bayliss, 1976; Robertson and Hoffman, 1977; Kramer, 1978; McKaye *et al.*, 1979; Bruton, 1979; Vadasz *et al.*, 1979; Barton, 1980; Ferraro, 1980; Honma *et al.*, 1980; Murawski *et al.*, 1980; Borowsky and Difley, 1981; *et al.*, Crivelli, 1981; Hussain *et al.*, 1981; Kawamura, 1981; Moyer and Zaiser, 1981; Shelton *et al.*, 1982; Kohda and Watanabe, 1983; Robertson, 1983; Milton and Arthington, 1984; Liley and Tan, 1985).

The status of available information on the post hatching life history of not only the mahaseers but also of other carps in the Indo-Pakistan subcontinent, particularly the behavioural biology, marks a major vacuum. Investigations on the sociobiological organization of fish populations and schooling behaviour at various life history stages have been extensively carried out on both freshwater and marine species in other parts of the world. These studies have approached this area from the point of view of behavioural analysis per se, the causative factors, adaptive value and/or from the stand point of implications for fishery biology, management and aquacultural practices (Keenleyside, 1955; Hunter, 1966; McCann *et al.*, 1971; Pitcher, 1973; Breder, 1976; Sakamoto *et al.*, 1976; Fishelson, 1977; Pitcher and Partridge, 1979; Aoki, 1980, 1982). The works of Breder (1976) and Aoki (1980) serve as excellent reviews.

The present program of research represents an attempt to gather some systematic information on the movements and spawning behaviour of the putitora mahaseer in spite of the constraint of difficult field conditions and unavoidably narrow and more or less qualitative methodology. Since it became possible during the course of field visits to observe aggregations of juveniles, observations were carried out in the field to describe their schooling behaviour as well. It was hoped that the above two aspects will be a modest contribution toward strengthening the available body of information on the biology of the putitora mahaseer and also be of use in future programs aimed at further development of Rawal Lake fishery.

## Materials and Methods

### Breeding Behaviour.

Breeding behaviour of the putitora mahaseer was studied in the field during the years 1983 and 1984. Preliminary observations incidental to fishing activity in the lake in August 1983 and in earlier years provided a reasonable basis for selection of the observation areas and sites in the Rawal Lake, the Ramli and Kurang streams. The stretch of the lake and parts of the streams where observations were made are shown in Fig. 1 (Chapter 2). Visits to this area at various times also revealed that breeding movements and spawning activity occur during the night (between sunset and dawn). Therefore, planned observations were conducted during this period. Most of the planned behavioural studies were made in 1984 during the months of July, August and September. The most suitable times for observations were soon after sunset, close to dawn or when the moonlight was sufficient. At such times the fish could be seen relatively easily when these were close to the water surface or in shallow water. A camp was set up at the Rawal Lake and the Kurang stream at appropriate times of the month. This camp served as a working station for the observer and his assistants.

A total of 50 visits (50 nights) were spread over the observation months in 1983 and 1984. Since the conditions (weather, visibility and fish encounters) were not necessarily always favourable, many of these visits were unproductive. Successful observations (when fish encounters occurred) were possible only on 30 of these visits. The general approach in planned studies was to observe the fish quietly with a binocular from behind shrubs, bushes and trees along the shore line of the lake and margins of the stream. This entailed watching the fish with the least possible noise. It should be noted that a greater stretch of the stream bed becomes inaccessible during the monsoon season especially owing to rapids and uncertainty of depth at night. During the monthly observations in 1983, the observer made notes of fish activities and attempts were also made to photograph the fish using an Asahi Pentax Camera equipped with a telescopic lens and a flashgun. The photographic results turned out to be unsatisfactory since the distance between the camera and the breeding schools and the prevailing conditions of light were not appropriate. In view of this, photography was discontinued. Instead, a portable tape recorder was used to record the behavioural events. This method of recording observations was adopted during the observation periods in the year 1984. Clarity of observations was better whenever the observer managed to position himself close enough to schools of fish. The closest distance ever achieved without disturbing the fish was 4-5 meters but this was possible only rarely. Throughout the various observation sessions, the attempt was to gain maximum information regarding size of breeding schools and behavioural interactions in order to identify courtship (if any) and the spawning act. Since the visibility at night was one of the major constraints, there was a limit in respect to clarity of detail that could be collected.

In order to determine the size (numbers) and sex composition of the breeding groups, attempts were made to collect a given group in its entirety. For this purpose cast nets were used with the assistance of fishermen. The fish could be sexed on the basis of sexual dimorphism evident only during the breeding season. The validity of this could be checked by dissecting the fish for examination of the gonads. Care was taken not to disturb or kill too many breeding groups and in most cases the fish were released into the stream following external observations for sexing the individuals.

Attempts were also made to collect eggs during the morning following the night observations. Initially the stream was scanned, as far as possible, by scooping gravel and stones from the stream bed but only few eggs could be collected close to sites where the spawning act was deemed to have occurred. Additional efforts were made by anchoring fine-meshed netting (5 x 4 meters) at the bottom of the stream at 5 different locations which were suspected to be used as spawning sites. At other times small metal cans were also secured between the rocks and the stones at various places along the stream bottom to serve as traps for the eggs. However, these devices were invariably swept away by water currents particularly on nights when heavy rains occurred or stormy conditions prevailed.

Schooling Behaviour of Juveniles.

Schooling behaviour of juvenile mahaseer was studied in the field during the period November 1984 to July 1985 in various parts of the Ramli stream, the Kurang stream and in inlets of these streams at the Rawal Lake. Some observations were also made in streams at Hassan Abdal (50 km from Islamabad). All studies were conducted between 6.00 A.M. and 5.00 P.M. The selection of study sites was made by walking along the streams for considerable distances (approximately 100 m at a time). Shallow pools were identified where the juveniles occurred singly or in groups. The observations focussed on (1) whether the juveniles occurred as solitary individuals or in groups, (2) size of groups (3) pattern and direction of movements, (4) orientation of individuals relative to each other or to other objects (e.g. food) in the pools, (5) distance between individual fish, and (6) any notable details of behavioural interactions as well as responses to disturbance. The observations were made monthly. For every month observations were made twice daily (morning and afternoon) on 5 consecutive days in order to check for any variations in and/or reproducibility of observation details. The replicate observations were generally made at approximately the same times and, as far as possible, in the same general area where the previous observations occurred. An observation is defined here as an encounter with a solitary individual or an aggregations of fish. Each observation lasted at least 5 minutes but a longer duration was necessary when aggregations were encountered.

At the end of the monthly observations samples of juveniles were collected using fine meshed scoop, cast, and plankton nets and at times with push seines. The total length of individual fish, whether solitary or in groups was quickly measured in the field to the nearest mm and the fish were returned to the pools. During the period November 1984 to July 1985, the total length of the juveniles encountered ranged between 7 to 16 mm. The duration for which the individuals maintained a particular orientation relative to the neigbors was determined with a stop watch.

# Results

## Breeding Behaviour.

Breeding activity in the putitora mahaseer begins in late July and continues through August, September to almost early October (see Chapter 2). This activity coincides with the onset of monsoon rains (Fig. 27 , Chapter 2) which cause a rise in the lake level and also result in inundation and flooding of the shallow breeding grounds in the Ramli and the Kurang streams. The midday surface water temperature in the Rawal lake and the Kurang stream during August and September of 1983 was 26 and 25.5$^{o}$C respectively, the oxygen level and the pH ranged respectively between 5.2 to 5.4 mg/L and 7.8 - 8.0. The mid day surface water temperature in July, August, September and October 1984 varied between 27-24.8$^{o}$C. The oxygen level varied between 6.8 - 7.2 mg/L and the pH ranged between 7.8 - 8.0. The monthly temperatures (pooled averages for 1983 and 1984) are as shown in Fig. 27, Chapter 2.

The males and females cannot be distinguished externally in the non-breeding season but during the breeding season some sexual dimorphism becomes evident owing to slight differences in body colouration and the size of the belly. The two sexes assume a yellowish tinge ventrolaterally as well as on the pectoral, ventral, anal and caudal fins. However, the fins of the female have a deeper tinge appearing almost orange. The dorsal area of the trunk and the surface of head appear darker grey in the males than in the females. In addition, the belly of the females appears noticeably distended particularly in the months of August and September when the ovaries are fully ripe.

Preliminary observations in 1983 combined with more detailed and planned observations in 1984 revealed that movements of the fish associated with breeding activity occur during the night (between sunset and dawn). The fish start migrating from deeper parts toward shallow areas of the lake and into the streams in late July. Such activity was repeatedly monitored, near the inlets of the lake where groups of fish could be seen leaving it to enter the Ramli and the Kurang streams. During this upstream migration the fish make considerable noise by their splashing movements in the water. Two successive stages of the breeding state are definable, namely (1) courtship and (2) spawning act, in the months of August and September.

Courtship.

This stage of breeding behaviour is a rather protracted phase characterized by several independent groups of fish spread over different sites in the streams. The fish emerge from deeper pools and move toward shallower areas. One of the common features is that the individual groups consist of a leading fish followed by several other fish (Fig. 1). Occasionally a fish from the tailing group would approach the leading fish and either nudge the lateral side of the latter with its tail (tail-flapping, Fig. 2), or move in front of it nudging its snout and then rejoin the tailing group (Figs. 3, 4). Male to male aggression in these groups is absent. This behavioural interaction occurs periodically involving other individuals from the tailing group. The fish ultimately return to deeper water before dawn irrespective of whether spawning occurred on a particular night or not.

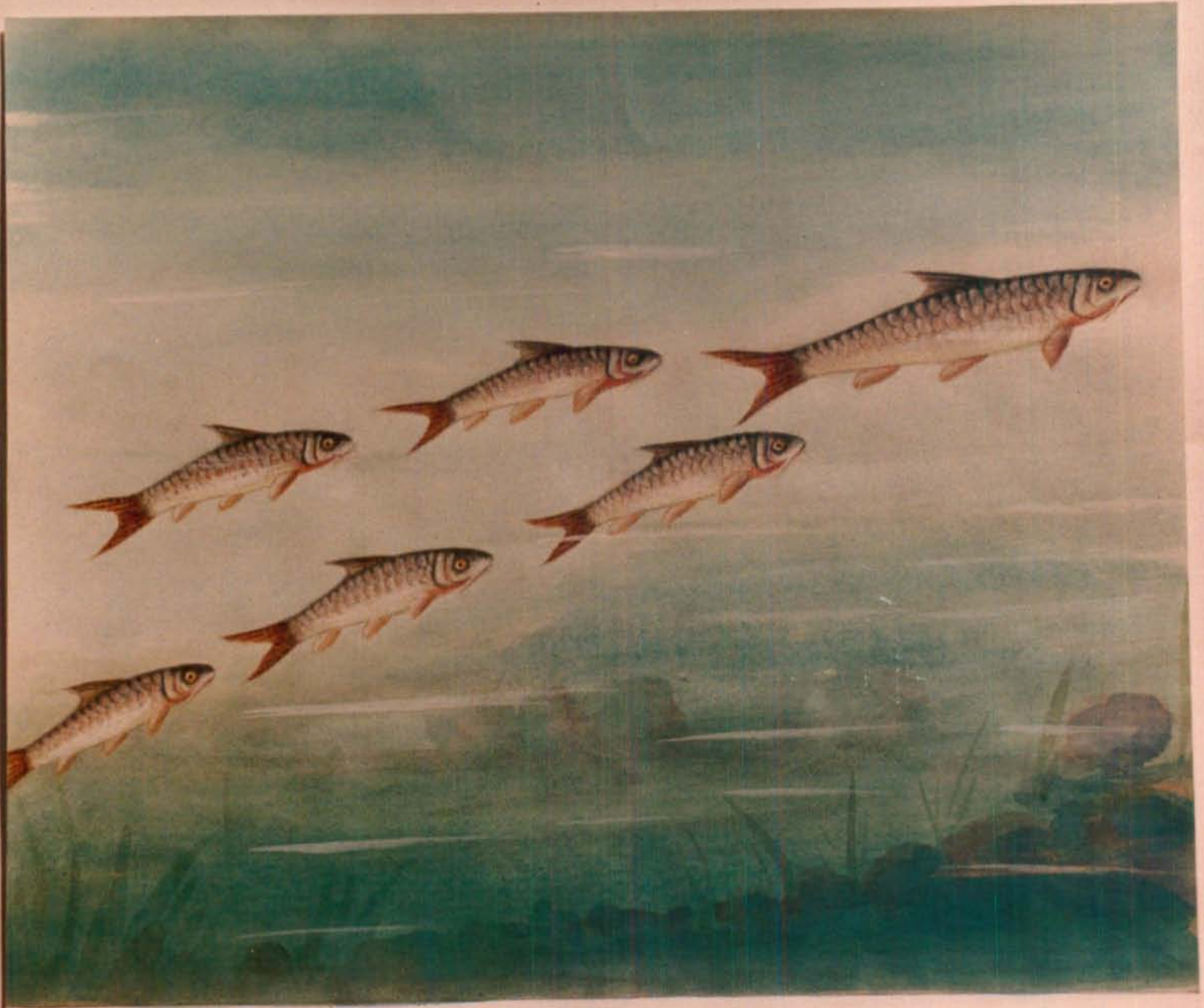


Fig.1

Fig.2

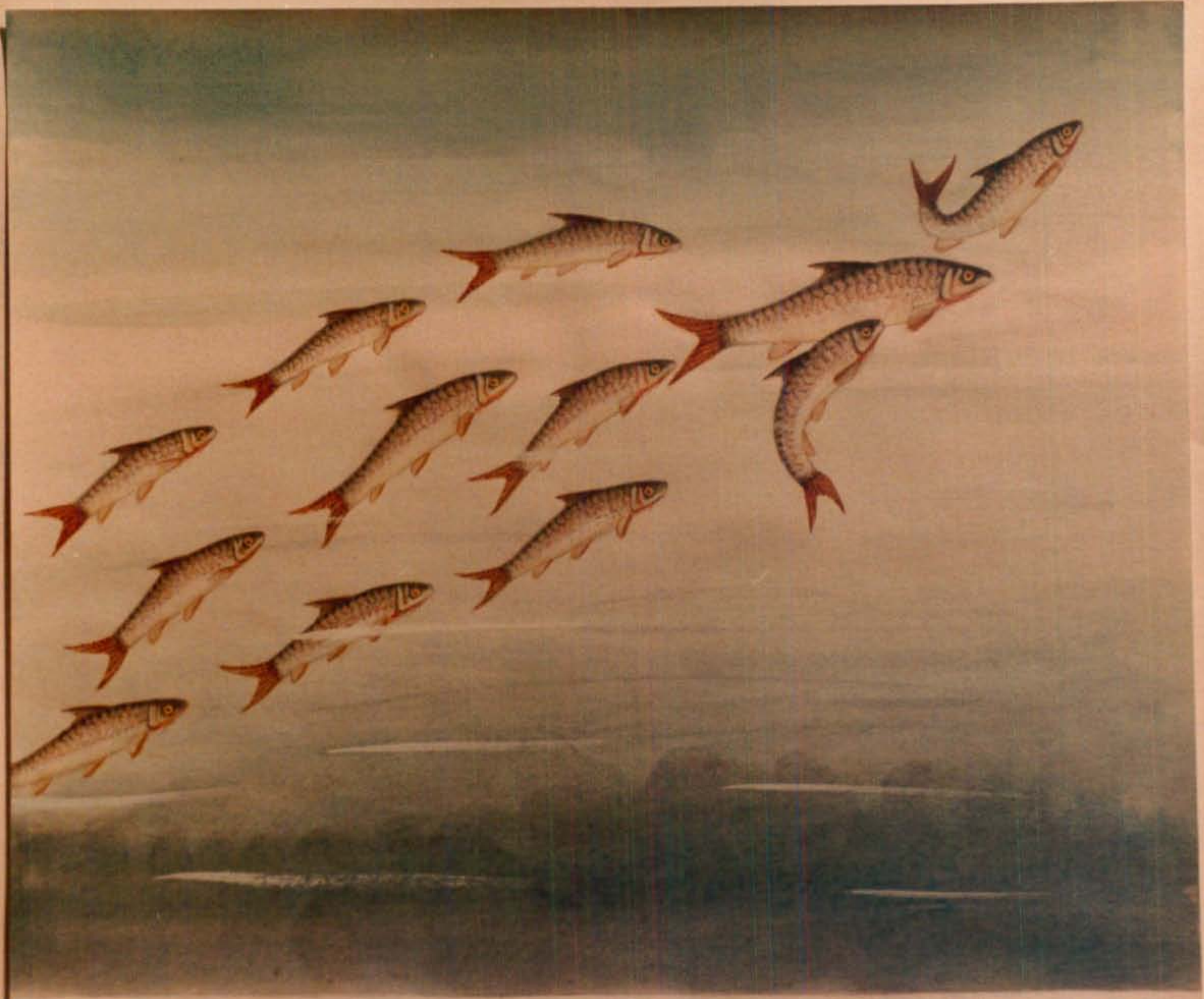


Fig.3

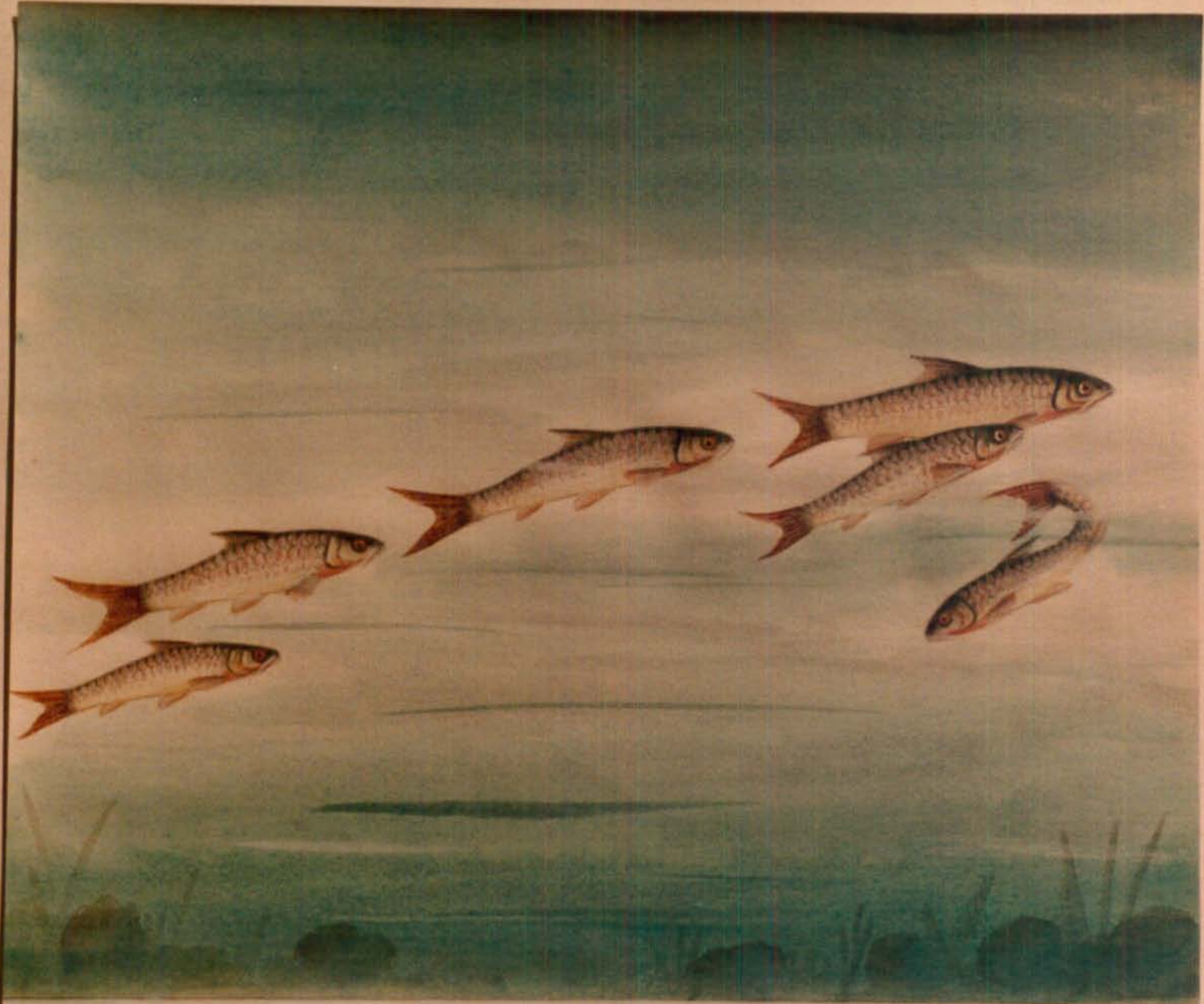


Fig. 4

The exact size of the schools of fish engaged in the activity described above could not be determined precisely. According to visual estimates made on nights when the moon light was sufficient or on the basis of observations made just prior to dawn, the groups appeared to consist of 10-30 fish. Attempts made to catch the individual groups in their entirety were mostly unsuccessful. However, in one attempt 7 fish could be caught. In another attempt 10 fish were trapped in the net. The maximum number of fish trapped in any one attempt did not exceed 15 fish. These catches did not contain all members of the respective schools since several of them seemed to have escaped. In the group consisting of 7 fish, one was a female and the rest males. In the group of 10 fish, all were males. Where 15 fish occurred in the catch 2 were females and the rest males. These observations collectively suggest that the leading fish in the courting groups is a female which is being chased by several males.

Spawning act.

The spawning act is consummated when the fish locate shallow areas in the streams. These grounds are characterized by a pebbly and rocky bottom with boulders strewn here and there. The spawning act is initiated when the female approaches water rushing over rocks and boulders. It jumps into the column of water and simultaneously one of the males from the tailing group also jumps into the water column. The two fish make a momentary contact and display quivering and jerky movements with their bodies arching upward as their ventral aspects come into apposition (Fig. 5). This apparently signifies release of eggs and sperms and culmination of the spawning act. The fish move away from each other turning laterally on their sides (Fig. 6). On rare occasions more than 3 fish (presumably a female and other males) are seen to engage in the act. The entire process is rather rapid and given the limitations of visibility the precise details of posture and orientation could not be determined with the desired level of confidence. The spawning pair having separated the individuals move back. The male joins the group of males waiting nearby while the female resumes its upstream orientation between the males and the site where the spawning act occurred. After a lapse of 5-10 minutes, the female fish is once

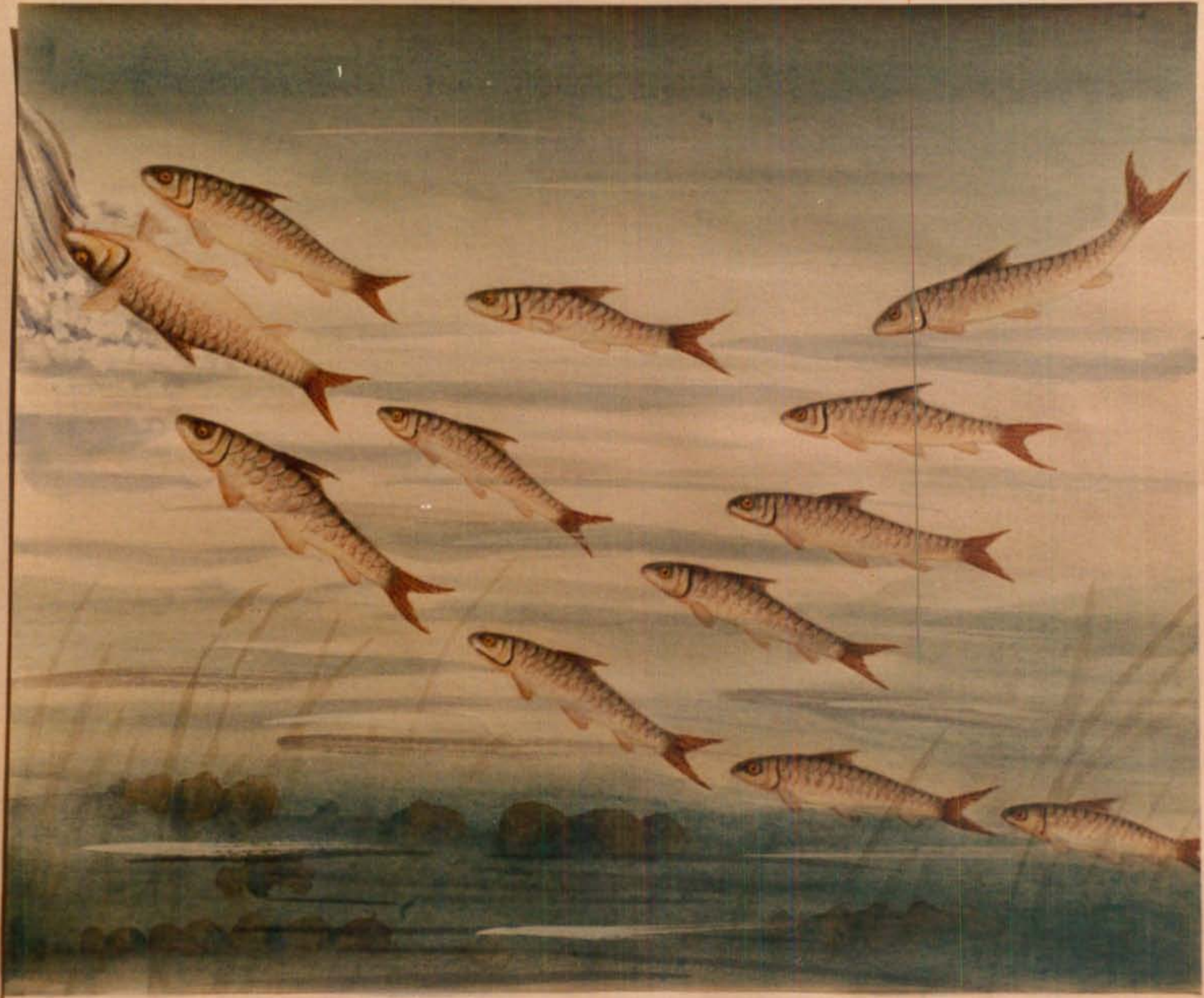


Fig.5

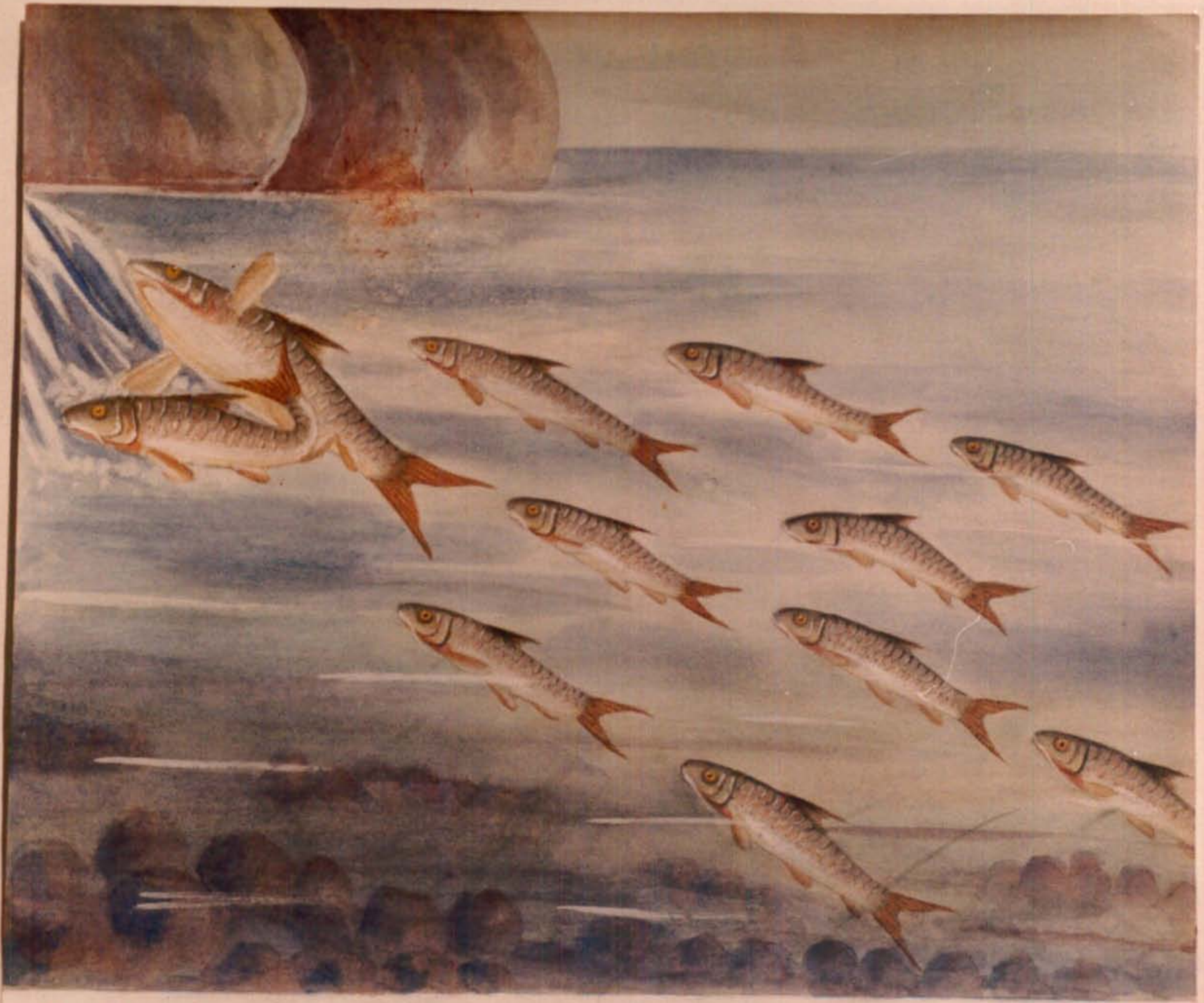


Fig.6

again led by one or two males toward the water column and the spawning act is repeated. This kind of spawning activity is repeated several times before the fish disperse moving back into deeper water. There is considerable jumping, splashing and agitation of water causing loud noise.

Surveys of the spawning ground in the morning revealed eggs scattered here and there at the bottom of the stream but only at a considerable distance from the site where the spawning act could be observed. The eggs of the mahaseer being heavier than water settle at the bottom but, apparently, are either carried away by the water current or get trapped in between rocks and in crevices and hence difficult to collect. Attempts to collect the eggs from the spawning sites by using fine meshed nets and metal cans placed at the stream bottom also did not prove successful. These were often rolled over and swept away by the water current.

Schooling Behaviour.

Throughout the 9-month period of observations, fish smaller than 7 mm T.L. were not encountered.

Therefore, information on the behaviour of smaller juveniles could not be obtained. The details of the schooling behaviour of the juveniles ranging between 7-160 mm T.L. are as follows:

November.

A total of 167 observations were made in the month of November. The size of the juveniles ranges between 7-12 mm T.L. ($\bar{x}$ = 9.5 mm T.L.). The fish usually occur as solitary individuals, dispersed in the observation area swimming quietly or feeding (nibbling at rocks, stones and vegetation). Stationary individuals are also encountered. The distance between the solitary individuals is commonly greater than 40 cm (about 40 fry lengths). Occurrence of juveniles in groups is only occasional. Such groups, when seen, appear to be loosely organized and the number of individuals in such groups does not exceed 5. These groups are considered loose because the distance between the neighbours varies between 30-100 mm (i.e. 3 to 11 fry lengths). Also, the orientation of the fish in these groups varies considerably. Often a fry is seen to approach another fry from behind (head to tail approach or at an angle toward the tail, Fig. 7) ultimately assuming parallel orientation. The two fish come as close as one fry length or even make momentary contact but within an average of 2 seconds the fry dart away from each other in opposite directions (Fig. 7). Thus, parallel orientation in such an interaction is merely momentary. Whenever these groups of fish are disturbed by throwing a pebble in the water, the individuals dart away in various directions rather than as a group. The fry in these groups generally appear to behave independently while feeding or during quiet behaviour and thus display a non-polarized behaviour. Figure 10 shows frequency of solitary individuals and "schools" of various size.

December.

A total of 140 observations were made in the month of December. Spot collection of fish in December revealed that the juveniles had reached a size range of 13-15 mm T.L. ($\bar{x}$ = 14 mm TL). The fish again occur mostly as solitary individuals separated from one another by a variable but considerable distance (40 cm or more). They are often seen feeding (nibbling

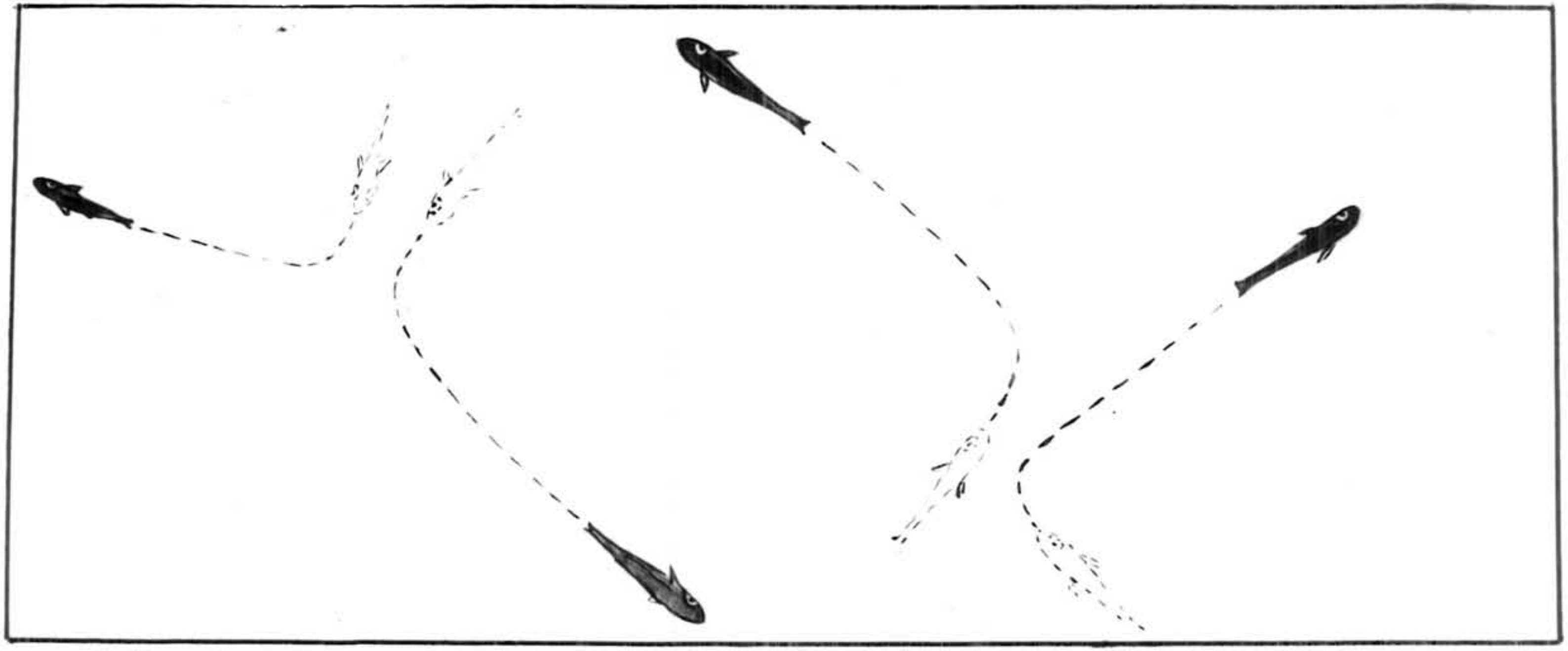


Fig. 7

at rocks, sand and vegetation) but stationary individuals are also encountered. The fry also occur in small groups but the incidence of such groups is very infrequent. Again, the number of individuals per group does not exceed 5 and the individuals are spaced, about 3 to 10 fry lengths apart. Occasionally a fry in the group is seen approaching another individual from behind (head to tail orientation, Fig. 8) coming as close to it as a fry length or even less. The two fry assume parallel orientation. This orientation, however, lasts for an average of 8 seconds after which the fish move away in different directions but stay as part of the loose group. The spacing, direction of movement, swimming speed and orientation remain changeable in such groups suggesting a non-polarized state. Rarely groups of fry are seen where the individuals are oriented parallel (Fig. 9) to one another for extended periods. The maximum number of individuals in such groups does not exceed three. The fry are seen to move as a cohesive group rapidly swimming in one direction following each other or maintaining parallel orientation. Aggregates of such fish remain cohesive even on being disturbed with the fry darting away in unison. The above details, thus, reveal that both non-polarized

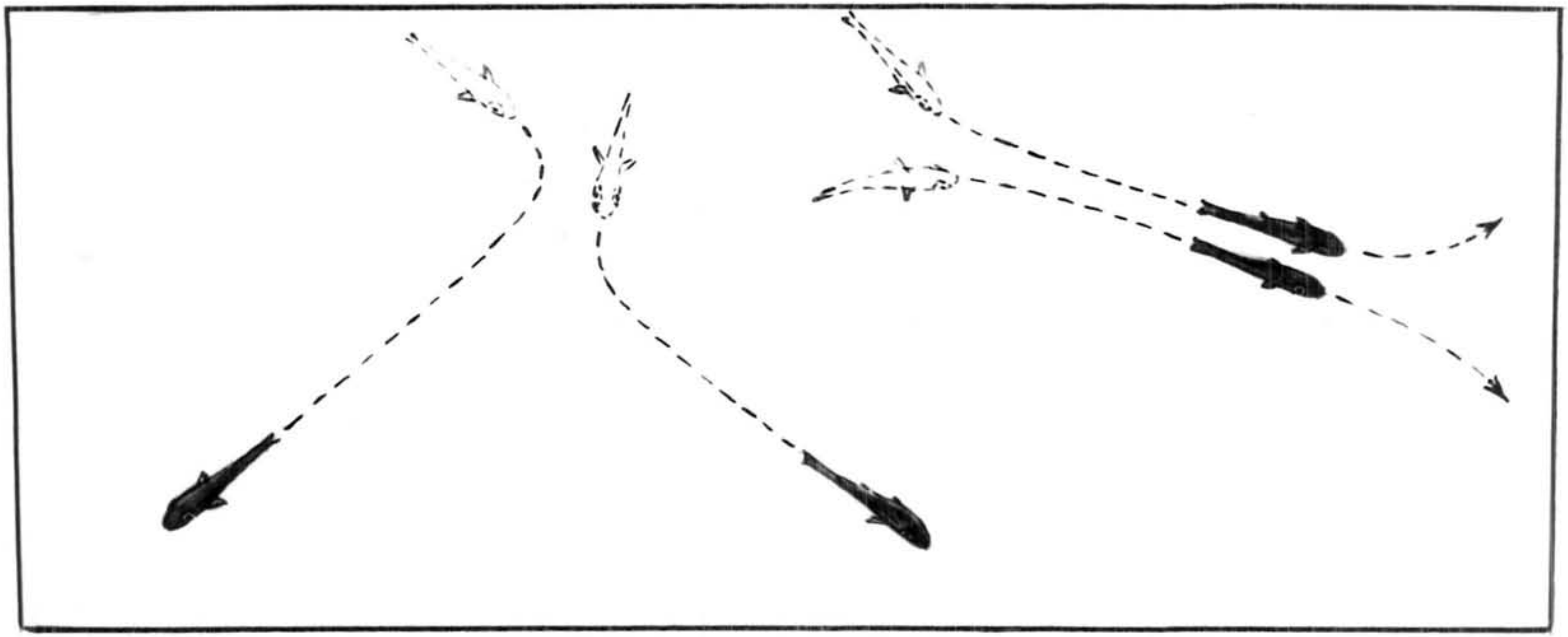


Fig.8

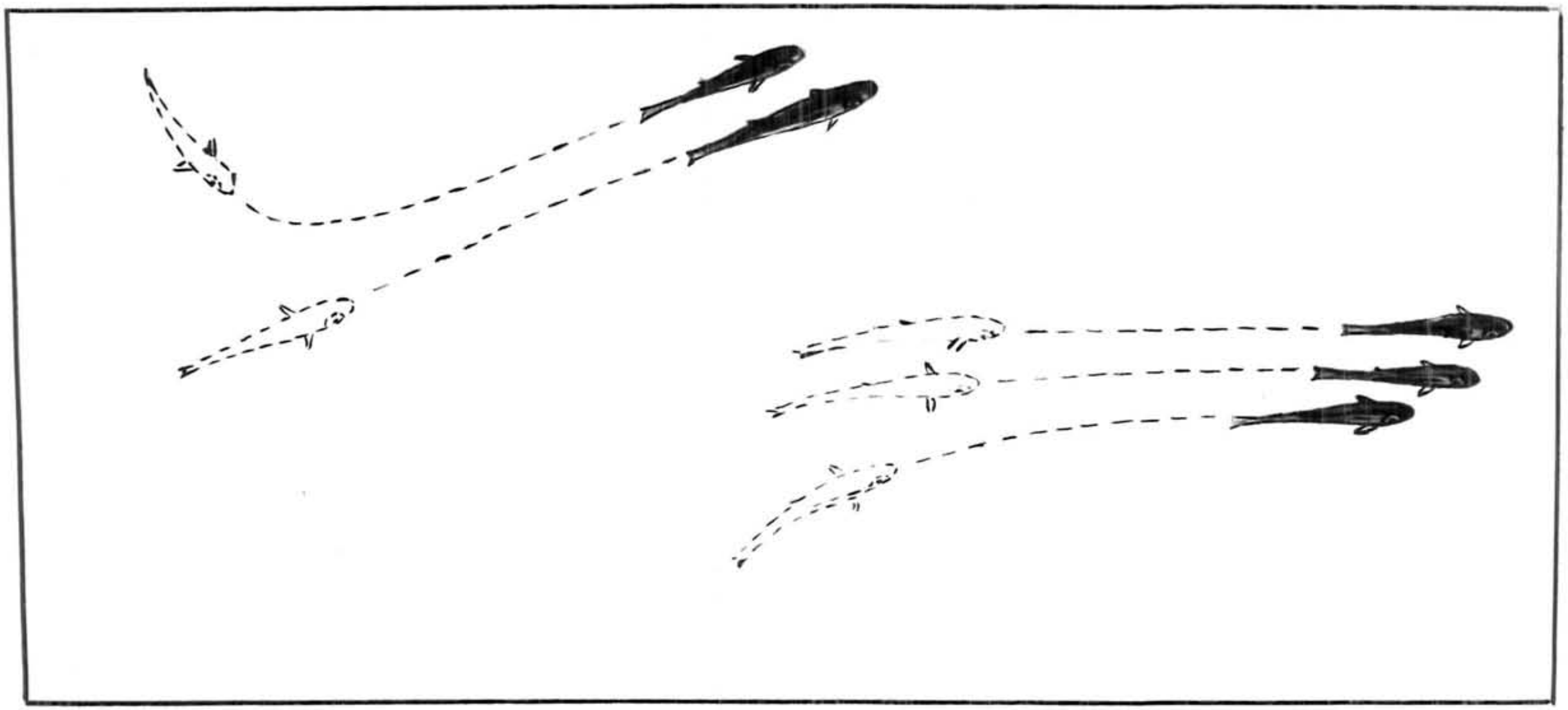


Fig.9

and polarized groups occur when the juveniles have achieved an average of 14 mm T.L. Where the groups appear to be polarized, no particular individual dominates the group as leader. Figure 10 shows frequency of solitary fish and "schools" of various size.

January.

A total of 140 observations were made in this month. The fry ranged in size from 41-70 mm T.L. ($\bar{x}$ = 45 mm T.L.). The behaviour of the fish in this month did not differ much from that seen in December. Most fish occur as solitary individuals (40 cm or more apart) maintaining a stationary position or swimming leisurely often nibbling at rocks, sand and vegetation. Group formations are also noticeable but their incidence is infrequent. When seen, the number of individuals, usually of uniform size, per group varies between 2 to 5. The individuals are spaced about 3 to 10 fry lengths apart. These frequently display a head to tail orientation where one of the fish approaches the other from behind (Fig. 8) coming as close as a fry length or even less. Parallel orientation is assumed for 8 to 15 seconds after which the fish move away in different directions. Rarely, groups of fry are seen with individuals oriented parallel to one another for extended periods (Fig. 9). The maximum number of fish in these groups remained 5 or less. All members in a given group appear to be of a uniform size. The fry form what appear to be cohesive groups where all individuals follow a particular direction and maintain a certain spacing and a similar speed of movement. When such aggregates of the fry are disturbed the individuals dart away as a group and thus appear polarized. The situation remains nearly comparable to that described for the month of December.

February.

The fry range in size from 21-90 mm T.L. ($\bar{x}$ = 70 mm T.L.) in the month of February. A total of 160 observations in this month revealed that the fish occur in groups of variable size ranging between 2-20 individuals. In about 3% of the observations the fry occur as solitary individuals (Fig. 10). Usually, the smaller fish (21-60 mm) occur singly, spaced more than 40 cm apart or in loose groups. Larger fish (60 mm upward) generally have a tendency

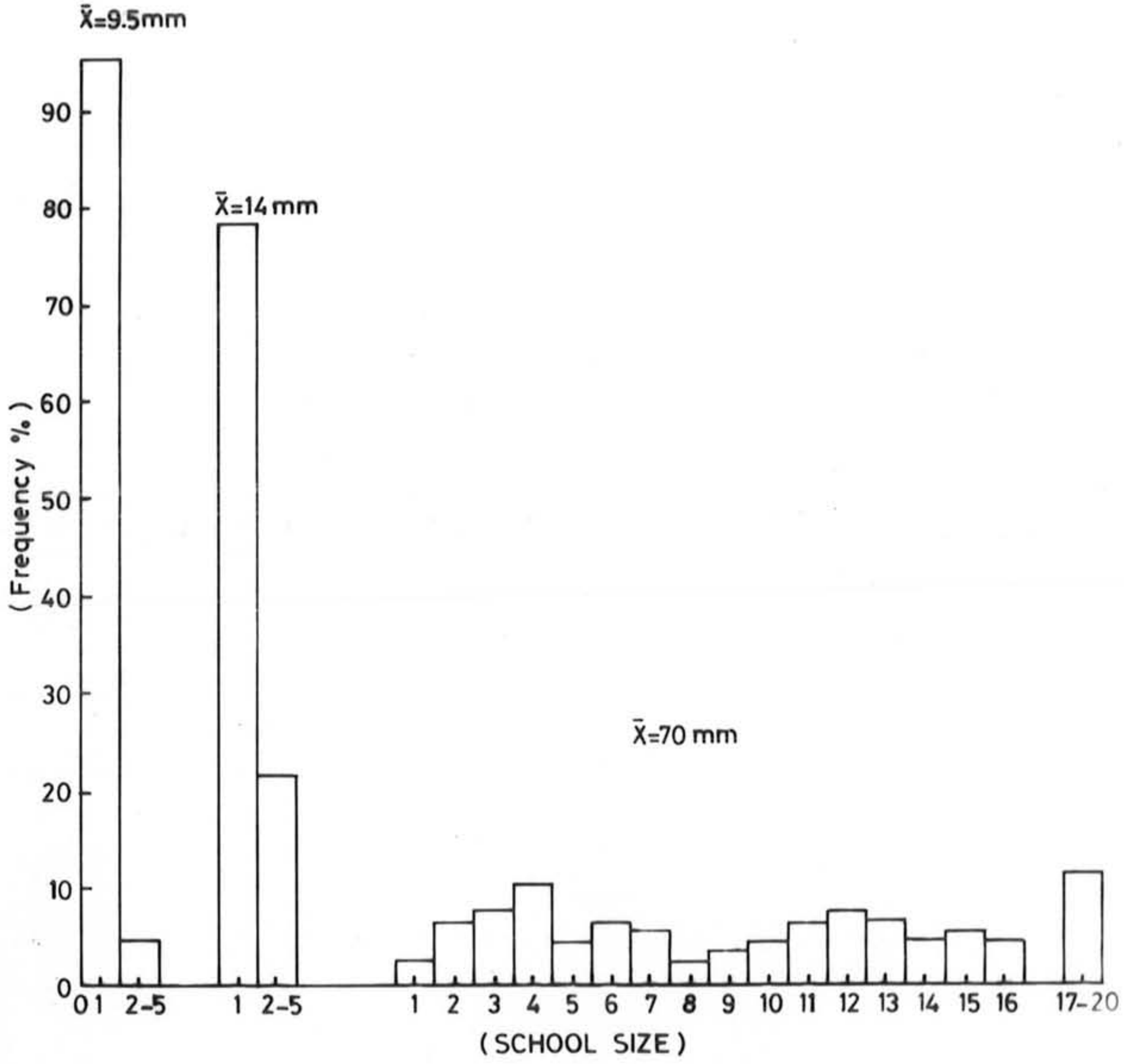

X̄=9.5mm
X̄=14 mm
X̄=70 mm
(Frequency %)
0
10
20
30
40
50
60
70
80
90
0 1
2-5
1
2-5
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17-20
(SCHOOL SIZE)

Fig.10

to form groups, each consisting of individuals of nearly uniform size. They maintain a particular distance from the neighbours which varies between occasional momentary contacts to 1 to 2 fry lengths. All fish swim in one direction maintain parallel orientation (Fig. 9) and appear more active than those in the non-polarized groups. The groups appear cohesive since all individuals maintain spacing, their orientation and direction, and change speed of swimming uniformly. The group organization is maintained even if the fish are disturbed. All fish dart in one direction rapidly following a leader and occupy a different location in the observations area. Thus, the fry form schools of variable size with the fish displaying a polarized behaviour. No particular fish acts to dominate the group as leader. The leadership role changes frequently and could be assumed by any fish in the group. Figure 10 shows frequency of occurrence of schools of various sizes.

March to July.

The fish in the months March to July ranged between 21 to 160 mm T.L. with most fish being larger than 80 mm T.L. Observations in these months revealed that the fish generally occur in schools. Occurrence of solitary individuals is only sporadic. The groups vary in size from 2 to 30 individuals. The frequency of schools comprising 2-5 individuals is far less than that of schools of a larger size. Even when the schools consist of 2 individuals the fry maintain a head to tail and/or parallel orientation. The distance between the neighbours does not exceed 1-2 fry length. The fish in the groups swim at a uniform speed in a given direction. Whenever a fish moves in some direction all other fish follow it with the former serving as the leader. However, the leadership role is changeable and readily assumed by any one fish in the group. Cohesiveness of the groups is also evident from the fact that whenever fish are disturbed by throwing a pebble at them, all fish stay together while darting away in some given direction. This behaviour is also observed whenever attempts were made to catch the fish. The individuals, if separated, would dart to join the larger group. Thus in the months beyond March when the juveniles have advanced considerably in size (over 70 mm in T.L.) the groups appear internally organized and represent polarized schools.

# Discussion

## Breeding Behaviour.

Although hardly any systematic work has been done on breeding behaviour of fishes in the Indo-Pakistan subcontinent and none on fishes in Pakistan, a considerable body of information exists on this aspect of both freshwater and marine fishes from other parts of the world (Needham and Taft, 1934; Royce, 1951; Tinbergen, 1951; Weisel and Newman, 1951; Morris, 1954; Lowe, 1956; Mount, 1959; Brawn, 1961; Swee and McCrimmon, 1966; McInerney, 1969; Polder, 1971; Kortmulder, 1972; Keenleyside, 1979; Crivelli, 1981; Shelton *et al.*, 1982; Robertson, 1983; Milton and Arthington, 1984). The common carp, *Cyprinus carpio*, provides an example where groups or schools of fish migrate from deeper parts of lakes to shallow breeding grounds with several males following a single female, gently nudging and pushing it, until the breeding sites are located (Swee and McCrimmon, 1966; McCrimmon 1968). The courtship is rather simple and the female responds to the male overtures by raising its tail and releasing the eggs as the males fertilize them. The putitora mahaseer shows a nearly comparable breeding behaviour. The female fish approaching a ripe condition in late July to early August become active and start migrating upstream from deep water of the lake toward shallow, stony, pebbly and rocky breeding grounds of the Ramli and the Kurang streams. A single female is pursued by several males during which time the males court it by tail-flapping and nudging it until the group reaches very shallow areas where water currents are rather swift. The female moves into the water current, makes jerky quivering movements, turns laterally and sheds the eggs while a male simultaneously joins it, brings its vent in apposition to that of the female and releases sperm as its body stiffens and arches in the act. This act is repeated periodically involving the same female but not necessarily the same male. The eggs sink to the bottom. Spawning in such conditions of swift currents is known for other species as well such as (trout, Needham and Taft, 1934). No parental care or special preparations for reception of the eggs seems necessary in the case of the putitora mahaseer. Pathani (1983) has recently studied the breeding behaviour of the putitora mahaseer in Bhimtal lake of Naini Tal, India, and the results are similar.

He has reported a simple courtship ritual which is comparable to that described in the present work. According to him 2 to 7 males chase a female toward the breeding sites, the coutship is a long process as shown here in the present study. Although it was not possible to determine the sex ratio with certainty in the present study, the limited number of collections of the spawning schools suggests that it may be similar to the ratio shown by Pathani (1983). Such ratios of males to females (5:1) have been reported for other group-spawning fishes as well (Shelton *et al.*, 1982). The details of the spawning act provided by Pathani show that the female makes rapid movements of the caudal region shedding the eggs as the male contacts its body while swimming around it and fertilizes the eggs. The two sexes then return to deeper waters of the lake. Spawning of the mahaseer in the Bhimtal lake occurs in the upper region of the lake as well as in some inshore areas (lake margins) where the bottom is pebbly and sandy. The temperature in this area is 23.5$^{O}$C and the oxygen level is high. The depth at which spawning occurs does not exceed 5.50 m. Spawning occurs at night but Pathani has also observed spawning during midday and in the evening.

In the present work in the Rawal Lake area, spawning has been observed only during the night and only in the streams. That the fish spawn within the lake as well and also during the day time cannot be entirely ruled out without further investigations, since no special attempts were made presently to explore such a possibility. With few exceptions (e.g. slight variations in water temperature), the details of the breeding behaviour of the Rawal lake and Bhimtal lake populations of the putitora mahaseer appear generally comparable. There is no evidence to support the view either in this study or that by Pathani (1983) that the mahaseer digs a hollow in the gravel for reception of eggs as was reported by Thomas (See Pathani, 1983). Many cyprinid species which scatter their eggs on unprepared breeding sites rely for egg protection on physical contours of the bottom, cracks and crevices in the rocky or stony substrate (Keenleyside, 1979). While the steelhead trout (Salmonidae) builds nests (Needham and Taft, 1934), the lake trout sheds the eggs on unprepared grounds (Royce, 1951). The spawning grounds of the Ramli and the Kurang streams are characterized by pebbles, stones, rocks and even boulders as has also been stated earlier by Khan (1939) for mahaseers of the Punjab region. Hence, the eggs are likely to get trapped in deep spaces in the substrate. In the Bhimtal lake, the texture of the breeding grounds is sandy and gravelly (Pathani, 1983) as is also the case for the breeding grounds of mahaseers in Himachal Pradesh, India (Jhingran and Sehgal, 1977). It seems that regional differences may occur in regard to temperature regimes and physical features of the spawning sites where the mahaseers thrive and breed in the widely differing ecological conditions in the Indo-Pakistan subcontinent.

Schooling Behaviour.

Schooling in fishes at various levels of life history is important both from the stand point of survival of the species and in the context of fishery biology. The phenomenon is common in various species, whether marine or freshwater, which form schools in the juvenile stage or throughout life (Shaw, 1978; Keenleyside, 1979, Aoki, 1980). Schooling may not necessarily be established from the beginning of independent existence in some species but it may evolve over a period of time either in the juvenile stage or later in life close to adulthood, for example, in preparation of spawning behaviour (salmonids: Keenleyside, 1979). The cyprinids are among fishes where schooling is evident from the early stages of life and may continue until death. In the present study it was possible to study the schooling behaviour of the mahaseer juveniles only from the 7 mm stage onward. The study shows that schooling behaviour, particularly in respect to intensity of social organization, emerges in this species gradually over a period of time. In keeping with the modern view, the term school used here refers to a grouping motivated by biosocial factors resulting in mutual attraction, parallel orientation of individuals, a consistent spacing, direction and uniformity of change in swimming speed (see Keenleyside, 1955, 1979; Breder, 1976; Aoki, 1980). Between the solitary individual and the above type of schools with a polarized state are fish "aggregations" which are apparently caused by extrinsic factors (e.g. food, light) and "non-polarized" schools where the internal structure is diverse, spacing, orientation and swimming speed of the fish are variable (Keenleyside, 1979; Aoki, 1980).

Whereas no information could be gathered about mahaseer fry between hatching and prior to the size range studied here, individuals with an average length of 9.5 mm generally occur as solitary individuals which remain widely spaced and show only occasional and temporary group formation characterized by variable orientation, spacing and speed of movement. These loose groups probably represent mere aggregations of the fry apparently formed in relation to food and feeding activity rather than through internal machanisms which give rise to biosocial attraction (see Keenleyside, 1955, 1979). The individuals in these groups disperse independently on being disturbed. However, a non-polarized status may equally be assigned to such groups since no specific tests could be used at this time to ascertain factors involved in the formation of such groups. The interesting aspect of the present study is evidence for a gradual emergence of a polarized state as the fry approach a particular size (see data for December and January). The transition between the solitary state and the polarized state is represented by what may be termed as aggregations or a non-polarized state. Whereas solitary individuals and loose groups do exist in February, their incidence is very low and generally such states characterize relatively smaller fish (21 to approximately 60 mm T.L.). Individuals larger than this size usually form polarized schools. Such a polarized state appears well established in the months to follow (March-July) when the fish undergo a progressive increase in size.

The present study represents mainly a qualitative analysis of schooling behaviour and its emergence. Admittedly the study approach could be far more fine-tuned in terms of methodology and quantification of behavioural patterns. However, the parameters used in defining aggregational, non-polarized and polarized states are the ones which have been commonly applied in any study of schooling behaviour (Keenleyside, 1979, Breder, 1976, Aoki, 1980). Also, since the intention in this work has not been to analyse mechanisms of behaviour per se but to identify development and existence of schooling phenomenon which have value for fishery biologists and planners, the observations presented provide some understanding of this aspect.

# CHAPTER - 5

## Food and Feeding Behaviour

### Aims and Rationale

A variety of fish species occur in the Rawal Lake. The most notable of these are the three common major carps, namely, rohu (*Labeo rohita*), thaila (*Catla catla*) and mrigal (*Cirrhinus mrigala*) as well as the putitora mahaseer. The common carp (*Cyprinus carpio*) has been recently introduced. Whereas much is known regarding the feeding habits, gut anatomy and feeding behaviour of the first three species of fishes and the common carp (Sarbahi, 1939; Mookerjee and Das, 1945; Mookerjee and Ghosh, 1945; Islam, 1951; Kapoor, 1954; Das and Moitra, 1955, 1956; Hussain, 1955; Khanna, 1961; Chakarborty and Singh, 1963; Kamal, 1964; Kapoor *et al.*, 1975; Miah and Dewan, 1977; Nazneen, 1977; Akhtar, 1979; Miah *et al.*, 1983; Bari and Nazneen, 1984) only marginal information has become available on the feeding habits of the mahaseers. Hora and Mookerjee (1936) have referred to the putitora mahaseer as more of a carnivore while the related tor mahaseer has been shown to be mostly a herbivore (Desai and Karamchandani, 1968). Ali and Hussain (1968) have given a brief description of the feeding habits of juvenile putitora mahaseer from the Rawalpindi area of the Punjab. In a recent study in India feeding habits of the tor mahaseer have been examined (Malhotra, 1982).

Rohu, thaila and mrigal have been commonly stocked in a polyculture system owing to the different niches they occupy as column, surface and bottom feeders respectively. The feeding behaviour and interactions of these species with the putitora mahaseer in the Rawal Lake have so far not been studied. At present nothing is known regarding the feeding habits and behaviour of the putitora mahaseer in the context of the environmental conditions in the Rawal lake and its feeding interactions with other species of fish living therein.

The present work on the putitora mahaseer represents an attempt to (1) study its feeding behaviour through field observations, (2) analyze gut contents as a means of determining its food and feeding habits, and (3) correlate its feeding habits with morphology of its alimentary tract. It was hoped that information on these aspects together with that described in the previous chapters would be valuable in not only gaining some understanding of the biology of this species but also in providing insight in respect to its food requirements in the field and interaction of this species with others in the lake.

## Materials and Methods

### Behavioural Study.

Observations on the feeding behaviour of the mahaseer were made in the field in shallow and accessible areas of the Rawal lake and the Kurang stream. All observations were made with a field binocular. Fish movements could be detected with relative ease during the daylight period in shallow marginal areas. However, after sunset when visibility becomes progressively reduced, the observations had to be restricted to periods immediately after dusk or to nights when the moon light was sufficient.

Gut Morphology and Contents.

A total of 113 specimens of the mahaseer (56 males, 57 females) were used for this part of the study. These were collected from the Rawal lake with gill nets and pooled with specimens obtained from local fishermen having access to the Rawal lake at certain times of the year. The samples of the fish were brought to the laboratory soon after collection. Gross morphological features of the mouth and the buccal cavity were recorded. The pharyngeal region was examined with attention to gill rakers and pharyngeal teeth. The gut was studied to note regional differentiation. The relative length of the gut (RLG, total length of gut as percent of total body length) was determined using two separate groups of 10 fish each having a mean size of 270 and 420 mm (S.L.) respectively.

As is well known for cyprinids in general the mahaseer also lacks a true stomach. Instead the part of the gut immediately next to the esophagus is relatively enlarged forming what is known as the intestinal bulb. Beyond this lies the remainder of highly coiled, narrow and long intestine. Preliminary checks revealed that the food in the part of the gut posterior to the bulb is usually in an advanced stage of digestion. Therefore, it was decided to dissect out only the intestinal bulb for examination of food contents. Only those bulbs which appeared nearly full were saved in 10% formalin. These were later cut open and their contents washed out in glass petri dishes. The food items were sorted out with the aid of a microscope under appropriate magnifications. The food organisms were studied and identified using available literature on local aquatic fauna and flora (Ali, 1967; 1970; Ali *et al.*, 1975; Khalil and Ahmed, 1976; Baqai *et al.*, 1977; Khatoon and Ali, 1978a, b, 1981; Ahmad and Younus, 1979; Ali and Qureshi, 1979). These were classified according to taxonomic categories and whenever possible down to the generic level. Analysis of the gut contents was based on both the numerical count and the frequency methods (see Pillay, 1953; Bruton, 1979). In the first case, the numerical counts of each item in the guts were made on monthly basis. The counts of each item in all guts examined were recorded for each month and tabulated as percent of total contents. The data were also pooled to obtain percent of individual items in all guts examined during the year. In the second case, the number or percentage of guts containing each food item was determined to yield frequency data.

## Results

### Behavioural Observations.

Field observations showed that the feeding activity of adult mahaseer in the lake occurs in marginal areas as well as at some distance from these where aquatic vegetation and a variety of other organisms thrive. Feeding occurs both during the early hours of the day (beginning before dawn) and in the late afternoon until sunset. The fish emerge from deeper areas of the lake in groups of 2-5 individuals and start moving into shallow areas prior to dawn and retreat into deeper water well before noon. In the late afternoon also they emerge from the deeper parts and show feeding activity in the shallows along the margin and near inlets of the Ramli and the Kurang streams. As far as could be judged feeding also occurs during the night.

During the day feeding periods, the fish occur in loose groups of 2-10 individuals. Once in the feeding areas, the fish spread out and feed singly or in groups of 2-4 fish. The fish are seen nibbling at and browsing on rooted and floating plants. They scrape plant material from submerged rocks and stones and are often seen picking detritus from the bottom. Some times they are seen lunging at food organisms on the surface of water. In the dry months of the year (May, June and early July) the water level of the lake falls considerably exposing the muddy slope of the lake. This restricts the feeding grounds to shallow narrows rich in vegetation and to offshore areas where small islands of reed are located at some distance from the lake margin. At such times of the year, catches of the mahaseer are reported by fishermen mainly from the vicinity of these reedy areas of the lake. These parts are particularly rich in algae, insects and crustacea. In the dry months when the water level in the streams is also low, the fish are often seen searching for food in riffle areas but they quickly retreat into deeper pools if disturbed. With the onset of rains in the monsoon months (July to September), feeding movements of fish are particularly noticeable

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in the marginal parts of the lake especially in the inlets. It is in this season that the fish start migrating upstream in preparation for spawning and in search of spawning grounds. Feeding activity does not occur during the courtship period but when the courting groups disperse and settle in deeper pools feeding may occur. However, evidence in this regard could not be gathered owing to practical difficulties in making observations.

Anatomical Features.

The mouth of putitora mahaseer is subterminal with the lower jaw being shorter than the upper jaw. The margins of the jaws are usually sharp but in some individuals fleshy lips have also been encountered. The jaws as well as other parts of the buccal cavity are entirely devoid of teeth. However, a pair of strong pharyngeal teeth are present behind the last gill arch in the posterior pharynx. These possess a row each of 4 stout and pointed teeth bordering a row of medial molariform tuberosities. The pharyngeal teeth operate against a median horny pad in the posterior roof of the buccal cavity.

The gill arches bear rows of very short gill rakers. These are present on both the anterior and posterior surfaces of the arches. On an average 15 rakers occur on the anterior face of the first arch and 25 rakers on its posterior face. The longest rakers on the anterior side measure 4 mm (mean size) and the distance between the rakers varies from 1.0 mm to slightly less than 2.0 mm. The length of rakers decreases gradually on the more posterior arches. On the posterior face of the 1st arch the mean length of the longest rakers is 2.0 mm and the distance between the rakers decreases to less than 1.0 mm. On the posterior arches the average number of rakers remains 25, the longest rakers measure 1.5 mm or slightly less but the distance between the rakers remains less than 1.0 mm. When the gill arches are appressed the rakers interdigitate.

The gut beyond the posterior pharynx consists of a short esophagus, an intestinal bulb and a thin walled, long and coiled intestine which opens terminally to the outside through the anus. The esophagus extends as far as the transverse septum. Its epithelium shows longitudinal folds. A true stomach is absent.

The anterior part of the intestine, however, is slightly enlarged and has relatively thicker walls. This represents the intestinal bulb, a common feature in other cyprinids as well. The bile duct opens into the gut at the posterior border of the bulb but anterior to the point where it makes the first $180^{o}$ turn of the intestinal coil. The mucosa of the bulb has a papillated appearance and is thrown into fine longitudinal folds. The average length of the bulb, using the point of entry of the bile duct as the demarcation between it and the rest of the intestine, is $50 \pm 8$ mm and $80 \pm 10$ mm (mean size of fish 270 mm and 420 mm S.L. respectively). Beyond the intestinal bulb the rest of the gut continues as a narrow, highly coiled and thin-walled intestine. The intestine in the two groups of fish studied ($\bar{x}$ size = 270 and 420 mm) measures $550 \pm 20$ and $1130 \pm 40$ mm. The mean RLG (relative length of the gut for the two groups is 2.0 and 2.7 respectively.

Analysis of Gut Contents.

Monthly analysis of the gut contents revealed that the fish feed on a variety of food organisms including those sifted from detritus. The monthly sample size and proportions of male and female fish are shown in Table 1. The following list enumerates the taxonomic variety of the food consumed.

MACROVEGETATION:

(Vascular plants)

*Vallisnaria*

*Ceratophyllum*

*Potamogeton*

*Hydrilla*

*Marsilea*

ALGAE:

Cyanophyta (blue-green algae)

*Nostoc*

*Oscillatoria*

Chlorophyta

*Chara*

*Cladophora*

*Zygnema*

*Spirogyra*

*Mougeotia*

*Closterium*

*Cosmarium*

INSECTA:

Dragon fly, adults and nymphs (Odonata)

May fly adults and nymphs (Ephemeroptera)

Waterboatman and Waterbug (Hemiptera)

Coleopterans

Trichopterans (mainly caddis worms)

Chironomid larvae

Mosquito larvae

CRUSTACEA:

*Chydorus*

*Moina*

*Daphnia*

Cyclops

*Diaptomus*

MOLLUSCA:

Gastropoda

Snails and Shells

*Dichotomosiphon*

*Volvox*

*Oedogonium*

*Schizomeris*

Chrysophyta (diatoms)

*Navicula*

*Frustulia*

*Pinnularia*

*Gomphonema*

*Nitzschia*

*Synedra*

*Diatoma*

*Eunotia*

*Tribonema*

FISH:

Mainly Small Carps:

*Barilius*

*Pseudoxygaster*

Table 2, 3, and 4 show variations in relative proportions of food organisms identified in the guts examined each month (numerical analysis). The mean yearly percentages of individual food types as well as of the major food categories are also shown in these tables. The most abundant food items are represented by macrovegetation (33.7%, Table 2) and algae (40.4%, Table 3). Adult insects, larvae and nymphs, crustaceans and gastropods are also

Table 1. Numbers of mahaseer specimens and mean size (S.L.) collected during 1983.

| Months | Male | | Female | |
|---|---|---|---|---|
| | Number | $\bar{x}$ Length (SL) (mm.) | Number | $\bar{x}$ Length (SL) (mm.) |
| January | 5 | 318 | 4 | 341 |
| February | 3 | 276 | 5 | 407 |
| March | 4 | 300 | 4 | 506 |
| April | 5 | 286 | 5 | 342 |
| May | 3 | 322 | 3 | 366 |
| June | 6 | 350 | 6 | 388 |
| July | 5 | 292 | 7 | 363 |
| August | 4 | 320 | 3 | 390 |
| September | 3 | 263 | 5 | 340 |
| October | 6 | 338 | 6 | 400 |
| November | 5 | 294 | 5 | 370 |
| December | 7 | 310 | 4 | 450 |

Table 2. Monthly percentage analysis of Macrovegetation (vascular plants) in the gut of *T. putitora*.

| Food organism | Jan. | Feb. | Mar. | Apr. | May | Jun. | Jul. | Aug. | Sep. | Oct. | Nov. | Dec. | Yearly average ( % ) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Vallisnaria* | 8.5 | 9.0 | 11.7 | 8.9 | 7.4 | 5.8 | 10.7 | 8.3 | 9.7 | 8.1 | 9.8 | 10.7 | 9.05 |
| *Ceratophyllum* | - | - | - | 4.8 | 5.4 | 5.3 | - | - | - | - | - | - | 1.29 |
| *Hydrilla* | 4.9 | 3.9 | 4.0 | 5.2 | 4.1 | 2.9 | 5.8 | 6.6 | 5.8 | 4.8 | 5.6 | 7.4 | 5.08 |
| *Marsilea* | 3.6 | 2.7 | - | - | - | - | - | - | - | - | 3.5 | 4.2 | 1.17 |
| *Potamogeton* | 3.7 | 2.4 | 3.5 | 3.7 | 2.6 | 1.5 | 2.8 | 3.5 | 4.0 | 5.4 | 4.1 | 5.4 | 3.55 |
| Unidentified plants, Roots and Semidigested plant matter | 17.0 | 18.5 | 15.3 | 10.2 | 12.0 | 14.5 | 13.2 | 11.6 | 13.0 | 15.6 | 12.9 | 9.8 | 13.63 |
| Total of all items (%) | 37.7 | 36.5 | 34.5 | 32.8 | 31.5 | 30.0 | 32.5 | 30.0 | 32.5 | 33.9 | 35.9 | 37.5 | 33.7 |

Table 3. Monthly percentage of algae in the gut of *T. putitora*.

| Food organism | Jan. | Feb. | Mar. | Apr. | May | Jun. | Jul. | Aug. | Sep. | Oct. | Nov. | Dec. | Yearly average (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Spirogyra* | 15.5 | 13.7 | 12.3 | 10.9 | 7.1 | 7.5 | 7.8 | 9.4 | 8.6 | 12.7 | 11.5 | 12.5 | 10.8 |
| *Chara* | - | - | - | - | 7.2 | 6.5 | 5.4 | 4.7 | 4.3 | - | - | - | 2.3 |
| *Ulothrix* | 13.9 | 10.9 | 9.0 | 8.2 | 5.0 | 4.8 | 3.8 | 5.8 | 6.8 | 7.5 | 8.0 | 8.4 | 7.7 |
| *Mougeotia* | - | - | 0.8 | 0.2 | 0.8 | 0.5 | 0.8 | 0.5 | 0.9 | 0.4 | - | - | 0.4 |
| *Zygnema* | - | - | - | - | - | 3.3 | 3.2 | 4.5 | 3.3 | - | - | - | 1.1 |
| *Cladophora* | 2.1 | 2.9 | 2.8 | 3.2 | 2.8 | 2.0 | 2.3 | 1.9 | 1.7 | 1.4 | 1.5 | 2.0 | 2.2 |
| *Closterium* | - | - | - | - | - | - | - | - | - | 2.8 | 3.5 | 3.8 | 0.8 |
| *Cosmarium* | - | - | - | - | - | - | - | - | - | 2.5 | 3.9 | - | 0.5 |
| *Dichotomosiphon* | - | 0.1 | - | 0.3 | 0.4 | 0.2 | 0.1 | 0.1 | - | - | - | - | 0.1 |
| *Oedogonium* | - | 2.6 | 3.6 | 3.0 | 2.7 | 1.9 | 2.5 | 2.3 | 2.8 | 2.0 | - | - | 1.9 |
| *Schizomeris* | 0.1 | 0.3 | 0.6 | 0.9 | 0.8 | 0.3 | 0.1 | 0.1 | 0.1 | - | - | - | 0.3 |
| *Tribonema* | - | 0.2 | 0.4 | 0.8 | 0.5 | 0.3 | 0.3 | 0.1 | - | - | - | - | 0.2 |
| *Volvox* | - | - | - | 0.8 | 1.1 | 1.2 | 1.8 | 1.2 | 1.0 | 1.9 | - | - | 0.8 |
| *Nostoc* | - | - | - | - | 1.2 | 1.9 | 2.6 | 1.9 | 2.1 | - | - | - | 0.8 |

Contd...

Table 3. (contd.)

| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Oscillatoria* | - | 3.6 | 2.1 | 2.9 | 2.2 | 2.2 | 2.8 | 2.2 | 2.0 | 2.4 | 2.0 | 1.5 | 2.2 |
| Unidentified semi digested algae | 9.4 | 4.5 | 5.8 | 4.1 | 2.7 | 3.8 | 2.2 | 4.2 | 5.7 | 5.8 | 6.6 | 9.8 | 5.4 |
| *Bacillaria* | - | - | 1.2 | 1.5 | 1.2 | 0.5 | 0.8 | - | - | - | - | - | 0.4 |
| *Diatoma* | - | - | 0.5 | 0.2 | 0.7 | 0.1 | 0.7 | 0.3 | - | - | 0.6 | - | 0.3 |
| *Eunotia* | - | 0.4 | 0.2 | 0.9 | 0.2 | 0.4 | 0.4 | - | 0.5 | - | 0.9 | 1.2 | 0.4 |
| *Frustulia* | - | - | - | 0.5 | 0.2 | 0.1 | 0.5 | - | - | - | - | - | 0.1 |
| *Gonphonema* | - | - | 0.5 | 0.1 | 0.9 | 0.2 | 0.7 | - | - | - | - | - | 0.2 |
| *Navicula* | - | 0.8 | 0.6 | 0.5 | 0.9 | - | - | 0.2 | - | 0.9 | 0.8 | 0.8 | 0.5 |
| *Nitzchia* | 0.5 | 0.1 | 0.7 | 0.8 | 0.2 | - | - | 0.4 | - | 0.7 | 0.5 | 0.9 | 0.4 |
| *Pinnularia* | - | 0.5 | 0.5 | 0.2 | - | - | - | - | 0.4 | - | 0.9 | 0.8 | 0.3 |
| *Synedra* | - | 0.2 | - | - | 0.7 | - | - | - | - | 0.5 | 0.8 | 0.6 | 0.2 |
| Total of all items | 41.5 | 40.8 | 41.6 | 40.0 | 39.5 | 37.7 | 38.8 | 39.8 | 40.2 | 41.5 | 41.5 | 42.3 | 40.4 |

Table 4. Monthly percentage of animal types in the gut of *T. putitora*.

| Food organism | Jan. | Feb. | Mar. | Apr. | May | Jun. | Jul. | Aug. | Sep. | Oct. | Nov. | Dec. | Yearly average (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Trichopteran larvae (mainly caddisworms) | - | - | - | 2.1 | 2.8 | 5.1 | 4.3 | 6.2 | 5.1 | 2.5 | 1.0 | - | 2.4 |
| Chironomid larvae (Diptera) | - | - | - | - | 3.2 | 4.3 | 2.9 | 3.6 | 3.0 | 1.5 | - | - | 1.5 |
| Mayfly and nymphs (Ephemeroptera) | - | - | - | - | 1.8 | 2.2 | 1.9 | 1.2 | 0.5 | 0.3 | - | - | 0.7 |
| Dragonfly and nymphs (Odonata) | - | - | - | 2.8 | 3.0 | 3.0 | 3.5 | 3.3 | 2.8 | 1.8 | - | - | 1.7 |
| Waterbug and waterboatman (Hemiptera) | 9.8 | 8.1 | 7.4 | 5.8 | 3.5 | 4.4 | 3.8 | 2.8 | 3.4 | 4.7 | 6.9 | 9.4 | 5.8 |
| Coleopteran adults and larvae | - | 2.8 | 2.9 | 2.0 | 1.3 | 3.4 | 2.3 | 2.9 | 2.5 | 2.1 | - | - | 1.9 |
| Semi digested insect material | 3.4 | 4.9 | 2.6 | 7.6 | 2.5 | 3.5 | 3.2 | 3.2 | 4.7 | 5.0 | 6.0 | 7.0 | 4.5 |
| *Chydorus* | 1.2 | - | 1.8 | 1.2 | 0.9 | - | 0.5 | - | 0.8 | 2.1 | 3.5 | - | 1.0 |
| Cyclops | 1.7 | 1.8 | 2.7 | 1.3 | 2.5 | 3.5 | 1.0 | 2.1 | 1.4 | 2.2 | 2.4 | 3.0 | 2.1 |

Contd..

Table 4. (Contd.)

| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Daphnia* | - | - | 1.3 | 1.6 | 2.1 | - | 1.4 | 1.0 | 0.9 | - | - | - | 0.7 |
| *Diaptomus* | 2.5 | 1.5 | 1.5 | - | 1.3 | - | 1.1 | 1.2 | 1.8 | 1.8 | 2.5 | - | 1.8 |
| *Moina* | 2.1 | 3.0 | 3.0 | 2.3 | 3.3 | 2.0 | 2.1 | 2.1 | - | - | - | - | 1.7 |
| Gastropods (shells) | 0.8 | 0.6 | 0.7 | 0.5 | 0.8 | 0.9 | 0.8 | 0.6 | 0.4 | 0.6 | 0.7 | 0.8 | 0.7 |
| Total of all items | 21.5 | 22.7 | 23.9 | 27.2 | 29.0 | 32.3 | 28.8 | 30.2 | 27.3 | 24.6 | 23.1 | 20.2 | 25.9 |

Table 5. Monthly records showing food preference (dominant and subdominant food items) according to numerical analysis. The items have been listed in order of abundance.

| | |
|---|---|
| Jan. | *SPIROGYRA*, *Ulothrix*, *Vallisnaria*, Waterboatman, *Hydrilla*, *Marsillea*, *Potamogeton*, *Diaptomus*. |
| Feb. | *SPIROGYRA*, *Ulothrix*, *Vallisnaria*, Waterboatman, *Hydrilla*, *Cladophora*, *Marsillea*, *Potamogeton*. |
| Mar. | *SPIROGYRA*, *Vallisnaria*, *Ulothrix*, *Hydrilla*, *Potamogeton*, *Oedogonium*, *Cladophora*, Waterboatman. |
| Apr. | *SPIROGYRA*, *Vallisnaria*, *Ulothrix*, Waterboatman, *Hydrilla*, *Ceratophyllum*, *Potamogeton*, Dragon flies. |
| May | *VALLISNARIA*, *Spirogyra*, *Chara*, *Ceratophyllum*, Dragon flies, *Hydrilla*, *Cladophora*, Waterboatman. |
| Jun. | WATERBOATMAN, *Spirogyra*, *Chara*, *Vallisnaria*, *Ceratophyllum*, Trichoptera, *Ulothrix*, Chironomids. |
| Jul. | *WALLISNARIA*, *Spirogyra*, Trichoptera, *Hydrilla*, *Ulothrix*, *Chara*, Waterboatman, *Zygnema*. |
| Aug. | *SPIROGYRA*, *Vallisnaria*, *Hydrilla*, Trichoptera, *Ulothrix*, *Zygnema*, Chironomids, *Potamogeton*. |

Table 5. (Contd.)

| | |
|---|---|
| Sep. | *VALLISNARIA, Spirogyra, Ulothrix, Hydrilla, Trichoptera, Chara, Potamogeton,* Waterboatman. |
| Oct. | *SPIROGYRA, Vallisnaria, Ulothrix, Potamogeton,* Waterboatman, *Closterium, Oscillatoria, Cosmarium.* |
| Nov. | *SPIROGYRA, Vallisnaria, Ulothrix,* Waterboatman, *Hydrilla, Potamogeton, Cosmarium, Marsillea.* |
| Dec. | *SPIROGYRA, Vallisnaria,* Waterboatman, *Ulothrix, Hydrilla, Potamogeton, Marsillea, Closterium.* |

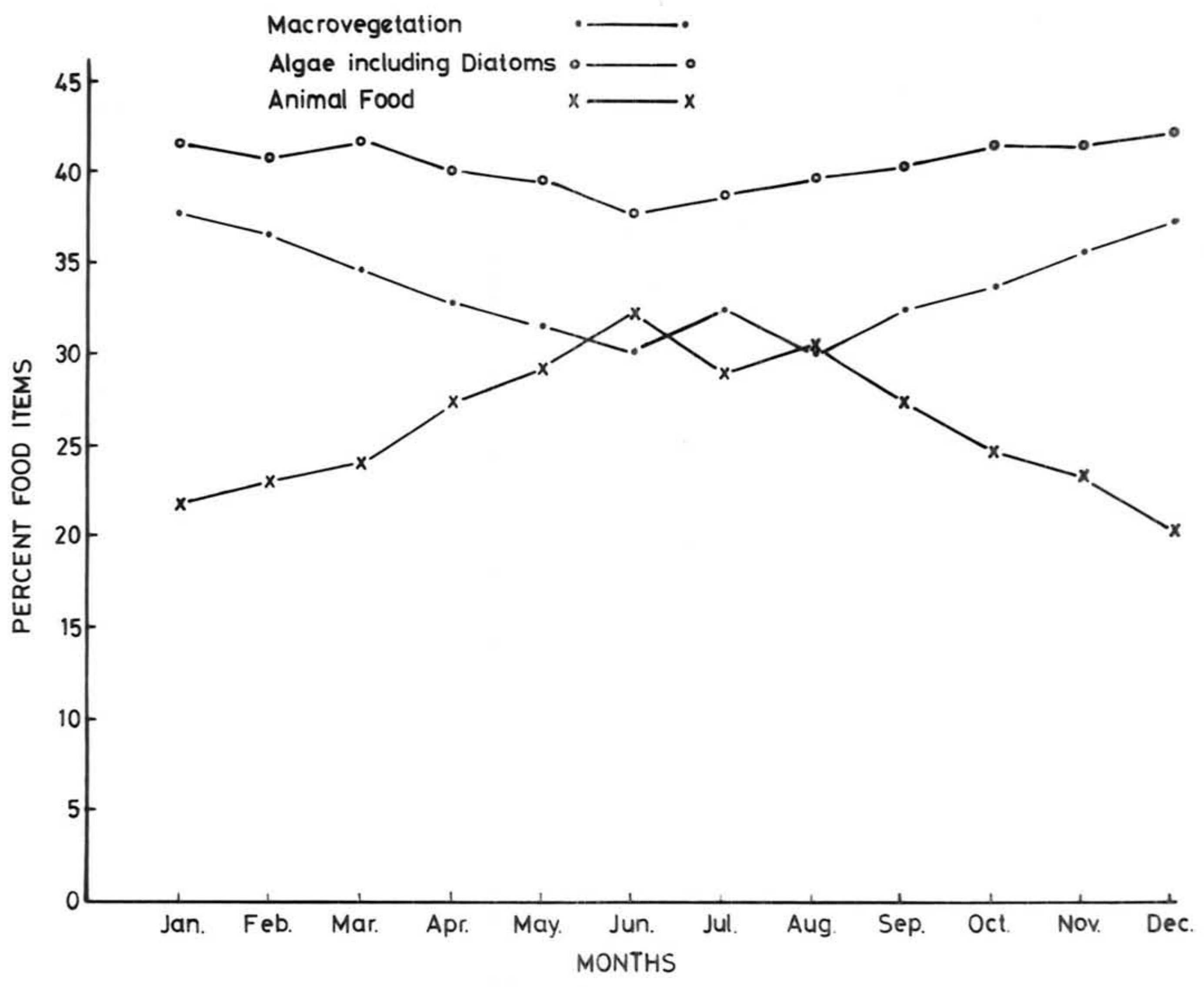
Macrovegetation
Algae including Diatoms
Animal Food
PERCENT FOOD ITEMS
45
40
35
30
25
20
15
10
5
0
Jan.
Feb.
Mar.
Apr.
May.
Jun.
Jul.
Aug.
Sep.
Oct.
Nov.
Dec.
MONTHS

Fig.1

*Vallisnaria* replacing it in May and September and waterboatman becoming dominant in June. The subdominant species interchange from month to month but *Vallisnaria* and *Ulothrix* appear prominently. Food preferences were also determined on the basis of the frequency method. A summary of the food items occurring in most stomachs during the year is given in Table 6. The most frequent items are distributed in three main categories namely macrovegetation, algae and Insecta. The most important items in order of frequency are waterboatman and waterbug, *Hydrilla*, *Spirogyra*, *Vallisnaria*, *Ulothrix*, *Potamogeton*, trichopherans, cyclops and *Cladophora*. The order of dominance and subdominance according to this method, thus, turns out to be different from that based on the numerical method. However, those items which appear most preferred according to the numerical method occur prominently in the list of preference based on the frequency method.

Table 6. Food preference of the mahaseer based on frequency method (% of guts containing the item).

| Food | Frequency (% of total stomachs) |
|---|---|
| MACROVEGETATION: | |
| *Hydrilla* | 99.11 |
| *Vallisnaria* | 91.15 |
| *Potamogeton* | 73.45 |
| *Marsilea* | 25.66 |
| *Ceratophylum* | 20.35 |
| ALGAE: | |
| *Spirogyra* | 98.23 |
| *Ulothrix* | 90.26 |
| *Cladophora* | 52.21 |
| *Oscillatoria* | 47.78 |
| *Oedogonium* | 38.93 |
| *Chara* | 32.74 |
| *Zygnema* | 23.00 |
| *Volvox* | 22.12 |
| *Closterium* | 19.46 |

Contd...

Table 6. (contd.)

| | |
|---|---|
| INSECTA: | |
| Waterboatman and Waterbug | 100.00 |
| Trichoptera | 60.00 |
| Odonatan nymphs | 49.00 |
| Coleoptera | 49.00 |
| Mayfly nymphs | 25.00 |
| Chironomids | 44.00 |
| CRUSTACEA: | |
| *Chydorus* | 23.00 |
| Cyclops | 53.00 |
| *Daphnia* | 19.00 |
| *Diaptomus* | 28.00 |
| *Moina* | 28.00 |

## Discussion

There is considerable diversity in feeding behaviour and habits of fishes. The adaptive correlates are complex but undoubtedly show relationships with morphological developments for searching, locating and ingesting food and the characteristics of habitats in which given fish populations live. The precise strategies adopted by different species to obtain food range from individual feeding to group feeding. The latter in turn may involve non-polarized groups (loose groups) or polarized schools employing specialized social hunting, foraging and grazing techniques (Bruton, 1979; Keenleyside, 1979). The organization of feeding behaviour of fish is not only governed by the food types or prey behaviour and their effective exploitation but also by predation and its avoidance. The putitora mahaseer attains a large size and thus does not experience predatory pressures in the adult state in the localities studied. The present results show that the mahaseer's feeding periodicity is spaced in the morning and afternoon hours and probably also in the early hours of night. Although the putitora mahaseer has been shown here to be omnivorous, it is primarily dependent on plant food (macro-vegetation and algae). Since browsing on rooted plants demands little in terms of behavioural specializations, social mechanisms of feeding are not necessitated. The feeding behaviour of the mahaseer described here appears to be a generalized one. The fish move in groups of variable size but once the group reaches the shallow feeding areas it often breaks up into solitary individuals feeding independently. It is not uncommon, however, that as an individual fish locates food one or more other individuals temporarily join it causing formation of loose groups of two or more fish. Other diurnally active fish are also known to display such a behaviour (Keenleyside, 1955; Fishelson, 1977; Keenleyside, 1979).

The putitora mahaseer is a marginal feeder. The individuals scan the substratum (bottom feeding), the water column as well as the surface water for food. They nibble and browse on plant leaves, graze algae from submerged rocks and stones, engulf crustacean and other planktonic organisms in the manner of particulate feeding, pick flotsam containing fallen insects and jump to catch insects moving on the water surface. Detritus is invariably turned over and taken in for sorting out food organisms. During the day time, the individuals must depend in part but to a large extent on the visual sensory system for locating food. If indeed feeding occurs in this species at night as well, it cannot be defined as yet in terms of the specific behavioural and sensory mechanisms since not enough effort was made at present to do so. As mentioned earlier the fish move at night in schools, particularly during the breeding season, but whether such an organization is assumed as a feeding strategy also cannot be stated with any certainty.

The subterminal mouth with relatively sharp jaw margins is suited for bottom feeding, off the surface of rocks and stones in addition to the usual pipette suction method of feeding employed by cyprinid fishes (Bruton, 1979). The pharyngeal teeth provide the requisite mechanism for tearing off leaves of rooted plants, partially macerating these and crushing shelled organisms such as snails before their passage farther down the gut. The grass carp, *Ctenopharyngodon idella*, lacks teeth in the mouth but uses its pharyngeal teeth for grasping leaves and tearing pieces from it (Cross, 1969). Pharyngeal teeth are present in a variety of fish species and are a common feature in cyprinids (Sarbahi, 1939; Islam, 1951; Girghis, 1952; Kapoor, 1954; Das and Moitra, 1956; De Silva *et al.*, 1977). These are used for tearing plant material and partial crushing and break down of food prior to its entry into the esophagus.

The mahaseer has very short gill rakers on the gill arches. Although these are poorly developed, these probably suffice to retain small organisms as planktonic algae, crustaceans, insect larvae and nymphs. Whereas the spacing of the gill rakers varies between less than 1.0 mm to almost 2.0 mm, the effective distance is considerably reduced when the rakers of anterior and posterior arches interdigitate.

The gut of the mahaseer lacks a true stomach and the intestine is highly coiled in the manner characteristic of cyprinid fishes (Sarbahi, 1939; Islam, 1951; Girghis, 1952; Kapoor, 1954; Hussain, 1955; Das and Moitra, 1956; De Silva *et al.*, 1977; Nazneen, 1977; Kapoor *et al.*, 1975; Akhtar, 1979; Bari and Nazneen 1984). Das and Moitra (1956) have shown that a true stomach is absent in such herbivores as *Cirrhinus* spp; *Amblypharyngodon mola* but it is present as a highly muscular structure in carnivorous species (*Mystus* spp., *Callichrous Papda*, *Chela bacaila*, *Wallagonia attu*, *Ophicephalus striatus*, *Ambassis* spp.). Such a correlation has also been established in other fishes (Khanna, 1961). The omnivorous species show variations in this respect; in some cases a stomach is present and in others it is absent (Das and Moitra, 1956). The putitora mahaseer lacks it in spite of omnivorous habits but since it shows a predominance of plant material in the gut, this may not be too surprising. In addition, to the above aspect, the relative length of the gut has also been taken to be a good indicator of feeding habits of fishes. Das and Moitra (1956), Khanna (1961) and Bari and Nazneen (1984) have presented substantial evidence that this ratio of the intestine to body length is very high in the herbivores and usually below 1.0 in the carnivores (from 5.0 - 21 in herbivores, 0.34 - 1.49 in carnivores). The omnivorous species fall in the range 1.0 - 3.0 (Das and Moitra, 1956; Khanna, 1961). The RLG for the putitora mahaseer is also in this range.

Analysis of feeding habits of fishes based on gut analysis has been a well established methodological approach. There is always danger of introducing biases in results owing to presence of partially or completely digested food organisms prior to their recovery. Similarly, conclusions regarding food preferences may be affected depending upon whether analysis is based on numerical counts, frequency of occurrence of food items or weight of food organisms (Pillay, 1953; Desai and Karamchandani, 1968; Hobson, 1974; Bruton, 1979). The analysis of gut contents of the mahaseer could be based only on the numerical and frequency of occurrence methods. Weight determinations were left out in view of technical problems and the fact that any advantages this method offers would be offset by errors in compensating for partly digested or fully digested material particularly if it cannot be readily assigned to given categories of food.

The omnivorous feeding habit of the mahaseer is evident not only through direct observations on feeding behaviour but is also reflected in the variety of food collected from the gut. Both macrovegetation (parts of rooted vascular plants) and algae form the predominant component of the diet. Food of animal origin comprising mainly insect and crustacean types is considerably less in proportion. These observations agree with those of Desai and Karamchandani on *Tor tor* (1968). That the fish feed at various levels in the marginal areas of the lake is evident from the variety of food items and particularly the invariable presence of sand or mud, detritus and such objects as date-stones in the gut. The incidence of both macrovegetation and algal food show seasonal fluctuation but the variation is only slight. The fish essentially continue feeding on these items throughout the year. In the monsoon and the winter following thereafter, the proportion of macrovegetation increases presumably correlating with a spreading shoreline owing to inundation and a rise in water level of the lake. The proportion of animal food is generally low in several months of the year (December, January, February, March and April) when only a few animal representatives comprising mostly waterboatman but occasionally also dragon fly and *Moina* occur in the diet. However, the variety and the numerical value of animal material rises appreciably and sharply during the summer and monsoon months. According to the numerical analysis, the dominant species in the diet interchange between *Spirogyra* and *Vallisnaria*. *Spirogyra* is dominant in most months of the year. Waterboatman was encountered in dominant position only in June. Frequency analysis, on the other hand, provides a somewhat different order of preference namely waterboatman (and waterbugs), *Hydrilla*, *Spirogyra*, *Vallisnaria* *Ulothrix* and *Potamogeton*. The percentages of the first four of these items are not appreciably different. Furthermore, the most important items according to the numerical method are also included in the order of preferences based on the frequency of occurrence method. Although some data have been recently published (Ahmed *et al.*, 1985) on the physicochemical features of the Rawal lake, none are available on its fauna and flora. Therefore it is not possible to correlate the seasonal variations in the diet or even the relative abundance of the various food items in the diet with cyclic patterns of biotic variety in the lake.

The presence of sand, mud, and such items as date-stones in the gut indicates that the species also feeds on the bottom in marginal areas of the lake. This is also evident from the fact that individuals are actually seen picking detritus. It seems that like other species of fish which actively take in detritus to sort out fragmented plant material, animal material and microorganisms, (Keenleyside, 1979), the mahaseer also depends on detritus for its nutritional sources. Detritus and sand are of common occurrence in guts of other bottom feeding carps as well (*Cirrhinus mrigala*: Kamal, 1964; *Cyprinus carpio*: Swee and McCrimmon, 1966; Nazneen, 1977; Akhtar, 1979; Crivelli, 1981; Bari and Nazneen, 1984).

Past studies on the tor mahaseer resident in the Indian region (*Tor tor*: Hora and Mookerjee, 1936; Desai and Karamchandani, 1968) have shown it to be principally herbivorous largely feeding on macrovegetation and algae although molluscs and insects are also included in the diet. This is in keeping with the generally herbivorous habits of the major Indo-Pakistani carps (Hussain, 1955, *Catla catla*, *Cirrhinus mrigala*, *Labeo* spp.; Das and Moitra, 1956, several species; Khanna, 1961, *Barbus* spp., *Amblypharyngodon mola*; Kamal, 1964, *Cirrhinus mrigala*; Kapoor, 1954; Kapoor *et al.*, 1975, *Puntius* spp., *Tor tor*; De silva *et al.*, 1977, several spp.; Bari and Nazneen, 1984, *Labeo* spp., *Puntius* spp., *Serotherodon mossambicus*). In a brief reference, Hora and Mookerjee (1936) state that the putitora mahaseer is more of a carnivore than a herbivore. There is no mention of the age of fish examined in their study. The only other available information on the putitora mahaseer from waters of Pakistan has come from Ali and Hussain (1968) who have reported mainly animal food material including planktonic organisms in the diet of this species.

These authors have argued that the species is basically carnivorous. The only plant materials detected by these workers are *Ulothrix*, *Spirogyra* and some other unspecified filamentous algae. The relative proportions of the various items have not been indicated. This study evidently was based on the gut contents of juvenile mahaseer ranging in size between 7-15 mm. Therefore, valid comparisons with the present results derived from examination of adult mahaseer of considerably larger size are not possible. Many species of fish show shifts in dietary composition with age and at particular times during their life history (Keenleyside, 1979). In addition, and within limits, the composition of the diet often depends on the available fauna and flora in given bodies of water -- the fish adapting to prevailing conditions in the absence of choice food materials. The differences in terms of which category (plant or animal) predominates in the food and reflected in the observations of early workers studying the putitora mahaseer (Hora and Mukerjee, 1936; Ali and Hussain, 1968) may be owing to the biotic conditions in the streams from where the mahaseer specimens were obtained for gut analysis. The present observations show that the population of the putitora mahaseer thriving in the Rawal lake and its tributaries is omnivorous and presumably adaptable to changing biotic conditions.

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# CHAPTER - 6

## GENERAL DISCUSSION

In this study of the breeding biology and behaviour of the putitora mahaseer information has been collected on (1) gonadal maturational rhythm and breeding cycle (2) size and age at first maturity, (3) fecundity in relation to body length, weight, ovarian weight and age, (4) spawning behaviour, (5) schooling behaviour of the juveniles, and (6) food and feeding behaviour. It has been shown that this species breeds during the period July to September with spawning continuing as late as early October. The peak spawning months are August and September. Males mature first in their 2nd year and the females on completion of 3-years. The average length and weight of the two sexes at this time are 170 mm and 104 g and 326 mm and 551 g respectively. The males not only mature at a smaller size and younger age but also become reproductively active ahead of the female as the breeding season approaches. The spawning movements of the fish become evident during late July when schools

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comprising a single female and several males emerge from the lake and migrate upstream toward shallow spawning sites in the Ramli and the Kurang streams. The breeding behaviour is a 2-phase affair. There is a long but simple courtship period followed by consummation of the spawning act. The spawning sites are shallow, pebbly and rocky areas of the streams with swift water currents. Neither preparation of the substratum for receiving the eggs nor care of the fertilized eggs is involved. The absolute fecundity of the species in the Rawal lake conditions is low, ranging between 7,570 to 29,210 eggs. Multiple regression analysis reveals a positive relationship of fecundity with body size (length and weight), ovarian weight and age. There is evidence of only a gradual development of schooling in the juvenile over a period of time. The fry initially behave as solitary individuals but as size increases they occur in polarized schools. The adult mahaseer feed singly or in loose groups consisting of a few individuals. The feeding activity takes place in the forenoon and afternoon but may also occur at night. The adult mahaseer is a marginal feeder gathering food from the bottom, mid and surface water. It is an omnivore but primarily depends on plant material (macrovegetation and algae). Data have been presented pertaining to seasonal variations in the composition of the diet and dominant items of food. The omnivorous habits of the fish are also reflected in the ratio of the length of the gut to the length of the body (RLG = 2.0 - 2.7).

The available information on the breeding cycle of the putitora mahaseer has been conflicting. In this context it is noteworthy that the populations of this species examined in these various works belong to widely differing ecological conditions. The populations in the Rawal lake and the Bhimtal lake in Naini Tal (Pathani, 1983) perhaps thrive in some what comparable conditions. On the other hand the results of studies by Qasim and Qayyum (1961) and Bhatnagar (1964) are based on populations thriving in the plains with very different environmental conditions and hence are discordant from those presented here. It has been generally argued that the most dominant factor which triggers breeding activity in the cyprinids is the monsoon rain causing flooding of shallow breeding sites (Khan, 1939; Hora, 1939; Alikunhi and Rao, 1951;

David, 1953; Qasim and Qayyum, 1961; Bhatnagar, 1964; Swee and McCrimmon, 1966; Desai, 1973; Chaturvedi, 1976; Crivelli, 1981; Pathani, 1983). According to Khan (1943) and Qasim and Qayyum (1961), *Cirrhina mrigala*, *Labeo rohita* and *Labeo calbasu* delay spawning if the monsoon rains are delayed and even resorb the eggs in situations of drought. Thus, differences in the timing of onset of breeding activity amongst populations residing in different ecological conditions and also owing to annual variations in rainfall can be anticipated. The disagreement in the observations of Pathani (1983) and the present results in regard to the timing of onset of the breeding condition are, therefore, not too surprising.

Besides photoperiod, the significance of temperature in regulating breeding seasonality in fishes cannot be berated (DeVlaming, 1974). Swee and McCrimmon (1966) and Shields (1957) have demonstrated that the common carp (*Cyprinus carpio*) in North America shows breeding activity in a temperature range of 17-23$^{\circ}$C. A primary significance of temperature in controlling spawning activity in the mahaseers has also been ascribed by David (1953) and Desai (1973) for populations residing in the Rivers Mahanadi and Narmada, India, respectively where the temperature during the breeding season fluctuates between 20-28°C. Perhaps, Crivelli (1981) has rightly pointed out that both temperature and rainfall are important. The first controls gonadal maturation and induces spawning preparedness while the latter is essential for deposition of eggs and their survival. The monsoon season in Islamabad begins in July, continues through September and is accompanied by a drop in temperature from peaks in June or early July (28°C in June to 24°C in October). This is also a period when the daily temperature is relatively most stable. The midday water temperature in the Rawal lake in the winter reaches such low values as 12-14°C. Therefore it is unlikely that the putitora mahaseer would breed in such conditions and indeed there is no evidence to support that mature ovaries occur in the mahaseer population at this time as has been reported (on the basis of a single specimen) by Butt and Hayat (1978) for this species in Mardan District of North West Frontier Province. Whether the latter observation is valid requires further validation through examination of representative population samples.

The late maturation of the putitora mahaseer (i.e. 2 year old males, 3 year old females) as shown presently and by Pathani (1983) is by no means unique to this group of carps but is characteristic of other carps as well. The female *Labeo calbasu* become mature in the 3rd year of life (Gupta and Jhingran, 1973, Pathak and Jhingran, 1977). Late maturation is also known for rohu, thaila, mirgal (Woynarovich and Horvath, 1980). The male and female common carp in lake St. Lawrence, Ontario, Canada mature when 2 and 3 years of age respectively (Swee and McCrimmon, 1966) and this has also been supported by Crivelli (1981). The observations on first maturity presented here are in agreement with those of Pathani (1983, *Tor putitora*, *Tor tor*) and Desai (1973, *Tor tor*). However, Chaturvedi (1976) indicates that the tor mahaseer in Udaipur, India, achieve first maturity in their 1st year of life. Although there are some questions regarding the accuracy of age determination (see Pathani, 1983), differences in timing of maturity within the same species but from different latitudes have been recorded (common carp, Woynarovich and Horvath, 1980).

In comparison with other major carps, the absolute fecundity of the mahaseer population in the Rawal lake is generally much lower (7,570 to 30,295 eggs). A similarly low fecundity has been reported for this species from Naini Tal by Pathani (1983). The relatively low fecundity of the various mahaseers appears to be a group-specific characteristic. When fecundities of a variety of major carps for a range of body weights comparable to those bracketed for the putitora mahaseer in this study are examined the absolute fecundity values fall between 36000 to well over 700,000 eggs (*Labeo rohita*, Varghese, 1976; *Labeo fimbriatus*, Rao, 1974; *Cyprinus carpio*, Swee and McCrimmon, 1966, Parmeswaran *et al.*, 1972; *Labeo calbasu*, Pathak and Jhingran, 1977). Bagenal (1967, 1973) has discussed various factors which have a bearing on fecundity. One of the widely acclaimed correlations, in this reference, is between size (diameter) and numbers of eggs spawned. Fish producing large numbers of eggs must lay smaller eggs and vice-versa. It is true that the eggs of the mahaseer are larger in size than those of the common carp and *Labeo calbasu* (see Pathak and Jhingran, 1977; Woynarovich and Horvath, 1980). However, in comparison with the size of eggs of rohu, the mahaseer eggs do not differ so strikingly as to explain the low fecundity of the putitora mahaseer. Another factor which appears intimately connected with fecundity is availability of food and hence food reserves which should be mobilized in the production of eggs (Bagenal, 1967; Gorbach, 1972). In this regard also it is difficult to judge, at present, whether the low fecundity of the putitora mahaseer reported here is related with the prevailing biotic conditions in the Rawal lake since no information is available on this aspect of the lake ecology. Also, nothing is known about the biology and fecundity of the rohu, mirgal, thaila and the common carp populations inhabiting the Rawal lake. Such information is important for a more realistic comparative evaluation of the fecundity and interrelationship with Rawal lake ecology. Pathani (1981) has stated that the low fecundity of the putitora population in related with low temperatures and productivity of the Bhimtal lake. In contrast to the data for this species, Desai (1973) and Chaturvedi (1976) have shown much higher fecundity for the tor mahaseer (28000 - 1,50,000 + eggs) of comparable length-weight range but belonging to widely different ecological conditions. The fecundity of this species of the mahaseers though higher than that of the putitora species is also lower than that of the other carps named above. Whether a low fecundity is a group-specific feature of the mahaseers remains a question open to further work and comparative analysis.

Behavioural adaptations are an integral part of the overall scheme of survival strategies adopted by species of fish. The breeding behaviour in fishes depends in part on mechanisms which ensure attraction between sexes culminating in fertilization of eggs in suitable environmental situations. The behaviour itself is definable as courtship, mating and/or spawning (Keenleyside, 1979). Courtship is often an elaborate process particularly in species where fertilization is internal and also where the members do not form schools for a greater part of their life (or in the adult state). Thus, mate attraction at the right time becomes an unavoidable necessity for breeding success. The classical example of mate attraction and care of the young is that of *Gasterosteus aculeatus* (Tinbergen, 1951). Aside from these advantages provided by courtship in fish reproduction, some of the other adaptive functions it serves are arousal of motivational states, the requisite motor patterns and synchrony in mating in addition to ensuring involvement of only the conspecifics in the spawning activities (Morris, 1956; Bastock, 1967; Baylis, 1976; Keenleyside, 1979). Where species spend most of their life time in schools, attraction between the sexes is not likely to be in any jeopardy and also a less elaborate courtship ritual may be sufficient to cause consummation of the spawning act. The family Cyprinidae contains many species which scatter their eggs in the spawning grounds. The putitora mahaseer is no exception in this regard (see also Pathani, 1983). The breeding behaviour appears to be a generalized one with the courtship act being rather simple. The spawning occurs on unprepared sites but those which have been adaptively selected. This is also true for other major carps (e.g. *Cirrhinus mrigala*: Khan, 1943) and also for the common carp (*Cyprinus carpio*: Swee and McCrimmon, 1966; Parmeswaran *et al.*, 1972; Crivelli, 1981). The ratio of the spawning females and males of the putitora mahaseer as reported by Pathani (1983) is 1 female to 2-7 males) and although no definitive estimates could be made in the present work it may not be too different for the population examined in the Rawal lake. Ratios as high as 1:10 have been reported for the common carp (Shields, 1957), 1:5 for salmonids (Hartman, 1969), and 1:5 for shads (*Dorosoma* spp; Shelton *et al.*, 1982). This apparently serves as an adaptation ensuring fertilization of the eggs as soon as these are shed in cases where an elaborate courtship involving single pairs is absent. Moreover, inhibition of aggressive tendencies during courtship amongst the males in the spawning groups further aids in success of the consummatory act (Keenleyside, 1955, 1979). Aggressive tendencies amongst the males of the putitora mahaseer have neither been observed at this time nor reported by Pathani (1983).

Among the behavioural aspects of fishes, schooling behaviour is an interesting area of study. In the putitora mahaseer, it has been shown that schooling patterns emerge during the juvenile stage over a certain period of time after hatching.

While the schooling behaviour with biosocial interaction as its central organizer is determined internally by the physiological condition of the individuals (Keenleyside, 1955, 1979; Breder, 1976; Aoki, 1980), its continuation, persistence or cessation in given species is undoubtedly influenced by such factors as feeding, reproductive and escape (from predators) motivations (Keenleyside, 1955). The primary value that schooling has lies in escape from enemies (Breder, 1959; Shaw, 1970, 1978). Fish schools, owing to shifts in position of the individual fish in it, can confuse predators (Pitcher, 1973). Feeding advantages offered by schooling to the fish are of equal significance. Location of food by one member of the school serves as a signal to neighbours to join without special effort of their own. The school, thus, represents a unit with a repertoire of sensory mechanisms for effective communication amongst its members (Aoki, 1980). The fact that the juvenile mahaseer seem to spend time mostly as solitary individuals during the very early stages of their life raises questions in terms of their survival and effectiveness in exploitation of environmental resources. It is likely that their small size provides

2.2)



advantages in avoiding enemies (not readily detectable as opposed to a large fish or a whole school) and also allows better feeding conditions in the absence of competing conspecifics (Seghers, 1981).

In reference to the behavioural organization of the adult mahaseer, observations were possible in this study only incidental to an examination of their feeding habits and behaviour. The feeding behaviour of the adults seems to be a generalized one. The fish are seen in schools as these emerge for feeding but soon break up into groups of 2-5 individuals or the members assume a solitary disposition. The group formation is temporary and unstable. A similar behaviour is known to occur in the case of the common carp (Swee and McCrimmon, 1966, Crivelli, 1981) which is also an omnivore and a bottom feeder with a pronounced detritivorous habit. The mrigal (*Cirrhinus mrigala*: Akhtar, 1979; Bari and Nazeen, 1984) and *Cirrhinus latia* (Nazneen, 1977) also have comparable habits. According to Aoki (1980) and Shelton *et al.*, (1982), the behaviour of many species of fishes changes as progressive development from the juvenile to the adult state occurs. The threadfin shad (*Dorosoma petenense*) is predominantly schooling and planktivorous throughout life whereas the gizzard shad (*Dorosoma cepedianum*) showing a similar behaviour in early life shifts to a solitary and detritivorous habit beyond the first year of life. The kind of food consumed by the putitora mahaseer in the Rawal lake and probably also in other residential circumstances is such that a specialized social organization in the form of polarized schools does not appear adaptive or necessary. Independent, solitary or at best a loose aggregation is quite suitable. Also, being one of the large-sized species resident in the lake, the members of the population are not threatened by predation or enemies during their existence as adults. Therefore, adaptive pressure for polarized schooling does not exist as a means of enhancing survival. These speculative statements, however, should not be construed as definitive conclusions regarding the question of schooling behaviour in the adult mahaseer until further studies are conducted on analysis of schooling behaviour per se of the adult mahaseer.

The data presented on the diet and feeding habits of the putitora mahaseer in the Rawal lake and its tributaries are by no means complete. A survey of the feeding habits and gut analysis of the juveniles is essential to provide a realistic picture of the position of this species relative to the other carps thriving in the lake. The diversity of the food items in the gut of the adults and their feeding behaviour, however, clearly reveal that these are omnivorous with major dependence on plant material. This is in agreement with the observations of Desai and Karamchandani (1968) on the related tor mahaseer. The absence of a true stomach and the values of RLG (being higher than those for cornivorous species: Das and Moitra, 1956, Khanna, 1961; Kapoor *et al.*, 1975; Miah and Dewan, 1977; Nazneen, 1977; Miah *et al.*, 1983; Bari and Nazneen, 1984) also support the present conclusion. It should, nevertheless, be noted that adaptations of given populations of this species (as is also true for other nonspecialized fish species) may vary according to biotic conditions prevailing at given times in the habitat. Less preferred food organisms may be consumed when the primary choice is lacking. Already in the present study it has been shown that, at particular times of the year, the putitora mahaseer predominantly takes in animal diet. Thus, the observations of Hora and Mookerjee (1936) on the putitora mahaseer suggesting a more carnivorous habit may not necessarily be entirely untrue. The samples of the fish may have been taken from localities where the biotic composition could support consumption of predominantly animal material.

The data and details presented in this report collectively constitute a much needed body of information on some of the most important aspects of the biology of the putitora mahaseer inhabiting the Rawal lake. The most important species of fish thriving in this lake are rohu, mrigal, thaila, putitora mahaseer and the common carp has been recently introduced. As far as could be ascertained, stocking of the lake with the seed of rohu and mrigal has also been periodically carried out. A polyculture situation characterizes the lake. While it is well known that the rohu, mrigal and thaila are compatible species occupying different niches, the common carp is a prolific breeder and shares feeding habits in common with the mrigal. The putitora mahaseer has been shown in this study to have low fecundity and bears similarities in its feeding habits especially with those of the mrigal and the common carp. Although the breeding season of the putitora mahaseer may only marginally overlap with that of the other four species (as far as can be judged on the basis of the available information), interaction between these species at other times of their life may occur. Unfortunately, no information is available on the productivity and detailed ecological conditions of the Rawal lake. Also, nothing has been published as yet regarding the biological aspects of rohu, mrigal and thaila populations of the lake. Therefore, it is not possible to assess the relative position these species of carps occupy in the lake or how they interact at various times of their life. In order to fully appreciate the status of the mahaseer as a food resource, its future and the impact of the reservoir, a considerable body of information needs to be gathered. Lone (1983) has provided a useful summary of the fishery potentials, pros and cons of stocking and fish culture practices and management requirements pertaining to man-made reservoirs. The putitora mahseer migrates upstream in search of suitable breeding grounds and feeds in marginal areas of the lake (subjected to considerable seasonal fluctuations in water level). The data further reveal a low fecundity of the species. These observations and other details given in the present work draw focus on the impact of the dam and the impoundment on the biology and success of the mahaseer species as a commercially exploitable food resource. With future scientific investigations aimed at understanding the population dynamics of not only this species but also of the other major carps coexisting in the lake together with the desired information on biology of the various fish species and limnoligical data, it should be possible to determine the impact of current human and other influences on the resource potential of the lake. New directions are liable to emerge as bases for planning and appropriate management of the lake fisheries.

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