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Gut morphometric parameters of rainbow trout (*Oncorhynchus mykiss*, Walbaum 1792) from Kashmir

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Abstract
Oncorhynchus mykiss, introduced in Kashmir more than a century ago, has established itself in almost all cold-water streams of the valley. For the study about 200 samples of *O. mykiss* was collected from the national trout fish farm Kokernag and different morphometric parameters related to the alimentary canal was analyzed. The highest gut weight (64.27g), intestinal length (335mm) and liver weight (16.81g) was observed in brood stage of the fish. The highest intestinal coefficient (1.2) and Zihler's index (5.56) was found in fry stage whereas gut length (310mm) and relative gut length (1.2) was found to be highest in table size of fish. The digestive somatic index (0.24), hepatosomatic index (4.14%) and gastrosomatic index (24.13%) was seen highest for the fingerling stage. These indices helped to provide a technical knowhow of the digestive physiology of the species and knowledge regarding alimentary canal morphology is increasingly important for fish digestive functioning and for improving protocols for the fish nutrition.

Keywords: *O. mykiss*, Zihler's index, intestinal coefficient

Introduction
Teleosts are representing a great source of food supply for homosapiens in these days and conformed to every type of aquatics, fishes being an awesome package of nutrition for the people in developing countries and these reflect the versatility in their feeding which makes them unique creatures. A remarkable diversity of ontogenic and functional characteristics is shown in the digestive tract of fishes and has a correlation to different feeding habits, taxonomy, body shape, weight, size and sex. For framing the fish nutrition protocols the knowhow of alimentary canal metrics of teleosts is increasingly important for fish digestive physiology. For understanding the related mechanics of histophysiological and nutritional functions digestive tract structure and identification is essential. In case of fishes lesser is known about digestive processes than in mammals. The conventional classification of fishes on the basis of food preferences are (Pujante *et al.*, 2017) [15] as carnivorous, herbivorous and omnivorous. The classification can still extend on the basis of gut morphometric parameters, *i.e*. relative gut mass (RGM), relative gut length (RGL), and Zihler's Index (ZI, which is the relation between gut length and ten times the cube root of body mass) (German and Horn, 2006; Zihler, 1981) [9, 19]. Various indices are being studied for understanding the dietary strategy of fishes based on gut length, among which the RGL and ZI have been investigated as potential indices (German and Horn, 2006; Al-Hussaini, 1947) [9, 1]. RGM (also called digestive somatic index) is basically the reflection of the tissue quota that has been customized by the teleost to their alimentary canal and can be used to estimate the feeding patterns (German and Horn, 2006) [9].
The study will provide clarification on some aspects of their nutritive physiology and therefore, could also help to solve nutritional problems in fish feeding. Assessing development of digestive system through the simple metrics of various parameter of gut will help in precise understanding of feed and nutritional requirement at different developmental stages of *O. mykiss* and will help to provide better feeding and rearing practices for trout in raceways as this fish established itself a queen in commercial markets so this will help in boosting fish production and inturn give an urge to economy.

Technical programme
The research work was carried out in Fishery Biology Laboratory, Faculty of Fisheries, SKUAST-K, Rangil, Ganderbal.

Sample collection: The study was based on the collection of different developmental stages of *O. mykiss* from Kokernag Trout Fish Farm. The collection of samples was done randomly and transported to Fishery Biology Laboratory at Faculty of Fisheries, Rangil, in insulated boxes containing ice packs. In the laboratory, the fish samples were cleaned under running tap water, and then dried with a clean cotton cloth. After cleaning, total length and total weight of the individuals were measured using measuring scale and electronic weighing balance upto the nearest millimeter (mm) and gram (g), respectively. Ventral dissection of the fish was performed and the alimentary canal is removed for further studies.

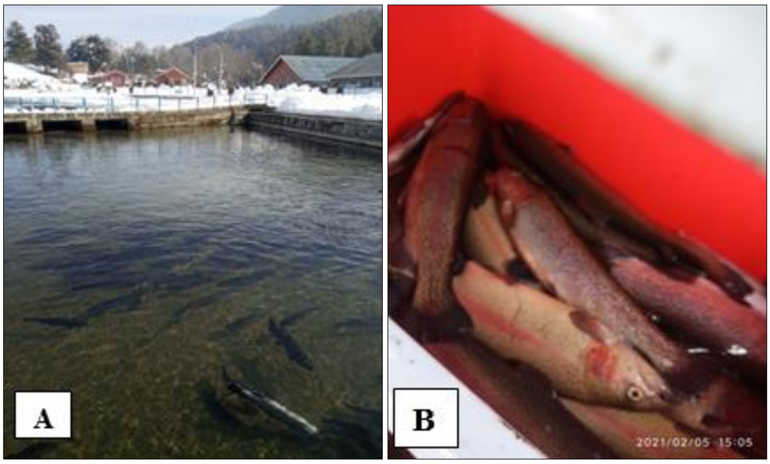

Fig 1: Showing the sampling site – A. Kokernaag Trout fish farm and B. collection of sample

Gut morphometric indices

1. Relative Length of Gut: Relative length of gut (RLG) was calculated by dividing the gut length by total length of fishes. The relationship between gut length (GL) and total length (TL) was estimated by the formula given by Al Hussaini (1949) [2] as:

$$RLG = \frac{GL}{TL}$$

Where, (GL) is total length of gut and (TL) is total length of fish.

2. Intestinal Coefficient: For each specimen, the standard length (SL; cm) and body weight (g) was recorded. After dissecting the digestive tract and the length (mm) of intestine (CI; mm) was measured. Subsequently, the intestinal coefficient (CO) was calculated using the equation of Angelescu and Gneri (1949) [3]:

$$CO = \frac{CI}{SL}$$

3. Relative Gut Mass: This is also called as digestive somatic index (DSI) and this gut parameter were calculated by following formula according to German *et al.*, (2004) [10] as: RGM = gut mass (g) x [body mass (g)]$^{-1}$, and represents the ratio between gut weigth and body weight.

4. Zihler's Index: This parameter was calculated by Zihler (1981) [19] formula and represents the relation between the gut length and ten times the cube root of body mass as: Index (ZI) = gut length (mm) x [10 x (body mass (g) $^{1/3}$)]$^{-1}$

5. Hepatosomatic index: This parameter represents the ratio of liver weight and body weight and was calculated by following formula (Parmeswaram and Liese, 1974)

$$HSI = \frac{\text{Liver weight}}{\textit{Body weight}} \times 100$$

6. Gastrosomatic index: This gut morphometric parameter shows relation between the alimentary canal weight and weight of fish and will be calculated by following formula of Desai (1970).

$$GaSI = \frac{\text{Total Weight of the alimentary canal of fish}}{\text{Total weight of fish}} \times 100$$

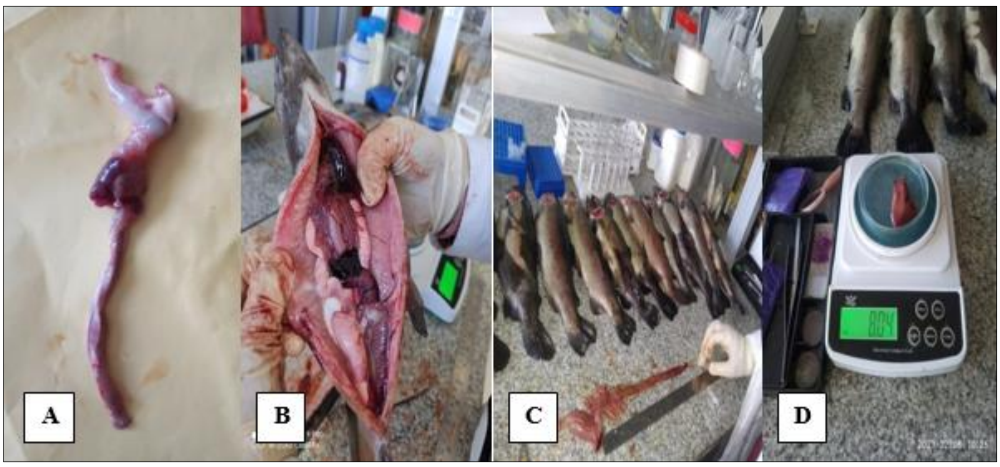

Fig 2: A. Alimentary canal of fry B. Dissection of O. mykiss C. Measurement of gut morphometric paramters and D. Estimation of liver weight

Results and Discussion

Table 1: Descriptive statistics of fry stage of *O. mykiss*

Statistics	N	Min	Max	Mean	SE	SD	25prcntil	75prcntil
TL	40	42	77	63.31	1.32	8.38	58.25	69.75
SL	40	32	65.1	53.13	1.21	7.66	48.25	57.5
WEIGHT	40	1.35	6.1	3.60	0.19	1.26	2.41	4.54
G.L	40	26	90	54.44	1.90	12.06	46.75	61
G.WT	40	0.14	0.86	0.45	0.03	0.19	0.27	0.57
CI	40	25	75	41.1	1.58	9.99	32.25	48.1
L.WT	40	0.01	0.12	0.04	0.00	0.02	0.02	0.06
RLG	40	0.50	1.28	0.85	0.02	0.13	0.79	0.92
CO	40	0.403	1.20	0.77	0.02	0.15	0.65	0.90
RGM/DSI	40	0.05	0.16	0.12	0.00	0.02	0.10	0.13
ZI	40	2.12	5.56	3.58	0.09	0.57	3.26	3.88
HSI	40	0.29	2.47	1.19	0.08	0.51	0.75	1.55
GaSI	40	5.95	16.71	12.21	0.31	2.01	11.00	13.49

Table 2: Descriptive statistics of Fingerling stage of *O. mykiss*

Statistics	N	Min	Max	Mean	SE	SD	Median	25prcntil	75prcntil
TL	40	60	125	91.51	2.33	14.75	90	80	103.62
SL	40	55	100	76.57	1.81	11.49	75	65	85
WEIGHT	40	3	21.5	10.56	0.78	4.98	9.43	6.51	14.5
G.L	40	55	125	87.55	2.57	16.30	85.5	79.25	95
G.WT	40	0.22	4.5	1.58	0.18	1.15	1.14	0.66	2.5
CI	40	40	100	69.02	2.18	13.80	70	60	79.25
L.WT	40	0.01	0.87	0.12	0.02	0.13	0.10	0.07	0.13
RLG	40	0.68	1.18	0.95	0.01	0.10	0.95	0.88	1.02
CO	40	0.72	1.14	0.89	0.01	0.10	0.88	0.82	0.96
RGM/DSI	40	0.03	0.24	0.13	0.00	0.04	0.12	0.10	0.16
ZI	40	3.22	5.01	4.09	0.06	0.38	4.13	3.85	4.38
HSI	40	0.15	4.14	1.11	0.09	0.62	1.01	0.77	1.40
GaSI	40	3.69	24.13	13.69	0.71	4.52	12.39	10.15	16.97

Table 3: Descriptive statistics of Yearling stage of *O. mykiss*

Statistics	N	Min	Max	Mean	SE	SD	Median	25prcntil	75prcntil
TL	40	126	177	149.37	1.75	11.08	147	142	157
SL	40	100	145	123.87	1.66	10.55	123.5	119.25	130
WEIGHT	40	30	69.5	45.04	1.52	9.62	43.45	37.05	51.07
G.L	40	120	172	143.42	1.79	11.32	142.5	135	150
G.WT	40	3.06	9	5.45	0.19	1.26	5.5	4.5	6.03
CI	40	90	129	109.97	1.59	10.07	110	102.25	115
L.WT	40	0.05	1.14	0.63	0.03	0.24	0.64	0.48	0.78
RLG	40	0.83	1.08	0.96	0.00	0.05	0.96	0.91	1
CO	40	0.76	1.03	0.88	0.01	0.06	0.88	0.84	0.93
RGM/DSI	40	0.08	0.19	0.12	0.00	0.02	0.11	0.10	0.13
ZI	40	3.54	4.98	4.05	0.03	0.24	4.02	3.88	4.19
HSI	40	0.11	2.02	1.38	0.06	0.40	1.42	1.17	1.59
GaSI	40	8.28	19.73	12.32	0.43	2.77	11.62	10.34	13.81

Table 4: Descriptive statistics of Table size stage of *O. mykiss*

Statistics	N	Min	Max	Mean	SE	SD	Median	25prcntil	75prcntil
TL	40	220	310	258	3.64	23.03	255	240	275
SL	40	24	260	214.67	5.71	36.11	217.5	205	233.75
WEIGHT	40	143.92	379.35	235.19	8.85	55.99	222.29	194.45	277.44
G.L	40	205	310	262.75	3.67	23.23	262.5	246.25	280
G.WT	40	12.72	46.61	25.03	1.20	7.61	22.66	20.19	30.18
CI	40	140	240	196.05	4.25	26.89	202.5	180	218.75
L.WT	40	1.44	5.4	2.85	0.13	0.85	2.73	2.28	3.1575
RLG	40	0.79	1.2	1.02	0.01	0.09	1.01	0.96	1.1
CO	40	0.71	1.07	1.10	0.21	1.37	0.89	0.84	0.96
RGM/DSI	40	0.07	0.17	0.10	0.00	0.02	0.11	0.09	0.12
ZI	40	3.46	5.2	4.29	0.05	0.37	4.31	4.11	4.48
HSI	40	0.74	2.35	1.24	0.05	0.35	1.25	0.96	1.39
GaSI	40	6.9	16.62	10.68	0.33	2.12	10.69	9.05	12.04

Table 5: Descriptive statistics of Brood stage of *O. mykiss*

Statistics	N	Min	Max	Mean	SE	SD	Median	25prcntil	75prcntil
TL	40	310	388	341.2	2.96	18.77	342	325	355
SL	40	262	350	290.87	2.98	18.89	292.5	272.5	302
WEIGHT	40	359	660.74	530.69	11.43	72.29	532.06	505.46	588.69
G.L	40	250	400	337	5.47	34.64	343.5	320	360
G.WT	40	19.41	64.27	37.73	1.80	11.43	37.96	28.29	45.97
CI	40	200	335	266.1	5.06	32.06	267.5	251.25	288.75
L.WT	40	4.25	16.81	8.60	0.39	2.46	8.59	7.19	10.07
RLG	40	0.71	1.15	0.98	0.01	0.10	1	0.95	1.06
CO	40	0.68	1.13	0.91	0.01	0.11	0.92	0.83	1.01
RGM/DSI	40	0.03	0.12	0.07	0.00	0.01	0.07	0.05	0.08
ZI	40	3.09	5.13	4.17	0.07	0.44	4.20	4.01	4.38
HSI	40	0.90	2.82	1.62	0.06	0.42	1.53	1.35	2.00
GaSI	40	3.66	12.05	7.12	0.31	1.97	7.06	5.32	8.76

The information regarding biometrics of the alimentary canal is crucial as it is directly related to the survival of fish in the aquatics and fish always have to maintain its healthy presence with the fluctuating environment in waters and for this reason, better digestion of food is atmost important part and this can only be possible by having a proper technical knowhow of its gut morphometry which helps in formulating the feed for fishes. The rudimental operation of fish metabolism is its digestion because it determines the availability of nutrients needed for all biological concerns (Solovyev and Gibsert, 2016) [17]. Among the gut morphometric parameters of fry stage of *O. mykiss*, showed the minimum value for the liver weight (L.WT = 0.01g) while maximum value for the gut length (G.L = 90mm) are given in Table 1. This stage also showed the maximum value (Table 1) of Zihlers index (ZI = 5.56). Similarly Fingerling stage also showed the minimum value for the liver weight (L.WT = 0.01g) and maximum value for the gut length (G.L = 125mm) are shown in Table 2. The yearling stage showed minimum value for the liver weight (L.WT = 0.05g) and maximum value for the gut length (G.L = 172mm) are presented in Table 3. The table size and brood stage of *O .mykiss* also showed the maximum values for gut length as 310mm and 400mm (Table 4 and Table 5). Whereas minimum value for the digestive somatic index (DSI = 0.07) for the table size (shown in Table 4) and (DSI = 0.03) for the brood stage is seen (Table 5). The lowest gastro somatic index was seen in brood stage of *O. mykiss* (GaSI = 3.66%) (shown in Table 5) owing to its low feeding activity as all the focus of physiology is on the reproductive development of fish and more than half of gut is being occupied by the gonads and the highest was observed in fingerling stage (GaSI = 24.13%) presented in Table 2. The lowest hepato somatic index (Table 3) was observed in yearling stage (HSI = 0.11%) and the highest value was seen in fingerling stage (HSI = 4.14%) given in Table 2. Various authors reported HSI values for the fishes like Craig *et al.*, (2000) [7] studied seasonal changes in body composition of adult red drum *Sciaenops ocellatus*, with highest HSI in spring (March–April) and October by minimal values for HSI and found liver composition varied dramatically throughout the year. Study of HSI is also important because it describes the status of energy stored in fish and is thus considered as good indicator of feeding and metabolic activity (Jan and Jan, 2017) [12]. Arockiaraj *et al.*, (2004) [4] studied HSI catfish *Mystus montanus and* reported (HSI) of 0.358 to 21.33 in females and the corresponding values for males were 0.619 to 3.25 respectively. The transfer of energy stored in hepatic reserves for the gonad development is responsible for the low HSI values in spawning phase of fishes (Zin *et al.*, 2011) [20].

Strong correlations of HSI with feeding intensity mostly shows the availability of food in the aquatic systems directly indicated by the increase in body weight and liver weight of fish. Gut morphometry is essential in providing an insight to understand the biological aspect and physiology of species and helping to formulate the feeding protocols of fish thereby contributes to better nutrition and fish conservation and management practices (Rodrigues and Menin (2005) [16], Xiong *et al.* (2011) [18] and Germano *et al.* (2014) [11]. Several authors has correlated the intestinal length with feeding strategy of fish and deriving the important gut morphometric parameter called intestinal coefficient which basically shows the amount of tissue dedicated to alimentary canal. Different CO values are seen for the fishes with varying feeding strategy and for a meat eater fish the value ranges from 0.2 and 2.5 (Al- Hussani, 1949., Angelescu and Gneri, 1949 and Bertin, 1958) [2, 3, 5]. The length of the intestine is related to feeding habits, more so in iliophagous, herbivorous, and omnivorous and to a lesser extent in carnivorous and insectivorous fish species. The master organ, intestine involved in digestive physiology is basically a tube wherein food travel and digestion occurs in alkaline medium and finally lead to nutrient absorption (Canan *et al.*, 2012) [6]. According to this pattern, high CO values are associated with herbivorous species, whereas intermediate values are associated with omnivorous, and low values with carnivorous fish species (Canan *et al.*, 2012) [6]. The study showed the lowest CO values for the fry stage (0.77±0.02) and the highest values was obtained in table size stage of *O. mykiss* (1.10±0.21) validating its carnivore nature. The trophic categories of fish species is widely decided by the intestinal coefficient. Classifying the fish by estimating its Relative gut length RLG = 0.5 – 2.4 is carnivore, RLG = 1.3- 4.3 is omnivore and RLG = 3.6- 6.0 is herbivore (Al-Hussani, 1949) [2] is also one of the important way to study the dietary pattern of teleost. The gut length (310mm) and Relative gut length (1.2) was found to be highest in table size of fish and RLG showed range from 0.85±0.05 (Fry stage) to 1.02±0.01 in table size indicated its carnivore feeding habit Similarly Mohammedizadeh *et al.*, 2010 [13] while studying feeding habits of saw tooth barracuda, reported that fish showed relative length of gut RLG= 0.34+0.002 and is strongly carnivore and reported highest level of GaSI in January and July and lowest in June and October, our study showed the maximum GaSI index for fingerling stage (13.69±0.71) owing to its faster growth period and minimum value was seen in brood stage (7.12±0.31) because the fish was in its spawning phase and reflected lowest feeding intensity.

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