



## Comparative morphometric analysis of two cyprinids with reference to feeding habits

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### Abstract

Morphometric analysis helps understanding more of the fish and the correlation between different features. Though mammals exhibit morphometric changes as an adaptive strategy against environment change, and fishes are highly sensitive to these changes. Here the relation between the brain structure and the feeding habits of two fish species *Carassius auratus* and *Botia striata* of the order Cypriniformes are studied from the point of morphology with reference to its feeding habits. Thirty fishes from each species were studied. In *C. auratus*, total length, total weight and brain weight ranged between 4.9 and 10.4, 3g and 18.2 g, 0.00006 and 0.00021 g respectively and in *B. striata* the values were 3.5 and 7.7, .58g and 7.1 g, 0.00002 and 0.00008 g. In both species total length of the fish against all measured characters shows a significant (< 0.01) positive linear correlation. In *B. striata* all measurements in the brain against brain length shows high positive correlation and significant values while in *C. auratus*, all correlations were significant but length of cerebrum and length of optic lobe shows slightly less correlation value (0.895, 0.762) against brain length. The brain morphology and morphometric analysis reveals that vision and olfaction are highly developed for feeding in surface feeders *C. auratus* by the presence of vagal lobe than the bottom feeder *B. striata*. In *B. striata* the absence of vagal lobe and the presence of highly developed facial lobe with the presence of barbels is an indication of gustation enabled feeding. These studies reveal more about the feeding habits of these species.

**Keywords:** Botia, Carassius, Cyprinids, feeding habits, morphometry, optic lobe, cerebrum, cerebellum, facial lobe, vagal lobe, olfactory tract, olfactory lobe, barbels.

### Introduction

The shape and size variations in organs and organisms are measured using different statistical procedures known as morphometrics. The external body part measurements are known as morphometrics and the countable characters are the meristic characters. It is the easiest tool in specimen identification (Nayman, 1965<sup>[30]</sup>; Tripathy, 2020)<sup>[35]</sup>. Morphometric analysis aids in understanding more of an organism's development, growth variations, and their structure (Kováč *et al.*, 1999)<sup>[26]</sup>. Moreover, it helps researchers in taxonomic characterization as well as evolutionary studies. The characteristic shapes, sizes, fin numbers internal characters, all aid in recognition, identification, and classification (Strauss & Bond, 1990)<sup>[40]</sup>. It also helps in analyzing relationships between various parts of the body (Carpenter *et al.*, 1996)<sup>[11]</sup>.

Compared to other vertebrates, fish are known to exhibit most varied physical features (morphological) within populations in same species and between individual species (Brraich & Akhter, 2015<sup>[8]</sup>; Kaur *et al.*, 2019)<sup>[22]</sup>. The relation between the structure of the brain and the feeding habits of fish is of research preference from the point of physiology, morphology and distribution of fishes. It gives a clue to the structural changes taking place in the animal due to its adaptation to a particular environment (Mookerjee *et al.*, 1950)<sup>[29]</sup>.

Two fish under study are *Carassius auratus* and *Botia striata*. Commonly known as gold fish, *Carassius auratus* belongs to Cyprinidae family of order Cypriniformes. A warm water teleost, it is a surface feeder mostly feeding on algae with omnivorous nature. Colored gold, it is the most

favorite aquarium fish and its features include thick lips, depressed snout without barbels and lateral line sense organs. *Botia striata*, or Zebra Loach from Cobitidae family are also aquarium fish of order Cypriniformes and is a bottom feeder that feeds on algae and is also omnivorous. It has brown stripes on its dorsal and ventral body surface and has big snout with short barbels.

### Cyprinids and feeding habits

Fishes feed in a variety of food sources like phytoplankton, and algae as well as zooplanktons (Lagler *et al.*, 1977)<sup>[27]</sup>. Night feeders find food by smell and taste while other fishes feed by sight (Sherly, 2012)<sup>[38]</sup>. The feeding activity depends on reflex systems like olfactory, optic, tactile, gustatory and acoustic lateral organs and it reflects the structure of the brain. By a critical analysis of the brain of a live fish, the senses utilized by a particular species can be distinguished and identified (Evans, 1952)<sup>[13]</sup>.

The development of the gustatory system enhances the capability of fishes to gather their food and to recognize substances that can be ingested. In fishes, gustatory organs are distributed throughout the skin, barbels, lips, mucous membrane of the buccal cavity, inside the pharynx, on gills and in oesophagus as taste buds innervated with nerves originating from the dorsal surface of the medulla oblongata. It is in the form of swellings as somatic sensory, facial and vagal lobes. The somatic sensory receives impulses from the taste buds distributed on the surface of the superficial skin around the head and the fins. The facial lobes are connected with the taste buds of the lips, barbels and the anterior part of the buccal cavity (Sreekala *et al.*,

2011)<sup>[39]</sup>. The presence or absence of sensory barbels is an important factor determining the feeding habit and the brain structure. The taste buds on the barbels are innervated by fibres of the seventh cranial nerve which exerts a profound influence on the structure of the hind brain and more particularly the structure of the facial lobe. The vagal and glossopharyngeal nerves supply the taste buds of the mucous membrane of the posterior oral cavity and the associated structures (Sreekala *et al.*, 2011)<sup>[39]</sup>. Food habits of *carassius auratus* was studied by calculating important relative index (IRI) for each food such as flora, consisting of small aquatic plants and algae, fauna including insects, mollusca and crustacean, and also detritus. Algae was found to have the highest value of IRI than the others components (Saoud, 2006)<sup>[36]</sup>.

### Cobitidae and feeding habits

Fishes in cobitidae family do not have scales, but have barbels which helps in gustation. These fishes have an elongated body with movable suborbital spine and are omnivorous feeder. Their bottom-facing mouth and single row of pharyngeal teeth helps their scavenging nature. The bottom feeders feed mainly by the sense of taste at the bottom of the habitat. In bottom feeders, feeding depends on taste buds located on their entire body. Since the eyes are comparatively small, such fishes detect food mainly by taste buds and these taste buds cause an enlargement of vagal or facial lobes. Similarly, fish that feed largely by sight at the surface of water exhibit very small facial and vagal lobes (Bhimachar, 1937)<sup>[7]</sup>. These visual stimulus triggers the feeding acts of fishes with movements, colours, and shape of the objects perceived each having a role in the feeding act (Lagler *et al.*, 1977)<sup>[27]</sup>. The external morphology of the olfactory bulb, olfactory tract and fore brain do not show any correlation with feeding habits. The greatest modification of the fish brain correlated with feeding activity has been found in the medulla oblongata (Evans, 1952)<sup>[13]</sup>.

For the study of fish brains in relation to feeding habits, the fishes were classified into different groups. Bhimachar (1935)<sup>[6]</sup> divided them into taste and sight feeders. He differentiated taste feeders further into mouth and barbel taste feeders. According to Mookerjee *et al.* (1950)<sup>[29]</sup>, the classification is based on fishes which feed by taste, feed by both taste, and sight or, only by sight. Khanna and Singh (1966)<sup>[24]</sup> classified the fishes as sight and mouth taste feeders, barbel taste feeders and sight feeders. Saxena (1967)<sup>[37]</sup> categorised them into bottom feeders, mid water feeders and surface feeders. Bottom feeders were further divided into olfactory and lateral line sense feeders and olfactory sense and taste feeders. Mid and surface water dwellers were again divided into sight feeders and taste feeders.

### Fishes in Kerala and feeding habits

Evaluations based on topographic views of fish brains permit reasonably accurate predictions of feeding habit and certain aspects of habitat preferences displayed by fishes (Davis and Miller, 1967)<sup>[12]</sup>. There are detailed studies on the food and feeding habits of certain fishes seen in the waters of Kerala. A detailed account of food and feeding habits of *Etroplus suratensis* known locally as 'Karimeen' has been given by Jayaprakas (1980)<sup>[20]</sup>. *E. suratensis* is regarded as herbivorous surface feeder consuming

substantial quantities of diatoms, filamentous algae, aquatic macrophytes and zooplankton. It feeds by taste and sight. Being a surface feeder the optic lobes are naturally highly developed and due to its herbivorous nature the vagals are moderately developed and facial lobes are absent (Jayaprakas, 1980.)<sup>[20]</sup> Babu (1981)<sup>[4]</sup> studied the feeding habits of *Amblypharyngodon chakiensis*, a teleost fish. He has designated this fish as herbivorous bottom feeder. The eyes are comparatively small. The optic lobes are moderately developed. There are taste buds responsible for detecting and picking out the food from the materials.

Catfishes, commonly seen in rivers are generally bottom feeders equipped with sensitive barbels (3 pairs) originating from the snout. The barbel possesses taste buds. A majority of the catfishes are active only at night (crepuscular feeders) and occur in muddy and turbid waters. *Mystus gulio*, is an omnivorous bottom feeder and its principal food is detritus, and also feed on insects, worms, blue green algae and molluscs. It gathers food with the senses of touch and taste rather than by sight. The presence of numerous taste buds on barbels has been reported in several catfishes. According to Bardach *et al.* (1967)<sup>[5]</sup> and Atema (1971)<sup>[2]</sup> it is the sense of taste that guides the fishes to the food. In most fishes and vertebrates, the sense of taste serves as a close-range receptor for discriminating food item (Ovalle and Shinn, 1977)<sup>[32]</sup>. Herrick (1905)<sup>[15]</sup> suggested that catfishes, recognizes food only by actual touch. But according to Hara (1971)<sup>[16]</sup>, catfishes locate food by olfaction using highly developed olfactory system. It also recognizes the food with barbels that enables touching food items. The cutaneous gustatory organs are innervated by the facial nerve. The brain is characteristically modified to suit feeding nature. The olfactory bulb and the olfactory tracts are well-developed while optic lobes are poorly developed (Mookerjee *et al.*, 1950)<sup>[29]</sup>.

There are different morphological analyses done on *Carassius auratus* or gold fish. In a study, the fish length ranges between 9.5 cm to 16.2 cm. and other morphometric ratios such as fork length, snout length, and orbital diameter are identified. The pre dorsal length and pre pelvic length in these species falls approximately within the same range and no allometric growth was seen with increase in total length (Acharya *et al.*, 2019)<sup>[1]</sup>. In another study of *Carassius auratus*, number of scales, fins, gill rakers were found. Total vertebrae ranged between 28-30 and mean of body weight ranged from 0.99 of CPL/CPD to 3.47 of HL/ED (Al-Faisal, 2010)<sup>[3]</sup>.

This study analyzes various characteristic features of two fish species *B. striata* and *C. auratus* and its different brain regions, and shall also find the correlation between the identified regions. The *Carassius auratus* or gold fish, an aquarium fish from the Cyprinidae family and *Botia striata*, or Zebra Loach from Cobitidae family are peaceful fishes. A comprehensive analysis and evaluation of brain patterns was done by consistent and appropriate logical procedures of specimens studied in-vivo.

### Materials and Methods

Live thirty fishes each of *B. striata* and *C. auratus* species were collected from nearby aquarium shop. Their identification was done based on standards (Jayaram, 1981<sup>[21]</sup>; Talwar & Jhingran, 1991)<sup>[34]</sup>. The fishes were dissected and fixed in 10% formalin and photographed under standardised conditions. The morphology of different brain

lobes were carried out and studied by Hubbs and Lagler method (Hubbs and Lagler, 1947) [19].

**Morphometric analysis**

Different morphometric measures were carried out using necessary tools, scale, and digital weighing balance. Eleven morphometric measurements such as total weight of fish (FW), Fish length (FL) such as Standard Length (SL) and Total Length (TL), Brain Length in mm (BL), Brain Weight in mg (BW), Length of olfactory tract in mm (OTL), Length of olfactory bulb in mm (OBL), Cerebellum (CLM) in mm, optic lobe in mm (OL), Cerebrum length (CebmL), Facial Lobe (FLL) and Vagal Lobe (VLL) were obtained by measuring using Distance measurements was done with an accuracy of ± 0.5 mm by using scale, and for weighing, digital weighing balance was used.

**Statistical analysis**

The statistical analysis of two fish species were done separately and mean, standard deviation (S.D.), and also

correlation coefficient between the body length and length of different organs were found. For these JASP (Version 25) software was used. From the measured values relationship between Total Length and weight of fish (FW), Brain length and olfactory tract, brain length and olfactory lobe, Brain length and cerebral hemisphere, Brain length and optic lobes, Brain length and cerebellum, brain length and medulla (Facial Lobe (FLL) and Vegal Lobe (VLL) in Carassius was determined while in *Botia striata* correlation between brain length and FLL was estimated.

**Results**

Eleven morphometric measurements such as total weight of fish (FW), Fish length (FL) such as Standard Length (SL) and Total Length (TL), Brain Length (BL), Brain Weight (BW), Length of olfactory tract (OTL), Length of olfactory bulb (OBL), Cerebellum (CebmL), Length of optic lobe (OptL), Cerebrum length (Cebm), Facial Lobe (FLL) and Vagal Lobe (VLL) were found. The characteristic features of the fish, its abbreviations and details are given in Table 1.

**Table 1:** Morphometric features of fish considered for analysis

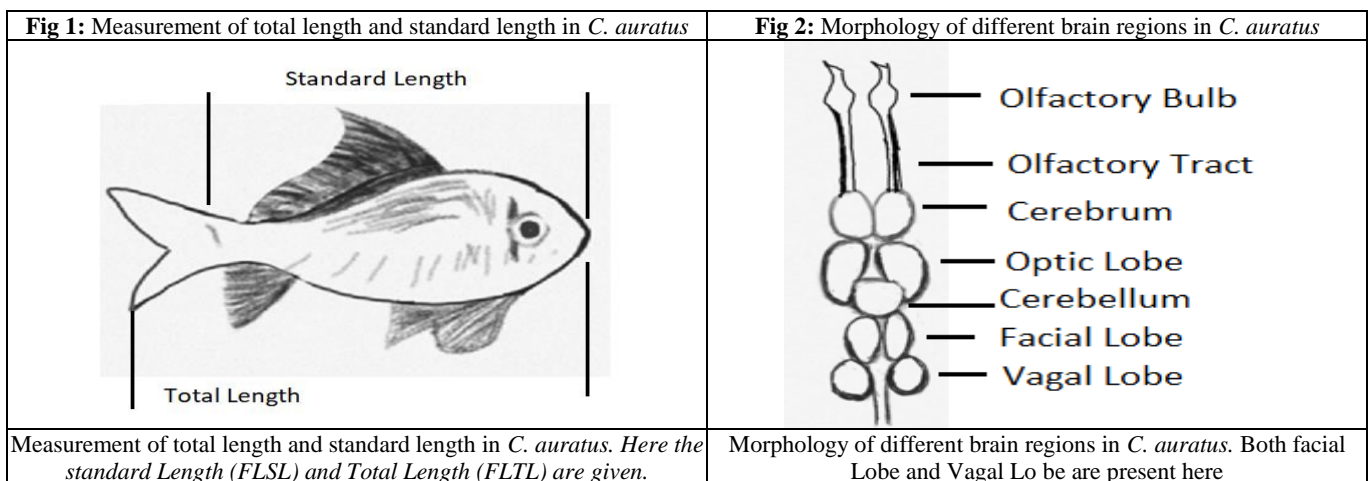
SI No	Fish Characters measured	Abbreviations used	Details
1	Fish total length	FLTL	Tip of snout till the end of caudal fin
2	Fish standard length	FLSL	Tip of snout to the starting tip of caudal fin
3	Fish Weight	FW	-
4	Brain Length	BL	From olfactory bulb to brain stem
5	Brain Weight	BW	-
6	Olfactory tract Length	OTL	Olfactory tract found in the anterior part of the cerebrum
7	olfactory bulb Length	OBL	Olfactory bulb found in the endings of the olfactory tract
8	Cerebrum Length	Cebm	Found in the forebrain
9	Optic Lobe Length	OptL	Found in the midbrain
10	Cerebellum Length	CebmL	Found in the hindbrain
11	Facial Lobe Length	FLL	Found in the hindbrain
12	Vagal Lobe	VLL	Found in the hindbrain

Table 1. The fish characteristics analysed with the abbreviations used in the analysis and the details including the location of the parts are given.

**Morphometrics and statistical analysis of *C. auratus***

The size of experimental fish ranges from 4.9 to 104 cm in total length (TL) and 3 to 18.2 gm in weight respectively. Fig 1 shows measurement of total length and standard length in *C. auratus* and in Fig 2, morphology of different brain regions are depicted.

From the original measurements obtained, Mean, Standard Deviation, Coefficient of variation, Variance, Range and correlation coefficient was estimated using JASP software and is given in Table 2. From the estimated correlation coefficient, it is found that there is a positive correlation between all the measurements against total length of the fish.



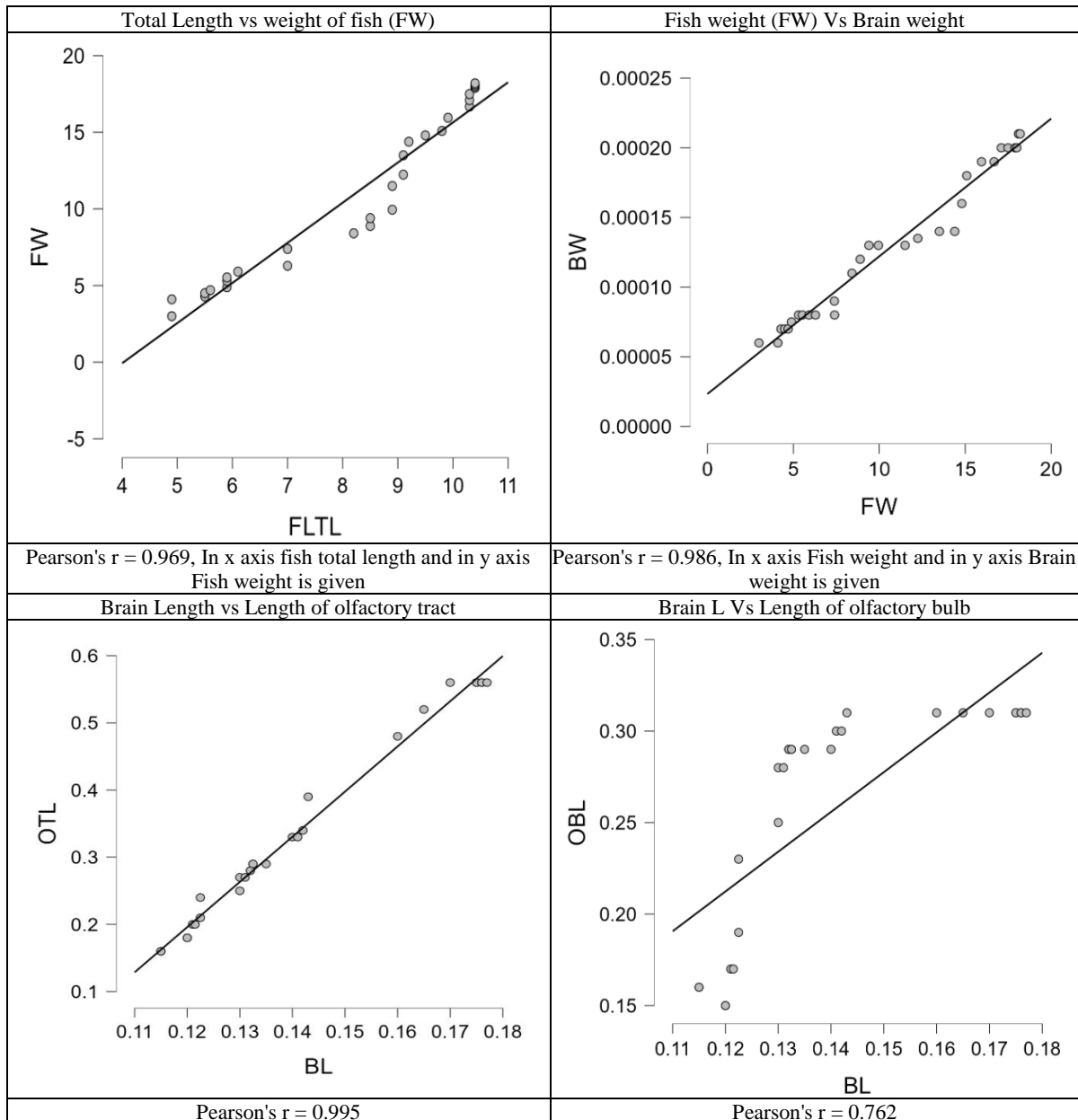
**Table 2:** Mean, Standard Deviation, Coefficient of variation, Variance, and Range between different morphometric characters of *C.auratus*

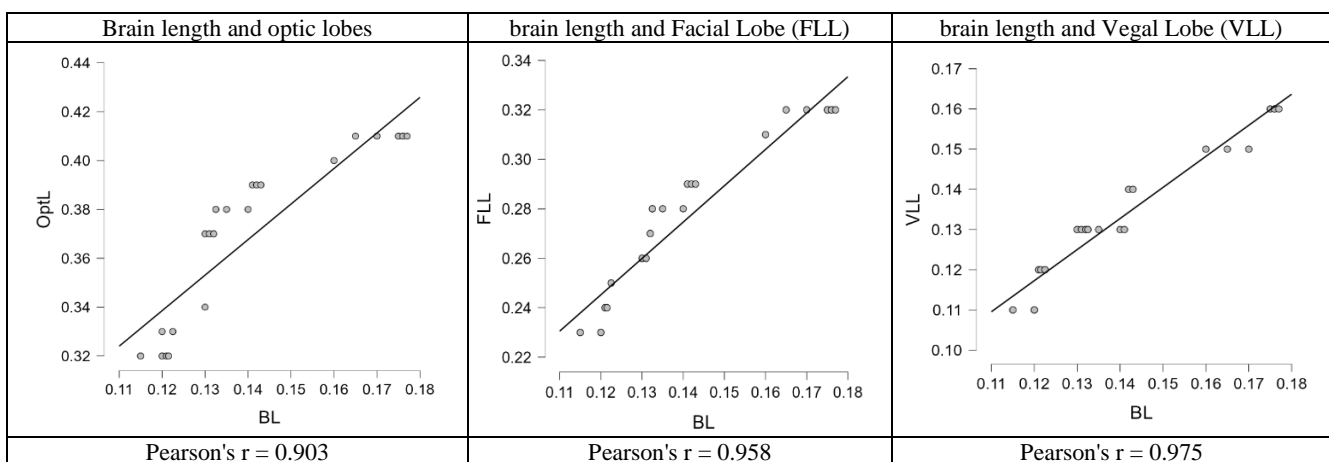
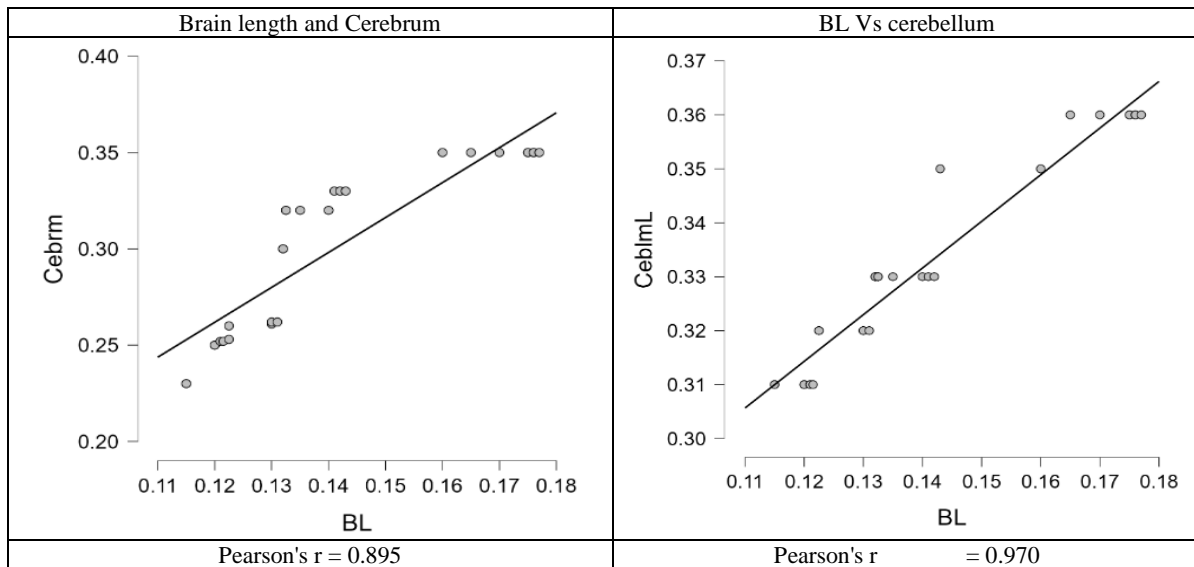
Fish Characters	Mean	Standard Deviation	Coefficient of variation	Variance	Range	Correlation Coefficient
FLTL	8.110	1.957	0.241	3.828	5.500	
FLSL	6.687	1.996	0.298	3.983	5.300	
FW	10.696	5.286	0.494	27.944	15.200	0.969
BL	0.142	0.022	0.154	4.786×10-4	0.062	0.906
BW	1.290×10-4	5.299×10-5	0.411	2.808×10-9	1.500×10-4	0.962
OTL	0.341	0.148	0.433	0.022	0.400	0.918
OBL	0.259	0.062	0.240	0.004	0.160	0.929
Cebrm	0.301	0.044	0.147	0.002	0.120	0.988
OptL	0.370	0.035	0.095	0.001	0.090	0.979
CeblmL	0.333	0.020	0.059	3.803×10-4	0.050	0.935
FLL	0.277	0.034	0.121	0.001	0.090	0.977
VLL	0.134	0.017	0.129	3.007×10-4	0.050	0.929

Table 2. Mean, Standard Deviation, Coefficient of variation, Variance, and Range between different morphometric characters of *C.auratus*. Correlation coefficient is between Total length and all other measurements.

A good positive linear correlation between value of 0.906 and 0.988 is observed between total length and all the observed measurements. The linear correlation is observed between total length and fish weight and is depicted in Fig 3. a. Here dependent variable total length is taken on x-axis and fish weight is given on y-axis. In all other cases the

different organs within the brain region are taken in the Y-axis and dependent variable brain length on X-axis. Independent variables such as length of olfactory tract, olfactory bulb, optic lobes, cerebellum, cerebrum and length of facial Lobe (FLL) are given on y-axis. Significant correlation exist between all these observations.





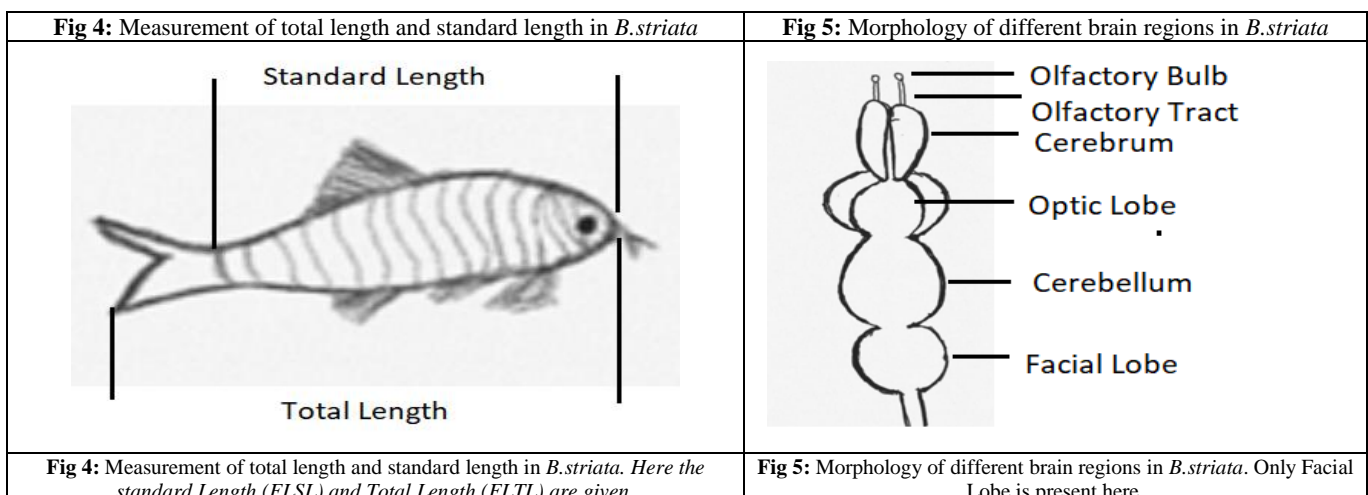
**Fig 3:** Correlation between different characters in *Carassius auratus*

Correlation between different features in *C.auratus* and the observed correlation coefficient for each relation are given here. Fig 3a. shows the correlation between fish length and fish weight. From Fig 3. b. to 3. i correlation between brain

length and different brain regions are shown. From Fig 3. c to j, brain length is in the x axis and brain parts are given in the y axis. All correlation obtained significant p value < .001.

**Morphometrics and statistical analysis of *B. striata***

The size of experimental fish ranges between 3.5 and 7.7 cm in total length (TL) and 0.58 and 7.1 g in weight. In Fig 4, different measurement such as total length and standard length of *B.striata* and in Fig 5, morphology of different brain regions are given.



From the original measurements obtained, mean, standard deviation, coefficient of variation, variance, range and correlation coefficient was estimated using JASP software and is given in Table 3.

**Table 3:** Mean, Standard Deviation, Coefficient of variation, Variance, and Range between different morphometric characters of *B.striata*.

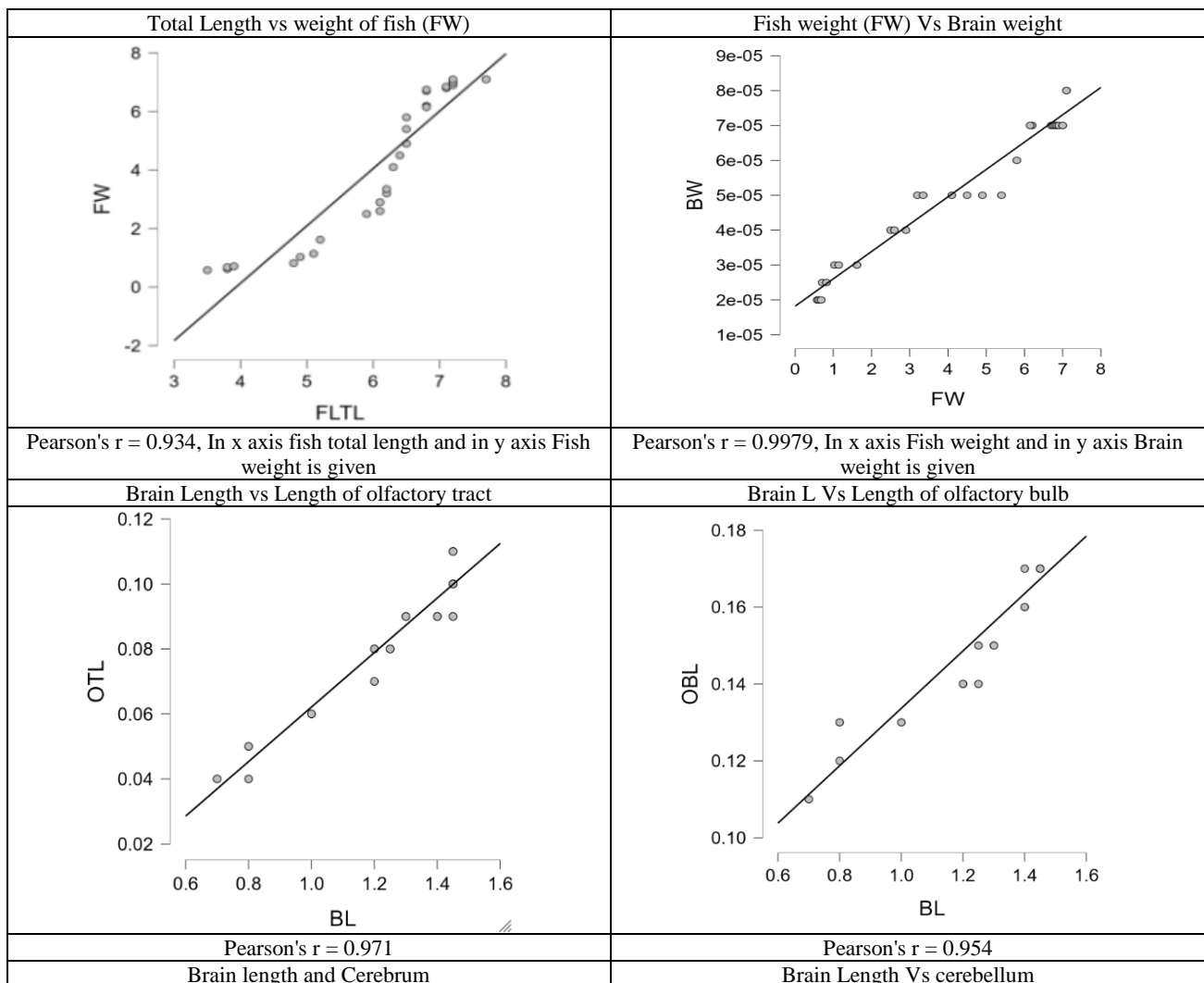
Characters	Mean	Standard Deviation	Coefficient of variation	Variance	Range	Correlation Coefficient
FLTL	6.110	1.199	0.196	1.438	4.200	
FLSL	5.010	0.891	0.178	0.793	2.900	
FW	4.270	2.518	0.590	6.339	6.520	0.934
BL	1.277	0.239	0.187	0.057	0.750	0.963
BW	$5.167 \times 10^{-5}$	$2.014 \times 10^{-5}$	0.390	$4.057 \times 10^{-10}$	$6.000 \times 10^{-5}$	0.945
OTL	0.085	0.021	0.242	$4.257 \times 10^{-4}$	0.070	0.980
OBL	0.154	0.019	0.121	$3.495 \times 10^{-4}$	0.060	0.938
CebmL	0.195	0.019	0.100	$3.775 \times 10^{-4}$	0.060	0.954
OptL	0.253	0.022	0.086	$4.754 \times 10^{-4}$	0.070	0.963
CerblmL	0.568	0.030	0.052	$8.786 \times 10^{-4}$	0.090	0.958
FLL	0.277	0.027	0.098	$7.390 \times 10^{-4}$	0.110	0.943

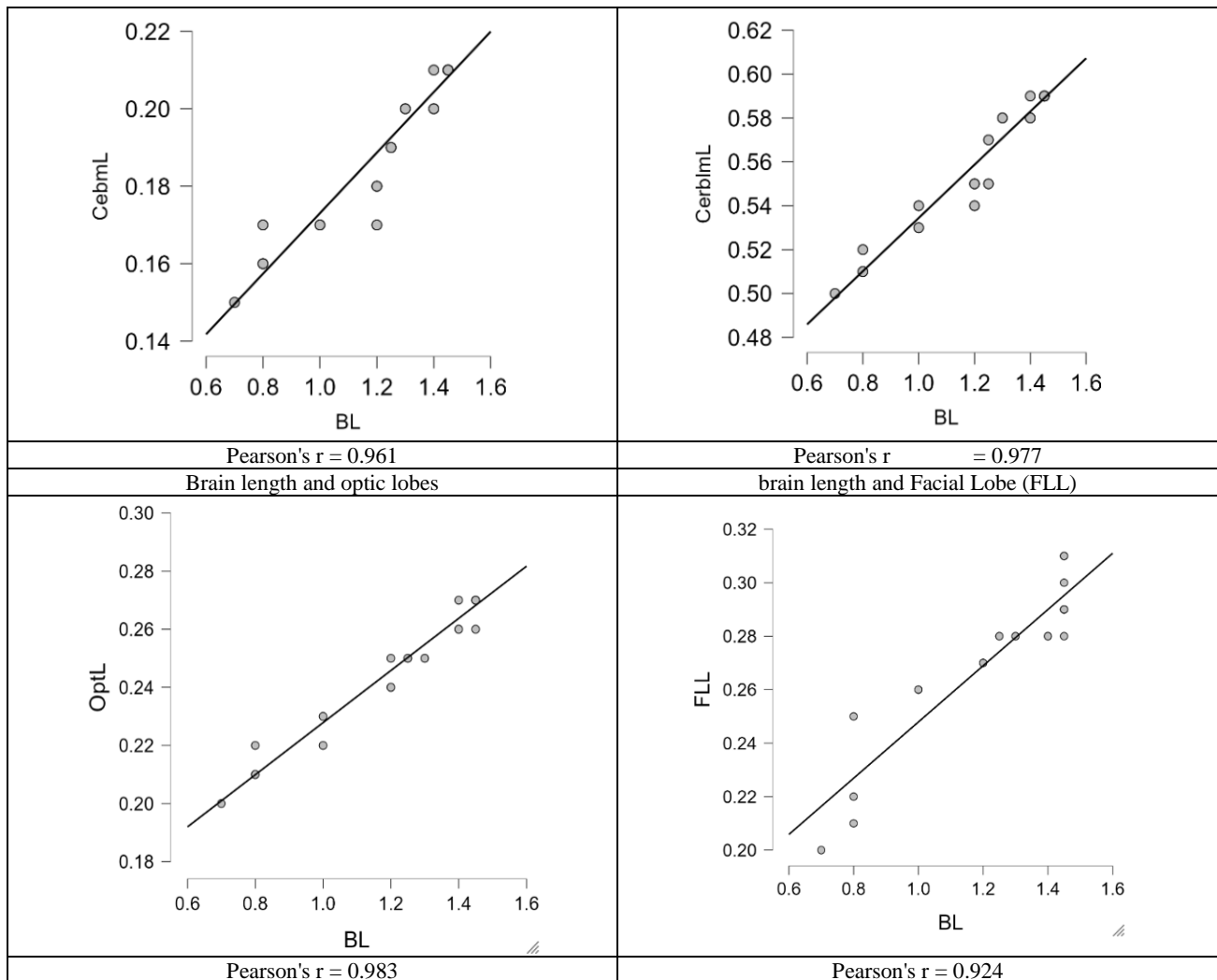
Table 2. Mean, Standard Deviation, Coefficient of variation, Variance, and Range between different morphometric characters of *B.striata*. Correlation coefficient is evaluated between total length and all other measurements.

From the estimated correlation coefficient, it is found that there is a positive correlation between all the measurements against total length of the fish. Linear correlation value range between 0.938 and 0.980. Linear correlation is also observed between total length and fish weight and is depicted in Fig 6. a. Here dependent variable total length is

taken on x-axis and fish weight is given on y-axis. In all other cases the different organs within the brain region are taken in the Y-axis and dependent variable brain length on X-axis. Independent variables such as length of olfactory tract, olfactory bulb, optic lobes, cerebellum, cerebrum and length of facial Lobe (FLL) are given on y-axis.

**Fig 6. Correlation between different characters in *Botia striata***





Correlation between different features in *B.striata* and the observed correlation coefficient for each relation are given here. Fig 2a. shows the correlation between fish length and fish weight. From Fig 6. b. to 6. h correlation between brain length and different brain parts are shown. From Fig 6. c to h, brain length is in the x axis and brain parts are given in the y axis. All correlation obtained significant p value < .001.

Significant correlation exists between all these observations. In *C.auratus* the correlation between and brain length and cerebrum (0.895) and olfactory lobe (0.762) is slightly less than that in *B.striata*.

According to range differences, the morphometric characters are divided into three categories. One is the narrow range group, that are genetically controlled characters, the characters with moderate change goes to intermediate group, and group with maximum range variation are environmentally controlled characters (Bhatt, et al., 1998). From our observation in both fish species, vast range was observed in fish weight and can be considered as environmentally controlled while six characters with low range variations can be considered as genetically controlled. This goes along with the observation made in the morphological analysis in *Labeo rohita* in two different studies (Kaur et al., 2019 [22]; Yadav & Paul, 2023) [43]. Moreover, studies show that environmental conditions, such as food abundance induce morphological differences and lead to enhancement of morphological diversification (Wimberger, 1992) [41]. Fishes are more sensitivity to

environmental changes making them highly adaptive undergoing suitable changes in its morphology (Hossain et al., 2010) [18].

**Comparison between *C.auratus* and *B.striata***

The condition factor between two fish species auratus and striata are given in table

SI No:	Fish species	Mean Length	Mean Weight	Condition Factor
1	<i>C.auratus</i>	8.110	10.696	2.00
2	<i>B.striata</i>	6.110	4.270	1.87

Wellness of fish influenced by the biological and ecological factors are represented by Fulton's Condition Factor (K), where  $K = (\text{Weight (g)} / \text{Length (cm)}^3) * 100$ . Higher K value represents fish condition (Khallaf et al., 2003) [23], here *C.auratus* is found to be in better condition than *B.striata*.

**Discussion**

The allometric analysis of brain and body development have been criticized on several accounts. The selective pressures that determine body weight are different for animals that are adapted to different types of environments. Vertebrates that fly such as birds and bats have a heavy selective pressure on them to reduce body weight in the interest of efficient utilization of energy. The vertebrates that live in an aquatic environment have pressure on them to keep body weight to

a minimum because of the buoyancy of their body mass in water. Thus the variability in body weight selective pressures seems to be matched by a comparable variability in brain weight selective pressures. Even though these problems of variability may limit allometric analysis, the allometric representation offers an opportunity to see the range of variation in brain size that can be found for a given body weight as well as variation in body weight found for a given brain weight (Butler and Hodos, 2005) <sup>[10]</sup>. In the present investigation, similar observations were obtained. The brain size of the fishes are often connected to their habitat and life style, the shark species with largest brain relative to body mass are bethopelagic or pelagic or chiefly found in reef or coastal oceanic sub habitats (Yopak *et al* 2007) <sup>[44]</sup>.

Gonda *et al* (2011) <sup>[14]</sup> investigated the variation in brain size and structure in wild caught nine spined sticklebacks. They observed not only absolute and relative brain size but also the relative size of different brain parts of nine spined sticklebacks varied in wild. Significant population differences were found in the relative size of the telencephalon, optic tectum, and cerebellum. They also found significant habitat specificity in the relative size of the telencephalon with marine fish tending to develop larger telencephalon than pond fish. Lisney *et al* (2007) <sup>[28]</sup> compared the relative volume of the sensory brain areas, the olfactory bulbs, and optic tectum in juveniles and adults of 7 species of elasmobranchs. The relative volume of each brain areas was expressed as proportion of the total sensory brain areas between juveniles and adults. In all species, the optic tectum was relatively larger in juveniles whereas the size of the olfactory bulbs were relatively greater in adults. The result suggests that vision is relatively more important than olfaction in juvenile elasmobranchs. In our study in *C. auratus*, the surface dwelling fish possess highly developed brain regions like optic lobe, that increases in size proportionally with their increase in body weight and brain weight but telencephalon (cerebrum) which is slightly less developed compared to brain length.

Van Staaden *et al* (1994) <sup>[42]</sup> reported the relationship between brain and body size and address patterns of brain form variation among 189 species of Cichlids of the African Great lakes. The cichlids exhibit variation in the form of brain structures concerned with vision, olfaction and the lateral line. The greatest variation was observed in the development of association centers, particularly in the telencephalon. Similar variations were found in *C. auratus* telencephalon (cerebrum and olfactory bulb). Budeau & Verts, (1986) <sup>[9]</sup> quantitatively compared the size of the brain and brain structures to the habitat complexity in mammals and found that brain and brain structures indeed correlate with complex habitats. Pollen *et al* (2007) <sup>[33]</sup> found in Cichlids that environmental and social features differentially affect the brain. Environmental fluctuations correlated with more brain structures than did social factors. While five out of seven of the brain measures correlated with habitat measures, only two brain structures, the telencephalon and hypothalamus correlated social factors. Specifically both social organization and number of individuals were positively correlated with telencephalic size, social organization was negatively correlated with hypothalamic size.

According to Nieuwenhuys *et al.*, (2014) <sup>[31]</sup>, animal's life style reflex in the organisation of its central nervous system.

The relationship has been particularly well studied in teleost fishes whose unparalleled diversity among the vertebrates has allowed scientist to study relationship between brain structure and sensory ecology. In particular, the relative size or complexities of the peripheral sense organs are found to scale positively with the input to the related brain centers. Both measures provide an accurate indication of the relative importance of a particular sensory system in any given species (Kotrschal *et al.*, 1998) <sup>[25]</sup>.

In *B. striata*, as a bottom dwelling fish, it possess less developed optic lobes compared to their body weight and brain weight. But in our analysis we found a positive correlation of optic lobe to brain length, while in *C. auratus* no such high positive correlation was found. *B. striata* uses gustation in their feeding, so the brain morphology show well developed facial lobes, poorly developed optic lobes and absence of vagal lobes, and olfactory lobes are moderately developed. *C. auratus*, a visual feeder possess highly developed olfactory system, visual system and gustatory system. So the brain morphology in *Carassius auratus* shows two senses such as olfaction, vision, that are highly developed than in *B. striata*. In *B. striata* gustation is more developed due to its bottom feeding nature.

### Conclusion

This analysis verifies correlation between total length of fish with other morphometric characteristics of *C.auratus* and *B.striata*. The results shows a positive correlation between total length and other found morphometric parameters and also brain length with length of parts in brain in both fishes. The results indicate a proportional increase with respect to total length. With respect to feeding habits study revealed the existence of an enhanced vagal lobe in *C.auratus* showing the role of gustation. In *B.striata* the facial lobe, barbels and skin take part in gustation. By adding quantitative elements into the measured morphometrics, differences between the species were able to be represented more accurately. This shall help researchers to know more about these fishes and its feeding habits.

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