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Reproductive Strategy and Dynamics of the Endangered Himalayan Fish *Schizothorax richardsonii* in Kumaun Himalayan Snow-fed Rivers, Uttarakhand, India

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Abstract: *Schizothorax richardsonii*, an endangered fish in Uttarakhand's Himalayan rivers, is economically and ecologically vital but increasingly vulnerable. Gonadosomatic Index (GSI) reveals spawning biology, while maturity stages indicate reproductive health. The study assessed females (60-780 g, 17-44 cm) and males (52-278 g, 17-26 cm), with GSI ranging from 0.305 to 9.69 and 0.18 to 9.70 in both sexes. Maximum GSI was recorded from August to October (primary breeding) and a slight peak from late February to April (secondary breeding). Six maturity stages were identified which are based on ova morphology and its frequency distribution, including ova diameter (0.6–2.5 mm), ova radius (0.32-1.29 mm), ova area (0.33–4.53 mm^2), and ova perimeter (2.09–8.08 mm), observed annually in various months, highlighting sexually dimorphic traits during breeding and challenges in differentiation outside the breeding season. These findings aid in the sustainable management of *S. richardsonii* in hilly regions.

Keywords: *Schizothorax richardsonii.* Reproductive biology, Breeding, Maturity stages, Gonadosomatic index, Spawning, Gonadosomatic Index

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Introduction

Schizothorax richardsonii, commonly known as 'Asela,' inhabits the rivers of Uttarakhand, particularly in the snow-fed rivers of Kumaun Himalayan and Sub-Himalayan regions. However, factors such as overfishing, destructive techniques, and population pressure have led to a significant decline in its population, rendering this fish vulnerable (Vishwanath, 2010). This fish is an important food source, and it has its own economic and ecological significant role for the local communities of Uttarakhand (Negi and Negi, 2010). Therefore, to uplift its prevalence in hilly areas, assessing its reproductive health through GSI and maturity levels is crucial in order to

successfully manage and enhance fish production in aquaculture (Grandcourt *et al*., 2009; Muchlisin *et al*., 2010; Tubert *et al*., 2012).

The Gonadosomatic Index (GSI) is crucial in fish biology, providing insights into reproductive conditions and spawning biology by measuring gonad weight (Sindhe and Kulkarni, 2004). It is essential for developing breeding strategies, especially for endangered fish in impacted aquatic environments (Saksena, 1987; Hojo *et al.*, 2004; Hismayasari *et al*., 2015). Observing annual changes in maturity levels helps determine the fish reproductive season, contributing to effective breeding pattern studies (Sivakumaran *et al*., 2003; Brown *et al*., 2003). Ova diameter offers detailed information on maturity, developmental stages, and spawning initiation (Jan and Ahmed, 2019). Sexual dimorphism in *S. richardsonii* is apparent in breeding coloration, reflecting variations in reproductive organs and external structures, enhancing insights into behaviour, habitat ecology, and life history (Anderson, 1994).

Therefore, due to continuous vulnerable position of *S. richardsonii* in its distributional region, it is vital to completely investigate its reproductive dynamics, as this will provide crucial insights into fish breeding seasons and maturation stages. The objectives of this study were to determine the annual gonadal changes in GSI by analysing distinct maturity stages, and to study the sexual dimorphism developed during breeding period, and at last to establish possible statistical relationship among reproductive parameters of male and female specimens of *S. richardsonii*. This study examined the spawning patterns and maturity stages of *S. richardsonii* fish across the rivers of the Kumaun Himalayas in Uttarakhand and the outcomes of this research hold immense value in sustainably managing the fish populations within its natural aquatic water bodies.

Materials and Methods

Study site and sampling:

Male and female fish *Schizothorax richardsonii* were collected from the local market on annual basis from three snow-fed rivers, the Eastern Ramganga (29°82'23'' to 80°20'29''E), the Kali (30°14'32'' to 81°01'19''E), and the Saryu (29°66'56'' to 80°14'89''E), of Uttarakhand, India. Samples were identified on the spot with standard literature (Jayaram, 2010).

Gonadosomatic índex:

After wiping, the fish lengths (cm) and weights (g) were measured. Further, sexes were visually identified after dissection and the gonads were measured and weighed as accurate as 0.01 g, to estimate the gonado-somatic index using standard Ebisawas' equation (2006).

Maturity stages:

Based on the study of ova morphology, frequency distribution, and external gonad features like size, color, shape, and texture, the maturity stage of each gonad was classified according to ICES scale (Wood, 1936; Brown *et al*., 2008). For ova morphology, the ovaries were fixed in 99% alcohol then ova diameter, radius, area, and perimeter were measured using occulometer (Kawakami *et al*., 2010), and Motic Image Plus 2.0 Digital Microscopy Software. Frequency polygons were determined according to Palekar and Karandikar (1952).

Sexual dimorphism:

Geometric morphometric measurements, following Webster and Sheets (2010), were used to record fish color, body shape and structure.

Statistical analysis:

Statistical analysis and inter-relation of annual data was analyzed by the PAST programme 4.08 version (Hammer *et al*., 2001) and MS Excel data analysis software (Heiberger and Neuwirth, 2009).

Results and Discussion

Female *Schizothorax richardsonii* ranged from 60 to 780 g, and length between 17 to 44 cm, and male specimens ranged 52 to 278 g in weight and 17 to 26 cm in length.

Gonadosomatic index (*GSI*):

The results of this study revealed that the monthly variation of the GSI values for *S. richardsonii* male and female specimens ranged from 0.305 to 9.69, and 0.18 to 9.70, respectively (Table 1). For both sexes, the highest peak of GSI values (> 5) were recorded from August to October, and the lowest from May to July and November to January, while a slight peak was also noticed from late February to April (Fig. 1). The lowest peak of GSI value in various month suggests that this period may be the resting or preparatory period for fishes, while highest peak GSI value shows that the fish spawns twice in a year with intense breeding (shows primary breeding period) from August to October in former, and less intense breeding (shows secondary breeding period) from February to April in later. The GSI value of females shows that they spawn earlier than males during the secondary breeding period from February to April, while both gonads show similar breeding pattern in primary breeding period from August to October (Table 1).

Understanding the breeding biology and reproductive dynamics of fish species holds significant importance. The Gonadosomatic Index (GSI) serves as a key indicator, revealing intense breeding activity from August to October and a secondary period from February to April. This aligns with previous studies, confirming biannual spawning in the Indian Himalayan region. Our GSI findings closely resembles with findings of Joshi *et al*. (2016) and Ciji *et al*. (2021), with a peak in September-October and a low in November-December, consistent with earlier reports by Abuzinadah (2001), Wagle (2014), and Joshi *et al*. (2016).

Maturity stages:

This study observed ova characteristics, revealing a diameter range of 0.6 to 2.5 mm, radius from 0.32 to 1.29 mm, area from 0.33 to 4.53 mm^2, and perimeter from 2.09 to 7.92 mm throughout (Table 2). Smallest diameters occurred in November (0.6 mm) and December (0.9 mm), while the largest were in September (2.5 mm) and October (2.3 mm). A slight peak in February and April (1.9–2.4 mm) indicated spawning, affirming two annual spawning cycles: August to October (primary) and February to April (secondary) (Table 2).

Throughout the year, this study classified *S. richardsonii* into six maturity stages (Fig. 2) via gonad examination. Monthly calculations of ova diameter frequencies revealed distinct patterns. The annual distribution of maturity stages showed Stage I fishes from November to January, Stage II from November to March, Stage III from January to April, Stage IV from April to July, Stage V from May to October, and Stage VI from July to October (Table 3). These stages are as follow:

(i) *Stage I* (*Resting phase*):

Transparent and shrunken ovaries, long strips, ova not clear (Fig. 3). The ova diameter ranged from 0.6-0.9 mm, with peak value at 0.8 mm (Fig. 4). Testes reduced in size and show reabsorption (Fig. 5).

(ii) *Stage II* (*Preparatory phase*):

Ovaries red and translucent, eggs small without yolk, visible to naked eye (Fig. 3). The ova diameter ranged from 0.9 – 1.7 mm, with a peak at 0.9 mm (Fig. 4). Testes were elongated and whitish in colour (Fig. 5).

(iii) *Stage III* (*Secondary breeding phase*):

Ovaries elongated, occupying over half of the body, opaque (Fig. 3), with ova diameter ranging 1.9-2.4 mm, peaking at 2.2 mm (Fig. 4). Testis milky, slightly lobed, and elongated, exhibiting oozing on slight pressure (Fig. 5).

(iv) *Stage IV* (*Resting phase*):

Ovaries large, occupies half length of the body, bright yellow in colour and opaque (Fig. 3). The ova diameter ranged from 0.8 – 1.8 mm, with peak value at 1.0 mm (Fig. 4). Testes have convoluted, creamy milky texture (Fig. 5).

(v) *Stage V* (*Preparatory phase*):

Ovaries large, spread almost entire length of fish, abdomen bulgy, large, and opaque eggs, blood vessels covered (Fig. 3). The ova diameter ranged

Table 1: Annual variations in Gonadosomatic Index of fish *S. richardsonii*

	GSI (Combined)		GSI (Male)		GSI (Female)	
Month	Average	Range	Average	Range	Average	Range
November	0.623±0.71	0.18-2.06	0.305±0.16	0.18-0.54	1.26±1.13	0.46-2.06
December	0.277±0.13	0.15-0.46	0.32±0.14	0.15-0.46	0.19±0.05	0.15-0.23
January	0.585±0.05	0.53-0.65	0.56±0.04	0.53-0.61	0.65±0	0.65-0.65
February	1.10±0.44	0.558-1.86	0.97±0.31	0.558-1.23	1.35±0.72	0.84-1.86
March	1.64±0.88	0.41-2.72	1.78±0.79	0.88-2.72	1.35±1.32	0.41-2.29
April	5.04±2.62	1.56-9.76	4.39±2.04	1.56-7.71	6.80±3.55	1.71-9.76
May	1.42±0.73	0.68-2.39	1.17±0.68	0.68-1.96	1.79±0.83	1.21-2.39
June	0.66±0.32	0.27-1.128	0.61±0.31	0.27-1.128	0.99±0	0.99-0.99
July	0.49±0.39	0.1-1.0	0.80±0.31	0.44-1.0	0.18±0.07	0.10-0.24
August	5.19±2.28	2.07-7.45	4.27±2.28	2.07-7.45	7.05±0.35	6.80-7.30
September	7.47±3.72	4.6-12.9	5.70±1.55	4.60-6.80	9.25±5.16	5.60-12.90
October	9.69±2.86	6.67-14.05	9.69±1.71	8.48-10.9	9.70±3.86	6.67-14.05

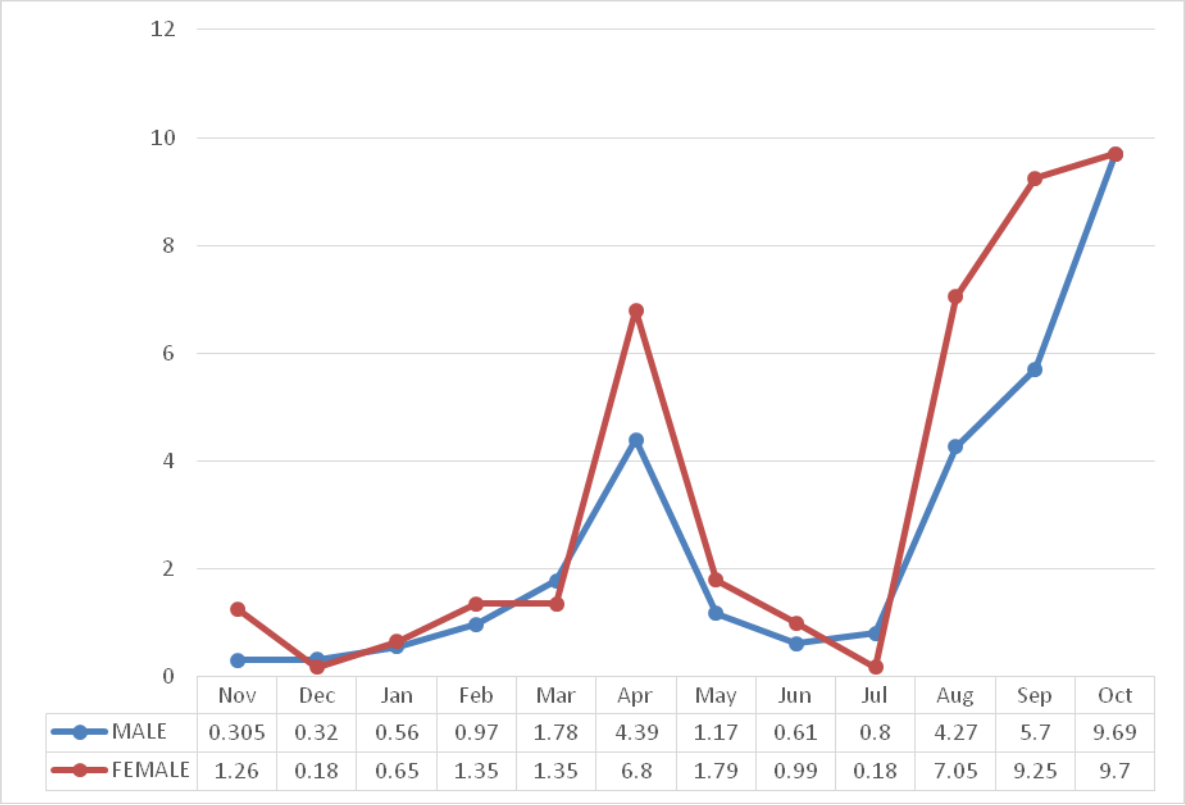

Fig. 1: Annual comparison in Gonadosomatic Index of male and female specimens of *S. richardsonii.*

Table 2: Annual variation of ova morphology of fish *S. richardsonii*

S. No.	Months	Average ova diameter (mm)	Ova radius (mm)	Ova area (mm^2)	Perimeter (mm)	GSI (female)
1.	November	0.6	0.32	0.33	2.09	1.26±1.13
2.	December	0.9	0.45	0.64	2.84	0.19±0.05
3.	January	1.7	0.98	3.04	6.18	0.65±0
4.	February	1.9	1	3.13	6.27	1.35±0.72
5.	March	2.2	1.09	3.76	6.87	1.35±1.32
6.	April	2.4	1.26	5	7.92	6.80±3.55
7.	May	1.8	0.93	2.7	5.82	1.79±0.83
8.	June	0.8	0.4	0.52	2.61	0.99±0
9.	July	1.9	0.96	2.89	6.03	0.18±0.07
10.	August	2.1	1.04	3.42	6.56	7.05±0.35
11.	September	2.5	1.29	5.2	8.08	9.25±5.16
12.	October	2.3	1.2	4.53	7.54	9.70±3.86

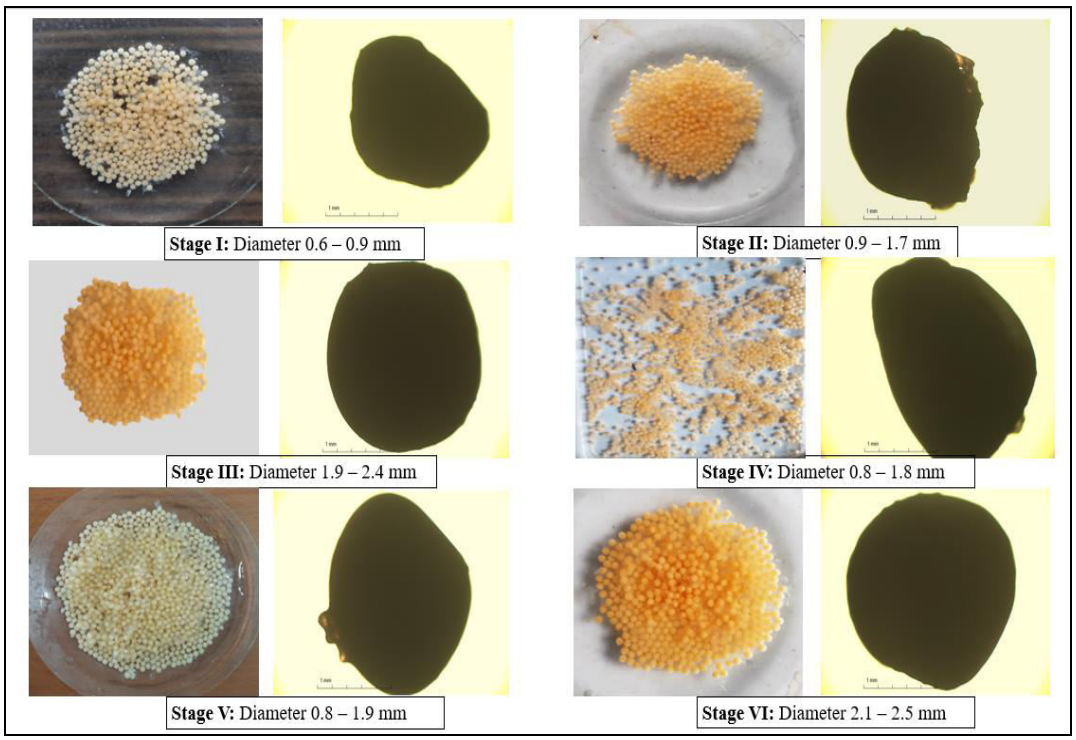

Fig. 2: Annual maturity stages (I-VI) distribution, depicting macroscopic ova on the left and microscopic ova morphology with intra-ovarian diameter on the right.

Table 3: Percentage frequency distribution of maturity stages of *S. richardsonii*

S. No.	Months	Percentage of fish					
		Stage I	Stage II	Stage III	Stage IV	Stage V	Stage VI
1.	November	98	2	-	-	-	-
2.	December	94	6	-	-	-	-
3.	January	74	23	7	-	-	-
4.	February	-	36.4	63.6	-	-	-
5.	March	-	51.4	48.6	-	-	-
6.	April	-	-	65.2	34.8	-	-
7.	May	-	-	-	76.4	23.6	-
8.	June	-	-	-	48.2	51.8	-
9.	July	-	-	-	26	41.6	32.4
10.	August	-	-	-	-	17.2	82.8
11.	September	-	-	-	-	4	96
12.	October	-	-	-	-	21.35	78.65

Fig. 3: Gonadal maturity stages of female fish *S. richardsonii.*

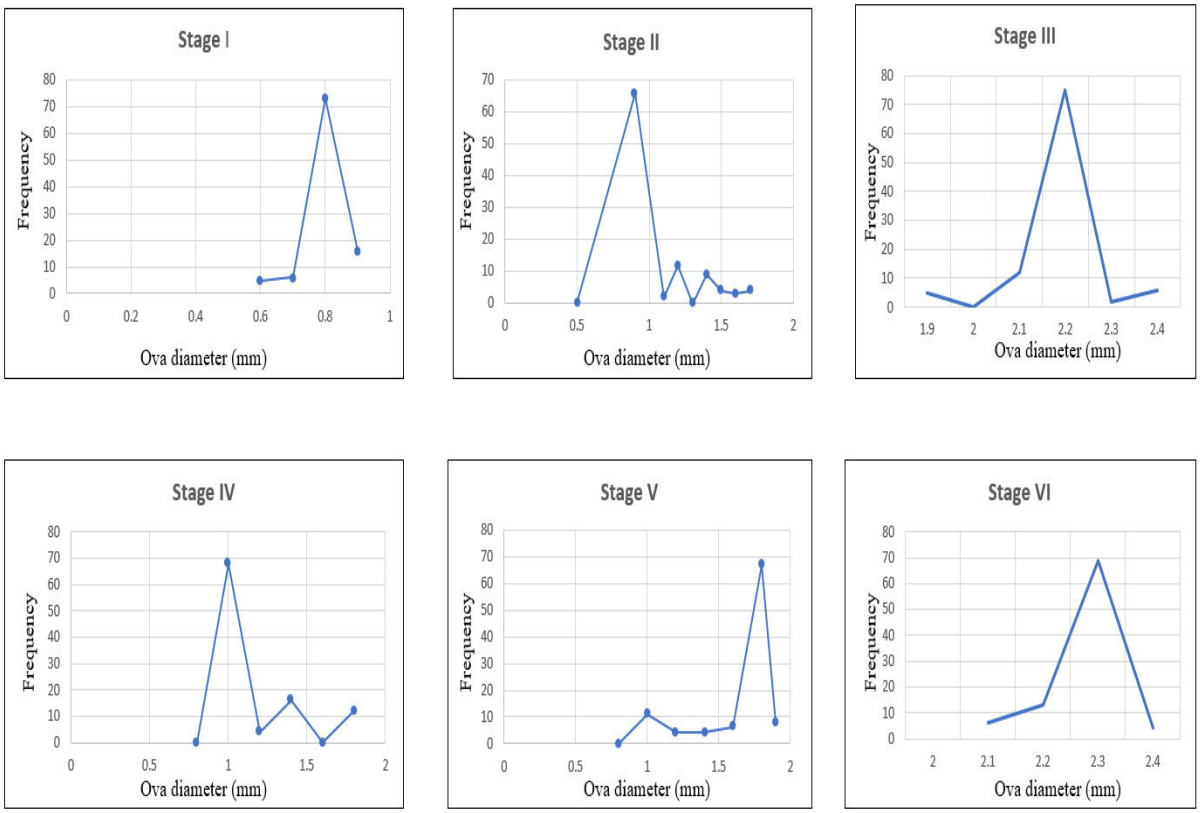

Fig. 4: Ova diameter frequency distribution in each maturity stages of fish *S. richardsonii*

Fig. 5: Gonadal maturity stages of male fish *S. richardsonii.*

Table 4: List of major findings to explain sexual dimorphism of fish *S. richardsonii*

	Male	Female
Size	Slightly smaller and slenderer, typically around 20-25 cm long.	Generally larger and more robust than males, reaching up to 30 cm in length.
Coloration	Males display a reddish-orange stripe running along their body and fins	Females develop a subtle rosy hue on their belly and fins.
Head	Males have larger heads as compared to females	Female have smaller heads mostly
Snout	Males have rough snout due to presence of well-developed nuptial tubercles	Females have smooth snout as compared to males
Fin	Mature males develop faint yellow colour of the fins during the breeding season which distinguish them from females.	Fins, particularly the dorsal and anal fins, are rounded and shorter.
Tubercles	Males develop small, white breeding tubercles on their head and pectoral fins, aiding in grip during spawning.	Females lack these breeding tubercles.
Abdomen	Males have normal abdomen without any bulging	Female abdomen shows bulging at breeding period

from 0.8 – 1.9 mm, with peak value recorded at 1.8 mm (Fig. 4). Testes are thread like structure and transparent (Fig. 5).

(vi) *Stage VI* (*Primary breeding phase*):

Bulged abdomen with fully mature ovaries containing ripe transparent ova, extruding under pressure (Fig. 3); ova diameter ranged 2.1-2.5 mm, peaking at 2.3 mm, indicative of maximum recorded ova (Fig. 4). Testes highly enlarged, convoluted, exhibiting oozing (Fig. 5).

Studying gonad development and maturity stages provides insights into fish reproductive biology and breeding patterns. This involved macroscopic and microscopic examinations of gonads and oocytes, similar to Wagle (2014), and measuring ova diameter, with findings aligning with Joshi *et al.* (2016) and Bahuguna *et al.* (2011). Fish were categorized into six maturity stages based on ova progression and gonadal changes which are in agreement with observations of Joshi *et al.* (2016). Ovaries and testes-maintained gametogenesis during the resting period between spawning peaks, offering insights into *S. richardsonii* reproductive status and confirming findings across various studies.

Sexual dimorphism:

The study on sexual dimorphism in *S. richardsonii* from Kumaun Himalaya revealed that adult females generally have larger, more robust bodies, while males exhibit larger heads and mouths across populations. In many cases, females have longer standard lengths and pelvic girdles compared to males. During the breeding season, males show elongated dorsal and anal fins with reddish coloration, while females have rounder, shorter fins and a bulged abdomen (Table 4, Fig. 6). Except for body size, sexual dimorphism in most external traits was similar between males and females.

S. richardsonii begins spawning at two years old, reaching a length of 18-24 cm (Yadav *et al*., 2014). Sexual dimorphism is prominent, particularly during the breeding season (Rai *et al*., 2002). Mature males exhibit a rough snout with well-developed nuptial tubercles, and they develop a faint yellow body colour and reddish

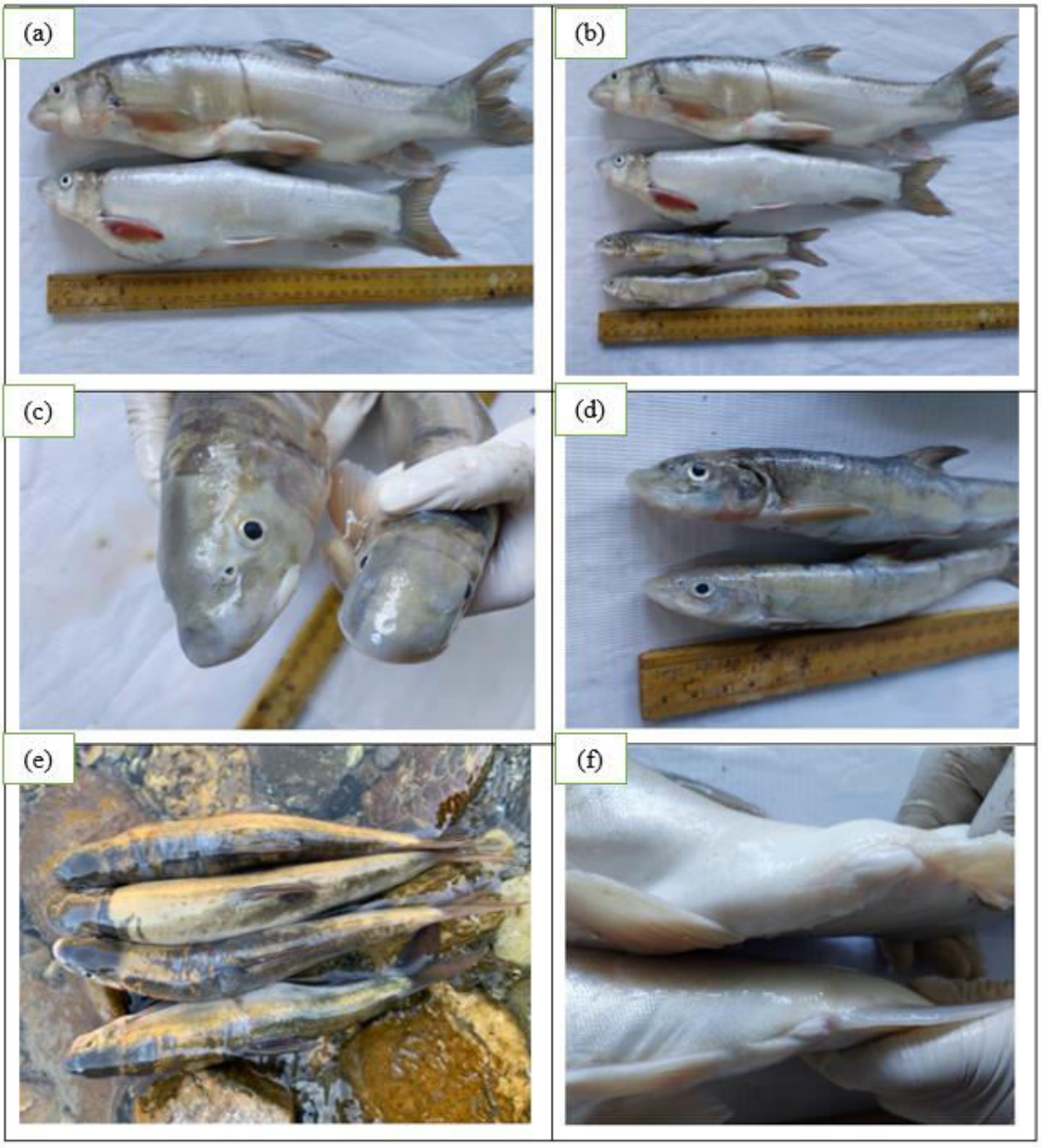

Fig. 6: Sexual dimorphism in *S. richardsonii* fish is evident in (a) male and female distinctions, (b) age-related variations, (c) snout disparities, (d) head differences, (e) mature male coloration variations, and (f) additional bulging in females.

fins during breeding, distinguishing them from females. Females spawn twice a year: August-October and February-April (Rai *et al*., 2002).

Conclusion

This study on *S. richardsonii* in Kumaun Himalayan River concluded monthly GSI variations, with females showing higher GSI, indicating advanced gonad development. Fish exhibit biannual breeding with occasional irregular breeding. Morphological analysis of gonads and ova indicates distinct maturity stages and varying ova sizes, suggesting different reproductive phases. Ova diameter examination categorizes six

different maturity stages, offering a comprehensive reproductive framework. Information about sexual dimorphism reveals that males and females usually differ not only in reproductive organs, but also in external structures that are not directly related to reproduction. This provides valuable insights for the range-wide management and sustainable conservation of this vulnerable fish species.

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References

Bahuguna SN, Tripathi AK, Khan A. (2011) Morphological and biochemical studies of the milt (Spermatozoa) of the snow-trout fish *Schizothorax richardsonii* (Gray). Environ Conserv J. 12(1,2): 23-28.

Brown P. (2003) Carp population biology in Victoria. Queenscliff: Marine and Freshwater Resources Institute, Department of Primary Industry; Feb. ISBN: 1741064155.

Brown-Peterson NJ, Wyanski DM, Saborido-Rey F, Macewicz BJ and Lowerre-Barbieri SK. (2011) A standardized terminology for describing reproductive development in fishes. Mar Coastal Fish. 3(1): 52-70.

Brown-Peterson N, Lowerre-Barbieri S, Macewicz BJ, Saborido-Rey F, Tomkiewicz J and Wyanski DM. (2007) An improved and simplified terminology for reproductive classification in fishes. www.usm.edu/gcrl/research/gonadal_terminology.php.

Ciji A, Sharma P, Rajesh M, Kamalam BS, Sharma A, Dash P and Akhtar MS. (2021) Intra-annual changes in reproductive indices of male and female Himalayan snow trout, *Schizothorax richardsonii* (Gray, 1832). Aquacult Res. 52(1): 130-141.

Ebisawa A. (2006) Reproductive and sexual characteristics in five *Lethrinus* species in waters off the Ryukyu Islands. Ichthyological Res. 53(3): 269-280.

Grandcourt EM, Al Abdessalaam TZ, Francis F, Al Shamsi AT and Hartmann SA. (2009) Reproductive biology and implications for management of the orange-spotted grouper *Epinephelus coioides* in the southern Arabian Gulf. J Fish Biol. 74(4): 820-841.

Hammer Ø, Harper DA and Ryan PD. (2001) PAST: Paleontological statistics software package for education and data analysis. Palaeontologia Electronica 4(1): 9.

Heiberger RM and Neuwirth E. (2009) R through Excel: A spreadsheet interface for statistics, data analysis, and graphics. doi:10.1007/978-1-4419-0052-4.

Hismayasari IB, Marhendra AP, Rahayu S, Saidin SD and Supriyadi DS. (2015) Gonadosomatic index (GSI), hepatosomatic index (HSI) and proportion of oocytes stadia as an indicator of rainbowfish *Melanotaenia boesemani* spawning season. Int J Fish Aquat Stud. 2(5): 359-362.

Hojo RE, Santos GB and Bazzoli N. (2004) Reproductive biology of *Moenkhausia intermedia* (Eigenmann) (Pisces, Characiformes) in Itumbiara Reservoir, Goiás, Brazil. Revista Brasileira de Zoologia 21: 519-524.

Jan M and Ahmed I. (2019) Reproductive biology and histological studies of ovarian development of *Schizothorax plagiostomus* in river Lidder from Kashmir Himalaya. J Appl Ichthyol. 35(2): 512-519.

Jayaram KC. (2010) The freshwater fishes of the Indian Region. 2nd edn., Narmada Publishing House, Delhi, India.

Joshi KD, Das SCS, Khan AU, Pathak RK and Sarkar UK. (2016) Reproductive biology of snow trout, *Schizothorax richardsonii* (1832) in a tributary of River Alaknanda, India and their conservation implications. Intern J Zool Invest. 2(1): 109-114.

Kawakami T, Aoyama J and Tsukamoto K. (2010) Morphology of pelagic fish eggs identified using mitochondrial DNA and their distribution in waters west of the Mariana Islands. Environ Biol Fishes 87: 221-235.

Muchlisin ZA, Musman M and Azizah MS. (2010) Spawning seasons of *Rasbora tawarensis* (Pisces: Cyprinidae) in Lake Laut Tawar, Aceh Province, Indonesia. Reproductive Biol Endocrinol. 8: 1-8.

Negi RK and Negi T. (2010) Assemblage structure of stream fishes in the Kumaon Himalaya of Uttarakhand State, India. Life Sci J. 7(1): 9-14.

Palekar VC and Karandikar KR. (1952) Maturity and spawning period of *Thrissocles purava* (Ham.) as determined by ova-diameter measurements. Proce Indian Acad Sci Section B 35:143-154.

Rai AK, Pradhan BR and Basnet SR. (2002) Present status of snow trout in Nepal. FAO Fisheries Technical Paper No. 431, FAO, Rome, pp. 213-220.

Saksena DN. (1987) On the use of gonadosomatic index and volume of gonads as indicators of gonadal state in Indian freshwater goby *Glassogobius giuris* (Ham) with a note on the role of temperature in fish reproduction. Int J Acad Ichthyol. 8:1-8.

Sindhe VR and Kulkarni RS. (2004) Gonadosomatic and hepatosomatic indices of the freshwater fish *Notopterus notopterus* (Pallas) in response to some heavy metal exposure. J Environ Biol. 25(3): 365-368.

Sivakumaran KP, Brown P, Stoessel D and Giles A. (2003) Maturation and reproductive biology of female wild carp, *Cyprinus carpio*, in Victoria, Australia. Environ Biol Fishes 68(3): 321-332.

Tubert C, Nostro FL, Villafañe V and Pandolfi M. (2012) Aggressive behavior and reproductive physiology in females of the social cichlid fish *Cichlasoma dimerus*. Physiol Behavior. 106(2): 193-200.

Vishwanath W. (2010) *Schizothorax richardsonii*. The IUCN Red List of Threatened Species 2010: e. T166525A6228314.

Wagle SK. (2014) Studies on gonadosomatic index, fecundity and hatchability of domesticated stock of asala *Schizothorax richardsonii* (Gray) from Nallu River of Lalitpur District. Our Nature 12(1): 19-27.

Webster MA and Sheets HD. (2010) A practical introduction to landmarkbased geometric morphometrics. Quant met Paleobiol. 16: 168-188.

Wood H. (1936) Scottish herring shoals. Prespawning and spawning movements. Scotland Fish. Bd. Sci. Invest. 1: 1-71.

Yadav CNR, Ghosh TK and Subba BR. (2014) General biology and status of *Schizothorax richardsonii* in Nepal. Nepalese J Biosci. 4(1): 34-39.