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BEHAVIOURAL AND FUNCTIONING INTERACTIONS IN THE SCHIZOTHORACID COMMUNITY IN THE RIVER MANDAKINI: AN ASSESSMENT THROUGH ALTERING SEX RATIO PATTERNS[1]

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The interrelationships and functioning of three closely related species, *Schizothorax plagiostomus* Heckel, *Schizothorax richardsonii* Gray and *Schizothoraichthys progastus* McClelland (Teleostei, Family Cyprinidae, Subfamily Schizothoracinae), comprising the snow trout or schizothoracid community, as reflected by the altering sex ratio patterns, have been assessed quantitatively. Observations were made for two years, from January 1991 to December 1992, at four landing sites: Bheri (1,020 m), Chandrapuri (827 m), Agastyamuni (760 m) and Tilwara (724 m), covering the lower stretch of over 30 km of the high altitude glacier-fed River Mandakini in the Garhwal Himalaya. The water characteristics of the river (total water discharge, water velocity and water temperature) were measured at Chandrapuri. The total fish catch of these species from all the sites was first pooled and arranged according to sex, percentage, breeding and non-breeding seasons. The sex ratio was determined. These species breed twice a year, from March to May and August to October, with well-defined non-breeding intervals. These species individually followed a similar pattern of response to changes in the environment, as revealed by the altering sex ratio patterns i.e., highest values during first breeding season of 1991 and 1992 (2.65:1, 3.0:1, 3.89:1 and 2.56:1, 3.86:1, 4.75:1 respectively) when water parameters began rising from the lowest in the extreme winter. The lowest values of sex ratio were observed during the second breeding seasons of 1991 and 1992 (2.03:1, 1.51:1, 1.58:1 and 1.59:1, 1.82:1, 1.74:1 respectively) when water characteristics values were at a peak, or just began plummeting from the peaks of monsoon. The corresponding values of sex ratio in the entire schizothoracid community were observed as 2.78:1, 2.83:1 and 1.91:1, 1.61:1 respectively, during the first and second breeding seasons of 1991, 1992. Sex ratio begins to alter at the commencement of just rising and/or peak, or just plummeting periods. Altering sex ratio pattern is one of the indicators of the beginning of the breeding process. That is the fish take the changes in surroundings as the cue to initiate breeding process. Both the species and the community of schizothoracine fishes alter their sex ratio pattern in response to changes in their surroundings. This pattern can serve as an indicator of the functioning and interrelationship at individual, population, species and community levels. Patterns of sex ratio change must be utilized for assessing the behavioural and evolutionary processes over a period as well as an effective tool in the regulative management of snow trout community in the high altitude glacier-fed hillstreams of Garhwal Himalaya.

Key words: Schizothoracid community, sex ratio, River Mandakini, functioning interactions, behavioural indicators, evolutionary processes

INTRODUCTION

Odum (1971) and Kendeigh (1980) described the conceptual framework of biotic communities. In fluvial systems, unidirectional flow and gradient determine the mobility of the subject. This offers entirely different challenges in the ways of studying the biotic communities therein. The biotic communities in the rapidly flowing hillstreams are heterogeneous assemblage of several plant and animal taxa of diverse features with intricate relationships. The upstream and downstream boundaries of the habitat(s) and movement of the residents for diverse purposes are difficult to determine. In view of these restraints, the behavioural attributes in terms of altering sex ratio patterns of schizothoracid or snowtrout community consisting of *Schizothorax plagiostomus* Heckel, *Schizothorax richardsonii* Gray (both bottom dwellers and feeders, herbivorous) and *Schizothoraichthys progastus* McClelland (column dweller and feeder, carni-omnivorous) are analysed as further extension of earlier works (Bhatt 1993; Singh 1995, 1997; Singh and Subbaraj 2000; Singh *et al.* 1996) focusing on the high altitude glacier-fed hill stream, Mandakini in Garhwal Himalaya.

The sex ratio of fish population is an effective indicator of functioning, behavioural strategies and catch composition (Nikolskii 1980; Engenwaji 1992). In the Indian subcontinent, with immense scope of diversity and potentials of fish fauna, the assessment of functioning and interrelationships through sex ratio and/or similar indices of fishes at population, species and community levels remains unexplored, thus, eliminating their advantageous uses for determining the characteristics, planning and management of cultivable and non-cultivable fishes to any worthwhile level (Pantulu 1961; Bhatt 1993; Nautiyal 1994).

The dominant status, economic potentials yet hitherto little explored avenues of schizothoracid community, in the entire Himalayan region, in general, and in Garhwal hills in particular, offer enough incentives for assessing the functioning interrelationships, their observable indices (sex ratio change being one of these), and response(s) to the milieu of changing surroundings of glacier-fed hillstreams in the region like River Mandakini.

MATERIAL AND METHODS

The study is based on the analysis of the total fish catch of *Schizothorax plagiostomus*, *Schizothorax richardsonii* and *Schizothoraichthys progastus* in the lower stretch of over 30 km of glacier-fed high altitude River Mandakini, which finally meets with the still larger River Alaknanda at Rudraprayag (*JBNHS 94(2)*, 1997: Fig. 1, p. 418). The random sampling of adult specimens was made at four landing sites — Bheri (1,020 m), Chandrapuri (827 m), Agustmuni (760 m), and Tilwara (724 m). Since all these three species breed twice a year, from March-May and August-October, the data were analysed and computed on the basis of a pooled number as sample size, percentage of males and females in the total catch, breeding and non-breeding seasons with respect to individual species separately. The ratio of M:F (M - number of males, F - number of females) during the corresponding seasons gave the sex ratio of each species.

The data of water parameters of River Mandakini — total water discharge (m^3/sec), water velocity (m/sec) and water temperature (°C) — during the corresponding study period have been obtained from the Uttar Pradesh Irrigation Department, Srinagar Garhwal as measured at Chandrapuri (*JBNHS 94(2)*, 1997: Fig. 1, p. 418), and were converted into mean monthly values of respective seasons.

RESULTS

Sample size: The study is based on analysis of a total of 5,587 adult specimens. Examination of the total fish catch from all the four landing sites when pooled together revealed evident variations. The highest representation of *Schizothorax plagiostomus* [total 4,585 (82.07%), males 3,120 (81.95%), females 1,465 (82.30%)] placed this species on the top status not only in the schizothoracid community, but also among all the fish species resident in River Mandakini. *Schizothorax richardsonii* also had a good representation [total 674(12.06%), males 455(11.96%), females 219(12.30%)] but *Schizothoraichthys progastus* happened to be poorly represented [total 328(5.87%), males 232(6.09%), females 96(5.39%)] (Fig. 1). Despite this enormous variation in sample size, the percentage of males and females during the corresponding period suitably conformed to the respective structural representation in the community (Fig. 2). Further, the sample size did not cast its shadow on the overall response(s) patterns.

Percentage of males and females: The analysis of fish catch in terms of sex percentage of two years offered similarity of patterns which the three species exhibited respectively (Table 1, Fig. 1). For the entire community, the corresponding values of percentage of males were 9.31, 13.12 and 12.83, 14.39 respectively during the first and second breeding season of 1991 and 1992. For females the percentages were found to be 3.35, 6.87 and 4.53, 8.93 respectively during the corresponding breeding and non-breeding seasons of 1991 and 1992 (Fig. 2).

Sex ratio: It is an effective and definite indicator of response(s) and interactions within the community as well as to the changing surroundings. The analysis samples of *Schizothorax plagiostomus*, *Schizothorax richardsonii* and *Schizothoraichthys progastus* revealed a consistent pattern of sex ratio alterations (Table 2, Fig. 1). All three species showed higher sex ratio (2.78:1, 2.83:1 respectively) during the first breeding season of the year but lower figures (1.91:1, 1.61:1 respectively) during second breeding of the year (Fig. 2).

Water parameters of the River Mandakini (Figs 1, 2): The habitat of the three species of schizothoracid community in the River Mandakini, when analysed and quantified for total water discharge, water velocity and water temperature, presented an overview conforming to the overall picture of what had been stated so far. The mean monthly values of river characteristics began rising from March-May 1991, 1992 from the lowest figures during extreme winters and remained moderate — total water discharge (36.96, 88.32 m^3/sec), water velocity (0.745, 0.686 m/sec) and water temperature (11.05, 11.61 °C) — when males in the community comprised the highest representation. Conversely, during the second breeding season in August- September, October 1991, 1992 these parameters were either at the peak or had just started coming down from the peak values of monsoon; i.e., 155.34, 170.63 m^3/sec; 1.805, 1.919 m/sec and 15.05°, 15.8 °C respectively when the sex ratio touched the corresponding lowest values. Thus, the water parameters of the River Mandakini perfectly simulate and stimulate the picture of the community response(s) as a whole when viewed along with the corresponding data.

DISCUSSION

(a) Major structural features such as dominant species like forms or indicators, and (b) physical habitat of the community and functional attributes such as type of

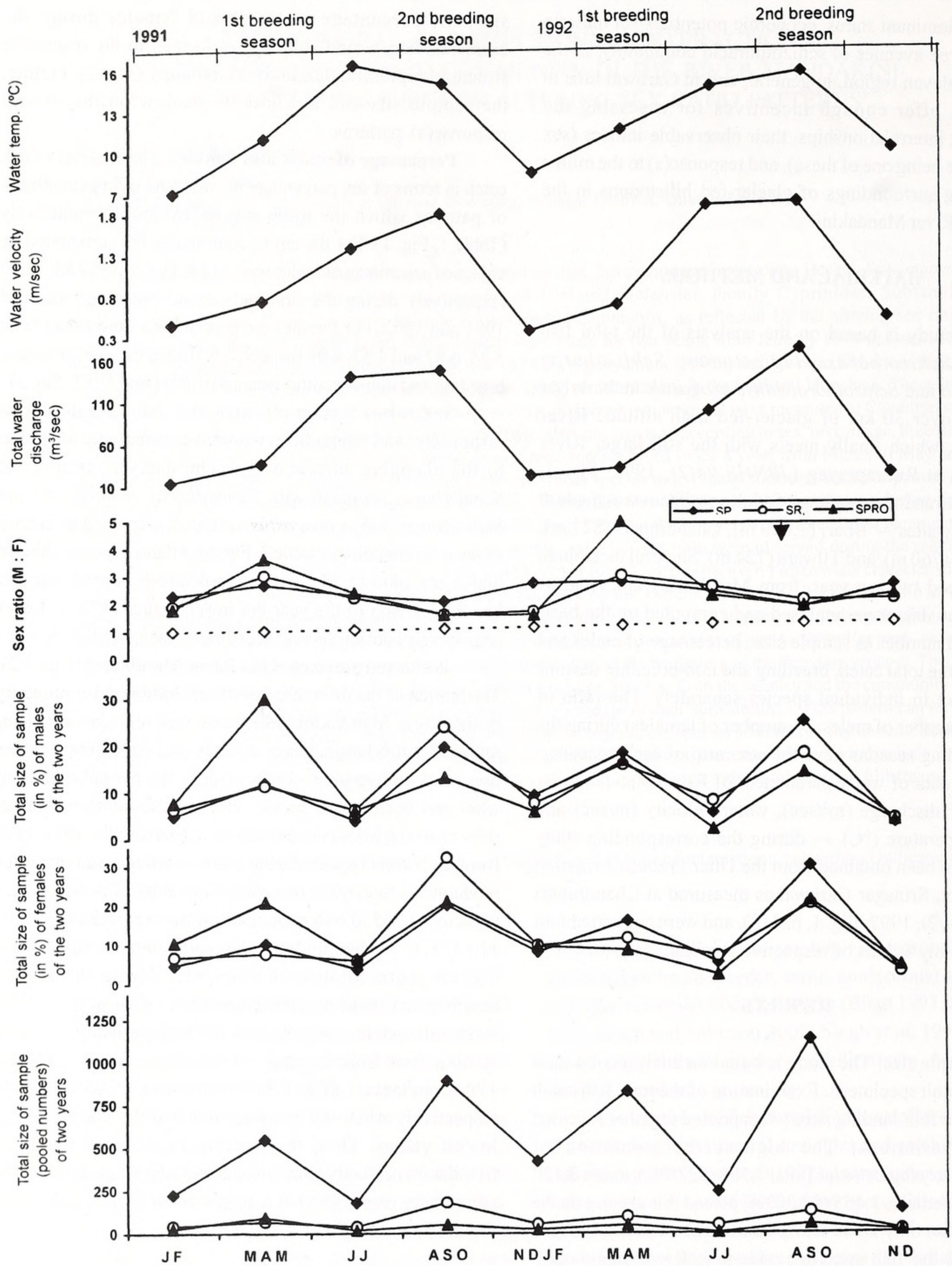

Fig. 1: Sex ratio of *Schizothorax plagiostomus* (SP), *Schizothorax richardsonii* (SR) and *Schizothoraichthys progastus* (SPRO) in relation to sample size, percentage of females and males and water parameters (total discharge, velocity & temp.) during breeding and non breeding seasons of 1991-1992 in the river Mandakini

community, metabolism etc. are a convenient basis for naming and classifying the community (Odum 1971). Of these, functional approaches offer better alternatives for comparison of all communities in widely different habitats. Regarding the fish communities within the geographical regions, the major approaches must include - (1) Zonal approach for recognizing, classifying and listing in a sort of check-list of community type, (2) gradient analysis approach involving the arrangement of population along uni- or multi-dimensional environmental gradient axis with community recognition based on statistical comparison. Also, there are certain specifically interesting questions about fish communities - (i) To what extent can fish in similar habitat be predicted? (ii) How are fish communities organized? Does the last member of the sensitive species result in the collapse or irreversible changes in the community? (iii) How is the state of development or completeness measured, and hence assessment of the extent to which it has been degraded by environmental change(s). Notable examples of such studies of temperate fish communities of North America include those by Harvey, 1975, 1978; Johnson *et al.* 1977; Tonn and Magnuson 1983.

The analytical studies of fish communities in the Indian context are not addressed to in right perspectives despite the sizable scope of diversity, functional changes within shorter time and space (Shastri *et al.* 1982), potentials of newer distinct approaches likely to emerge. In Garhwal region, Kumar (1991) analysed microzoobenthic communities of River Alaknanda, and Rawat (1992) undertook the analysis of community structure of plankton in high altitude Lake Deoria Tal.

The functional approach of community analysis of Indian fishes in diverse fluvial systems wherein the subject as well as physical habitat have high mobility and, hence, the community functioning and interactions are at continuous change — are rather obscure obviously due to low feasibility. However, Bhatt and Pathak (1992) have explained a few species at community level.

From quantitative and qualitative estimates of present study, the topmost status of schizothoracid community is evident among various animal communities inclusive of those of other fish communities resident in River Mandakini. Based on dominance, various species of schizothoracid community may be arranged, from higher to lower ranks, as (1) *Schizothorax plagiostomus*, (2) *Schizothorax richardsonii*, (3) *Schizothoraichthys progastus* (Singh *et al.* 1996) and so on. The variation in the quantitative values of different functional attributes (including sex ratio, breeding seasons) at different sites is due to the continuum of complex dynamics, altering interactions of individuals-individuals, individual-population, population-population, population-species, species-species, species-community, community-community and also with surroundings in each case and at each level apart from working modalities.

The highest absolute numbers of specimens during breeding seasons, especially at Chandrapuri and Tilwara (*JBNHS 94(2)*, 1997: Fig. 1, p. 418, where smaller rivulets debouch into river Mandakini), percentage of males and females in the total catch during March, April, May 1991, 1992 and then during August, September, October, 1991, 1992 respectively, are convincing proof of these species breeding twice a year (see Singh 1997). At the onset of breeding, potential male and female brooders migrate from lower stretches of larger glacier fed hill streams (like Ganga, Alaknanda etc.) to the upper reaches of their tributaries. Small glacier / non-glacier fed streams or rivulets with faster water velocity, lesser turbidity etc. are more conducive environs for brooders, spawn and juveniles. Destinations like Chandrapuri and Tilwara (sites of confluence) are more preferred sites for spawning and breeding purpose.

Singh (1997) mentioned several intrinsic and extrinsic factors interacting together and collectively responsible for

Table 1: Profile of pecentage of males and females of three species of schizothoracid community during breeding and non-breeding seasons of 1991-1992 in the River Mandakini

Species	Sex	November-February (1st Non-breeding)			March-May (1st breeding)		June-July (2nd Non-breeding)		August-October (2nd breeding)	
		Jan-Feb 1991	Nov-Dec 1991 Jan-Feb 1992	Nov-Dec 1992	1991	1992	1991	1992	1991	1992
Sp. 1	Male	5.03	9.68	3.01	12.72	19.07	3.09	5.26	19.10	22.18
Sp. 2	Male	6.37	7.25	2.42	11.21	17.80	6.15	7.69	23.52	17.58
Sp. 3	Male	7.76	5.60	3.45	31.89	16.38	6.03	1.72	12.93	14.22
Sp. 1	Female	4.70	7.92	2.73	10.24	15.77	3.75	5.19	20.00	29.69
Sp. 2	Female	6.85	7.76	2.74	7.76	9.59	5.94	6.85	32.42	20.09
Sp. 3	Female	10.42	9.38	4.16	19.79	8.33	6.25	2.08	19.79	19.79

Sp. 1 = *Schizothorax plagiostomus*, Sp. 2 = *Schizothorax richardsonii*, Sp. 3 = *Schizothoraichthys progastus*

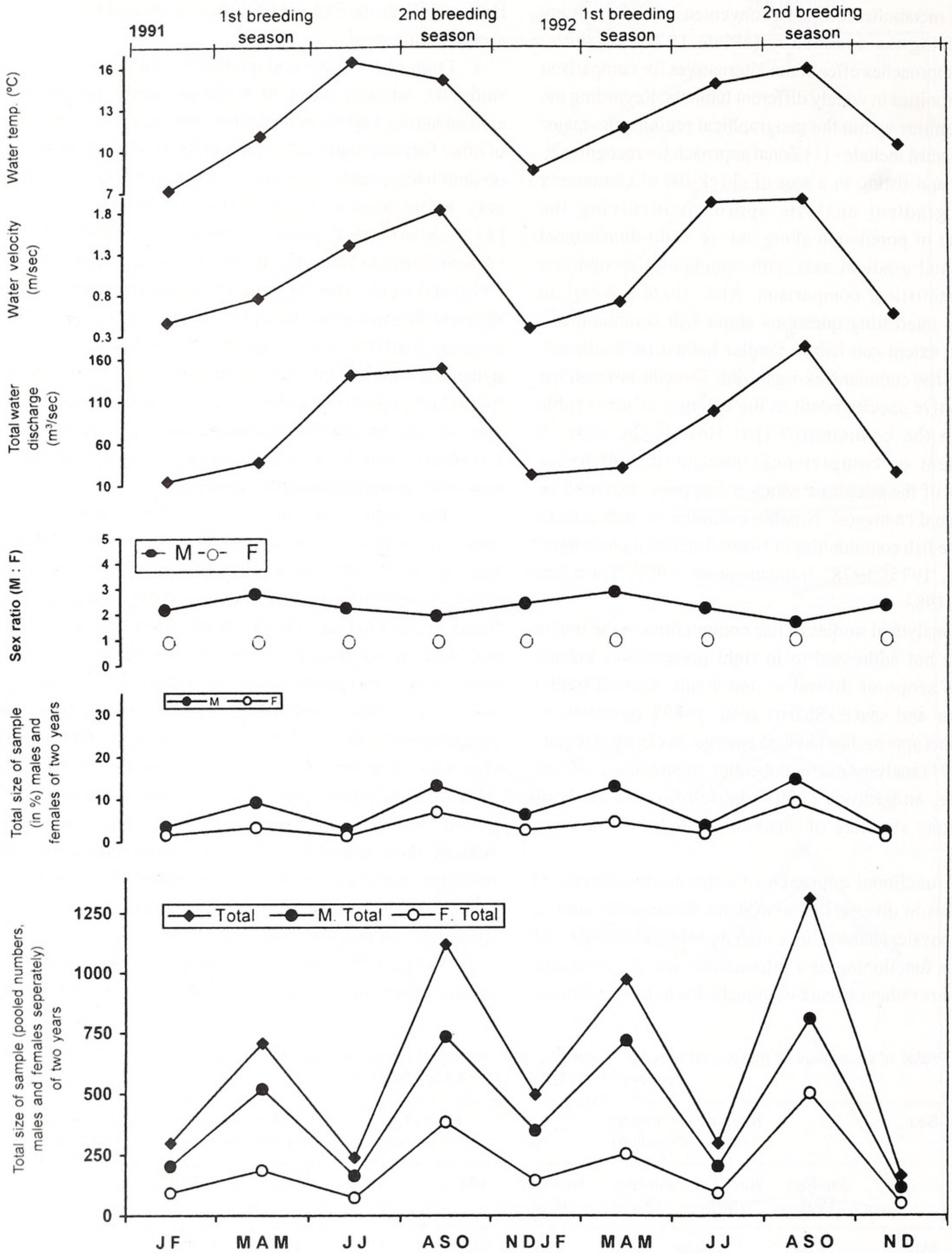

Fig. 2: Sex ratio of Schizothoracid community in relation to pooled numbers as well as males and females separately, % of females & males and water parameters (total discharge, velocity & temp.) during breeding and non-breeding seasons of 1991-1992 in the River Mandakini (Compare with Fig. 1)

Table 2: Profile of the sex ratios of three species of schizothoracid community during breeding and non-breeding seasons of 1991-1992 in the River Mandakini

Species	November-February (1st Non-breeding)			March-May (1st breeding)		June-July (2nd Non-breeding)		August-October (2nd breeding)	
	Jan-Feb 1991	Nov-Dec 1991 Jan-Feb 1992	Nov-Dec 1992	1991	1992	1991	1992	1991	1992
Sp. 1	2.28:1	2.60:1	2.35:1	2.65:1	2.56:1	2.24:1	2.16:1	2.03:1	1.59:1
Sp. 2	1.93:1	1.94:1	1.83:1	3.00:1	3.86:1	2.16:1	2.33:1	1.51:1	1.82:1
Sp. 3	1.80:1	3.67:1	2.00:1	3.89:1	4.75:1	2.33:1	2.00:1	1.58:1	1.74:1
Schizothoracid Community	2.17:1	2.38:1	2.26:1	2.82:1	2.79:1	2.23:1	2.18:1	1.91:1	1.61:1

Sp. 1 = *Schizothorax plagiostomus*, Sp. 2 = *Schizothorax richardsonii*, Sp. 3 = *Schizothoraichthys progastus*

higher male sex ratio during the first breeding season of the year: (i) earlier departure of males and late arrival of females, (ii) fresh recruitment of new batches of subadults into brooders, (iii) difficulties encountered by female brooders during upstream migration because of their full-grown belly and relatively lower water discharge to cope with the larger sized females. The conditions otherwise are conducive for spawning and breeding resulting from moderate conditions, and (iv) vulnerabilities of female brooders to their predators and other natural hazards. Also, environmental conditions during the first breeding season favour the male, whereas females are favoured during the second breeding period of the year. Another possibility of sex ratio alterations may be sex dependent mortality and intersexes in population (an entirely new dimension).

Since the present assessment is based on the data of three closely related species of schizothoracids, it indicates a similar picture of response(s) as evident from sex ratio variations in relation to changing river characteristics. This similarity lends further credence to their close genetic kinship as they inhabit and share common habitat (the river Mandakini and likes in the Himalayan region) and also encounter similar challenges and opportunities, use similar cues and stimulants. Obviously, they must have evolved similar behavioural repertoire, functioning strategies and response(s) at individual, population, species and community levels. Varying sex ratio patterns, mobilization of spawning grounds (Singh 1995) are among these. Such behavioural responses of the community also include the interplay of intra- and inter-specific convergence, divergence/diversity, which are at the helms of evolutionary processes. Sex ratio alterations also reflect the pattern diversity of stratification (Pielou 1966), zonation, activity, reproduction, social, co-action, stochasticism etc. However, many significant questions emanate out of such a scenario, namely levels of intra- and inter-specific convergence and divergence/diversity while inhabiting similar habitat and using similar cues for spawning, breeding and other vital processes? Here lie the possibilities of preponement and/or postponement of such changes in behavioural indices and indicators (like sex ratio alterations) by a few hours/days enough for such resource mobilization, resource partitioning and minimizing the competition for resources at successive levels within the community which must have been too intense. It is also indicative of intelligent designing of behavioural strategies of schizothoracids in nature for mobilization of transitional but moderate resources in terms of timing and space for breeding.

This analysis of altering sex ratio patterns in *Schizothorax plagiostomus*, *Schizothorax richardsonii* and *Schizothoraichthys progastus* presents an overall picture in the River Mandakini in particular and other glacier-fed hillstreams of Garhwal region in general. This study of schizothoracid community, though raising several questions to be answered from various points of view, should be utilized in two ways; first, in revealing the processes of signalling of individual-population-species-community responses, convergence-divergence at behavioural, physiological and environmental levels, and second, in regulative management of schizothoracid fishery in glacier-fed high aititude hillstreams of Garhwal region.

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REFERENCES

Bhatt, K.C. (1993): Present status and olfaction of snowtrout in the river Mandakini (Garhwal Himalaya). Ph.D. dissertation, HNB Garhwal University, Srinagar Garhwal, India. Pp. 1-152.

Bhatt, S.D. & J.K. Pathak (1992): Himalayan Environment: Water Quality of Drainage Basins. Shri Almora Book Depot, Almora. Pp. 1-318.

Engenwaji, H.M.G. (1992): Reproductive Biology of four African catfishes (Osteichthys: Claridae) in Anambra river basin, Nigeria. *Hydrobiologia 242*: 155-164.

Harvey, H.H. (1975): Fish population in large group of acid stressed lakes. *Verh. Internat Verenin Limnol. 19*: 2406-2417.

Harvey, H.H. (1978): Fish communities of Manitoulin Island lakes. *Verh. Internat Verenin Limnol. 20*: 2031-2038.

Johnson, M.G., J.H. Leach, C.K. Minns & C.H. Oliver (1977): Limnological characteristics of lakes in relation to association of Wallege (*Stizostedion vitreum vitreum*), Northern pike (*Esox lucius*), lake trout (*Salvenius namayeush*) and small mouth bass (*Micropterus dolomieui*). *J. Fish Res. Bd. Canada. 34*: 1592-1600.

Kendeigh, S.C. (1980): Ecology with special reference to animal and man. Prentice Hall India Pvt. Ltd., New Delhi. Pp. 35-138.

Kumar, N. (1991): Ecological studies on the microzoobenthic communities of some hillstreams of Alaknanda river basin. Ph.D. dissertation, HNB Garhwal University, Srinagar Garhwal, India. Pp. 1-216.

Nautiyal, P. (1994): Riverine mahseer. *In*: Mahseer - The Game Fish. (Ed.: Nautiyal, P.), Rachna Publishers, Srinagar Garhwal. Pp. B23.

Nikolskii, G.V. (1980): Theory of fish population dynamics. (translated by J.E.S. Brodley, Ed.: Jones, R.), Bishen Singh Mahendra Pal Singh, Dehra Dun & Otto Koeltz Science Publishing, Koenigesten, Germany. Pp. 88-138.

Odum, E.P. (1971): Fundamentals of Ecology. 3rd ed., W.B. Saunders Co., London. Reprinted by Natraj Publishers, Dehra Dun, 1996. Pp. 145-161.

Pantulu, V.R. (1961): Determination of age and growth of *Mystus gulio* Ham. by use of pectoral spine in observation in its biology and fisheries in the Houghly estuary. Proc. *Nat. Inst. India Sci.* B22: 4.

Pielou, E.C. (1966): Species diversity and pattern diversity in the study of ecological succession. *J. Theoret. Biol. 10*: 370-383.

Rawat, M.S. (1992): Limnological studies on a high altitude lake Deoria Tal of Garhwal Himalaya. Ph. D. dissertation, HNB Garhwal University, Srinagar Garhwal, India. Pp. 1-165.

Shastri, N.K., M.S. Islam & S. Pathak (1982): Dynamics of phytoplanktonic fluctuations in a lentic waterbody. *In*: Aquatic Environment (Ed.: Gautam, A.), Ashish Publishing House, New Delhi. Pp. 55-89.

Singh, N. (1995): Spawning grounds of *Schizothorax richardsonii* Gray (Fam. Cyprinidae, Teleostei) in the high altitude river Mandakini of Garhwal Himalaya. *J. Anim. Morphol. Physiol. 42(1-2)*: 9-14.

Singh, N. (1997): Sex ratio of hillstream snowtrout *Schizothorax plagiostomus* Heckel (Teleostei: Cyprinidae) in the upland river Mandakini of Garhwal Himalaya. *J. Bombay Nat. Hist. Soc. 94*: 417-421.

Singh, N. & R. Subbaraj (2000): A profile of the food and feeding of hillstream teleosts of Garhwal Himalayas. *J. Bombay Nat. Hist. Soc. 97(1)*: 155-157.

Singh, N., K.C. Bhatt & M.K. Bahuguna (1996): Schizothoracids in the river Mandakini of Garhwal Himalaya: a brief note of their status. *J. Anim. Morphol. Physiol. 43(2)*: 163-168.

Tonn, W.M. & J.J. Magnuson (1983): Community analysis in Fishery management: an application with Wisconsin Lakes. *Trans. Fish. Soc. 112*: 377-3 86.

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