**Journal of Fisheries**
Volume 8 Issue 3 December 2020 Pages 878–884
Peer Reviewed | Open Access | Online First

eISSN 2311-3111
pISSN 2311-729X

**Original Article**

# Are haematological and biochemical properties of freshwater spotted snakehead *Channa punctata* (Bloch, 1793) season and sex dependent?

**Minakshi Singh**[1] • **Ankur Kashyap**[1,2] • **Mohammad Serajuddin**[1]

[1] *Fish Biology Research Lab, Department of Zoology, University of Lucknow, Lucknow (U.P.), India*
[2] *Junior High School, Govindpur, Mohanlalganj, Lucknow (U.P.), India*

**Correspondence**
Dr. Mohammad Serajuddin; Fish Biology Research Lab, Department of Zoology, University of Lucknow, Lucknow (U.P.), India
lu.fisheries@gmail.com

**Manuscript history**
Received 8 February 2020 | Revised 11 September 2020 | Accepted 19 October 2020 | Published online 23 November 2020

**Citation**
Singh M, Kashyap A, Serajuddin M (2020) Are haematological and biochemical properties of freshwater spotted snakehead *Channa punctata* (Bloch, 1793) season and sex dependent? Journal of Fisheries 8(3): 878–884.

**Abstract**

Freshwater murrel, *Channa punctata* commonly known as "spotted snakehead" is a popular fish because of its taste and price. Haematological and biochemical profile of fish helps in understanding the fish health and play an important role in fisheries management. The present work was carried out to determine season (summer, monsoon and winter) and sex dependent variations in the blood profile of *C. punctata*. Haematological [red blood cell counts (RBC), packed cell volume (PCV) and haemoglobin (Hb)] and serum biochemical parameters [blood glucose, total protein, cholesterol, triglyceride (Tg), low density lipoprotein (LDL), very low density lipoprotein (VLDL), high density lipoprotein (HDL), serum calcium levels] of *C. punctata* were analysed which varied significantly with seasons ($p < 0.05$). The level of glucose, total protein, Tg, VLDL, RBC, Hb and PCV was low during monsoon season because of the growth and development of gonads compared to the summer and winter season. The level of cholesterol and LDL was high during monsoon. However, haematological and biochemical parameters were not sex dependent. The seasonal haematological and biochemical variations in the fish were mainly due to the physiological acclimatisation of the fish to variations in the environmental condition and feeding regime.

**Keywords:** *Channa punctata*; fish health; fish physiology; murrel; physiology; seasonal variation

## 1 | INTRODUCTION

Blood contains cells, proteins, sugars and fat particles from 1.3 to 7 percent of the total body weight of the fish (Acharya and Mohanty 2014). The studies of haematology and blood biochemistry of the fish are used to detect the physiological and pathological conditions in order to know the stress and health conditions which are considered important for fisheries management (Alyakrinskyaya and Dolgova 1984). The haematological and biochemical profile of the blood of the fish can be affected by several factors including age, health condition, size, sex, reproduction, season, photoperiod, water temperature, food, stress, pollutions and diseases. The response of the fish to the different environmental conditions is dependent on the haematological and biochemical parameters of the fish. The knowledge of the blood parameters, therefore, helps in understanding the relationship of the blood characteristics of the fish to their habitats and environment.

  

In hatchery condition, haematocrit, red blood cells (RBC) and haemoglobin (Hb) concentrations are frequently used haematological parameters for the assessment of the condition of the fish (Bhaskar and Rao 1990). Ebeh *et al.* (2017) studied the effect of season and reproductive cycle on blood parameters of *Protopterus annectens*. Variations in the blood parameters of different fish populations were also revealed in different studies (e.g. Percin and Konyalioglu 2008; Zorriehzahra *et al.* 2010; Fazio *et al.* 2016).

The snakehead murrel, *Channa punctata* (Bloch, 1793) is an important freshwater fish, commonly known as "spotted snakehead". It is a lean fish because of low lipid contents throughout the year (Ghosh 2006). This fish has great economic importance due to popularity as food and commercial value (Galib and Samad, 2009; Galib *et al.* 2010; Kashyap 2015). *Channa punctata* is distributed throughout the south Asian countries like Afghanistan, Pakistan, India, Sri Lanka, Nepal, Bangladesh, Myanmar and Yunnan in China (Froese and Pauly 2019). The fish is commonly found in rivers and ponds (e.g. Chaki *et al.* 2014; Galib *et al.* 2016, 2018) but has also been reported from brackish water (Pethiyagoda 1991) and beels (wetlands) and ditches (Rahman 1989; Imteazzaman and Galib 2013). The survey of literature indicated the paucity of information on the blood parameters of *C. punctata*. Only few researchers carried out the work on the different aspects of the physiology and biochemistry of the *C. punctata*. Srivastav and Srivastav (1998) studied changes in serum calcium and phosphate levels during vitelogenesis and testicular maturation in *C. punctata*. Malathi *et al.* (2012) compared blood parameters between the two channa species, *C. punctata* and *C. striata*. The effect of heavy metals in effluents on biomolecules of different tissues of *C. punctata* were also reported (Javed and Usmani 2015; Kalsoom and Nasreen 2019). Several studies (e.g. Javed *et al.* 2016; Parveen *et al.* 2017; Talukdar *et al.* 2017) showed the effects of effluents and acid mine drainage discharged from tannery, thermal power plant and coal mines respectively on haematological parameters of *C. punctata*. Abdel-Hameid *et al.* (2017) worked to find the requirement of copper to maximize the growth of fingerlings of *C. punctata*. Therefore, keeping in mind the paucity of the information on the blood characteristics the present study was under taken to find out the seasonal and sex wise variability in blood parameters of *C. punctata*.

## 2 | METHODOLOGY

### 2.1 Sampling

The specimens of *C. punctata* were collected using cast and drag nets with the help of a professional fisherman from the river Gomti at Lucknow (26°52' N 80°55' E) during monsoon, winter and summer seasons. A total of 30 specimens of the fish were used for the biochemical analysis after identification of the sex by observing their gonads. Ten specimens in each season (5 males and 5 females) were analysed. Total length (cm) and weight (g) of each specimen of the fish were measured using fish measuring board and weighing machine respectively. Blood was taken out from the heart of the fish with the help of syringe and immediately transferred into three different types of the vials: EDTA vial for haematological parameters, serum vial for calcium and biochemical parameters and fluoride vial for glucose. Blood samples of serum and fluoride vials were kept for half an hour at room temperature and centrifuged at 3000 rpm for 10 minutes to separate the serum and plasma for the analysis of biochemical parameters. All blood parameters were analysed at the Clinical Laboratory of the Department of Biochemistry, King George's Medical University, Lucknow.

### 2.2 Estimation of haematological parameters

The haematological parameters such as RBC, Hb concentration, packed cell volume (PCV) were analysed using Haematology 5 Parts Auto-analyser. The values of mean corpuscular volume (MCV), mean corpuscular haemoglobin (MCH) and mean corpuscular haemoglobin concentration (MCHC) were calculated using formulas as given by Dacie and Lewis (1984).

### 2.3 Estimation of biochemical parameters

The biochemical parameters such as glucose, total protein, triglyceride (Tg), cholesterol and high density lipoprotein (HDL) were estimated using their kits under Semi Biochemistry Auto analyser (Accurex AT112, Japan). Low density lipoprotein (LDL) and very low density lipoprotein (VLDL) were calculated following Friedewald *et al.* (1972). Serum calcium was estimated with the help of the kit (Randox Laboratories Ltd. Crumlin, UK) based on colorimetric method using Electrolyte Auto Analyser (Caretium machine).

### 2.4 Data analysis

Means of different biochemical parameters were compared seasonally and sex wise using univariate analysis of variance (ANOVA) at 5% significant level ($p < 0.05$). All the calculations were carried out using SPSS (version 12.0).

## 3 | RESULTS

Total length (mean ± SD) of fish was recorded as 19.7 ± 1.56, 20.51 ± 1.68 and 19.45 ± 1.51 cm in the specimens of summer, monsoon and winter season respectively. The mean total weight (mean ± SD) of fish in summer, monsoon and winter season was 78.12 ± 18.80, 93.1 ± 23.05 and 78.61 ± 17.64 g respectively.

Biochemical parameters of blood plasma (glucose, total protein, cholesterol, Tg, LDL, VLDL, serum calcium) and

haematological parameters (RBC, Hb, PCV) were significantly different ($p < 0.05$) between the seasons but these parameters were not significantly different ($p > 0.05$) between sexes (Table 1). The levels of biochemical parameters such as glucose, total protein, cholesterol, Tg, LDL, VLDL and haematological parameters (RBC, Hb, PCV) recorded during monsoon were significantly different ($p < 0.05$) from winter and summer while no significant difference ($p > 0.05$) in any of these parameters was recorded during winter and summer (Figures 1 and 2). The level of glucose, total protein, Tg, VLDL, RBC, Hb, PCV were the lowest during monsoon compared to winter and summer while level of cholesterol and LDL were higher during monsoon. The serum Ca level of the fish varied significantly among seasons ($p < 0.05$) and maximum value was recorded during winter whereas minimum was recorded in monsoon (Figure 2).

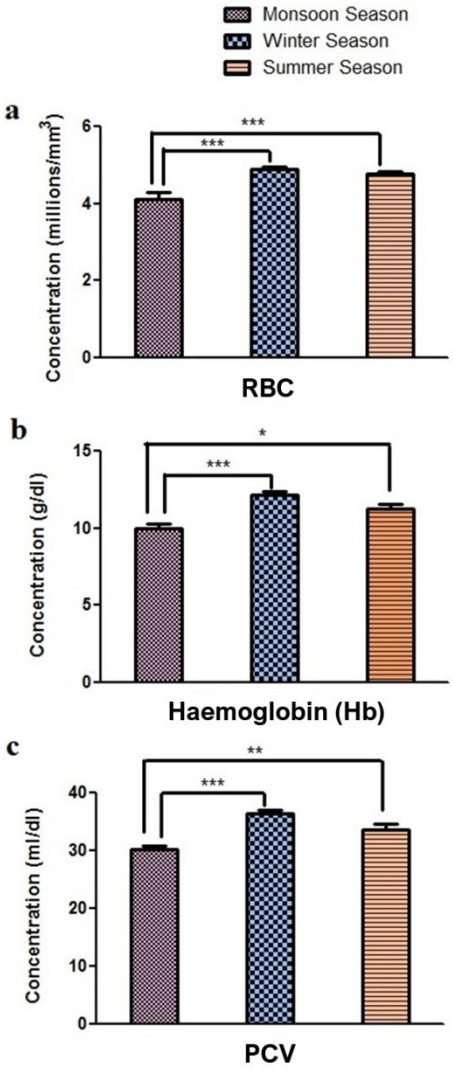


**FIGURE 1** Mean ± SEM of haematological parameters in different seasons: (a) RBC (b) Hb (c) PCV where *$p < 0.05$, **$p < 0.01$, ***$p < 0.001$.

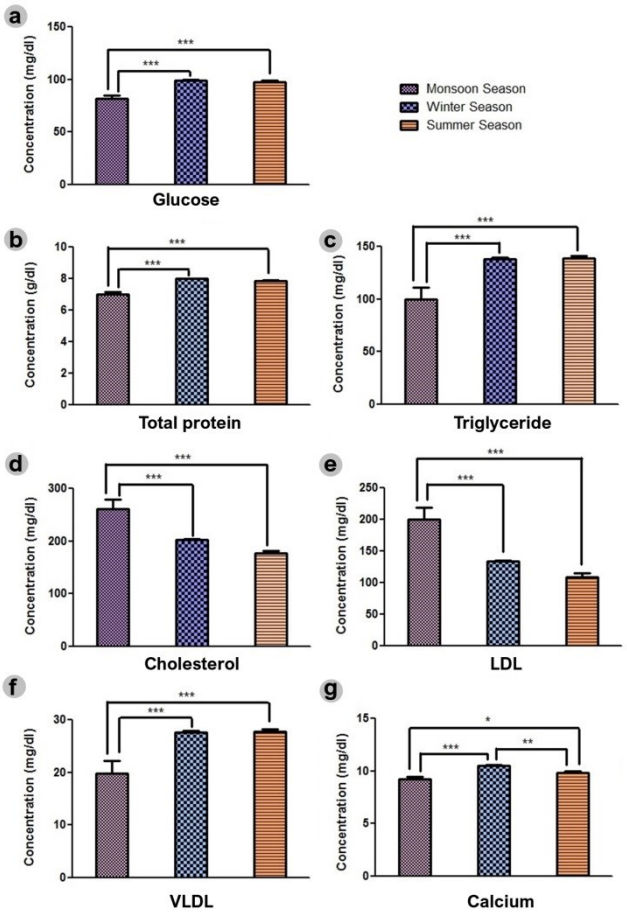


**FIGURE 2** Mean ± SEM of biochemical parameters in different seasons: (a) Glucose (b) Total Protein (c) Triglyceride (d) Cholesterol (e) LDL (f) VLDL (g) Ca where *$p < 0.05$, **$p < 0.01$, ***$p < 0.001$.

## 4 | DISCUSSION

The significant seasonal variability of the haematological parameters (RBC, Hb and PCV) recorded in the present study may be due to the fluctuations in dissolved oxygen concentration of the water and metabolic rate of the fish. Low level of RBC, Hb and PCV recorded during the monsoon season which may be because of availability of high level of dissolved oxygen in water as rivers are rejuvenated with water due to rainfall and less number of RBC is required in the blood to carry out the oxygen (Valverde and García 2005). However, there was no significant difference in the amount of RBC, Hb and PCV during winter and summer seasons. Fallah *et al.* (2014) also reported the seasonal fluctuations in the levels of RBC, Hb and PCV and emphasised that the values of RBC, Hb and PCV may increase during winter because of the depletion of oxygen in the water in order to cater the demand of the fish. No seasonal variation in MCV, MCH and MCHC was recorded in *C. punctata*. Similarly, a number of studies (e.g. Fallah *et al.* 2014; Latif *et al.* 2015) also reported no seasonal variation in MCV, MCH and MCHC while Pradhan *et al.* (2014) reported similar result for MCV in *Labeo rohita*.

**TABLE 1** Variation in blood parameters across seasons.

| Parameters | SS | *df* | MS | *F* | *p*-value |
|---|---|---|---|---|---|
| **Glucose** | | | | | |
| Between groups | 2046.8 | 2 | 1023.4 | 29.22 | **<0.001** |
| Within groups | 945.8 | 27 | 35.0 | | |
| Total | 2992.7 | 29 | | | |
| **Total protein** | | | | | |
| Between groups | 6.6 | 2 | 3.3 | 41.63 | **<0.001** |
| Within groups | 2.1 | 27 | 0.1 | | |
| Total | 8.7 | 29 | | | |
| **Cholesterol** | | | | | |
| Between groups | 31053.1 | 2 | 15526.5 | 19.23 | **<0.001** |
| Within groups | 21804.3 | 27 | 807.6 | | |
| Total | 52857.4 | 29 | | | |
| **Tg** | | | | | |
| Between groups | 9182.9 | 2 | 4591.5 | 11.150 | **<0.001** |
| Within groups | 11118.1 | 27 | 411.8 | | |
| Total | 20301 | 29 | | | |
| **HDL** | | | | | |
| Between groups | 1.854 | 2 | 0.9 | 0.087 | 0.917 |
| Within groups | 287.449 | 27 | 10.6 | | |
| Total | 289.303 | 29 | | | |
| **LDL** | | | | | |
| Between groups | 56643.1 | 2 | 28321.6 | 19.54 | **<0.001** |
| Within groups | 39127.9 | 27 | 1449.2 | | |
| Total | 95771.1 | 29 | | | |
| **VLDL** | | | | | |
| Between groups | 4688.3 | 2 | 2344.2 | 5.28 | **0.012** |
| Within groups | 11986.5 | 27 | 443.9 | | |
| Total | 16674.9 | 29 | | | |
| **Serum Ca** | | | | | |
| Between groups | 9.4 | 2 | 4.7 | 23.65 | **<0.001** |
| Within groups | 5.4 | 27 | 0.2 | | |
| Total | 14.8 | 29 | | | |
| **RBC** | | | | | |
| Between groups | 2.9 | 2 | 1.5 | 16.20 | **<0.001** |
| Within groups | 2.5 | 27 | 0.1 | | |
| Total | 5.4 | 29 | | | |
| **Hb** | | | | | |
| Between groups | 22.1 | 2 | 11.0 | 14.58 | **<0.001** |
| Within groups | 20.5 | 27 | 0.8 | | |
| Total | 42.6 | 29 | | | |
| **PCV** | | | | | |
| Between groups | 174.5 | 2 | 87.2 | 14.81 | **<0.001** |
| Within groups | 159.0 | 27 | 5.9 | | |
| Total | 333.5 | 29 | | | |
| **MCV** | | | | | |
| Between groups | 76.7 | 2 | 38.3 | 1.20 | 0.318 |
| Within groups | 866.6 | 27 | 32.1 | | |
| Total | 943.3 | 29 | | | |
| **MCH** | | | | | |
| Between groups | 9.6 | 2 | 4.8 | 1.43 | 0.256 |
| Within groups | 90.7 | 27 | 3.4 | | |
| Total | 100.4 | 29 | | | |
| **MCHC** | | | | | |
| Between groups | 88.5 | 2 | 44.3 | 2.13 | 0.139 |
| Within groups | 561.4 | 27 | 20.8 | | |
| Total | 649.9 | 29 | | | |

Bold values indicate outcomes significant at $p \leq 0.05$.

The lowest level of glucose was observed during monsoon season which may be because of the demand of more energy for the growth and development of gonads of the fish as the monsoon is the breeding season of *C. punctata* and the gonadal activity of the fish is considered to be at its peak at this stage (Kashyap *et al.* 2016). A number of researchers such as Gutiérrez *et al.* (1988), Kocaman *et al.* (2005), Bani and Vayghan (2011) and Nasari *et al.* (2014) also reported the decreased level of glucose during breeding season because of the development of gonads in the various fish species. Bani and Vayghan (2011) emphasised that the gonadal development cause the decrease in glucose level to fulfil the high energy demand in fishes. Gutiérrez *et al.* (1988) reported that insulin level increases during pre-spawning period which resulted into the low level of glucose necessary for promoting uptake of vitellogenin in oocyts. There was no significant difference in glucose level during winter and summer seasons in the present study. Release of glucose from glycogen stored in liver may increase the serum glucose level to minimise stressful temperature conditions or low availability of food in these seasons. Lermen *et al.* (2004) reported decreased hepatic glycogen level at low and high temperature in their studies.

The lowest level of total protein was also recorded during monsoon in the present study because of the utilisation of protein in the development and building up of the gametes in the fish. Hutchinson and Manning (1996) and Svobodova *et al.* (1997) reported low level of total protein during reproduction. There was no significant difference in the level of total protein between winter and summer seasons because the fish maintain a constant serum protein level for the homeostatic condition at low and high temperature. Serum protein level was found to be high at stress condition like starvation.

The level of Tg was lowest during monsoon in the present study may be because of its use in gonadal development. The low level of Tg was also noticed at late gonadal maturation stage in other studies (e.g. Kocaman *et al.* 2005; Nasari *et al.* 2014). Cholesterol is essential for the production of gonadal and adrenal steroid hormones and the level of cholesterol was found to be high during monsoon season in the present study. Babin and Vernier (1989) pointed out that nutritional, physiological and developmental states highly influence the plasma cholesterol level in fish.

LDL level was also high during monsoon in the present study. Consumption of lipids rich diet might have caused its increased level. VLDL is a lipoprotein and was lowest during monsoon in the present study which carries mainly large quantity of triglyceride. Thus the decrease in the level of serum Tg may decrease the VLDL level in serum. Tg, cholesterol, LDL and VLDL levels were the same during winter and summer seasons. No significant difference was found in cholesterol level in low and high temperature in the study carried out by Rossi *et al.* (2017) which indicates that the fish maintain its homeostasis in these seasons.

Serum Ca level was high during winter while low in monsoon in the present study. Calcium plays important role in gonad maturation mainly in vitellogenin formation in female. Vitellogenin is a serum protein takes part in yolk formation. Deposition of vitellogenin bound Ca in yolk may lead the low level of serum Ca. High level of Ca was reported by Srivastav and Srivastav (1998) during winter also in fish.

In present study, no significant difference was found in levels of all studied blood parameters between male and female individuals in any season. Several studies (Percin and Konyalioglu 2008; Pradhan *et al.* 2014; Ebeh *et al.* 2017) also reported similar result. Same metabolic activity of male and female may be the reason of equal level of blood contents in the body.

## 5 | CONCLUSION

The haematological and serum biochemical parameters significantly vary with seasons in *C. punctata*. The level of glucose, total protein, Tg, VLDL, RBC, Hb and PCV decreases during monsoon season because of the growth and development of gonads. This study of haematology and blood biochemistry of the fish could be used to detect the physiological and pathological condition of the fish with a view to determining their stress and health conditions which is considered important for fisheries management.

## ACKNOWLEDGEMENTS

The authors are thankful to the Head, Department of Zoology, University of Lucknow, India for providing research facilities.

## CONFLICT OF INTEREST

The authors declare no conflict of interest.

## DATA AVAILABILITY STATEMENT

All the datasets generated and analysed in this study are included in the manuscript and presented as tables and figures.

## REFERENCES

Abdel-Hameid NAH, Zehra S, Khan MA (2017) Dietary copper requirement of fingerling *Channa punctatus* (Bloch) based on growth, feed conversion, blood parameters and whole body copper concentration. Aquaculture Research 48(6): 2787–2797.

Acharya G, Mohanty PK (2014) Haematological and serum biochemical parameters in different sexes of walking cat fish, *Clarias batrachus* (Linnaeus, 1758). International Journal of Science and Research 3(8): 1914–1917.

Alyakrinskyaya IO, Dolgova SN (1984) Hematological features of young sturgeons. Vopr Ikhtiol 4: 135–139.

Babin PJ, Vernier JM (1989) Plasma lipoproteins in fish. Journal of Lipid Research 30(4): 467–489.

Bani A, Vayghan AH (2011) Temporal variations in haematological and biochemical indices of the Caspian kutum, *Rutilus frisii kutum*. Ichthyological Research 58(2): 126–133.

Bhaskar BR, Rao KS (1990) Use of haematological parameters as diagnostic tools in determining the health of milkfish, *Chanos chanos* (Forskal), in brackishwater culture. Aquaculture Research 21(1): 125–129.

Chaki N, Jahan S, Fahad MFH, Galib SM, Mohsin ABM (2014) Environment and fish fauna of the Atrai River: global and local conservation perspective. Journal of Fisheries 2(3): 163-172.

Dacie JV, Lewis SM (1984) Practical hematology. Churchill Livingstone, Edinburgh.

Ebeh HN, Ogbonna SA, Didigwu Nwani C (2017) Plasma biochemistry, haematological and biometric reference values of *Protopterus annectens* of Anambra River, Nigeria. Zoology and Ecology 27(1): 74–81.

Fallah FJ, Khara H, Roohi JD, Boorani MS (2014) Hematological parameters of pike *Esox lucius* in relation to different ages and seasons. Comparative Clinical Pathology 23(4): 949–953.

Fazio F, Saoca C, Piccione G, Kesbiç OS, Acar Ü (2016) Comparative study of some hematological and biochemical parameters of Italian and Turkish farmed rainbow trout *Oncorhynchus mykiss* (Walbaum, 1792). Turkish Journal of Fisheries and Aquatic Sciences 16(3): 715–721.

Friedewald WT, Levy RI, Fredrickson DS (1972) Estimation of the concentration of low-density lipoprotein cholesterol in plasma, without use of the preparative ultracentri-

fuge. Clinical chemistry 18(6): 499–502.

Froese R, Pauly D (2019) FishBase. World Wide Web electronic publication. www.fishbase.org, version (12/2019).

Galib SM, Mohsin ABM, Parvez MT, Lucas MC, Chaki N, ... Islam MN (2018) Municipal wastewater can result in a dramatic decline in freshwater fishes: a lesson from a developing country. Knowledge and Management of Aquatic Ecosystems 419, 37.

Galib SM, Rashid MA, Chaki N, Mohsin ABM, Joadder MAR (2016) Seasonal variation and community structure of fishes in the Mahananda River with special reference to conservation issues. Journal of Fisheries 4(1): 325-334.

Galib SM, Samad MA (2009) Harvesting, traditional preservation and marketing of fishes of Chalan Beel, Bangladesh. Aquaculture Asia XIV(1): 12-15

Galib SM, Samad MA, Hossain MA, Mohsin ABM, Haque SMM (2010) Small Indigenous Species of Fishes (SISF) in Chalan Beel with reference to their harvesting and marketing. Bangladesh Journal of Progressive Science and Technology 8(2): 251–254.

Ghosh S (2006) Composition and distribution of lipids and fatty acids in two jeol fishes of West Bengal. PhD thesis, University of Calcutta, Calcutta, India.

Gutiérrez J, Fernandez J, Planas J (1988) Seasonal variations of insulin and some metabolites in dogfish plasma, *Scyliorhinus canicula*, L. General and Comparative Endocrinology 70(1): 1–8.

Hutchinson TH, Manning MJ (1996) Seasonal trends in serum lysozyme activity and total protein concentration in dab (*Limanda limanda* L.) sampled from Lyme Bay, UK. Fish & Shellfish Immunology 6(7): 473–482.

Imteazzaman AM, Galib SM (2013) Fish fauna of Halti Beel, Bangladesh. International Journal of Current Research 5(1): 187–190.

Javed M, Ahmad I, Ahmad A, Usmani N, Ahmad M (2016) Studies on the alterations in haematological indices, micronuclei induction and pathological marker enzyme activities in *Channa punctatus* (spotted snakehead) Perciformes, Channidae exposed to thermal power plant effluent. SpringerPlus 5(1): 761.

Javed M, Usmani N (2015) Stress response of biomolecules (carbohydrate, protein and lipid profiles) in fish *Channa punctatus* inhabiting river polluted by thermal power plant effluent. Saudi Journal of Biological Sciences 22(2): 237–242.

Kalsoom S, Nasreen Z (2019) Risk assessment of persistent organic pollutants in fishes from Pakistan and its neighbouring countries. Journal of Fisheries 7(3): 726–740.

Kashyap A (2015) Intraspecific diversity and reproductive biology in freshwater murrel, *Channa punctatus* (Bloch). PhD Dissertation, Department of Zoology, Lucknow University, Lucknow, India.

Kashyap A, Awasthi M, Serajuddin M (2016) Reproductive biology of the freshwater murrel *Channa punctatus* (Bloch, 1793) from River Gomti of Lucknow region, Uttar Pradesh, India. Indian Journal of Fisheries 63(3): 126–130.

Kocaman EM, Yanik T, Erdogan O, Ciltas AK (2005) Alteration in Cholesterol, glucose and triglyceride levels in reproduction of rainbow trout *Oncorhynchus mykiss*. Journal of Animal and Veterinary Advances 4(9): 801–804.

Latif M, Ali M, Iqbal F (2015) Seasonal variations in hematological and serum biochemical profile of *Channa marulius* are complementary to the changes in water quality parameters of river Chenab in Pakistan. Pakistan Journal of Zoology 47(6): 1699–1707.

Lermen CL, Lappe R, Crestani M, Vieira VP, Gioda CR, Schetinger MR, Baldisserotto B, Moraes G, Morsch VM (2004) Effect of different temperature regimes on metabolic and blood parameters of silver catfish *Rhamdia quelen*. Aquaculture 239(1–4):497–507.

Malathi K, Kannathasan A, Rajendran K (2012) Comparative haematological studies on fresh water fishes *Channa punctatus* and *Channa striatus* (BLOCH). International journal of Pharmaceutical, Chemical and Biological Sciences 2(4): 644–648.

Nasari FH, Kochanian P, Salati AP, Pashazanoosi H (2014) Variation of some biochemical parameters in female yellowfin seabream, *Acanthopagrus latus* (Houttuyn) during reproductive cycle. Folia Zoologica 63(4): 238–245.

Parveen S, Singh D, Bharose R, Rout S, Khan MA, Ansari EF (2017) Tannery effluent effect on the haematological parameters of freshwater fish, *Channa punctatus*. Journal of Applied and Natural Science 9(1): 201–205.

Percin F, Konyalioglu S (2008) Serum biochemical profiles of captive and wild northern bluefin tuna (*Thunnus thynnus* L. 1758) in the Eastern Mediterranean. Aquaculture Research 39(9): 945–953.

Pethiyagoda R (1991) Freshwater fishes of Sri Lanka. The Wildlife Heritage Trust of Sri Lanka, Colombo.

Pradhan SC, Patra AK, Pal A (2014) Hematological and plasma chemistry of Indian major carp, *Labeo rohita* (Hamilton, 1822). Journal of Applied Ichthyology 30(1): 48–54.

Rahman AKA (1989) Freshwater fishes of Bangladesh. Zoological Society of Bangladesh. Department of Zoology, University of Dhaka.

Rossi A, Bacchetta C, Cazenave J (2017) Effect of thermal stress on metabolic and oxidative stress biomarkers of *Hoplosternum littorale* (Teleostei, Callichthyidae). Ecological Indicators 79: 361–370.

Srivastav SK, Srivastav AK (1998) Annual changes in serum calcium and inorganic phosphate levels and correlation with gonadal status of a freshwater murrel, *Channa punctatus* (Bloch). Brazilian Journal of Medical and Bio-

logical Research 31(8): 1069–1073.

Svobodova Z, Kolarova J, Kouril J, Hamackova J, Vykusová B, Kaláb P (1997) Haematological investigations in Silurus glanis L. females during pre-and post-spawning period. Polish Archives of Hydrobiology 44(1–2): 67–81.

Talukdar B, Kalita HK, Baishya RA, Basumatary S, Dutta A, Srivastava SK, Sarma D (2017) Effects of acid mine drainage of coal mines on some haematological parameters of *Channa punctatus* (Bloch). National Academy Science Letters 40(2): 91–94.

Valverde JC, García BG (2005) Suitable dissolved oxygen levels for common octopus (*Octopus vulgaris* Cuvier, 1797) at different weights and temperatures: analysis of respiratory behaviour. Aquaculture 244(1–4): 303–314.

Zorriehzahra MJ, Hassan MD, Gholizadeh M, Saidi AA (2010) Study of some hematological and biochemical parameters of Rainbow trout (*Oncorhynchus mykiss*) fry in western part of Mazandaran province, Iran. Iranian Journal of Fisheries Sciences 9(1): 185–198.

## CONTRIBUTION OF THE AUTHORS

**M Singh** designed the study, reviewed the literature, carried out the sample collection and data, laboratory work and prepared the first draft of manuscript; **AK** carried out the statistical analysis of collected data and helped in preparation of first draft of manuscript; **M Serajuddin** proposed and supervised the study, selected the species and revised the draft manuscript. All authors read and approved the final manuscript.

***M Singh*** https://orcid.org/0000-0002-5700-3187
***A Kashyap*** https://orcid.org/0000-0001-9678-8880
***M Serajuddin*** https://orcid.org/0000-0002-9850-5343