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Research Article

Seasonal variations in proximate composition and metallic elements of three cyprinids from a Central Himalayan river Alaknanda in Garhwal Himalaya, India

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Abstract
Fish is an irreplaceable, highly nutritious aquatic food in a balanced diet. On the contrary, fish can also be a source of metal contamination when ingested in excess through food and water. The aim of the present study was to determine the seasonal variations in the proximate body composition and levels of Na, K, Ca, Fe, Zn, Cu, and Pb in the muscle tissue of three fish species namely, *Schizothorax plagiostomus*, *Schizothorax progastus* and *Barilius bendelisis* dwelling in Central Himalayan river Alaknanda at Srinagar (Garhwal) in Garhwal Himalaya. The protein (21.01-21.74%) and carbohydrates (2.31-2.69%) were found maximum in summer season in all the studied fishes while lipid was found to be highest during monsoon season in *S. plagiostomus* (2.73%) and *S. progastus* (2.70%) and lowest (1.62-1.68%) in the winter season. *B. bendelisis* showed a different pattern of variation in lipid content being highest (6.32%) during summer and lowest (3.34%) in monsoon season. Significantly ($F=5.69$, $p<0.04$) high content of lipid was found in *B. bendelisis* as compared to *S. plagiostomus* and *S. progastus* during the three seasons. Na, Ca, K, and Fe were detected highest during monsoon, Pb, and Cu during summer and Zn during the winter season. However, Pb was not detected in all the fish samples during monsoon season. *B. bendelisis* was significantly ($p<0.001$) rich in Na and Ca, *S. plagiostomus* in K ($p<0.01$), and *S. progastus* in Fe ($p<0.001$) content during all three seasons. Ca was rich among macroelements while Fe among microelements in all the studied fishes. The amount of Zn (1.48-4.55 mg/100g), Cu (0.429-0.869 mg/100g), and Pb (0.117-0.447 mg/100g) were within the permissible limits of International food safety guidelines. The seasonal variations in the parameters are attributed to food availability, temperature changes, fish metabolism, and prevailing environmental conditions. Thus, these cyprinid species were regarded as safe and useful for human consumption.

Keywords: Alaknanda, Fish, Heavy metals, Lipid, Macroelements, Protein

INTRODUCTION

Fishes act as essential foodstuff due to their high protein content and affordability. Overall production of fishes in the world is about 167.2 million tons, of which about 146.3 million tons is the part of human food and rest is discarded as waste material (FAO, 2016). The fishery sector not only provides nutrition and food security but also improves employment and poverty in developing countries (Moreau and Garaway, 2018). There is a continuous increase in the demand of quality fish and fishery products as they have bountiful valuable, healthy substances like protein, lipid, vitamins, mineral elements, etc. The biochemical composition is used in the study of food or feed. The biochemical constituents form 95-98% of the total weight of the tissue (Pal *et al.*, 2018). Therefore, monitoring of changes in the biochemical parameters of fish species is required.

Fishes are also a good source of mineral elements which include calcium, sodium, potassium, zinc, phosphorus, iron *etc.* These elements have high bioavailability, *i.e.* they are readily absorbed by the body (Balachandan, 2002). Many essential elements have their role in metabolic processes and are essential to all living organisms (Durmus *et al*., 2017). The deficiency in these essential elements induces malfunctioning and causes diseases. Iron is required for the synthesis of haemoglobin so as to transport oxygen throughout the body. Calcium is important for the normal functioning of the muscular and nervous system and also for strong bones. Fish generally occupies the high position in aquatic food chains and are more susceptible to poisoning from chemicals in their diet as well as water. They are also well consumed by the human population. Also, contamination of the river ecosystem by metals has been receiving attention worldwide. Heavy metal accumulation in biota poses a risk to the wildlife and human health (Ali *et al*., 2017). Therefore, it is utmost important to determine the level of metals in their body tissue.

The river Ganga is one of the major Himalayan rivers having two main parent headstreams, Alaknanda and Bhagirathi which have their origin in the mountainous region of North Indian state Uttarakhand. Alaknanda, being the longer of the two, rises about 50 km north of Himalayan Nanda Devi peak at the confluence of Satopanth and Bhagirath Kharak glaciers near Vasudhara falls (3650m. a.s.l.). After covering a course of 191km, it merges with Bhagirathi river at Devprayag to form the river Ganga (Panwar *et al*., 2017). Alaknanda harbours a variety of flora and fauna. A majority of fish species belonging to family Cyprinidae flourish in this river ecosystem. The flow in the Alaknanda River is highly regulated and sometimes highly variable due to seasonal flash floods (SANDRP, 2014). A majority of people inhabit along the bank of this river and depend upon the fishes for their nutritional requirements and livelihood. Therefore, the knowledge of seasonal variation in proximate composition and concentrations of essential metallic elements like Na, Ca, K, Fe, Zn, Cu and Pb in the body tissue of the fishes dwelling in the river becomes important. The present study also verifies the interspecific differences in the levels of these elements.

MATERIALS AND METHODS

Collection, identification and measurements: The study was conducted on the fishes dwelling in Central Himalayan river Alaknanda, a parent stream of river Ganga at Srinagar in Garhwal Himalaya. A total of 180 fish samples, 60 of each cyprinid species (*Schizothorax plagiostomus*, *Schizothorax progastus* and *Barilius bendelisis*) were procured directly from local fish market at monthly interval for one year (2017 -18). As the fishes were procured from the local fish market and no harm was caused to live animals, there was no issue to take the approval of the Animal Ethic Committee.

Collected samples were transported to the laboratory in fresh condition for identification and body measurements. The fish species were identified using keys of Day (1878), Jhingran (1982), Talwar and Jhingran (1991) and Jayaram (2002). After necessary measurements, fish gut and skin were removed and samples were then packed in airtight plastic bags and stored in deep freezer at -21^{0}C until further analysis.

Proximate and mineral analysis: 1gm muscle tissue of each selected fish species was homogenized separately in 10 ml phosphate buffer followed by centrifugation at 10,000rpm for 20 minutes. The supernatant/ sample solutions collected were subjected to total soluble protein and total carbohydrate determination. Protein was estimated following Lowry *et al.* (1951). Total carbohydrates were estimated following the procedure of Dubois *et al.* (1956) Total lipid was determined according to Folch *et al.* (1954), using olive oil as a standard. Total moisture was evaluated by oven drying 1gm of fish muscle tissue at 105^0 C for 24 hours. The difference in initial and final weight represents the amount of moisture (AOAC, 2000). The results were expressed in percentage of wet weight of tissue. Minerals, Na, K, Ca, Fe, Zn, Cu and Pb were determined by acid digestion of tissue samples (0.5-0.6 g) in 1:3 HCl and HNO_3 in a closed digestion system at 150^0 C. Samples were allowed to undergo complete digestion for about 1-2 h until a clear solution was obtained (AOAC, 2000). Samples were then cooled and filtered. The final volume of filtrate was made up to 100 ml by using millepore water. Samples were allowed to run on ICP-OES (Thermo Scientific, iCAP 6000 Series) and the concentration of mineral elements was determined (AOAC, 2000).

Statistical analysis: The data so obtained were analyzed statistically with the help of Data Analysis Tool Pack available on MS-Excel. t-test was performed to determine the significance of the difference between means of two samples, and ANOVA was performed to find out the significance of difference among the means of the seasons.

RESULTS AND DISCUSSION

The proximate composition, macroelements and level of metals in the muscle tissue of *S. plagiostomus*, *S. progastus* and *B. bendelisis* are presented in Table 1 to 3. The proximate composition of the body tissue of these fishes varied significantly among the seasons. Moisture content in the three fish species ranged from 67.40 to 83.16% (Table 1). Highest moisture content was recorded in *S. plagiostomus* (79.72%) and *S. progastus* (79.26%) during monsoon season while lowest was observed during summer (77.81%) and winter season (77.62%). However, a different pattern of moisture content highest (76.92%) during winter and lowest (73.08%) during summer season was reported in *B. bendelisis*. Average moisture content was significantly ($p<0.05$) higher in *S. plagiostomus* and *S. progastus* than *B. bendelisis* during summer and monsoon. Percent protein values ranged from 10.14 to 27.86 in studied fishes (Table 1). Maximum protein content was

Table 1: Seasonal variations in proximate composition of three cyprinid species.

Proximate composition	Min-Max	Summer	Monsoon	Winter
Moisture (%)				
S. plagiostomus	77.16-81.62	77.81±0.42^{b}	79.72±1.91^{b}	78.70±1.30^{b}
S. progastus	75.54-83.16	78.33±1.02^{b}	79.26±2.66^{b}	77.62±2.70^{ab}
B. bendelisis	67.40-80.60	73.08±6.16^{a}	74.02±3.13^{a}	76.92±0.75^{a}
Protein (%)				
S. plagiostomus	11.14-25.92	21.74±2.82^{a}	19.41±3.52^{ab}	13.99±3.43^{b}
S. progastus	10.14-23.50	21.01±1.70^{a}	17.80±3.69^{a}	13.08±3.51^{a}
B. bendelisis	10.15-27.86	21.02±2.92^{a}	20.65±5.17^{b}	12.19±1.96^{a}
Lipid (%)				
S. plagiostomus	1.32-3.39	2.18±0.69^{a}	2.73±0.45^{a}	1.62±0.25^{a}
S. progastus	1.41-3.17	2.24±0.71^{a}	2.70±0.37^{a}	1.68±0.19^{a}
B. bendelisis	3.00-7.63	6.32±0.88^{b}	3.34±0.47^{b}	4.06±0.87^{b}
Carbohydrate (%)				
S. plagiostomus	1.14-2.71	2.37±0.48^{a}	2.02±0.5^{a}	1.41±0.20^{a}
S. progastus	1.21-2.84	2.31±0.35^{a}	2.26±0.52^{b}	1.38±0.12^{a}
B. bendelisis	1.12-3.01	2.69±0.45^{b}	2.14±0.68^{ab}	1.58±0.34^{b}

Min-Max- Minimum-Maximum. Values are represented as Mean±SD of 5 replicates. Values with different superscript in a row varied significantly (p<0.05).

recorded to be 21.74%, 21.01%, 21.02% during summer season and minimum to be 13.99%, 13.08%, 12.19% during winter season in *S. plagiostomus, S. progastus* and *B. bendelisis*, respectively. No significant difference (F=0.157, p=0.856) was observed in muscle protein content of studied fishes. Amount of carbohydrate was found maximum during summer (2.37, 2.31 and 2.69%) followed by monsoon (2.02, 2.26 and 2.14%) and winter season (1.41, 1.38 and 1.58%) in *S. plagiostomus*, *S. progastus* and *B. bendelisis* (Table 1). No significant difference (F=0.388, p=0.682) was observed in the amount of carbohydrate in studied fishes. The highest increment of protein and carbohydrate during summer and lowest during winter season was due to the variations in temperature conditions and availability of food items. During the summer season, the high temperature remains suitable for the growth of fish food like algae, zooplankton, worms and insects and their larvae which causes accumulation of more protein and carbohydrates in their muscle tissue. However, during winter conditions, low temperature results in less growth hence less protein accumulation. Lipid content ranged from 1.32 to 7.63% in studied fish species (Table 1). In *S. plagiostomus* and *S. progastus*, highest lipid accumulation (2.73% and 2.70%) was found during monsoon and lowest (1.62% and 1.68%) during the winter season while in *B. bendelisis*, highest value (6.32%) was recorded during summer and lowest (3.34%) during the monsoon season which is attributed to the variations in their reproduction period and food availability. Lipid content was significantly (p<0.001) higher in *B. bendelisis* than other studied fishes during all the three seasons. Carbohydrate content ranged from 1.12 to 3.01% and it was maximum during summer and minimum during winter in all the studied fish species in the present study. No significant difference (F=0.388, p=0.682) was observed in the amount of carbohydrate among the studied three species.

The maximum values for the studied macroelements were found during monsoon and minimum during winter season. Na ranged from 60.00-139.18 mg/100g in studied fishes (Table 2). Highest amount of Na was found to be 112.33, 125.46 and 131.55 mg/100g in *S. plagiostomus*, *S. progastus* and *B. bendelisis,* respectively while it was lowest 74.00, 66.67, and 84.67 mg/100g during winter season in all the above three species. A similar range of Na was also recorded by Joshi *et al.* (2017) for five Himalayan species of *Schizothorax* (*S. niger, S. curvifrons, S. esocinus, S. progastus* and *S. plagiostomus*) from three locations of western Himalaya. Na is an essential component and needed for muscle and nerve conduction processes, production of adrenaline hormone, electrolyte and acid-base balancing (Pirestani *et al*., 2009). Potassium (K), necessary in the regulation of blood pressure, cardiac diseases, kidney function, heart diseases, nerve and muscle conduction, carbohydrate metabolism, and acid-base equilibrium (WHO, 2012) was also found maximum during monsoon and minimum during the winter season in all the three studied fishes. The higher range of K concentration was recorded in the present study than the previous report of Shantosh and Sarojnalini (2018) on cobitid fishes of Manipur. Calcium (Ca) performs the function of blood clotting and bone and skeleton formation. Failure in the maintenance of extracellular calcium can increase the risk of hypertension, obesity, hyperparathyroidism, premenstrual syndrome and polycystic ovary syndrome (Mayanglambam and Chungkham, 2018). The

Table 2: Seasonal variations of macroelements in the muscle tissue of three cyprinid species.

Fishes	Min-Max	Summer	Monsoon	Winter
Na (mg/100g)				
S. plagiostomus	66.00-115.00	87.79±1.55[a]	112.33±3.79[a]	74.00±7.21[b]
S. progastus	60.00-128.89	98.00±2.65[b]	125.46±4.30[ab]	66.67±5.77[a]
B. bendelisis	83.00-139.18	118.67±2.31[c]	131.55±6.74[b]	84.67±1.53[b]
K (mg/100g)				
S. plagiostomus	245.00-340.00	309.76±1.01[c]	330.00±10.00[b]	251.00±5.29[b]
S. progastus	235.00-310.05	250.00±5.00[b]	294.59±6.57[b]	239.67±5.03[b]
B. bendelisis	208.00-281.11	216.33±5.51[a]	276.84±4.04[a]	212.67±4.51[a]
Ca (mg/100g)				
S. plagiostomus	310.00-430.00	363.82±9.94[b]	417.00±11.27[b]	349.00±9.17[b]
S. progastus	256.00-356.42	314.00±5.29[a]	355.41±1.14[a]	268.67±12.06[a]
B. bendelisis	443.00-559.32	480.33±19.50[c]	550.98±10.36[c]	451.33±8.02[c]

Min-Max- Minimum-Maximum. Values are Mean±SD of three replicates. Values with different superscript in a row varied significantly ($p<0.05$).

higher amount of Ca (417.00, 355.41 and 550.98 mg/100g) during monsoon and lower (349.00, 268.67 and 451.33 mg/100g) during winter season were observed in *S. plagiostomus*, *S. progastus* and *B. bendelisis*, respectively. The high abundance of Ca in muscle tissue during monsoon season was also reported by Ahmed and Bat (2015) in *Argyrops spinifer.* Similar findings regarding the seasonal abundance of macroelements were also recorded by Balogun and Talabi (1986) for *Katsuwonus pelamis*, Abdullahi and Abolude (2001) for *Chrysichthys nigrodigitatus*, *Bayrus filamentous* and *Auchenoglanis occidentals*, Abdullahi (2005) for *Malapterus electricus* and Chakraborty *et al*. (2014) for *Trichurus lepturus*. The present investigation indicated the presence of highest level of Ca among other studied macroelements during all the three seasons which is in agreement with the study of Jessica *et al*. (2015) for 55 Bangladeshi fish species, Shantosh and Sarojnalini (2018) for *Lepidocephalichthys guntea, Pangio pangia* and *Syncrossus berdmorei*, Mayanglambam and Chungkham (2018) for *Devario acquipinnatus*, *Glossogobius giuris*, *Hypsibarbus myitkyinae*, *Puntius chola* and *Tariqilabeo burmanicus* and Sharma and Singh (2019) for *Schizothorax richardsonii*. The abundant level of macroelements may be attributed to the fact that the body requires them in more amounts for structure and function of the body which was also noticed by Hei and Sarojnalini (2012). Also, there is no exact recommended value for macroelements in muscle tissue of fishes. Swann (2000) also reported that it is unclear that high levels of macroelements in fish tissues are harmful to fish, wildlife species and human consuming such fishes. In the present study, the amount of Na and Ca was significantly ($p<0.001$) higher in *B. bendelisis* while K was significantly ($p<0.01$) higher in *S. plagiostomus* during the three seasons.

Freshwater fishes occupy the top position of the aquatic food chain. High level of metals in fish muscle tissue originates from aquatic resources (Mansour and Sidky, 2002). The accumulation of metals inside the fish body provides evidence against fish exposure to the contaminated aquatic environment. The untreated sewage waste discharged into the river can induce acute toxic effects in fishes (Bhanot and Hundal, 2019).

The muscle tissue of studied fishes showed variation in metal accumulation of Fe, Zn, Cu and Pb in different seasons. Fe was recorded maximum to be 13.26, 22.49 and 14.47mg/100gm during monsoon and minimum to be 9.67, 16.00 and 8.67mg/100g during winter season in *S. plagiostomus*, *S. progastus* and *B. bendelisis*, respectively (Table 3). The range of Fe concentration was recorded higher than those previously reported for sea bass (2.47 mg/100g) by Erkan and Ozden (2007), Nile perch fillet (1.06 mg/100g) by Kabahenda *et al.*(2011) and *Alestes baremoze* (1.1-3.58 mg/100g) by Kasozi *et al.*, 2014). The present findings indicated a pretty good amount of Fe in muscle tissue of studied cyprinids which could suggest the inclusion of selected fish species in high Fe diet. Also, Fe accumulation was observed highest among the studied metals. The results were in agreement with the study of Njinkoue *et al*. (2016) for *Pseudotolithus typus* and *Pseudotolithus elongatus*, Jithesh and Radhakrishnan (2017) for *Diplodus annularis*, Khitouni *et al.* (2018) for *Trichiurus lepturus* and Danabasa *et al.* (2018) for *Barbus sp*. and *Cyprinus carpio.* The present findings of more Fe followed by Zn were also confirmed by the study of Cross *et al*. (1973), Hei and Sarojnalini (2012), Kumar *et al*. (2013), Durmus *et al*. (2017) and Sarma *et al*. (2018).

Zn and Cu are the essential elements which are regu-

Table 3: Seasonal variations of different metals present in the muscle tissue of three cyprinid species.

Fishes	Min-Max	Summer	Monsoon	Winter
Fe (mg/100g)				
S. plagiostomus	8.00-14.35	10.33±0.58^{a}	13.26±1.09^{a}	9.67±1.53^{a}
S. progastus	15.00-25.01	18.88±0.07^{b}	22.49±2.35^{b}	16.00±1.00^{b}
B. bendelisis	8.00-15.96	9.67±1.53^{a}	14.47±1.58^{a}	8.67±1.15^{a}
Zn (mg/100g)				
S. plagiostomus	1.50-4.55	1.667±0.21^{a}	1.549±0.01^{a}	4.21±0.50^{a}
S. progastus	1.70-4.11	2.833±0.32^{a}	2.40±0.61^{a}	3.997±0.14^{a}
B. bendelisis	1.48-4.03	2.933±0.90^{a}	1.807±0.57^{a}	3.927±0.10^{a}
Cu (mg/100g)				
S. plagiostomus	0.429-0.683	0.681±0.003^{b}	0.545±0.004^{a}	0.462±0.01^{a}
S. progastus	0.429-0.869	0.867±0.003^{c}	0.593±0.001^{ab}	0.447±0.02^{a}
B. bendelisis	0.589-0.665	0.662±0.003^{a}	0.635±0.01^{b}	0.593±0.01^{a}
Pb (mg/100g)				
S. plagiostomus	0.117-0.249	0.248±0.001^{a}	ND	0.118±0.001^{a}
S. progastus	0.311-0.441	0.435±0.01^{b}	ND	0.311±0.001^{c}
B. bendelisis	0.224-0.447	0.443±0.01^{b}	ND	0.226±0.002^{b}

Min-Max- Minimum-Maximum. Values are Mean±SD of three replicates. Values with different superscript in a row varied significantly ($p<0.05$)

lated by various metabolic processes (Beltcheva *et al*., 2011). Zinc deficiency leads to the loss of appetite, retardation of growth, skin changes, and abnormalities in immunological functions (Tuzen, 2009). Copper is an essential part of several enzymes and is essential for haemoglobin synthesis, fish growth and reproduction (Sivaperumal *et al.*, 2007) while excessive Cu causes kidney and liver damage (Tuzen, 2009; Ikem and Egiebor, 2005). In the present investigation, Zn contents were observed highest (4.210, 3.997 and 3.927 mg/100g) during winter and lowest (1.549, 2.40 and 1.807 mg/100g) during monsoon season in *S. plagiostomus*, *S. progastus* and *B. bendelisis* (Table 3). The overall amount of Zn was found to be higher in *S. progastus* than *S. plagiostomus* which was also reported by Joshi *et al.* (2017). Cu ranged from 0.429 to 0.869 mg/100g in studied three species of fishes. Cu concentration was found highest during summer (0.681, 0.867 and 0.662 mg/100g) followed by monsoon (0.545, 0.593 and 0.635 mg/100g) and winter season (0.462, 0.447 and 0.593 mg/100g) in the muscle tissue of *S. plagiostomus*, *S. progastus* and *B. bendelisis*. The concentration of Zn and Cu was observed to be significantly higher in the present study than the study of Rahman *et al*. (2018) and Romharsha and Sarojnalini (2018). Pb is non-essential and toxic metal which can be introduced into the ecosystem by natural (erosion of earth's crust and dust transport) and anthropogenic (industrial emissions, use of gasoline and phosphate fertilizers) means (Beltcheva *et al*., 2011). Pb content was recorded maximum (0.248, 0.435 and 0.443 mg/100g) in summer and minimum (0.118, 0.311 and 0.226 mg/100g) in winter season in *S. plagiostomus*, *S. progastus* and *B. bendelisis.* However, Pb content was not detected in fish samples collected during the monsoon season (Table 3). The average amount of Fe significantly (F=-26.91, p=7.41E-07) varied among the three cyprinids being highest in *S. progastus* however, no significant variation was found in the average amount of Zn, Pb and Cu among the three species in the present study. The overall trend of trace metals accumulation in all the three fish species has been depicted in Table 4. The concentration of lead detected in the present study was comparatively lower than studied other metals. The present range of Pb concentration is in agreement with the study conducted on *Crossocheilus latius latius* (0.112-0.349 mg/100g) and *Garra lamta* (0.111-0.358 mg/100g) by Sharma and Singh (2020). Low levels of Pb were also detected in *Oreochromis niloticus*, *Oncorhynchus mykiss*, *Cyprinus carpio* and *Pelteobagrus fluvidraco* (Taweel *et al.*, 2013; Reyahi-Khoram *et al*., 2016; Rajeshkumar and Li, 2018).

Zn, Cu and Pb metals were detected higher in the fish muscle during summer than monsoon, which may be attributed to a higher rate of respiration in fishes during the summer season. Generally, higher temperature conditions affect the level of dissolved oxygen by lowering its concentration in the aquatic environment, which increases the metabolic rate of fishes. Thus, the fish uses more water for higher feeding on plants and grasses, which leads to the uptake of high amount of

Table 4: Season-wise trend of metal accumulation in cyprinids of Alaknanda river.

Trace metal	Abundance order
Fe	Monsoon> Summer>Winter
Zn	Winter>Summer>Monsoon
Cu	Summer>Monsoon>Winter
Pb	Summer>Winter>Monsoon

metals through diffusion or active uptake. However, low content of metals is due to less activity of fish during other seasons (Zayed *et al*., 1994).

The findings of the present study regarding concentration of metals in the tissue of *S. plagiostomus*, *S. progastus* and *B. bendelisis* were also compared with the previous reports (Table 5). Comparison of our results with other studies demonstrates that our results of Fe concentration are higher than Sinha *et al*. (2002) while similar to Sarkar *et al.* (2017) and Joshi *et al.* (2017). Zn concentration in the present study was higher than Ali *et al.* (2017) but similar to Sinha *et al*. (2002), Sarkar *et al.* (2017), and Joshi *et al.* (2017). The concentration of Cu in the present study was higher than Sinha *et al*. (2002) and Ali and Khan (2018). However, Pb concentration was lower than the study of Ali and Khan (2018). It indicated that the concentration of metallic elements varied in water at different places. The studied metals, Zn, Cu and Pb are toxic metals, which can cause serious hazards. Therefore, maximum level of heavy metals has been set for human consumption by various authorities of food standards (FAO, 1983; FAO and WHO, 1972; WHO, 1995; FEPA, 2003). The level of Zn, Cu and Pb were below the acceptable limits (100, 30, 2 mg/kg for Zn, Cu and Pb) as set by WHO (1995) for fish. A comparison with FAO (1983) for fish also showed that Zn, Cu and Pb were lower than the guidelines for edible fish. Comparison with FEPA (2003) also showed that Zn and Pb were under the acceptable limits (Zn 75 and Pb 2.0 mg/kg) for human consumption. This study suggests that the studied fishes were able to accumulate metals with different intensity so these may be used to monitor the heavy metal pollution of parent stream of river Ganga and its impact on daily fish consumers.

The level of metal bioconcentration in freshwater fishes may vary which may be attributed to different metal concentration in water and sediments, feeding habits, metabolism, their ecological needs and also the season in which analysis was carried out (Ibrahim and Omar, 2013). Bat (2014) analyzed the level of heavy metals in fish collected from the Black Sea coast and suggested that they are the biomonitors for metal concentration in aquatic ecosystems as they occupy different trophic positions. Thus, fishes can be considered as a valid indicator for the pollution of the aquatic environment (Shakweer, 1998). The accumulation level of

Table 5: Comparative account of trace metal concentration in the fish muscle tissue in various studies.

Species	Region	Fe	Cu	Zn	Pb	Reference
Barilius bendelisis	Parent stream of Ganga river	8.00-15.96	0.589-0.665	1.48-4.03	0.224-0.447	[a]Present study
	Hel river, North East India	8.98	1.89	1.06	-	[a]Sarkar *et al.* (2017)
	Kharkai river, Jamshedpur, India	40	2	14	2	[b]Sinha *et al.* (2002)
Schizothorax plagiostomus	Parent stream of Ganga river, India	8.00-14.35	0.429-0.683	1.50-4.55	0.117-0.249	[a]Present study
	Kabul river, Pakistan	-	-	-	20.3	[b]Ali and Khan (2018)
	Swat river, Pakistan	-	1.07-2.05	7.53-12.80	-	
	Panjkora river, Pakistan	-	0.93-2.72	2.72-10.32	-	[b]Ali *et al*. (2017)
	Barandu river, Pakistan	-	2.02-4.05	10.17-18.00	-	
	Alaknanda river, India	11.83	1.14	2.64	-	[a]Joshi *et al.* (2017)
Schizothorax progastus	Parent stream of Ganga river, India	15.00-25.01	0.429-0.869	1.70-4.11	0.311-0.441	[a]Present study
	Alaknanda river, India	12.59	1.81	5.40	-	[a]Joshi *et al.* (2017)
Permissible level of metals in fish for human consumption		-	30	30	0.5	[b]FAO (1983)
		-	30	40	0.5	[b]FAO/WHO (1972)
		-	30	100	2	[b]WHO (1995)
		-	-	75	2.0	[b]FEPA (2003)

[a]Concentration in mg/100g, [b]Concentration in mg/kg. Blank cells indicate no information available.

heavy metals in the muscle tissue of studied fishes reflects less degree of water pollution by such metal elements. Therefore, it is concluded that the selected fish species of the Alaknanda river were free from pollution load and level of toxicity hence can be considered appropriate for consumption as a source of food.

Conclusion

It was concluded that besides the seasonal variations in nutrient profiling, all the selected fish species, namely, *S. plagiostomus*, *S. progastus* and *B. bendelisis* were found rich in protein and mineral elements. Bioconcentration of heavy metals, Zn (1.48-4.55 mg/100g), Cu (0.429-0.869 mg/100g), and Pb (0.117-0.447 mg/100g) in the muscle tissue of studied fishes collected from a Central Himalayan river Alaknanda at Srinagar (Garhwal) was found below the highest permissible limits as set by International food safety guidelines for fish consumption. Hence, these fishes were nutritious, safe and suitable for inclusion in daily diet. Conservation, management and stock augmentation of these fishes will be instrumental for ameliorating the malnutrition problem of the region.

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Conflict of interests

There is no conflict of interest regarding the publication of this article.

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