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Status (1993-1994) of the Endangered Fish Himalayan Mahseer *Tor putitora* (Hamilton) (Cyprinidae) in the Mountain Reaches of the River Ganga

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Abstract

The status of Himalayan mahseer was assessed during 1993-94 in the foothill section of river Ganga and the upstream tributary Nayar where brooders migrate from the Ganga to spawn during peak monsoon. Fishes measured to range from 14.5 to 98 cm, comprised 1+ to 9+ age groups in the foothill section of river Ganga while the largest fish of 128 cm (13+) was recorded from the Nayar. Males beyond 5+ age groups were rare. Lower age classes 2 to 4+ comprising immature and maturing stages accounted for more than 70% of total population. Observations on the oocyte growth revealed only maturing individuals (IIIrd stage of maturity) in the river Ganga and sexually mature from the river Nayar suggesting maturation during ascending migration (February-June). The sex ratio was male oriented in the lower age classes and female predominance in the higher age classes. Mahseer accounted for only 10-15% of total fish catch in the foothill section, compared with 29.44% in 1978 (Jammu) 39.2% in 1964 (Himachal), 40.5% in early 80's (Kumaun Lakes) and 63% in 1969 (Gobindsagar reservoir).

Introduction

The Himalayan or putitor mahseer *Tor putitora* (Hamilton) is considered as the most important and beautiful game fish endemic to India. Thomas (1897) and MacDonald (1948) described in detail the sporting and fighting qualities of mahseer among the other sport fishes;... "mahseer shows more sport for its size than the salmon".. Thomas (1897). Menon (1992) described that five valid species of genus *Tor* (*Tor putitora, T. tor, T. khudree, T. progenius* and *T. kulkarni*) occur in different parts of India. However, in addition to former four species the presence of 3 other species (*T. musullah, T. mosal* and *T. neilli*) was reported earlier by Jhingran (1982). Among the freshwater Cyprinid fishes mahseer (*Tor putitora*) is one of the largest species in India. The maximum size was recorded to be 274 cm. The mahseers occur naturally in rivers and streams and were introduced into the lakes of Kumaun in lesser Himalaya where it has ceased to exist now. It performs migration (Beavan 1877, Nautiyal 1994). Recent studies have its elaborate migratory behavior in response to physical, chemical and biological stimuli (Nautiyal 2002). It migrates not only for breeding but also for judicious use of food resources (Nautiyal et al. 2001). The putitor mahseer is distributed all along the Himalayas from Pakistan to northeast India. It is no longer found in Kashmir but thrives in Jammu. Mahseer are however, distributed from Euphrates and Tigris in Iraq (Dwivedi 2002) to southeast Asia (Desai 2003).

The National Commission on Agriculture (1976) in its report on fisheries stated that there was general decline in the mahseer fishery due to indiscriminate fishing of brooders and juvenile fishes and adverse effects of river valley projects. The reasons are not difficult to comprehend. In the Himalayan region of India it is accorded high priority as a table delicacy and therefore exploited extensively. The stress on the mahseer population is not only due to their overexploitation for its table value but also due to the rise in developmental activities, especially the growing number of hydroelectric-cum-irrigation projects which have fragmented and deteriorated its natural habitat (Nautiyal and Singh 1989). Consequently, mahseer population has vanished from some areas (Kashmir, Nainital) and declined rapidly over the last few decades owing to which it was accorded a 'threatened' status in India (Khan and Sinha 2000). The population size of putitor mahseer or for that matter any fish species or probably those with low fecundity, is probably low on the either extremes of its distribution range, which explains its extinction in Kashmir, when overexploited. Despite this the use of rugged methods like dynamite, bleaching powder, pesticides and damming along with indiscriminate fishing leading to mass mortality of brood fishes and juveniles has continued unabatedly especially in small streams, which are the breeding grounds of mahseer (Nautiyal 1994a), thus effecting the recruitment rates adversely.

Investigations on the different aspects of fishery including sport qualities of different species of mahseer commenced with Thomas (1897), Hora (1939, 1943), MacDonald (1948) and many others. Studies on the biology of

Tor putitora have been carried out by Mirza (1976), Das and Pathani (1978), Pathani (1979, 1981, 1982), Pathani and Das (1980), Johal and Tandon (1981), Nautiyal and Lal (1982, 84, 85a-c, 88, 94), Nautiyal (1994, 85, 89, 94a-b, 96, 2001, 2004a-b), Dasgupta (1991 a-c), Shreshta (1994), Bhatt and Nautiyal (1999), Bhatt et al. (1998 a, b 2000), Kishor et al. (1998), Kishor and Nautiyal (1999), Nautiyal et al. (1997, 1998). Resurgent interests on the valuability of mahseer due to its sport and fighting qualities and its threatened status (Dehadrai et al. 1994) has encouraged the authors to provide more information on this species to attract the attention of anglers and fishery scientists of the world and contribute scientifically towards the much needed data base for devising conservation measures (Kumar 2001) and promoting its recreational value (Soni 1994). It also vigourously contested as a candidate species for mono as well as composite culture (Joshi 1984; Jan and Dogra 2001; Ogale 2001).

Materials and Methods

Study area

The study was carried out during 1993-94 in the foothill stretch of the river Ganga near Ajeetpur-Hardwar (273 m asl at 29º52'50"N latitude; 78º10'23"E longitude) and Veerbhadra-Rishikesh (325 m asl 30º07'21"N, 78º19'10"E). Simultaneously, a few data was obtained from the rivulet Nayar (tributary of Ganga, Fig. 1) to complete some aspects of study. River Ganga originates as the river Bhagirathi from the Satopanth group of glaciers at Gaumukh. An important river Alaknanda originating from the Satopanth Bhagat Kharak group of glaciers joins it at Devprayag. The Nayar is a springfed stream, originating from the Dudhatoli hills in the lesser Himalaya and meets with Ganga at Vyas Chatti, 10 km downstream of Devprayag and 40 Km upstream of Rishikesh. Samples obtained from Banghat (560 m asl, 29º57'12"N and longitude 78° 45'E).

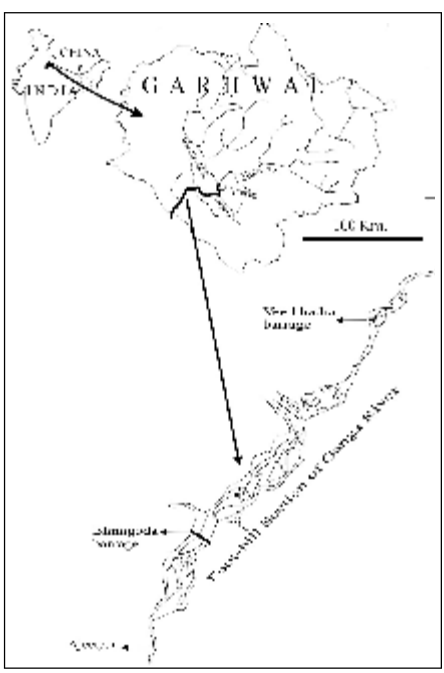

Fig. 1. Map showing the important tributaries of river Ganga and location of barrages in the foothill section

Procurement of fish samples

The foothill stretch of river Ganga has been extensively regulated by the construction of two barrages across the

river Ganga. Fish samples were obtained from the fish landing centre Ajeetpur (downstream of Bheemgoda barrage, Hardwar) and Veerbhadra (downstream of Veerbhadra barrage, Rishikesh) with the help of fishermen (nomadic Gujjar's). Fishes were landed using gill nets and cast nets. The size of gill net varied from 60 x 10 and 40 x 7 m. (l x w) with mesh size of 10 and 7 cm, respectively. The samples were given an abdominal incision and preserved in 10% formalin. Seasonal sampling was also conducted at Banghat in the case of Nayar to obtain mature fish and observe the migratory behavior of *T. putitora*.

Habitat

The habitat characteristics of the Ganga and Nayar have been considered briefly in the present study. Water temperature, water current velocity and pH were recorded with the help of graduated thermometer, float method and pH Scan (digital), respectively. Nephelometer was used to measure turbidity while dissolved oxygen was measured following Winkler's iodometric method (Welch 1952).

Age structure

Age structure was determined with the help of key scales (Bagenal 1978) obtained from the base of dorsal fin (Nautiyal 1990). For the determination of age, scales were subjected to analysis with the help of Carl Zeiss Jena Documeter. The number of annuli in each key scale was recorded as suggested by Bagenal (1978). The total number of annuli were recorded in each key scale to assess the age of an individual. Age was designated as 1+ (an annulus), 2+ (two annuli), 3+ (three annuli) and so on.

Mortality rate

Mortality rate was computed following the age frequency method (Rounseefell and Everhart 1985) by using the same scales. It was computed as follows:

The annual mortality rate (r) = (1-s) or (1-eΔ)

where s (survival rate) was computed in the following method:

$$\log s = \frac{\left[\sum_{y=x}^{n-1} \log f(y)\right] - \left[\sum_{y=x+1}^{n} \log f(y)\right]}{n}$$

or

$$\Delta = \log_{10} [(1/s)\ (1/\log_{10e})] = \log_{10e}\ (1/1-r)$$

where $1/\log_{10e} = 2.303$; f, frequency; y, age class; n, total number of age classes

Maturation and sex ratio

Prior to determining the various stages of maturity, homogeneity in the ova diameter was assessed by recording ova diameter in the anterior, middle and posterior portions of both ovaries in fishes of different sizes. The distribution of ova was found to be homogenous in each gonad as also reported earlier (Nautiyal and Lal 1985b). However, to maintain the uniformity, diameter of 200 ova from each part (anterior, middle and posterior) of the ovary were measured, thus amounting to 600 ova in each fish. The smaller ova were measured at 100X (1 omd = 0.016 mm) and larger ones at 20X (1 omd = 0.043 mm). The ocular micro-diameter (omd) was converted into millimeter. They were then classified according to Qasim's scheme adopted earlier (Nautiyal 1985 b) and percentage was computed to obtain polygon. Macroscopic observations were also made to ascertain the physical state of gonads in females and males.

For the determination of sex ratio, fish samples in each size class were segregated on the basis of their sex (male/female). The percentage of males and females and their ratio (M:F) were then computed for each size class and the differences were assessed using Chi square test.

Fishery

The total fish and mahseer catch, obtained on 3-7 days of every month was used to compute the mean total and mahseer catch per month, day and hour.

Results

In the mountain stretch of the Ganga mahseer commences ascending migration into the glacier-fed coldwaters of the Alaknanda and Bhagirathi from the foothill stretch sometime in February. The brooders ascend the Nayar during monsoon to lay their spawn from where they descend with the weakening of the monsoon depression. The nonbreeding population returns before the onset of the monsoon. Nautiyal (2001) designated it as triphased migration. The Nayar, thus harbors the larval and juvenile stages of putitor mahseer while the Ganga, the adolescents and adults.

Habitat

The river Ganga sustains a large volume of water with laminar and shooting flows in the foothill section. Riverbed was mostly covered with sand, silt and small boulders. On the contrary, the river Nayar was found to swirl through deep gorges with turbulent flow and riverbed comprising large

boulders, pebbles and gravel. Water temperature varied annually from 14-21ºC in the vicinity of barrages while slightly more (14.5-22 °C) in the downstream lotic section. The highest temperature was recorded during the month of March. Nayar exhibited higher amplitude in the thermal regime varying from 11-28ºC attaining peak during July and trough values in December. The water started to be turbid from summer in the Ganga and ranged from 0-1200 and 0-975 NTU in regulated and lotic sections, respectively. The peak of turbidity was recorded during June at both sites. However, peaks of turbidity at both sites were exceptional in the river Ganga during this period. Turbidity ranged from 1-46 NTU in the Nayar with highest turbidity during June. Monsoon, nevertheless was characterized by high turbidity. The pH was slightly alkaline in most of the months (except June and July) at both sites of river Ganga as well as in the Nayar. A significant difference was observed in the water current velocity between the regulated and lotic sections of the river Ganga. It ranged from 0.014 to 0.05 $m \cdot s^{-1}$ at the former site and 0.12 to 1.28 $m \cdot s^{-1}$ at the later site. Maximum velocity was observed during the monsoon (July to September). Dissolved oxygen in the Ganga varied from the 7.2 to 12.9 $mg \cdot l^{-1}$ at barrage site and 5.2 to 10.5 $mg \cdot l^{-1}$ in the downstream stretch. In the Nayar it was observed to range from 6.4 to 8.7 $mg \cdot l^{-1}$ with a maximum concentration in October and minimum in July.

Age composition and mortality

Tor putitora showed presence of 9+ age classes in the fish samples measuring from 14-98 cm in the river Ganga. Only 5 age classes were observed in the males while 9 in the females (Table 1). The samples from 1+ to 9+ age groups extended from 13-25, 16-34, 28-43, 34-52, 46-61, 52-67, 58-79, 79-85 and 97-100 cm size ranges, respectively. The highest frequencies in respective age groups were observed in 19-22, 25-31, 34-37, 43-46, 52-55, 58-61, 58-67 and 79-82 cm size classes. A single specimen was observed in the 9+ age group, which was 98 cm in size. Males and females showed more or less similar extended size ranges for the age groups 1+ to 5+ and 1+ to 9+, respectively. The age groups 2+ to 4+ accounted for 73% of the total samples. The 2+ was the most dominant age group (27.9%), followed by 3+ (26.01%) and 4+ (19.2%) in total population. The same group dominated the males (40.6%) as well as females (25.0%), followed by 3+ (25%) and 4+ (21.8%) in males and 4+ (21.6%) and 3+ (16.6%) in females (Table 1).

Mortality rate was computed to be 0.414 for the total fish population-males 0.499, females 0.381. Low mortality rates with higher survival rates were observed in the lower age classes (3+, 4+) while higher mortality rates were observed in higher (8+, 9+) age classes (Table 2).

Maturation

On the basis of micro and macroscopic observations, three maturity stages were observed in females in river Ganga. The samples, which pos-

sessed thread like ovaries were designated as “immature virgins” (stage I). Microscopic examination revealed that the ova were nucleated, transparent, round and ranged from 0.016-0.24 mm (Fig. 2). The mode fell at 0.016 – 0.08 mm. Largest size of the fish in this stage was recorded to be 33.0 cm The fish, which had not spawned even once in their lifetime and were in the process of maturing were categorised as “maturing virgins” (stage II). Fish

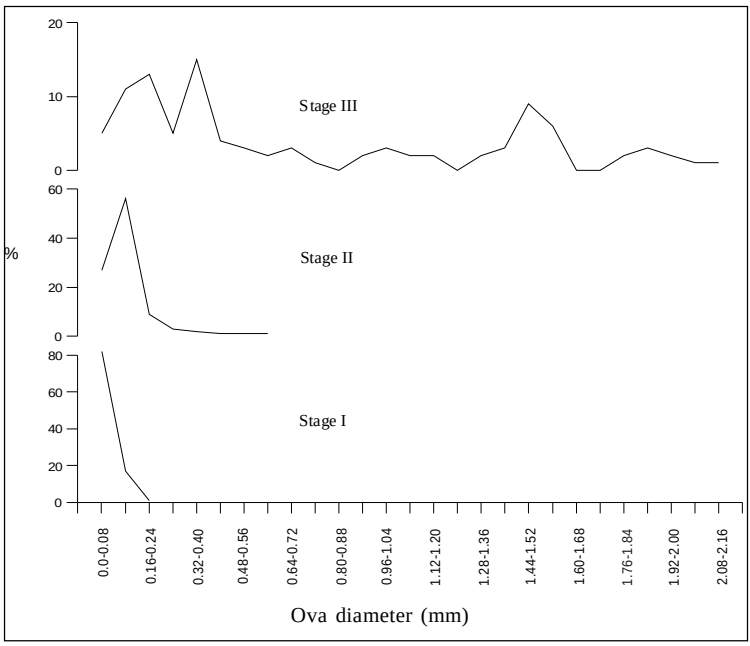

Fig. 2. Ova diameter frequency polygon for the maturity stages I to III in *Tor putitora* from the foothill section of river Ganga.

Table 1. Age structure of *Tor putitora* from the foothill stretch of the river Ganga

Age groups (year)	1+	2+	3+	4+	5+	6+	7+	8+	9+
Size range (cm)	13-25	16-34	28-43	34-52	46-61	52-67	58-79	79-85	97-100
Dominant class	19-22	25-31	34-37	43-46	52-55	58-61	58-61	79-82	97-100
% composition	6.27	27.9	26.01	19.2	10.3	4.4	3.5	1.35	0.4
Male (composition)	9.3	40.6	25.0	21.8	3.1	*	*	*	*
Female (composition)	6.6	25.0	16.6	20.6	8.3	10.0	10.0	3.3	1.6

‘*’ = Absent

Table 2. Mortality rates (r) in the different age groups of male and female populations of *T. putitora*.in the river Ganga

Age groups (year)	3+	4+	5+	6+	7+	8+	9+	Average
Total mortality rate	0.06	0.29	0.76	0.59	0.31	1.05	1.02	0.589
Male	0.48	0.13	1.94	*	*	*	*	0.499
Female	0.40	-	0.95	0.18	0.18	1.09	0.69	0.381

‘*’ = Absent

possessed whitish, dorso-ventrally flattened ovaries. Ova were not visible to naked eye and were semi-transparent, rounded, irregular, trigonal or pentagonal in shape. The ova diameter ranged from 0.016-0.64 mm with mode falling between 0.08-0.16 mm (Fig. 2). The fish in the second stage of maturity were found to measure from 37-58 cm in length. The fish of stage III (Ripening) were found to possess cylindrical and yellowish ovaries. The ova were yolked, opaque, spherical and visible to the naked eye. The ova diameter ranged from 0.032-2.20 mm with mode lying within 0.32-0.40 mm (Fig. 2). The fish in the 3rd stage of maturity ranged from 46-98 mm.

The authors did not come across the Ripe samples from the foothill stretch of Ganga. Therefore, Ripe samples were obtained from the river Nayar. In both Ripe 1 and Ripe 2 (stage IV) ovaries were cylindrical, possessing opaque, yolked and spherical ova. Ova were visible to the naked eye. The ova diameter in Ripe 1 ranged from 0.088-3.3 mm. The mode was found to occur at 2.2-2.4 mm. (Fig. 3). In the Ripe 2 ova diameter was found to range from 0.088-3.52 mm. The mode was found to occur at 2.86-3.08 mm. (Fig. 3). The fish of stage IV were found to range from 61-128 cm in length.

Sex ratio

The sex ratio of male to female (F/M) was found to range from 0.33- 3.0 except 49-55 and 61-98 cm size classes, where one of the sex was absent. The percentage of males was recorded to be high from 10-40 cm size classes (except 31-34 cm). In higher size classes percentage of females was recorded to be high (except 43-46 and 49-52 cm). The significant sex ratio was observed in the size class 67-70 cm (Table 3).

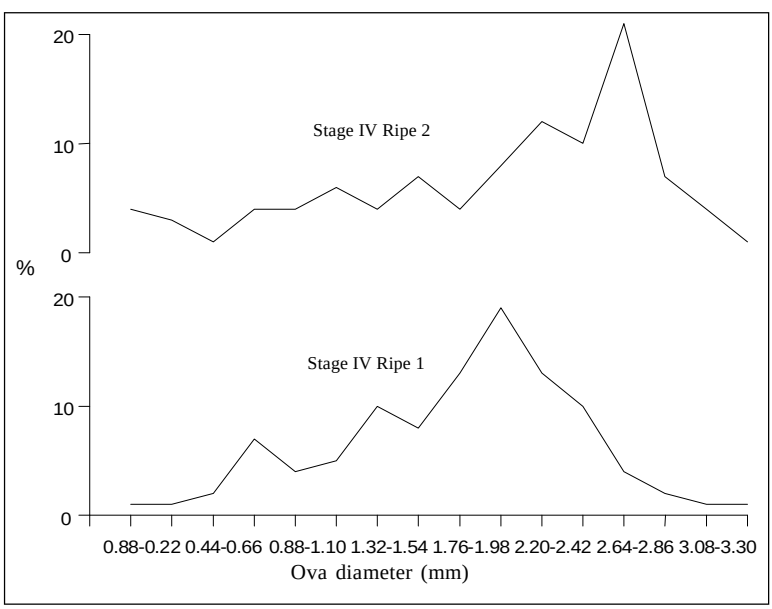

Fig. 3. Ova diameter frequency polygon for maturity stages IV Ripe 1 and Ripe 2 in *Tor putitora* from the Nayar

Fishery

Fishing was prohibited in the vicinity of Rishikesh to Hardwar owing to the religious nature of these towns. Between these towns the river falls under the jurisdiction of the Rajaji National Park. Instances of poaching were common in this Gujjar (nomadic tribes of India) inhabited stretch. Commercial fishing activity was legally allowed only downstream of Hardwar. Much of the fishing activity was concentrated around the Ajeetpur village about 10 km downstream of Hardwar. This study was conducted in 10-13 km stretch of Ganga, where the fishermen community (40-50 persons) was engaged in the fishing under a contract. Of these, 10-20 fishermen were found to land fish regularly using gill nets. Cast nets were used mainly during the monsoon floods. The total fish catch per month, day and hour ranged from the 600-2460, 20-82 and 2.2-9.1 kg, respectively (Table 4). The highest catch was recorded during the month of April while lowest catch was in July. As far as mahseer fishery was concerned the catch ranged from 1.5-22 kg•day^{-1} and 0.16-2.4 kg•hour^{-1}. The maximum catch was recorded during October while minimum in August. The catch per unit effort (CPUE) for total fishery was found to range from 2.0-8.2 kg. The most harvested size class of mahseer was found to be 28-31 cm (11.6%) followed by 37-40 cm (8.07).

In addition to normal fishing, exploitative fishery was also observed from Veerbhadra barrage, Rishikesh. The heavy fishing (80 quintal of total

Table 3. Size wise variations in the sex ratio of *Tor putitora* in the foothill stretch of the river Ganga

Size class (cm)	% age of male	% age of female	Sex ratio (M:F)	χ^2
10-13	100.0	*	1:0.0	1.00
13-16	100.0	*	1:0.0	1.00
16-19	66.6	33.3	1:0.5	0.32
19-22	75.0	25.0	1:0.3	1.00
22-25	66.6	33.3	1:0.5	1.00
25-28	66.6	33.3	1:0.5	1.32
28-31	60.6	39.4	1:0.6	0.68
31-34	33.3	66.6	1:2.0	0.66
34-37	60.0	40.0	1:0.66	0.20
37-40	50.0	50.0	1:1.0	0.00
40-43	40.0	60.0	1:1.5	0.20
43-46	63.0	37.0	1:0.57	0.81
46-49	28.5	71.5	1:2.5	1.28
49-52	100.0	*	*	2.00
52-55	*	*	*	-
55-58	50.0	50.0	1:1.0	0.00
58-61	25.0	75.0	1:3.0	1.00
61-64	*	*	*	
64-67	*	100.0	*	**(3.00)**
67-70	*	100.0	*	0.25
70-73	*	100.0	*	0.10
97-100*	100.0	*	0.11	

(3.00) Significant at P<0.1
'*' = Absent

fish; mahseer 10-15%) was observed as a result of closure of Chilla canal (power channel feeding the hydroelectric generation unit) for periodic cleaning.

Discussion

During the course of investigation the fish specimens from 14.5-98 cm in length were observed in the river Ganga whereas river Nayar was found to harbor fry, fingerlings and juveniles of putitor mahseer throughout the year and adolescents and sexually mature fish during the monsoon (rainy season). Most of the authors have reported 'spawning' as a prominent factor of migration from one habitat to another. A possible explanation for the migration and spawning of mahseer in a smaller stream is that the large volume of water, shooting flow and presence of more predators in river Ganga are not fit to the survival of fry and fingerlings of putitor mahseer. Secondly, the Himalayan mahseer seems to prefer the turbulent flow and a riverbed with sufficient boulders, gravel and pebbles. These characteristics were not found in the river Ganga in the foothill stretch. While the presence of adolescents (unable of spawning) in the river Nayar can be attributed to their learning behavior (Nautiyal 1994). Nautiyal et al. (2001) advocates food resource utilization as the motivating force for spawning migration. The turbidity due to rains and increment in the temperature (McDonald 1948) seem to be significant stimuli for the fish migration. Nautiyal (2002) has discussed the role of ecological factors in detail. Since, during the lean season water discharge of river Nayar cannot harbor fish of 128 cm as reported in this river during monsoon, therefore, fish prefers to ascend in this stream during monsoon when discharge of river become sufficient. Furthermore, a large number of fish of different sizes move upstream. The risk of being attacked

Table 4. Monthly variations in the total fish catch and mahseer catch in the foothill section of the river Ganga.

Months	Total fish catch			Mahseer catch	
	per month	per day	per hour	per day	per hour
September	1590	53±33.6	5.9	6.0	0.6
October	780	26±13.3	2.8	22.0	2.4
November	1080	49±34.0	5.4	11.0	1.2
December	1980	66±34.0	7.3	9.0	1.0
January	2190	72±33.9	8.0	8.5	0.94
February	1950	65±20.1	7.2	10.5	1.16
March	1680	66±17.2	7.3	16.5	1.8
April	2460	82±68.9	9.1	16.0	1.7
May	1410	47±18.9	5.2	11.0	1.2
June	720	24±12.1	2.6	4.5	0.5
July	600	20±8.1	2.2	2.5	0.27
August	NR	NR	NR	1.5	0.16

'NR' = Not recorded

by predators including fishermen is often high (Mather 1998). This danger may be lessened during monsoon when turbid waters decrease the chance of being detected by visual predators (Abrahams and Kattenfeld 1997).

Age distribution is an important characteristic, which influences both natality and mortality of organisms (Krebs 1994). Consequently, the ratio of various age groups in a population determines the current reproductive status of the population and indicates what may be expected in the future. Usually a rapidly expanding population, will contain a large proportion of young individuals; a stationary population a more even distribution of age classes and a declining population will contain a large proportion of old individuals (Odum 1971). The age structure of putitor mahseer appears to be in the first category i. e. large proportion of young individuals and therefore a rapidly expanding population. It, nevertheless is not a stable population.

In the Ganga stock males of 1-5+ measuring 14.5-57.0 cm and the females of 1-9+ measuring 18.5-98.0 cm indicated that the fish were mostly females comprising the potential brooder. High number of age classes have been linked to the survival rates (Kendeigh 1980). The high ratio of younger or immature to adult is a characteristic of a recovering population, which seems to be true in the present case also. The survival rates were found to be higher as compared with the mortality rates in the putitor mahseer stock of the river Ganga. According to Gulland (1978) mortality varies continuously with age. Usually, it is more convenient and also more reliable within an acceptable approximation, considering that fishing mortality changes abruptly. It can also be concluded that with an increase in age, the mortality also increases. Tandon and Johal (1996) opined that increase in mortality between particular age classes is due to substantial increase in the exploitation rate.

Absence of sexually mature fish (Ripe I and Ripe II) from the foothill section of Ganga indicated that putitor mahseer did not breed in the river Ganga. These fish were sampled from the river Nayar (12+). The results for the 1st and 2nd stages were more or less similar to fish stock of Nayar, studied by Nautiyal and Lal (1985b). But 3rd stage differed from the Nayar stock. The noticeable difference was in the modes of ova diameter as they were much advanced in the present samples. The modes are known to advance with the maturity of fish and its proximity to the spawning period (Somvanshi 1980).

Investigations on sex ratio revealed that the males were predominant in the lower size and age classes while females in the higher size classes. According to Nikolskii (1980), sex ratio varies considerably from species to species, but in the majority of species it is close to one. It differs from one population to another of the same species and may vary from year to year in the same population; males were often predominant at first and females at the end. Shreshta (1994) also found the predominance of females among the older age groups.

The state of fishery is a valuable indicator to show how fish stocks are reacting to the pressures of fishing (Nikolsky 1980). The Himalayan or Putitor mahseer contributed an average of 10–15% of total catch in the

foothill section of the river Ganga. In Jammu the Golden mahseer catch was 29.44% in 1978, while in Himachal it declined in 'chip' operation from 39.2% in 1964 to nil in 1967, 40.5 to 15.2% in Kumaun Lakes in the last 15 years, 63% from 1969 to 3.15% to 1990 in the Gobindsagar and in Pong reservoir 5-10% in the late 70's, 10.9% during 1987-88 (Nautiyal 1994a). All these facts indicate a decline over the last 30 years. The putitor mahseer is still providing good fishery in the Garhwal and Kumaun. However, if compared with its cousin *Tor tor* in central India, its fishery is certainly declining - 28% of total catch in the river Narmada (Karamchandani et al. 1967), from 100% in 1980 to 38% in 1990 in the Sukta reservoir, though not in Gandhisagar - 15% in 1963 to nil during 1985, as was the case far down south for Tungabhadra – 15% in 1958 to nil in 1961. The most disturbing trend was the abundance of juveniles and sexually immature individuals in the catch as observed earlier in 1980-82 by Nautiyal (1990). As earlier stated, much of the foothill stretch was prohibited to fishing due to the Rajaji National Park and religious nature of the towns. The religious sanctuary provided in a small segment of the foothill stretch has helped the population to survive, but it is not known for how long. Only if the effects of habitat fragmentation and overexploitation can be countered, the population may rejuvenate itself. The stocks have ceased to exist wherever they have been overexploited or their habitat has been degraded, especially on either extremes of their distribution range where they seem to exist in low numbers.

Acknowledgments

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References

Abrahams, M. and M. Kattenfeld. 1997. The role of turbidity as a constraint on predator–prey interactions in aquatic environments. *Behavioral Ecology and Social Biology* 40: 169-174.

Bagenal, T. 1978. *Methods for Assessment of Fish Production in Freshwaters*. Blackwell Scientific Publication, Oxford.

Beavan, R. 1877. *Handbook of Freshwater Fishes of India*. London.

Bhatt, J.P. and P. Nautiyal. 1999. Mortality and survival rates of Himalayan Mahseer *Tor putitora* in regulated section of the river Ganga between Rishikesh and Hardwar. *Journal of the Bombay Natural History Society* 96: 70-73.

Bhatt, J.P., P. Nautiyal and H.R. Singh. 1998a. Racial structure of Himalayan Mahseer, *Tor putitora* (Hamilton) in the Ganga between Rishikesh and Hardwar. *Indian Journal of Animal Sciences* 68: 587-590.

Bhatt, J.P., P. Nautiyal and H.R. Singh. 1998b. Comparative study of morphometric characters of Himalayan Mahseer, *Tor putitora* (Hamilton) between Ganga and Gobindsagar reservoir. *Indian Journal of Fisheries* 45:85-87.

Bhatt, J.P., P. Nautiyal and H.R. Singh. 2000. Population structure of Himalayan Mahseer, a large cyprinid fish in the regulated foothill section of the river Ganga. *Fisheries Research* 44: 267- 271.

Das, S. M. and S. S. Pathani. 1978. Studies on the biology of Kumaun Mahseer (*Tor putitora*). Adaptation of the alimentary tract to feeding habits and body weight. *Indian Journal of Animal Sciences* 48:461-465.

Dasgupta, M. 1991a Food and feeding habits of the mahseer, *Tor putitora* (Hamilton). *Indian Journal of Fisheries* 38 (4): 212-217

Dasgupta, M. 1991b. Length-weight relationship and condition factor (K-value) of *Tor putitora* (Hamilton) from Garo Hills, Meghalaya. *Indian Journal of Fisheries* 38 (1): 35-38

Dasgupta, M. 1991c. Biometry of mahseer *Tor putitora* (Hamilton) collected from Garo Hills, Meghalaya. *Indian Journal of Fisheries* 38:129-131.

Dehadrai, P.V, P. Das and S. R. Verma (eds.) 1994. *Threatened Fishes of India*. Proceedings of the National Seminar on Endangered Fishes of India held at National Bureau of Fish Genetic Resources, Allahabad 25- 26 April, 1992.

Desai, V.R. 2003. Synopsis of biological data on the tor mahseer *Tor tor* (Hamilton, 1822*). FAO Fisheries Synopsis.* No. 158. Rome, FAO. 36p.

Dwivedi, S.N. 2002. "Mahseer" the game fish of India-conservation in Madhya Pradesh, pp. 30-37. In: Vass K K & Raina H S (eds.) *Highland Fisheries and Aquatic Resource Management*. National Research Centre on Coldwater Fisheries (ICAR) Bhimtal.

Gulland, J.A. 1978. Fishing, fish and food production, pp. 381-402. In: S. D. Gerking (ed.), *Ecology of Freshwater Fish Production* Blackwell Scientific Publication, Oxford.

Hora, S.L. 1939. The game fishes of India. VIII The mahseer or the large scale barbels of India. I The putitor mahseer *Barbus* (*Tor*) *putitora* (Hamilton). *Journal of the Bombay Natural History Society* 41: 272-285.

Hora, S.L. 1943. The game fishes of India. XVI Further observation of mahseer of Deccan. *Journal of the Bombay Natural History Society* 44:1-8.

Jan, N.A and R.K. Dogra. 2001. Observations on first induced breeding of farm reared mahaseer Tor putitora (Hamilton.) at Anji Mahaseer Hatchery, Reasi in J&K State. *Applied Fisheries & Aquaculture* 1:45-46

Jhingran, V.G. 1982. *Fish and Fisheries Of India* (revised and enlarged 2nd edition). Hindustan Publishing Corporation, New Delhi.

Joshi,C.B. 1984. Artificial breeding of golden mahseer (Tor putitora). *Journal of the Inland Fisheries Society of India* 13: 73-74.

Johal, M.S. and K.K Tandon. 1981. Age, growth and length-weight relationship of *Tor putitora* from Gobindsagar reservoir, Himachal Pradesh. *Punjab Fish Bulletin* 43-48.

Joshi, C.B., K.L. Sehgal and S. Sunder. 1978. Observations on the fishery resources of the hill streams of Jammu Province with special reference to mahseer and other commercially important species. *Indian Journal of Fisheries* 25: 197-206.

Karamchandani, S.J., V.R. Desai, M. Pisolkar and G.K. Bhatnagar. 1967. Biological investigations on the fish and fisheries of Narmada river. *Bulletin of Central Inland Fisheries Research Institute* 10: 40.

Khan, M.A. and M. Sinha. 2000. Status of Mahseer Fisheries in north and north eastern India with a note on their conservation. *Journal Inland Fisheries Society*, India 32(1): 28-36.

Kendigh, S.C. 1980. *Ecology with Special Reference to Animal and Man*. Prentice Hall of India, New Delhi.

Kishor B. and P. Nautiyal. 1999 Size related variations in the feeding intensity of Himalayan Mahseer *Tor putitora* from the Ganga river system in Garhwal region p 279-281. In: *Proceedings 4th Asian Fisheries Forum*, Indian Branch 1996, Kochi

Kishor, B., J.P. Bhatt, V.S. Rawat, R. Nautiyal and P. Nautiyal. 1998 Variations in the food habits of the Himalayan Mahseer inhabiting the Ganga river system in Garhwal region. *Indian Journal of Fisheries* 45[1], 113-118

Krebs, C.J. 1994. *Ecology: The Experimental Analysis of Distribution and Abundance*. 4th edition. An imprint of Addison Wesley Longman, Inc.

Kumar, K. 2001. Suggested strategy for development of 'Mahseer fishing' in Himachal waters. *Fishing Chimes* 7 (8): 25-26.

MacDonald, A.S.J. 1948. Circumventing the mahseer and other sporting fish in India and Burma. *Journal of the Bombay Natural History Society*, 306.

Mather, M.E. 1998. The role of context-specific predation in understanding patterns exhibited by anadromous salmon. *Canadian Journal of Fisheries and Aquatic Sciences* 55: 232-246.

Menon, A.G.K. 1992. Taxonomy of the Mahseer fishes of genus *Tor* Gray with description of new species from Deccan. *Journal of the Bombay Natural History Society* 89: 210-228.

Mirza, M.R. 1976. Fish and fisheries of the Northern montane and submontane regions of Pakistan. *Biologia* 22: 107-120.

Nautiyal, P. 1990. Natural history of Garhwal Himalayan mahseer: growth rate and age composition in relation to fishery, feeding and breeding ecology, pp. 769-772. In: R. Hirano and I. Hanyu (eds.), *Proceedings of 2nd Asian Fisheries Forum*, Tokyo.

Nautiyal, P.1994a. The Himalayan or putitor mahseer *Tor putitora* (Hamilton), pp. B5-12. In: P. Nautiyal (ed.), *Mahseer The Game Fish* Jagdamba Prakashan, Dehradun.

Nautiyal, P. 1994b. The endangered Himalayan Mahseer. A decade of retrospection p 4:191-196. In: P.V. Dehadrai, P. Das, S. R. Verma, (eds.) *Threatened Fishes of India*, Proceedings of the National Seminar on Endangered Fishes of India held at National Bureau of Fish Genetic Resources, Allahabad 25- 26 April, 1992. NATCON Publication, Muzaffarnagar.

Nautiyal P. 1996 Conservation of mahseer in India: Research, a priority. *Fishing Chimes* 15 (12), 27

Nautiyal, P. 2001. Spawning ecology and threats to Mahseer. In: *Coldwater Aquaculture and Fisheries* (eds. H. R. Singh and W. S. Lakra), pp. 291-306. Narendra Publishing House, New Delhi.

Nautiyal, P. 2002. The Himalayan Mahseer: Migratory pattern in relation to ecological characteristics of the Ganga river system in Garhwal Himalaya, pp. 172-195. In: *Highland Fisheries And Aquatic Resource Management*. (eds. K. K. Vass and H. S. Raina), National Research Centre on Coldwater Fisheries (ICAR) Bhimtal.

Nautiyal, P. 2004a (in press). Fisheries ecology and bioconservation of Garhwal Himalayan Mahseer. In: P. Nautiyal et. al. (eds.) *Diversity in Structure and Function of Freshwater Environments*. Transmedia, Srinagar.

Nautiyal, P. 2004b. (in press) Population structure, an indicator of the ecological health of exploited fish population. In: J. S. Dutta Munshi and H.R. Singh (eds.), *Advances In Fish Biology*. Narendra Publishing House, Delhi.

Nautiyal, P. and H. R. Singh. 1989. River projects and endangered Mahseer, *Tor putitora* in Indian uplands of Garhwal region: A critical evaluation. *Himalayan Journal of Environment* 3: 129-134.

Nautiyal, P. and M.S. Lal. 1982. Recent records of Garhwal mahseer (*Tor putitora*) with a note on its present status. *Journal of the Bombay Natural History Society* 79: 639-695.

Nautiyal, P. and M. S. Lal. 1984. Preliminary observations on the migratory behavior of the Garhwal Himalayan mahseer. *Journal of the Bombay Natural History Society* 81:204-208.

Nautiyal, P. and M. S. Lal. 1985a. Food and feeding habits of Garhwal Himalayan Mahseer in relation to certain abiotic factors. *Matsya* 11:31-35.

Nautiyal, P. and M. S. Lal. 1985b. Studies on the natural history of Garhwal Himalayan mahseer *Tor putitora* I Maturation. *Indian Journal of Physical and Natural Sciences* 5:36-42.

Nautiyal, P. and M.S. Lal. 1985c. Fecundity of Garhwal Himalayan Mahseer, *Tor putitora*. *Journal of the Bombay Natural History Society* 82: 253-257.

Nautiyal, P. and M. S. Lal. 1988. Natural History of Garhwal Himalayan Mahseer *Tor putitora*: Racial Composition. *Indian Journal of Animal Sciences* 58:283-294.

Nautiyal P and M.S. Lal. 1994. Fishing techniques and the status of Himalayan Mahseer in the Nayar (Garhwal) p C 54-66. In: P. Nautiyal (ed.), *Mahseer The Game Fish*. Jagdamba Prakashan, Dehradun.

Nautiyal, P., J.P. Bhatt, B. Kishor, V.S. Rawat, R. Nautiyal and H.R. Singh. 1997. Assessment of fish food resource in relation to the migratory habits of *Tor putitora* [Ham.] found in the impounded sections of the river Ganga between Rishikesh and Hardwar. *Proceedings of the National Academy of Science* India 67 [B]: 203-212.

Nautiyal, P., J.P. Bhatt, V.S. Rawat, B. Kishor, R. Nautiyal and H.R. Singh. 1998. Himalayan mahseer: magnitude of commercial fishery in Garhwal hills. *NATCON Publication*, Muzaffarnagar.5, 107-114

Nautiyal, P., S. N. Bahuguna and R. P. Thapliyal. 2001. The role of eclogical factors in governing the direction, time and purpose of migration in Himalayan Mahseer *Tor putitora* (Ham.). *Applied Fisheries and Aquaculture* 1: 133-138.

NCA. 1976. *National Commission on Agriculture*. Reports on the Fisheries. Ministry of Agriculture, New Delhi.

Nikolsky, G.V. 1980. *Theory of Fish Poulation Dynamics as the Biological Background for Rational Exploitation and Management of Fishery Resources*. Otto Koeltz Science Publishers, Koenigstein.

Odum, E. P. 1971. *Fundamentals of Ecology*. Saunders College Publishing, Philadelphia.

Pathani, S.S. 1981. Fecundity of mahseer *Tor putitora* (Hamilton). *Proceedings of the Indian Academy of Science,* 90:253-260.

Patahni, S.S. 1982. Studies on the spawning ecology of Kumaun mahseer *Tor tor* (Ham) and *Tor putitora* (Ham). *Journal of the Bombay Natural History Society* 79:525-530.

Pathani S S 1979 Otolith as age indicator in the mahseer Tor putitora- (Hamilton).*Current Science* 48(21): 957-958

Pathani,S.S. and S.M. Das.1980. A note on length-weight relationship and seasonal condition factor of mahseer *Tor tor* and *T. putitora* (Hamilton). *Journal Inland Fisheries Society of India*. 12: 140-143.

Ogale, S.N. 2001. Multiple breeding in golden mahseer (*Tor putitora*). *Applied Fisheries and Aquaculture* 1: 31-33.

Rounseefell, G.A. and W.H. Everhart. 1985. *Fishery Science, Its Methods and Applications*. International Books and Periodicals Supply Service, New Delhi.

Shreshta, T.K. 1994. Ecostatus of mahseer in the rivers of Nepal, pp. C3-9. In: P. Nautiyal (ed.), *Mahseer The Game Fish*. Jagdamba Prakashan, Dehradun.

Soni, V. 1994. Mahseer, the endemic game – fish and its status in Northern Indian: An anglers view, pp. C49-53. In: P. Nautiyal (ed.), *Mahseer The Game Fish*. Jagdamba Prakashan, Dehradun.

Somvanshi, V. S. 1980. Study on some aspects of spawning biology of a hillstream fish *Garra mullya* (Sykes). *Proceedings of the Indian National Science Academy* 46: 105-113.

Tandon, K. K.and M. S. Johal. 1996. *Age and Growth in Indian Freshwater Fishes*. Narendra Publishing House, New Delhi.

Thomas, H.S. 1897. *The Rod in India*. W. Thacker and Co., London.

Welch, P.C. 1952. *Limnological Methods*. McGraw Hill Book Co., New York.

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