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A Comprehensive Analysis of Feeding Indices in *Schizothorax richardsonii*, a Himalayan endangered Species

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ABSTRACT:
Feeding indices in fish are tools used by researchers to know feeding behavior, habits, and diet. This study is about various feeding indices of the endangered fish *Schizothorax richardsoni* of Uttarakhand. The main objective of the study was to study the fish's feeding behavior. A total of 74 fish samples were collected monthly over 12 months. Sample collection and calculation of all indices were done according to the standard method. Seasonal variations in feeding were noticed in all samples. In April, the mean value of GaSI reached its peak at 20.38, indicating active feeding during this period; conversely, it was lowest in January. The RLG values ranged from 2.53 to 5.54, suggesting that fish is primarily herbivorous. Feeding intensity was increasing from November to January and May to June, indicating increased feeding activity during these periods, while it was decreasing in July to September and March to April. Fish weight-gut weight and fish length-gut length show strong positive correlations. With a comprehensive understanding of the fish's feeding behavior, researchers can gain valuable insights into the fish's ecological role and the health of the river ecosystem. Therefore, acquiring detailed knowledge is essential for achieving positive outcomes in its culture and conservation.

Keywords:
Feeding habit, Feeding intensity, Relative length of gut, Gastro-somatic index

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INTRODUCTION

Fish feeding indices serve as valuable tools and techniques employed by researchers and aqua culturists to evaluate the feeding patterns and dietary choices of fish populations. *Schizothorax richardsonii* (snow trout), often known as "Asela" belongs to the Cyprinidae family of the Pisces class of the main order Cypriniformes (Sharma et al., 2018). The fish is an endangered species, found in range of Himalayan Rivers, lakes, and streams. This present research was performed to find out the various fish indices of the fish *Schizothorax richardsonii* from the Kali Riverin Uttarakhand. Fish exhibit varying dietary preferences that change monthly due to shifts in

food organism composition across seasons. Numerous researchers, including (Krishna Rao, 2007) and (Chattopadhyay et al., 2014), have explored various feeding indices. In-depth knowledge of fish feeding habits is essential for selecting suitable species for aquaculture success.

Feeding indices including gastro-somatic index (GaSI), relative length of the gut (RLG) and feeding intensity. The gastro-somatic index gives the relationship between the weight of the alimentary canal and the weight of the fish (Mamun et al., 2004). The relative length of the gut is widely used to determine the feeding habitat of fishes, such as herbivores, carnivores, and omnivores. The relative length of the gut is a useful index that gives a broad idea of the food that fish consume (Verma, 2015). Feeding intensity gives an idea about the availability of food items in the environment (Baboli et al., 2013).

The main objective of the study was to conduct a comprehensive analysis of fish feeding behavior. Due to the limited availability of knowledge on this research, the primary aim of this study is to explain the feeding habitat of fish, their diet, the monthly variation of different food classes in their stomachs, and their feeding strength. This study will set a mark towards increasing and developing knowledge about various feeding indices, by understanding the feeding behavior and preferences of *Schizothorax richardsonii*, researchers can gain valuable insights into the fish's ecological role and the health of the river ecosystem.

MATERIALS AND METHODS

Study site and sampling spots

This study has been conducted on the snow-fed Kali River, which originates in the Kalapani region of the Vyas Valley in Uttarakhand's Pithoragarh district. Our study is situated among these five sampling locations due to the abundant presence of our fish species in these areas. These spots are Dharchula (S1), Jauljibi (S2), Ghigrani (S3), Jhulaghat (S4) and Pancheswar (S5) (Fig. 1; and Table 1). To the north of spot 1, this particular fish species is absent, and to the south of spot 5, the hilly terrain comes to an end.

Sample and data collection

Prior to the research, all fish samples were collected, on a monthly basis with help of commercially available local fishermen, and from local markets, with Ethical guidelines, in accordance with (Bennett et al., 2016).Fish were washed, cleaned, and weighted with a digital balance in grams, from the snout's tip to the caudal fin end, the total length of the fish was measured by a measuring scale in centimeters (Fig. 2). The samples were preserved in 10% formalin then transferred in plastic containers to the laboratory. Different types of data were collected such as numerical data, observational data, and physiological measurements.

Gastro-Somatic Index

It was calculated by Khan *et al*. (1988) method.

A. (Gastro somatic index (GaSI)) $= \frac{weight\ of\ gut}{weight\ of\ fish} \times 100$

The relative length of the gut

It was calculated According to Yamagishi *et al*. (2005).

B. (Relative length of gut (RLG)) $= \frac{Gut\ length}{Fork\ length}$

Feeding intensity

To observe the gut fullness based on Begum et al. (2008), into five different categories like empty (gut without food), poor intensity (1/4 gut filled), medium intensity (gut ½ filled), good intensity (gut 3/4 filled), high intensity (more than ¾gutfilled).

Table 1: Location of study area selected for sample collection

River	Sites	Latitude	Longitude	Altitude
Kal River	Dharchula	29°71'23"N	80°37'19"E	940m
	Jauljibi	29°70'07"N	80°37'64"E	996m
	Pipli	29°42'16"N	80°21'09"E	984m
	Jhulaghat	29°34'10"N	80°22'47"E	1020m
	Pancheswar	29°42'05"N	80°26'56"E	1117m

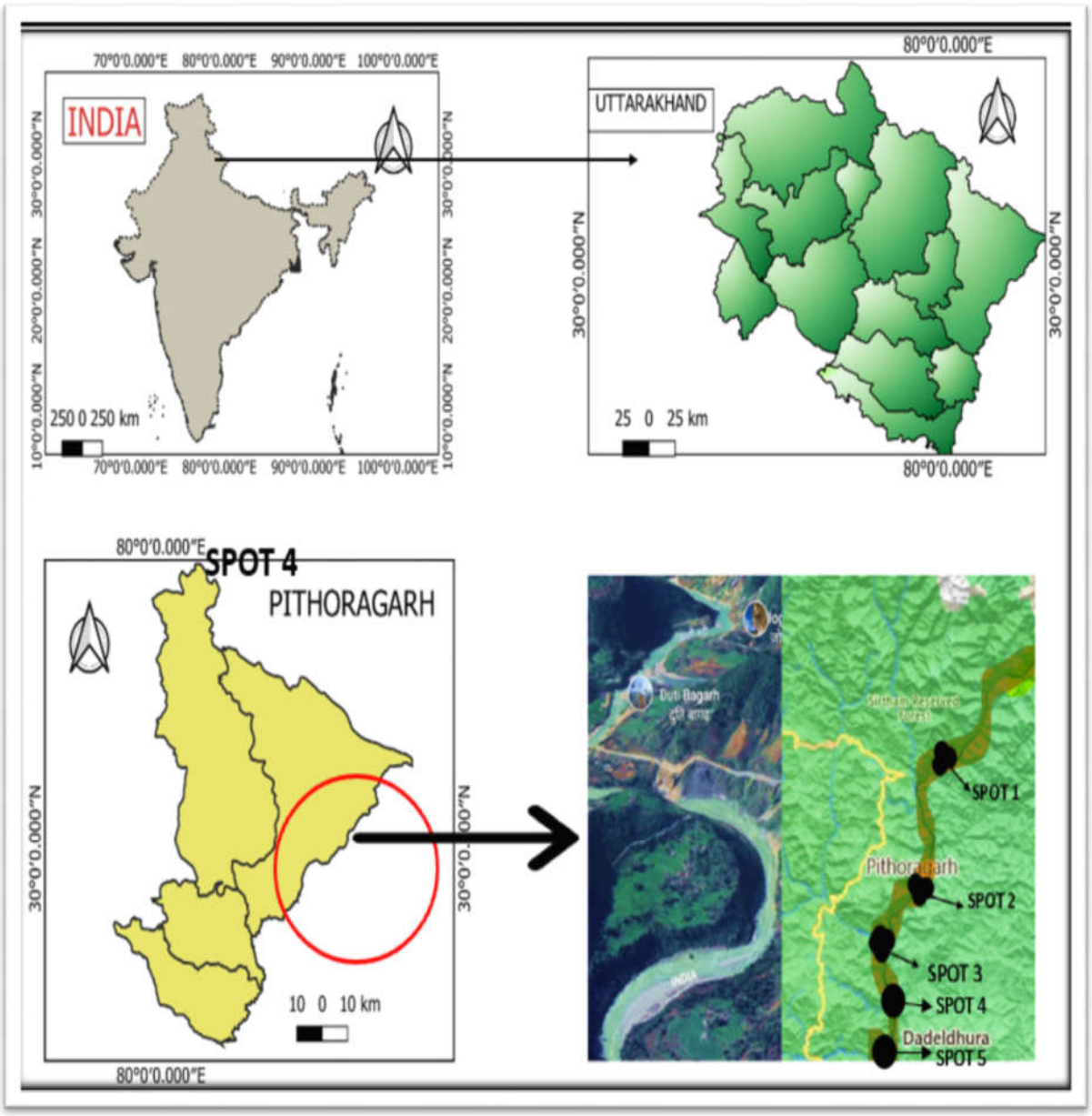

Figure 1: Various study sites in Kumaun Himalayan region

Figure 2: Fish weight, gut length and gut weight of fish

Statistical analysis

A least squares equation (Y = a + bX.) was employed to express the correlation between standard length (SL) and gut length, with 'a' as the intercept and 'b' as the slope. The significance of the correlation was tested using the coefficient 'r,' while 'R^2' determined the proportion of variability explained. Analysis utilized MS Office and PAST software (Hammer et al. 2001).

RESULTS

The study findings unveiled a monthly fluctuation in GaSI values for *S. richardsonii*, spanning a range from 20.38 to 4.8 (Fig. 3). The highest GaSI values were observed in both April and December, displaying two distinct peaks with mean values of 20.38 ± 11.31 and 12.09 ± 3.37, respectively. Conversely, the lowest GaSI values were documented in August and January, each showcasing two distinct troughs, with mean values of 4.8 ± 0.79 and 4.47 ± 0.66, respectively. The GaSI value is regularly increasing from April to June and then again decreasing July to November Table 2.

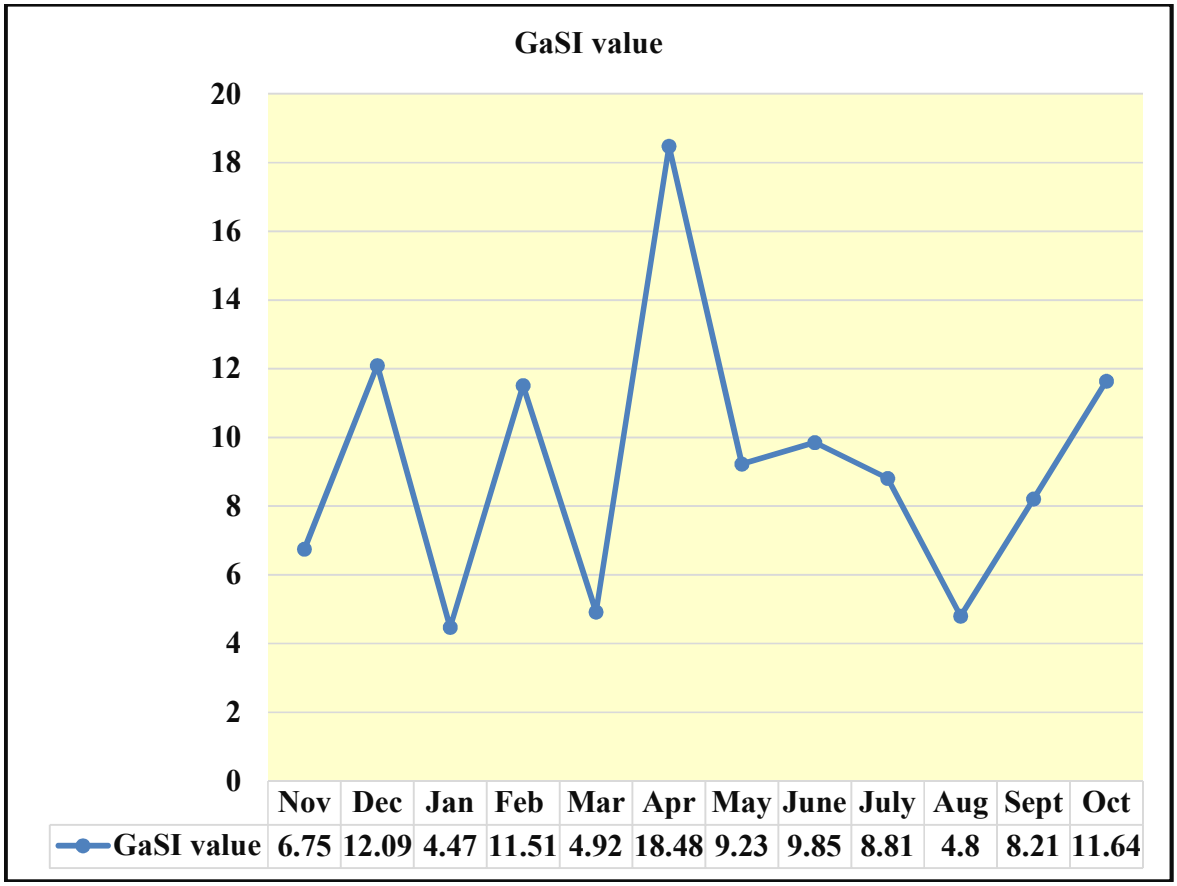

Figure 3: Average monthly GaSI values for *Schizothorax richardsonii*

The study's observations indicated the highest peak, signifying an abundant availability of essential food items during this season, while the lowest peak indicated a decrease in the quantity of basic food items. In the study, a positive correlation was found between the fish weight and gut weight. The regression equation derived from the data was Y=0.0461x + 5.9861. The coefficient of correlation, r, was determined to be 0.8059 (Fig. 4).

RLG values have been observed to range from 2.53 ± 0.33 to 5.54 ± 2.25, indicating monthly fluctuations in the gut length relative to the fork length Table 3. The regression analysis yielded an equation, ACL = 0.234 + 2.425 TL, demonstrating a significant linear relationship between these variables. A positive linear relationship has been established between the total length (TL) and alimentary canal length (ACL), with the observation that ACL is greater than TL. The coefficient of correlation (r) has been calculated to be 0.853, signifying a strong positive correlation between these variables (Fig. 5).

Table 2: Monthly summary statistics of GaSI value

Month	Gut weight	Fish weight	GaSI value	Remarks
November	2.51-7.04 4.62±1.64	49.18-95.89 69.13±69.13	4.93-10.01 6.75±2.02	Decreasing
December	6.41-17.77 12.43±3.58	76.07-130.84 104.34±14.65	4.09-16.75 12.09±3.37	Increasing
January	3.64-7.42 5.07±1.67	94.92-137.81 111.31±19.42	3.83-5.38 4.47±0.66	Decreasing
February	3.65-16.64 7.87±4.49	35.11-134.92 71.75±39.05	7.28-17.46 11.51±3.41	Increasing
March	2.51-19.50 9.07±6.40	89.36-390 156.17±110.75	2.7-12.21 6.09±3.11	Decreasing
April	1.85-18.09 9.53±4.62	28-120 53.94±27.40	2.01-42.29 20.38±11.31	Increasing
May	4.8-29.2 16.74±10.90	66.9-249 171.64±85.22	5.22-11.72 9.23±2.76	Increasing
June	3.7-22.6 11.78±7.51	102.4-160.1 126.27±22.51	2.51-21.08 9.85±6.96	Increasing
July	1.47-29.3 10.81±9.75	69.9-250 117.06±67.70	1.35-13.88 8.81±4.27	Decreasing
August	19.3-31.8 25.55±8.83	360-1200 780±593.96	4.24-5.36 4.8±0.79	Decreasing
September	15.8-80.2 48±45.53	560-750 655±134.35	2.1-14.32 8.21±8.64	Decreasing
October	21.4-58.57 39.82±13.41	126-620 389.2±197.16	6.60-16.98 11.64±3.70	Increasing

Fish gut fullness has been classified into five categories: empty, poor intensity, medium intensity, good intensity and high intensity are represented in Table 4. From the month November to January maximum fishes shows medium intensity and minimum fishes shows empty feeding intensity. From the month February to April maximum fishes shows poor intensity and minimum fishes shows high intensity. From the month May to June maximum fishes shows good intensity and minimum fishes shows empty feeding intensity. From the month July to October maximum fishes shows poor feeding intensity and minimum fishes shows high feeding intensity.

The monthly analysis of gut fullness, as presented in Table 5, provides valuable insights into feeding intensity. Feeding intensity has been meticulously calculated across various categories: 7.89% corresponds to an empty stomach, 33.02% indicates a poor stomach, 30.84% represents a medium level of gut fullness, 20.27% signifies a good level, and 8.06% reflects a high intensity of feeding. These findings are crucial for understanding feeding patterns and their implications for the studied subjects.

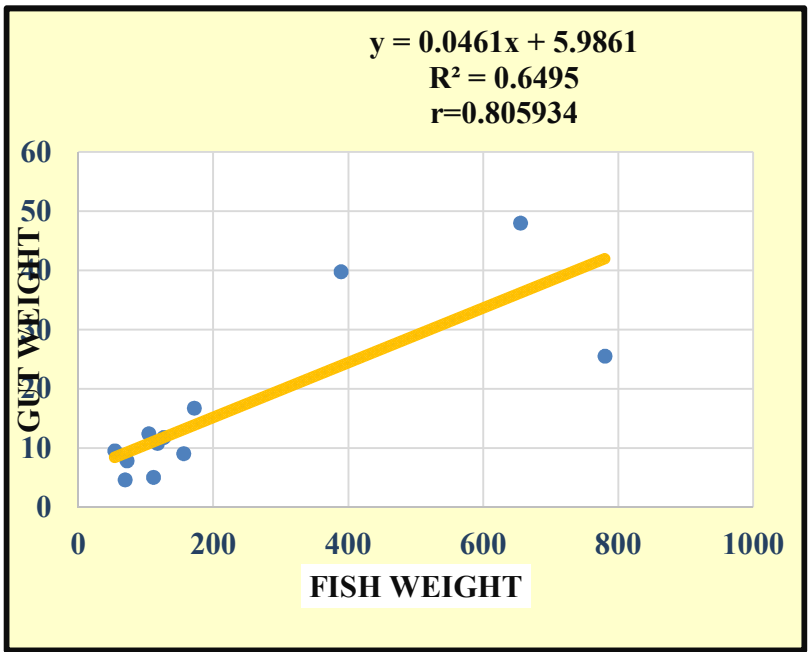

Figure 4: Linear correlation between Fish weight and gut weight

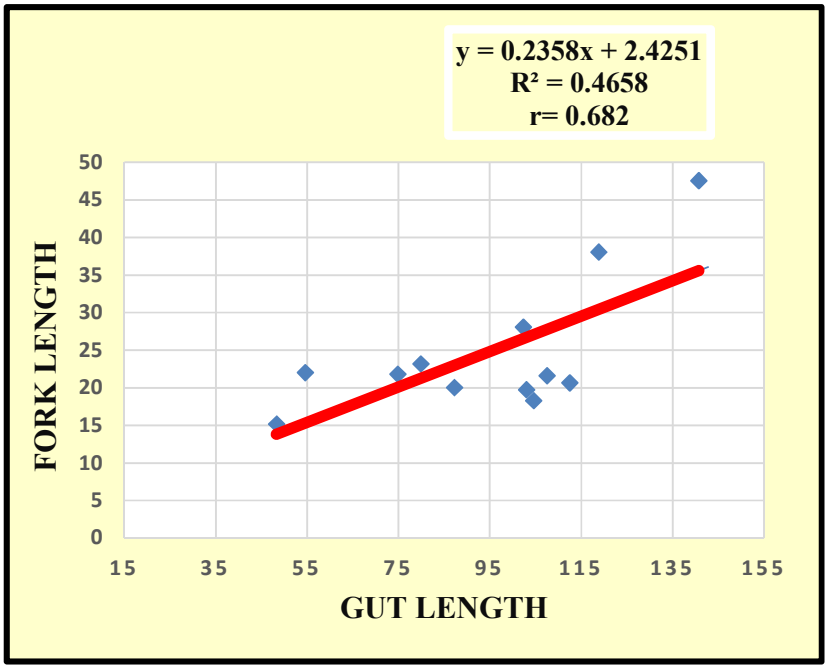

Figure 5: Linear correlation between Fork length and gut length

Table 3: Monthly summary statistics of RLG value

Month	Gut length	Fork length	RLG value
November	69-180 100.4±46.24	16-22.5 19.76±2.43	3.06-5.68 4.05±0.97
December	84-135 112.52±15.06	16.4-22.5 20.68±1.81	4.75-6.25 5.42±0.47
January	99.9-123.6 107.5±10.94	19.8-23.2 21.62±1.41	4.54-5.32 4.96±0.33
February	78.2-147.2 97.41±25.10	14.8-23.2 18.31±2.86	3.78-9.94 5.54±2.25
March	62.7-90.9 73.14±12.13	18.7-29.8 21.84±3.86	2.35-4.86 3.43±0.85
April	27.7-77.2 48.3±14.43	12.6-21.1 15.20±2.26	1.91-4.80 3.20±0.93
May	42.3-122.2 79.88±33.81	17.9-27 23.22±3.88	2.01-4.52 3.34±1.03
June	36.6-91.6 54.57±19.16	19.8-24 22.04±1.62	1.61-4.62 2.53±1.09
July	46.9-144.1 87.26±32.96	17.4-26.6 20.08±3.55	2.69-5.41 4.23±0.91
August	98.6-140.7 119.65±29.76	26.4-47.6 37±14.99	2.95-3.73 3.34±0.55
September	109.1-114.5 111.8±3.81	32-44.2 38.1±8.62	2.59-3.40 2.99±0.57
October	34.2-184.2 90.18±67.29	16.7-41 25.98±11.97	2.04-4.49 3.10±1.01

Table 4: Monthly summary statistics table of feeding intensity

Month	Empty	Poor	Medium	Good	High
November	1.94-4.19 3.12±1.03	4.73-15.44 11.02±5.52	10.68-57.97 37.12±22.14	13.34-60.19 34.94±21.04	1.16-24.73 14.26±9.40
December	1.39-4.12 2.64±0.93	3.42-6.95 5.42±1.13	47.52-69.94 55.23±6.50	12.63-23.94 18.32±3.54	11.87-27.85 18.31±5.24
January	1.98-4.65 3.04±1.25	2.16-5.15 3.69±1.26	42.25-45.96 44.41±1.77	32.56-39.12 36.83±2.94	9.98-14.1 12.02±1.76
February	4.91-10.65 7.54±2.40	41.13-65.65 50.8±8.32	15.03-36.37 26.52±7.45	6.39-16.21 11.09±3.65	1.47-6.94 4.01±2.03
March	5.12-14.17 8.67±3.29	50.62-56.76 53.21±2.14	20.71-28.12 24.96±3.30	5.45-17.14 9.82±4.72	1.86-3.96 2.95±0.77
April	5.38-36.89 13.37±10.37	19.55-59.48 46.47±9.57	7.52-38.96 22.43±7.28	3.49-19.03 13.6±4.39	3.01-7.96 5.11±1.46
May	1-5.45 3.06±1.69	4.26-17.54 11.82±6.76	17.52-39.24 28.97±8.15	33.09-51.63 39.14±7.53	12.29-25.92 16.97±6.09
June	1.71-6.98 3.20±1.78	4.91-10.32 7.24±1.79	18.86-24.43 21.93±1.96	51.84-58.08 54.13±2.43	8.06-16.76 13.44±3.03
July	4.76-9.83 7.47±1.98	20.56-66.49 44.32±17.85	15.15-39.13 29.58±8.34	9.65-29.24 15.37±7.30	1.02-8.88 3.23±2.94

August	10.68-11.32 11±0.45	57.23-60.19 58.71±2.09	19.39-21.94 20.66±1.80	5.24-7.25 6.24±1.42	1.94-4.81 3.37±2.02
September	11.92-21.29 16.60±6.62	50.05-70.07 60.06±14.15	9.03-16.84 12.93±5.52	6.03-8.98 7.50±2.08	0-5.34 2.67±3.77
October	7.8-19.91 14.94±5.83	18.42-73.21 43.51±22.57	11.67-42.71 27.89±14.05	3.49-22.8 11.29±8.61	1.23-3.5 2.35±1.29
Pool data	**2.64-16.61 7.89±5.09**	**3.69-60.06 33.02±22.86**	**12.94-55.24 30.84±13.41**	**6.25-54.13 20.26±15.02**	**2.35-18.32 8.05±6.03**

Table 5: Fluctuations in the proportion of various gut fullness

Month	Empty	Poor intensity	Medium intensity	Good intensity	High intensity
Nov	3.13%	11.03%	54.52%	19.80%	12.01%
Dec	2.64%	5.42%	55.24%	18.38%	18.32%
Jan	3.05%	3.69%	44.42%	36.83%	12.02%
Feb	7.55%	50.80%	26.53%	11.10%	4.01%
Mar	8.68%	53.21%	24.96%	9.82%	2.96%
April	13.38%	46.47%	22.44%	13.60%	5.11%
May	3.07%	11.83%	28.97%	39.14%	16.97%
June	3.21%	7.24%	21.94%	54.13%	13.44%
July	7.47%	44.32%	29.58%	15.37%	3.23%
Aug	11.00%	58.71%	20.67%	6.25%	3.38%
Sept	16.61%	60.06%	12.94%	7.51%	2.88%
Oct	14.95%	43.51%	27.90%	11.30%	2.35%
Pool data	7.89%	33.02%	30.84%	20.27%	8.06%

DISCUSSION

In current study, The GaSI of fish exhibited variations across different months. Low GaSI values indicated limited feeding activity and poor gut content, while increased GaSI values suggested higher food intake. (Mushahida-Al-Noor et al., 2013) observed a low GaSI value for other hill stream fish sp. GaSI gradually rises post-spawning, indicating increased feeding activity and during the pre-spawning season, maximal feeding activity is marked by high GaSI values and well-fed guts, implying ample food availability (Joadder, 2006). Earlier studies have reported similar findings of low GaSI values during the breeding season across various hill stream fish species (Begum et al., 2008 and Sarkar and Deepak, 2009). In the study, positive correlation was between the fish weight and the guts weight, as demonstrated by an established mathematical relationship. The coefficient of correlation (r) was calculated to be 0.8059, signifying a positive association between the two variables. Previous studies conducted by (Mondal and Kaviraj, 2010; Kanwal and Pathani 2012) have reported similar observations like us regarding the Gastric Somatic Index (GaSI) values in cold water fish species.

Variations in Relative Gut Length (RGL) values have been observed in *Schizothorax richardsonii*, ranging from 2.53 to 5.54. It was found that the ACL is larger than the total length these values indicate that the fish's feeding habits was herbivorous. Based on RGL values, Das and Moitra (2013) previously classified fish species as carnivorous (0.5-2), omnivorous (1.3-4.3), and herbivorous (2.5-6.0). A positive correlation was observed between the total length (TL) and alimentary canal length (ACL) in the established mathematical relationship**.** The coefficient of correlation, r, was determined to be 0.682, indicating the presence of a positive relationship between the variables. Similar findings were also reported by (Joadder, 2006) and (Saikia et al, 2015).

The FI values of 7.89%, 33.02%, 30.84%, 20.26%, and 8.05% for empty, poor, medium, good, and high gut, respectively, indicate continuous feeding with no observed cessation. The high percentage of fishes with food-filled guts suggests consistent food availability throughout the season. (Kanwal and Pathani, 2012) reported a similar observation of feeding intensity in *Garra lamta*. In their respective studies, (Gupta and Banerjee, 2013) observed significantly reduced feeding intensity in mature *Channa punctatus* species during May to June, while (Saikia et al., 2012) documented heightened feeding intensity in *Labeo rohita* during the periods of February to April and July to October. Additionally, (Kumar et al., 2007) and (Rajagopal, 2005) conducted investigations on bluegill and inland catfish, respectively, also assessing the monthly variations in feeding activity rates.

CONCLUSION

In conclusion, our research study was carried out in the snow-fed Kali River, Pithoragarh, Uttarakhand, which focused on assessing the feeding indices of *Schizothorax richardsonii* fish. Our research reveals seasonal variations in feeding behavior and demonstrates an annual cycle in fish activity**.** Seasonal variations in gut content were confirmed by GaSI, with minimum GaSI during breeding suggests energy allocation to gonadal development, while maximum GaSI post-breeding indicates ample food availability and intensive feeding. Value of RLG is between 2.53 to 5.54 throughout the year, this value strongly suggests that this species exhibited an herbivorous mode of feeding and thus ruling out occasional omnivorous or carnivorous tendencies. The level of gut fullness in the fish was categorized into five distinct levels, spanning from empty to high intensity. Monthly variations in the percentage of gut fullness were observed in all fish specimens.

Conflict of Interest

The author affirms that they have no financial, personal, or any other conflicts of interest concerning individuals or organizations associated with the content discussed in this article.

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