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 (Balachandran, 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 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 Saptapanth 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 markets 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°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 muscle tissue at 105°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 HNO₃ in a closed digestion system at 150°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...
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. plagioistomus, 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 season (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. plagioistomus, 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. plagioistomus 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. plagioistomus, 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. plagioistomus) 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

| Proximate composition | Min-Max | Summer | Monsoon | Winter |
|-----------------------|---------|--------|---------|--------|
| **Moisture (%)**       |         |        |         |        |
| S. plagioistomus       | 77.16-81.62 | 77.81±0.42<sup>b</sup> | 79.72±1.91<sup>b</sup> | 78.70±1.30<sup>b</sup> |
| S. progastus           | 75.54-83.16 | 78.33±1.02<sup>b</sup> | 79.26±2.66<sup>b</sup> | 77.62±2.70<sup>b</sup> |
| B. bendelisis          | 67.40-80.60 | 73.08±6.16<sup>a</sup> | 74.02±3.13<sup>a</sup> | 76.92±0.75<sup>a</sup> |
| **Protein (%)**        |         |        |         |        |
| S. plagioistomus       | 11.14-25.92 | 21.74±2.82<sup>a</sup> | 19.41±3.52<sup>ab</sup> | 13.99±3.43<sup>b</sup> |
| S. progastus           | 10.14-23.50 | 21.01±1.70<sup>a</sup> | 17.80±3.69<sup>a</sup> | 13.08±3.51<sup>a</sup> |
| B. bendelisis          | 10.15-27.86 | 21.02±2.92<sup>a</sup> | 20.65±5.17<sup>b</sup> | 12.19±1.96<sup>a</sup> |
| **Lipid (%)**          |         |        |         |        |
| S. plagioistomus       | 1.32-3.39 | 2.18±0.69<sup>a</sup> | 2.73±0.45<sup>a</sup> | 1.62±0.25<sup>a</sup> |
| S. progastus           | 1.41-3.17 | 2.24±0.71<sup>a</sup> | 2.70±0.37<sup>a</sup> | 1.68±0.19<sup>a</sup> |
| B. bendelisis          | 3.00-7.63 | 6.32±0.86<sup>a</sup> | 3.34±0.47<sup>a</sup> | 4.06±0.87<sup>a</sup> |
| **Carbohydrate (%)**   |         |        |         |        |
| S. plagioistomus       | 1.14-2.71 | 2.37±0.48<sup>a</sup> | 2.02±0.5<sup>a</sup> | 1.41±0.20<sup>a</sup> |
| S. progastus           | 1.21-2.84 | 2.31±0.35<sup>a</sup> | 2.26±0.52<sup>a</sup> | 1.38±0.12<sup>a</sup> |
| B. bendelisis          | 1.12-3.01 | 2.69±0.45<sup>a</sup> | 2.14±0.68<sup>ab</sup> | 1.58±0.34<sup>a</sup> |

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

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 Sharma 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 acquispinnatus, Glossogobius giuris, Hypsibarbus myitkiyinae, 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 Trichurus 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 regul-
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 Oreoichromis 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 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±0.58a    | 13.26±1.09a    | 9.67±1.53a   |
| S. progastus  | 15.00-25.01 | 18.88±0.07b    | 22.49±2.35b    | 16.00±1.00b  |
| B. bendelisis | 8.00-15.96 | 9.67±1.53a     | 14.47±1.58a    | 8.67±1.15a   |
| Zn (mg/100g) |           |                |                |              |
| S. plagiostomus | 1.50-4.55  | 1.667±0.21a    | 1.549±0.01a    | 4.21±0.50a   |
| S. progastus  | 1.70-4.11  | 2.833±0.32a    | 2.40±0.61a     | 3.997±0.14a  |
| B. bendelisis | 1.48-4.03  | 2.933±0.90a    | 1.807±0.57a    | 3.927±0.10a  |
| Cu (mg/100g) |           |                |                |              |
| S. plagiostomus | 0.429-0.683 | 0.681±0.003b    | 0.545±0.004a   | 0.462±0.01a  |
| S. progastus  | 0.429-0.869 | 0.867±0.003c   | 0.593±0.001ab  | 0.447±0.02a  |
| B. bendelisis | 0.589-0.665 | 0.662±0.003a   | 0.635±0.01b    | 0.593±0.01a  |
| Pb (mg/100g) |           |                |                |              |
| S. plagiostomus | 0.117-0.249 | 0.248±0.001a   | ND             | 0.118±0.001a |
| S. progastus  | 0.311-0.441 | 0.435±0.01b    | ND             | 0.311±0.001c |
| B. bendelisis | 0.224-0.447 | 0.443±0.01b    | ND             | 0.226±0.002b |
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 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) with other studies demonstrates 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.

### 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 | ^aPresent study            |
|                     | Hel river, North East India   | 8.98    | 1.89    | 1.06    | -       | ^aSarkar et al. (2017)     |
|                     | Kharkai river, Jamshedpur, India | 40     | 2       | 14      | 2       | ^bSinha et al. (2002)      |
| *Schizothorax progastus* | Parent stream of Ganga river | 8.00-14.35 | 0.429-0.683 | 1.50-4.55 | 0.117-0.249 | ^aPresent study            |
|                     | Kabul river, Pakistan         | -       | -       | -       | 20.3    | ^aAli and Khan (2018)      |
|                     | Swat river, Pakistan          | -       | 1.07-2.05 | 7.53-12.80 | -       | ^bAli et al. (2017)        |
|                     | Panjkora river, Pakistan      | -       | 0.93-2.72 | 2.72-10.32 | -       | ^bAli et al. (2017)        |
|                     | Barandu river, Pakistan       | -       | 2.02-4.05 | 10.17-18.00 | -       | ^bAli et al. (2017)        |
|                     | Alaknanda river, India        | 11.83   | 1.14    | 2.64    | -       | ^aJoshi et al. (2017)      |
| *Schizothorax progastus* | Parent stream of Ganga river | 15.00-25.01 | 0.429-0.869 | 1.70-4.11 | 0.311-0.441 | ^aPresent study            |
|                     | Alaknanda river, India        | 12.59   | 1.81    | 5.40    | -       | ^aJoshi et al. (2017)      |

| Reference                  | |
|-----------------|-----------------|
| ^aPresent study | ^bSarkar et al. (2017) | ^bSinha et al. (2002) |
| ^aAli and Khan (2018) | ^bAli et al. (2017) | ^bAli et al. (2017) |
| ^aJoshi et al. (2017) | ^bFAO (1983) | ^bFAO/WHO (1972) |
| ^bWHO (1995) | ^bFEPA (2003) |

| Species | Region                        | Fe      | Cu      | Zn      | Pb      |
|---------|-------------------------------|---------|---------|---------|---------|
| Permissible level of metals in fish for human consumption | -       | 30      | 30      | 0.5     |
|         | -       | 30      | 40      | 0.5     |
|         | -       | 30      | 100     | 2       |
|         | -       | -       | 75      | 2.0     |

*Concentration in mg/100g, ^bConcentration 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. bendelis* 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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