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Research Paper

Comparative morphometric studies on the gills of *Cyprinus carpio* var. *specularis* (Mirror carp) and *Oncorhynchus mykiss* (Rainbow trout) in Kashmir

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ABSTRACT

The aim of the present study was to describe the gill morphology of *Cyprinus carpio* var. *specularis* and *Oncorhynchus mykiss*. The study focused on the morphological features of gills, where differences in gill arches, gill rakers and gill filaments were explained. The results of the present study marked that there was interbranchial median elevation in *O. mykiss*. The gill rakers and gill filaments varied in numbers and length in both the species. Numberwise gill filaments and gill rakers were more in the *C. carpio* var. *specularis*. However, lengthwise the gill filaments and gill rakers were longer in *O. mykiss*.

Key words: *Cyprinus carpio* var. *specularis*, gill arches, gill filaments, gill rakers, *Oncorhynchus mykiss*,

Kashmir valley is called as paradise on earth, is highly bestowed with extensive scenic beauty and enormous natural resources. The ichthyofauna of the valley has been classified into three major groups including species having central Asian origin, exotic species and those that have been introduced lately into the water bodies (Das and Subla, 1963). The aquaculture in Jammu and Kashmir mainly constitutes of coldwater fishes including trouts and carps. Carp culture in this region is based on three exotic carp fish species *viz*: Silver carp, grass carp and common carp (Gohar *et. al*, 2016). The carp has been one of the oldest domesticated species of fish for food (Balon, 2006). They are hardy, fast growing fish species that are often referred as "natural specialist" or "ecological engineer" due to their adaptability to a wide range of ecological conditions (Yaqoob, 2021). Exotic varieties of carps were first introduced in India from Ceylon in 1939 and later again from Bangkok in 1957. In Kashmir, they were introduced in 1959 to augment the fish yield (Sehgal, 1989). Today it constitutes more than 50 per cent fish catch in lacustrine waters of Kashmir (Balkhi, 2007). *Oncorhynchus mykiss* commonly known as Rainbow trout is grown in coldwaters. Trouts are exotic species introduced into the coldwaters of Jammu and Kashmir, Himachal Pradesh and peninsular India (Thomas, 2013). Due to favourable climatic, environmental conditions in Kashmir, trout has well adapted here (Hassan and Pandey, 2012). Two commercially important species from the water sources of Kashmir have been selected for the present investigation. They include: *Cyprinus carpio* var. *specularis* (Mirror Carp) and *O. mykiss* (Rainbow Trout)

Mirror carp is a thermophillic, gregarious fish, dewelling mostly at the bottom of ponds, is an omnivorous (Santhanam *et al*., 1999). The body of mirror carp is broad and slightly compressed with scales present on some parts in an irregular pattern or scattered individually. The head is triangular, the snout is obtusely rounded, mouth is small, two pairs of barbels are present, maxillary barbels twice as long as the rostral pair (Talwar and Jhingran, 1992). Rainbow trout can be identified by their pinkish or reddish lateral strip, sometimes with lavender or orange overtones, from the gill cover running the lateral line of fish to the tail. Numerous spots are present on the back and extent about two-thirds of the way to the lateral line down the sides. The sides are silvery and largely free of spots, belly and ventral surface of the head are whitish. Rainbow trout fry begin feeding in stream, consuming aquatic and terrestrial invertebrates (zooplankton and insects). Insects remain their dominant food source throughout life, although they are opportunistic piscivores throughout their life (FAO, 2022).

All jawed fishes possess similar basic structure of the gills, but may show variation in design and configuration. Gills are formed by the filamentous outgrowths from the anterior and the posterior wall of each gill slit in the pharynx. The basic components of gills include the gill arches, gill filaments, gill rakers and the lamellae. Most of the fishes have four pairs of gills positioned bilaterally on each side of oral cavity (Wegner, 2011). The gills have a role in variety of key functions in fish, including breathing, ionic regulation, osmosis regulation, acid base balance, ammonia excretion, hormone production, modulation of circulating metabolites and immune defense (Rombough, 2007) .

The adaptation of gills to any particular environment provides a fascinating study regarding the comparative functional anatomy and physiology (Hughes, 1984). The structure and morphology of gills provide significant indications about the probable mode of life in the fishes. The morphometry of gills in fishes (gill arch length, number, length of filaments etc.) has a direct influence on gill surface area which affects the overall activity of the fish. The morphology of gills is described as a good indicator of the water quality and the general health status of the farmed fish (Peters, 1984). The study of gill morphometry has proved to be useful method for comparing fishes living in different habitats and adapting distinctive lifestyles (Hughes, 1995). The gill raker number is often used as a diagnostic character for studies in identification of stock, identification of species. It is with this background we understand the activeness, feeding habits and species variation. Considering the importance of above mentioned factors, the present study was carried out with the objective to investigate the comparative morphometrical study of the gills of *C. carpio* var. *specularis* and *O. mykiss*.

Fig. 1: Gill arch of Mirror carp

Fig. 2: Gill arch of Rainbow Trout

MATERIALS AND METHODS

Collection of sample: A total of 40 samples consisting 20 samples each of *C. carpio* var. *specularis* and *O. mykiss* were used for the present study, *C.carpio* var. *specularis* were collected from Dal lake and *O. mykiss* were collected from Kokernag hatchery units. These collected samples were kept in cool boxes, covered with crushed ice and transported to laboratory of Fisheries Resource Management, Faculty of Fisheries for further examination.

Fig. 3: Measurement of thread using vernier calliper for Rainbow Trout and Mirror Carp

Preparation of sample: General morphometrics: The samples of both the species were brought to the laboratory and put under running tap water to clean excess mucus and then dried with clean piece of cloth. Digital vernier Caliper was used to measure length to the nearest 0.01 millimeter (mm) and electronic weighing balance was used to measure the weight up to the nearest 0.5 gram (g) for the following morphometric characters in the fish (Jawad, 2012):

- **Total length (mm):** It was taken from the tip of the snout to the tip of the longer lobe of caudal fin.
- **Head length (mm):** It was taken from the tip of the snout to the most posterior portion of the operculum.
- **Weight (g):** The weight was recorded using electronic weighing balance upto the nearest 0.5 gram.

Gill morphometrics: To study the gill morphometrics four branchial arches from the left opercular cavity were carefully dissected out. Following dissection, the gill arches were carefully placed in separate petridishes and washed in order to remove excessive mucus. Each individual gill arch was then preserved in seperate container, filled with 5 per cent neutral formalin and kept stored at 4 ^{o}C in refrigerator untill they were used for further measurements (Salman *et al.*, 2005). The different measurements taken were:

- **Gill Arch length (GAL):** Length (mm) of each gill arch was recorded using a flexible wire or a thread, taking gill arch curve and then extending the same on a ruler or then measuring the same with the help of Vernier caliper (Azab *et al*., 2019) (Fig. 1, 2 and 3).
- **Gill Raker Number (GRN):** Number of gill rakers on the arches were carefully examined under a magnifying glass and were counted (Mansour, 2018).
- **Gill Raker Length (GRL):** Length (mm) of gill rakers representing all regions of the gill arch (anterior, middle and posterior) were recorded using Vernier caliper (Mansour, 2018).
- **Gill Filament Number (GFN):** Number of gill filaments in anterior and posterior hemibranchs, on each individual gill arch were counted and then multiplied by 2 to get total number of gill filaments on both sides of the gill arch (Hughes, 1984).
- **Gill Filament length (GFL):** The length of gill filaments were measured from the position where the filament joined the gill arch to the tip (Hughes, 1984).

Age Determination: Fish specimens which were used for studying general morphometrics and gill morphometrics were further used to collect opercular bones. The opercular bones were taken from fish samples with the help of scissors. They were then washed properly and then boiled in water for few minutes to clear or remove the attached tissue. Then, opercular bones was treated with 50% hydrogen peroxide (H_2O_2) for about 15 minutes, and washed with water. The opercular bones were dried on clean surface for 2-3 days. They were then observed under the microscope and the age of fish was determined by counting the number of annuli or year marks**.**

Statistical analysis: The data obtained during the present study was tabulated and analysed using student t-test analysis with standard statistical software-Microsoft Excel and SPSS software.

RESULTS AND DISCUSSION

The age of the fish can be calculated by counting the annual growth marks in calcified structures like opercular bones. During the present study in both the species experimental fishes used were of 1+ year and 2+ year age group. The comparative morphological study of the body parameters showed that the Mean $\pm$ SD of length (mm), weight (g) and head length (mm) of *C. carpio* var. *specularis* was 179.12± 20.4, 85.71+32.9 and 41.96± 7.1 respectively whereas, for *O. mykiss* it was 220.48 ± 39.4, 148.26± 78.3 and 41.40 ± 7.1 respectively (Table 1). There was significant difference ($p<0.01$) with respect to length and weight between the two species and non-significant difference ($p>0.05$) with respect to head length in both the species.

Table 1: Descriptive statistics of body parameters of of *C. carpio* var. *communis* and *O. mykiss*

Parameters	Species	N	Max.	Min.	Mean $\pm$ S.D	t-test
Length (mm)	*C. carpio* var. *communis*	20	212.22	148.84	179.12 $\pm$ 20.4	4.17^{**}
	O. mykiss	20	310.56	171.68	220.48 $\pm$ 39.4	
Weight (g)	*C. carpio* var. *communis*	20	179.02	44.17	85.71 $\pm$ 32.9	3.28^{**}
	O. mykiss	20	294.5	60.33	148.26 $\pm$ 78.3	
Head length (mm)	*C. carpio* var. *communis*	20	58.62	30.1	41.96 $\pm$ 7.1	0.24^{NS}
	O. mykiss	20	57.21	32.98	41.40 $\pm$ 7.1	

Fishes generally vary in shapes and sizes of gills, number of gill rakers and gill filaments carried by gill arches, and these differences are mainly as a result of the difference in style and their feeding habits. In the present studied species the shape of the gill arch was curved i.e it showed interbranchial median elevation in *O. mykiss* (diet dominated by animal matter) whereas, the gill arch was rounded in *C. carpio* var. *specularis* (diet dominated by both plant and animal matter). Alsafy (2013) observed that *Sparus aurata and Dicentrachus labrax* fed on large size food items including molluscs, small fishes, crustaceans and insects. So, their gills were

characterized by a prominent angle of curvature at the union of short epibranchials and long ceratobranchials of the first to fourth pairs of gill arches as in carnivorous feeder Kumari *et al*.(2005) In contrast, gill arches showed a lack of curvature in omnivorous feeder Eiras and Almeida (2000).

Descriptive statistics of gill parameters of gill arch one to gill arch four of *C. carpio* var. *communis* and *O. mykiss* is given in Table 2 to Table 5. The gill arch length (GAL) (mm) was highest in the first gill arch and decreased in fourth gill arch in *C. carpio* var. *specularis and O.mykiss*. The Mean ± SD of the first gill arch length in *C. carpio* var. *specularis* was 32.19 ± 4.5 whereas, in *O. mykiss* it was 32.67 ± 4.9.

Table 2: Descriptive statistics of gill parameters of arch 1.0 of *C. carpio* var. *communis* and *O. mykiss*

Parameters	Species	N	Max.	Min.	Mean ± S.D	t-test
GAL (mm)	*C. carpio* var. *communis*	20	36.76	20.3	32.19 ± 4.5	0.32^{NS}
	O. mykiss	20	48.06	26.12	32.67 ± 4.9	
GRN	*C. carpio* var. *communis*	20	31	20	26.20 ± 3.2	12.76^{**}
	O. mykiss	20	19	11	14.95 ± 2.2	
GRL (mm)	*C. carpio* var. *communis*	20	1.88	1.02	1.59 ± 0.2	13.09^{**}
	O. mykiss	20	5.13	2.67	3.27 ± 0.5	
GFN	*C. carpio* var. *communis*	20	192	110	163.30 ± 20.1	3.46^{**}
	O. mykiss	20	158	128	146.16 ± 7.8	
GFL (mm)	*C. carpio* var. *communis*	20	7.54	4.16	5.93 ± 0.9	2.51^{*}
	O. mykiss	20	10.21	5.11	7.05 ± 1.6	

There was no significant difference ($p>0.05$) between the gill arch length of both the species except for second gill arch length. The present study indicated difference in the length of gill arch in the studied species. Similar observations were made by Mansour (2018) while studying filteration area of gill rakers in *Coptodon zilli* and *Torpedo Scad.* The gill rakers in both species showed a gradual decline in height towards the dorsal and ventral ends of the gill arches. The rakers length decreased from the first to the fourth gills. The number of gills rakers appeared variable in the different gill arches. Similar observations were made by Mohammad and Saffanah (2021) in *C. carpio* and *Silurus Triostegus.* Alsafy (2013) observed the same while studying gill morphology in *S. aurata* and *D. labrax.* In the present study the gill raker numbers (GRN) were more in *C. carpio* var. *specularis* in all four gill arches. The number of gill rakers decreased from 1st gill arch to 4th gill arch in both the species.

Table 3: Descriptive statistics of gill parameters of arch 2.0 of *C. carpio* var. *communis* and *O. mykiss*

Parameters	Species	N	Max.	Min.	Mean ± S.D	t-test
GAL (mm)	*C. carpio* var. *communis*	20	36.76	20.3	27.66 ± 4.8	2.82^{**}
	O. mykiss	20	46.31	26.02	32.05 ± 4.8	
GRN	*C. carpio* var. *communis*	20	28	19	24.00 ± 2.7	11.77^{**}
	O. mykiss	20	18	9	13.58 ± 2.7	
GRL (mm)	*C. carpio* var. *communis*	20	1.88	1.04	1.52 ± 0.2	12.47^{**}
	O. mykiss	20	4.15	2.15	2.90 ± 0.4	
GFN	*C. carpio* var. *communis*	20	189	84	152.45 ± 22.5	2.52^{*}
	O. mykiss	20	151	108	137.79 ± 11.8	
GFL (mm)	*C. carpio* var. *communis*	20	7.5	3.66	5.58 ± 1.1	2.15^{**}
	O. mykiss	20	10.07	4.56	6.55 ± 1.6	

The Mean ± SD of the number of gill rakers from 1st gill arch to 4th gill arch in *C. carpio var. specularis* were 26.20 ± 3.2, 24.00 ± 2.7, 22.20 ± 2.5 and 19.90 ± 2.6 respectively whereas, in *O. mykiss* were 14.95 ± 2.2, 13.58 ± 2.7, 11.68 ± 2.1 and 7.37 ± 2.1 respectively. The gill raker numbers from 1st gill arch to 4th gill arch in both the species showed significant difference ($p<0.01$). The gill raker length (GRL) (mm) was longer in *O. mykiss* as compared to *C. carpio var. specularis.* The gill raker length decreased from 1st gill arch to 4th gill arch in both the species The Mean ± SD of gill raker length from 1st gill arch to 4th gill arch in *O. mykiss* was 3.27 ± 0.5, 2.90 ± 0.4, 2.41 ± 0.4 and 1.34 ± 0.3 respectively whereas, in *C. carpio var. specularis* was 1.59 ± 0.2, 1.52 ± 0.2,

1.41 ± 0.2 and 1.34 ± 0.3 respectively. The gill raker length in both the species showed significant difference ($p<0.01$) from 1st to 3rd gill arch whereas, the significant difference in 4th gill arch was ($p<0.05$). The dimensions of gills and organization of gill rakers reflect the feeding habits of fish. In omnivorous fishes, gill rakers are short (Moodie 1985, Mummert and Drenner 1986). In carnivorous fishes, gill rakers are long, hard, pointed adapted for protecting the gills, preventing the escape of the prey and assisting in swallowing (Rodridges and Menin, 2006). Fishes vary in the structure, shape, number and length of the rakers. These variations are mostly related to the feeding habits (Khalaf *et al*., 2016) and same seems true for the present study as *C. carpio* var. *specularis* being an omnivore had short gill rakers while, *O. mykiss* being a carnivore had hard and longer gill rakers.

Table 4: Discriptive statistics of gill parameters of arch 3.0 of *C. carpio* var. *communis* and *O. mykiss*

Parameters	Species	N	Max.	Min.	Mean ± S.D	t-test
GAL (mm)	*C. carpio* var. *communis*	20	33.5	10.9	25.66 ± 5.3	0.62^{NS}
	O. mykiss	20	34.21	18.82	26.63 ± 4.3	
GRN	*C. carpio* var. *communis*	20	27	19	22.20 ± 2.5	13.86^{**}
	O. mykiss	20	16	8	11.68 ± 2.1	
GRL (mm)	*C. carpio* var. *communis*	20	1.76	0.99	1.41 ± 0.2	9.32^{**}
	O. mykiss	20	3.19	1.59	2.41 ± 0.4	
GFN	*C. carpio* var. *communis*	20	176	82	139.95 ± 21.3	2.09^{*}
	O. mykiss	20	146	106	128.26 ± 11.9	
GFL (mm)	*C. carpio* var. *communis*	20	6.8	3.35	5.04 ± 1.0	1.92^{NS}
	O. mykiss	20	9.45	3.86	5.90 ± 1.6	

The gill filament numbers (GFN) were more in *C. carpio* var. *specularis* as compared to *O. mykiss*. The GFN decreased from 1st gill arch to 4th gill arch in both the species The Mean ± SD of GFN from 1st gill arch to 4th gill arch in *C. carpio* var. *specularis* was 163.30 ± 20.1, 152.45 ± 22.5, 139.95 ± 21.3 and 117.15 ± 22.1 respectively whereas, in *O. mykiss* was 146.16 ± 7.8, 137.79 ± 11.8, 128.26 ± 11.9 and 104.89 ± 15.0 respectively. The gill filament numbers showed significant difference ($p<0.01$) in 1st gill arch whereas, it showed significant difference ($p<0.05$) in 2nd and 3rd gill arch but there was no significant difference ($p>0.05$) between 4th gill arch of both the species. The gill filament length (GFL) (mm) in *O. mykiss* was longer as compared to *C. carpio* var. *specularis*. The gill filament length also decreased from 1st gill arch to 4th gill arch in both the species. The Mean ± SD of gill filaments length of *O. mykiss* from 1st gill arch to 4th gill arch was 7.05 ± 1.6, 6.55 ± 1.6, 5.90 ± 1.6 and 4.39 ± 0.8 respectively whereas, in *C. carpio* var. *specularis* was 5.93 ± 0.9, 5.58 ± 1.1, 5.04 ± 1.0 and 4.55 ± 1.0 respectively. The gill raker length showed significant difference ($p<0.01$) in 1st gill arch, whereas, it showed significant difference ($p<0.05$) in 2nd gill arch but there was no significant difference ($p>0.05$) in 3rd and 4th gill arch between both the species. Most of the gill filaments at the anterior and posterior ends of gill arches of both the species were short and reduced. In *O. mykiss*, gill filaments were longer which provide more surface for respiratory exchange as they are more active in nature (Khanna and Singh, 2006).

Table 5: Descriptive statistics of gill parameters of arch 4.0 of *C. carpio* var. *communis* and *O. mykiss*

Parameters	Species	N	Max.	Min.	Mean ± S.D	t-test
GAL (mm)	*C. carpio* var. *communis*	20	30.3	10.6	21.92 ± 4.1	1.19^{NS}
	O. mykiss	20	28.84	14.12	20.38 ± 3.8	
GRN	*C. carpio* var. *communis*	20	24	14	19.90 ± 2.6	16.25^{**}
	O. mykiss	20	11	3	7.37 ± 2.1	
GRL (mm)	*C. carpio* var. *communis*	20	1.52	0.5	1.11 ± 0.2	2.57^{*}
	O. mykiss	20	2.02	1.01	1.34 ± 0.3	
GFN	*C. carpio* var. *communis*	20	154	66	117.15 ± 22.1	2.00^{NS}
	O. mykiss	20	129	72	104.89 ± 15.0	
GFL (mm)	*C. carpio* var. *communis*	20	6.1	3.02	4.55 ± 1.0	0.52^{NS}

O. mykiss	20	6.21	3.27	4.39 ± 0.8

**Correlation is significant at the 0.01 level; *Correlation is significant at the 0.05 level; NS = Non Significant

CONCLUSION

The gill arch in *C. carpio* var. *specularis* was rounded, whereas that of *O. mykiss*, it showed interbranchial median elevation. The gill raker and gill filament numbers were more in *C. carpio* var. *specularis* but the gill raker and gill filament length was longer in *O. mykiss.*

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