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Correlations between alimentary measurements in fry, fingerling, yearling, table size, brood size stages of *O. mykiss* (Salmoniformes) from Kashmir

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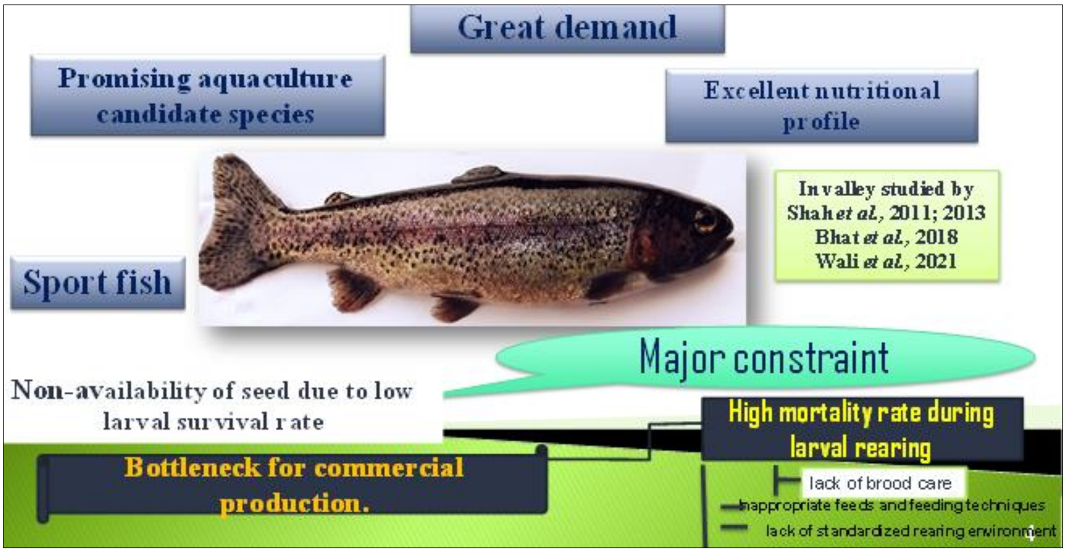
Abstract
The study includes the collection of 200 samples of *O. mykiss* from the national trout fish farm Kokernag, Jammu and Kashmir to analyze gut metrics of the alimentary canal of fish from fry to brood size stages. A significant correlation was also seen between the total length with gastro somatic index, hepatosomatic index, relative gut mass and zihlers index (r = 0.339, p<0.05, r=0.334, p<0.05, r = 0.330, p<0.05 and r = 0.316, p<0.05) in fry stage. Relative gut mass reflected a strong correlation with hepatosomatic (r = 0.815, p<0.01) and showed a weaker negative relationship with that of Zihler's index (r = -0.08) in fingerling stage. Correlations of gut morphometric parameters in yearling stage of *O. mykiss* showed total length is highly correlated with standard length (r = 0.903, p<0.01) followed by weight (r = 0.868, p<0.01), gut length (r = 0.672, p<0.01), liver weight (r = 0.647, p<0.01), intestinal length (r = 0.646, p<0.01) and gut weight (r = 0.379, p<0.01). The Pearson's relation for gut morphometric parameters in table size stage showed total length has higher significant relation with standard length (r = 0.970, p<0.01) followed by weight (r = 0.853, p<0.01), gut weight (r= 0.727, p<0.01) and a significant relation of total length with liver weight was observed (r = 0.362, p<0.05). Relative length of gut in broods has a strong connection with Zihler's index (r = 0.859, p<0.01) and is highly significant followed by intestinal coefficient (r = 0.477, <0.01), gastrosoamtic index (r = 0.493, p<0.01) and relative length of gut showed negative relation with hepatosomatic index. The intestinal coefficient in brood stage has a highly significant relation with Zihler's index (r= 0.700, p<0.01).

Keywords: Broods, correlation, fry, fingerling, intestine, kokernaag, *O. mykiss*, ziher's index

Introduction
Fish morphometrics has been a focus of ichthyological research for many years, although Galileo Galilei took the first steps in this field (Froese 2006) [4]. Fulton (1904) [6] established the scientific foundation for fish morphometry, particularly the mathematical relationship between weight and length and the integration of fisheries research into "allometry." These days, the most widely accepted and applied relationships for the majority of fishes are those that relate weight to body length (most commonly, total body length; in some cases, standard; and in others, fork; length). Power type correlations exist between length (TL) and weight (W), i.e., W = a Lb (Binohlan & Pauly, 2000 [2]; Froese & Pauly, 2011) [5]. Alimentary canal morphology and metrics also share the samec stragey and the teleost's, which today make up a significant portion of the human food supply, are adapted to all varieties of aquatic habitats and exhibit a wide range of feeding behaviour. The digestive tracts of fish exhibit a great range of morphological and functional traits, which are related to varied feeding habits, taxonomy, body shapes, weight, size, and sex. The improvement of fish nutrition protocols and understanding of fish digestive physiology depend increasingly on knowledge of the shape of teleosts' alimentary canals. Identification and comprehension of digestive tract structure are crucial for comprehending the mechanics of how histo-physiological and nutritional activities are connected. The digestive systems of fish are less well understood than those of mammals.



An excellent strategy to increase larval survival is to provide an adequate supply of acceptable food in good quality and quantity throughout the early larval stages. Due to the size and composition of the food, lack of understanding of the development of the digestive system, lack of understanding of the digestive enzyme profile, and insufficient digestibility, larvae do not accept designed diets. According to studies, the presence of digestive enzymes is a crucial sign of a larvae's capacity to thrive on formulated meals. The approach used by the alimentary canal (AC) in fish and vertebrates is the same (Wilson and Castro, 2010) [18]. Different fish gastrointestinal system morphologies are correlated with various phylogenies, ontogenies, food compositions, and habitats (Kozaric *et al.*, 2007; Hernandes *et al.*, 2009; Santos *et al.*, 2015; Xiong *et al.*, 2011) [8, 7, 12, 9]. Rainbow trout have very few physical adaptations for capturing and digesting meals while being largely carnivorous. Teeth are small and basic, lacking any further complex structures to capture, hold, or swallow prey. Salmonids swallow their food whole through a wide esophagus and Y-shaped stomach. The multiple pyloric caeca frequently have taxonomic importance among the various salmonid species. Near the pyloric end of the midgut, they branch. In the fat and connective tissue surrounding the pyloric caecae, the pancreas is diffusely scattered and challenging to see. The bile duct from the gall bladder to the upper midget may typically be followed in bigger specimens. The middle lobe of the liver is where the gall bladder starts. The midget and the hindgut blend together without any obvious differentiation. Other visceral organs include a kidney that is dorsal to the swim bladder and runs the full length of the visceral cavity, as well as a swim bladder with a thin, nearly transparent wall. The kidney covers the dorsal aorta and encloses the posterior vena cava on the ventral side of the spinal column. The urine channels on the kidney's ventral surface are normally visible. They converge somewhat anterior to the posterior end of the kidney and descend as a single duct around one side of the swim bladder. This portion of the urine duct that descends is enlarged to form the urinary bladder. The testicles and bladder are both connected to the urethra in mature males.

The gonads develop dorso-laterally in anterior visceral cavities in both sexes, but there are no ducts connecting the ovaries to the urogenital papilla, so eggs are simply shed into the visceral cavity. The only significant organ that has not been covered is the spleen. This is connected to the salmonids' primary visceral mass on the underside and is situated ventrally, directly above the pelvic fins. The rainbow trout typically serves as a representative of salmonids in general. It is a typical carnivorous fish with strong swimming abilities for catching prey, an easily extendable posterior stomach for swallowing fairly large prey, and a short intestine for processing food with little to no indigestible material. It is a relatively unspecialized (basic) fish. The gut is 0.6 to 0.8 times longer and shorter than other teleosts from esophagus to anus.

Alimentary Canal of *Oncorhynchus mykiss*

Carnivorous teleosts, in contrast to other fish, have unusually large stomachs and short intestines (Qu *et al.*, 2012) [10]. Numerous fish species have been studied to better understand the mechanisms of food intake, digestion, and absorption through the examination of the anatomy of their digestive tracts (Xiong *et al.*, 2011, Germano *et al.*, 2013, Lokka *et al.*, 2013) [19, 20, 9]. Establishing a feeding schedule for trout, a species that is becoming more and more important in aquaculture, might benefit from knowledge of the functional morphology of the alimentary canal. The environment in which fishes reside makes it difficult to maintain their growth, therefore improving food digestion is crucial. This is only possible by having a thorough understanding of the fishes' gut morphometry, which will help formulate the right feed (Wali *et al.*, 2022).

Sample collection

For our investigation, we collected 40 specimens from each of the five developmental phases of *O. mykiss*-fry, fingerling, yearling, table size, and brood size from the Kokernag Trout Fish Farm of the Department of Fisheries (J and K Government) in Anantnag. From June 2019 to February 2021, random fish samples were collected and delivered to the Faculty of Fisheries in Rangil in insulated boxes with ice packs. After cleaning the fish samples under running tap water, they were dried in the lab using a fresh cotton cloth. With the aid of a digital vernier calliper (True size) and an electronic weighing balance (Virgo Electronic Compact Scale), the length and weight of each individual were measured to the nearest millimetre (mm) and gramme (g), respectively. The fish's alimentary canal was visible after ventral dissection and was withdrawn for more research.

Plate A: Map of Kokernaag Trout Farm

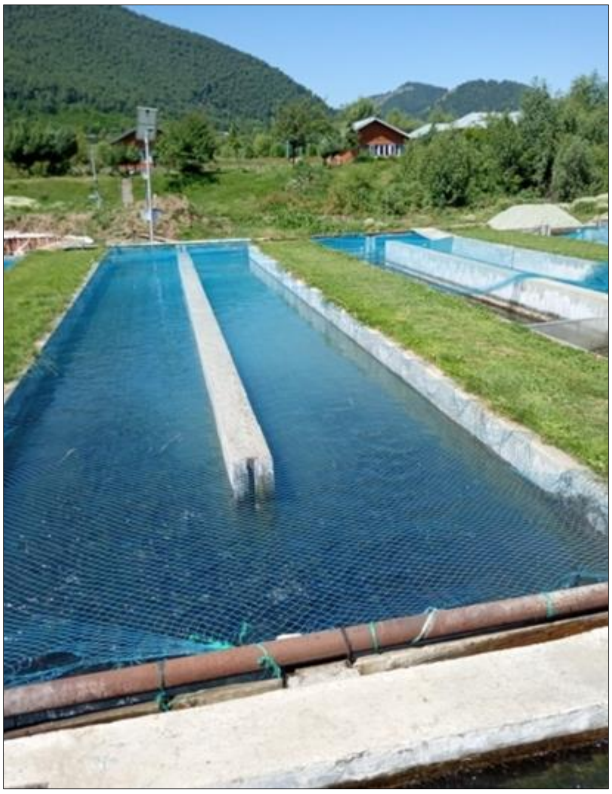


Plate B: View of Kokenaag Trout Farm C. Trout raceway

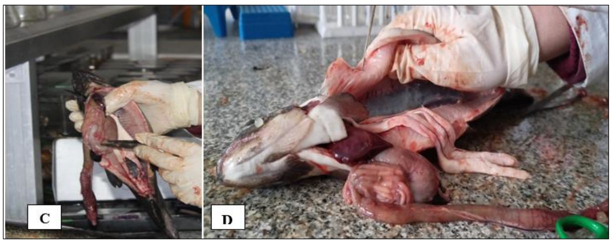


Plate A, and B: Dissecting Rainbow trout for extraction of Alimentary canal

Results and Discussion

Correlation between the total length, body weight and gut morphometric parameters in different life cycle stages of *O. mykiss*

Relationship between the total length, body weight and gut morphometric parameters of rainbow trout in fry stage are presented in table 1. The table reflects the total length has strong significant positive correlation with standard length, weight, gut weight, gut length, liver weight and intestinal length (r = 0.960, $p<0.01$, r = 0.913, $p<0.01$, r = 0.852, $p<0.01$, r = 0.743, $p<0.01$, r = 0.636, $p<0.01$ and r = 0.557, $p<0.01$). A significant correlation was also seen between the total length with gastrosomatic index, hepatosomatic index, relative gut mass and zihlers index (r = 0.339, $p<0.05$, r = 0.334, $p<0.05$, r = 0.330, $p<0.05$ and r = 0.316, $p<0.05$). A negative correlation was obtained between total length and intestinal coefficient (r =-0.062). Highly significant relation was obtained among standard length with weight, gut weight, gut length, liver weight and intestinal length (r = 0.855, $p<0.01$, r = 0.776, $p<0.01$, r = 0.710, $p<0.01$, r = 0.640, $p<0.01$ and r = 0.480, $p<0.01$) and a negative relation was reflected among the standard length and intestinal coefficient (r = -0.170). Results of the study revealed positive and highly significant relation between intestinal length and intestinal coefficient (r = 0.775, $p<0.01$) followed by relative gut length (r = 0.656, $p<0.01$) zihlers index (r = 0.648, $p<0.01$) and relative gut mass (r = 0.411, $p<0.05$). Gut weight has a positive highly significant relation with liver weight, gastrosoamtic index, relative gut mass and intestinal coefficient (r = 0.686, $p<0.01$, r = 0.688, $p<0.01$, r = 0.677, $p<0.01$ and r = 0.598, $p<0.01$). Study showed a positive significant relation among intestinal coefficient and zihlers index (r = 0.529, $p<0.05$) and a negative relation among intestinal coefficient with hepatosomatic index (r = -0.153, $p>0.05$). Relative gut mass has a positive strong correlation with gastrosoamtic index (r = 0.996, $p<0.01$).

Table 1: Correlation among the gut morphometric parameters of *O. mykiss* in fry stage

	TL	SL	WT	GL	GWT	CI	LWT	RLG	CO	RGM	ZI	HSI	GaSI
TL													
SL	0.960**												

WT	0.913**	0.855**											
GL	0.743**	0.710**	0.714**										
GWT	0.852**	0.776**	0.950**	0.688**									
CI	0.557**	0.480**	0.590**	0.801**	0.598**								
LWT	0.636**	0.640**	0.730**	0.570**	0.686**	0.384*							
RLG	0.217	0.203	0.256	0.807**	0.277	0.656**	0.280						
CO	-0.062	-0.170	0.055	0.402*	0.120	0.775**	-0.026	0.620**					
RGM	0.330*	0.215	0.441**	0.416**	0.677**	0.411**	0.326*	0.353*	0.311				
ZI	0.316*	0.318*	0.229	0.835**	0.240	0.648**	0.240	0.949**	0.529**	0.267			
HSI	0.344*	0.401*	0.356*	0.374*	0.326*	0.121	0.865**	0.249	-0.153	0.165	0.243		
GaSI	0.339*	0.226	0.441**	0.399*	0.680**	0.387*	0.319*	0.321*	0.275	0.996**	0.243	0.160	

**Highly significant P value <0.01 *Significant <0.05

Table 2: Correlation among the gut morphometric parameters of *O. mykiss* in fingerling stage

	TL	SL	WT	GL	GWT	CI	LWT	RLG	CO	RGM	ZI	HSI	GaSI
TL													
SL	0.937**												
WT	0.907**	0.946**											
GL	0.846**	0.888**	0.840**										
GWT	0.800**	0.805**	0.915**	0.745**									
CI	0.792**	0.818**	0.770**	0.942**	0.714**								
LWT	0.471**	0.468**	0.573**	0.451**	0.584**	0.462**							
RLG	0-.077	0.124	0.081	0.457**	0.071	0.452**	0.060						
CO	0.189	0.162	0.134	0.515**	0.183	0.692**	0.187	0.643**					
RGM	0.516**	0.503**	0.611**	0.481**	0.848**	0.488**	0.355*	0.043	0.157				
ZI	0.098	0.112	-0.020	0.508**	-0.041	0.509**	0.008	0.744**	0.755**	-0.059			
HSI	0.082	0.017	0.087	0.071	0.130	0.135	0.815**	-0.017	0.198	0.030	0.078		
GaSI	0.516**	0.503**	0.611**	0.481**	0.848**	0.488**	0.355*	0.043	0.157	1.000**	-.059	0.030	

**Highly significant P value <0.01 *Significant <0.05

Table 3: Correlation among the gut morphometric parameters of *O. mykiss* in Yearling stage

	TL	SL	WT	GL	G.WT	CI	L.WT	RLG	CO	RGM	ZI	HSI	GaSI
TL													
SL	0.903**												
WT	0.868**	0.843**											
GL	0.672**	0.695**	0.712**										
G.WT	0.379*	0.452**	0.571**	0.588**									
CI	0.646**	0.690**	0.695**	0.828**	0.510**								
L.WT	0.647**	0.590**	0.724**	0.619**	0.386*	0.725**							
RLG	-0.334*	-0.190	-0.132	0.471**	0.290	0.295	0.024						
CO	-0.266	-0.337*	-0.135	0.218	0.104	0.445**	0.197	0.611**					
RGM	-0.421**	-0.325*	-0.379*	-0.039	0.531**	-0.088	-0.259	0.454**	0.285				
ZI	-0.119	-0.073	-0.239	0.506**	0.123	0.288	-0.029	0.792**	0.464**	0.430**			
HSI	0.243	0.205	0.250	0.362*	0.159	0.504**	0.835**	0.183	0.381*	-0.022	0.190		
GaSI	-0.421**	-0.325*	-0.379*	-0.039	0.531**	-0.088	-0.259	0.454**	0.285	1.000**	0.430**	-0.022	

**Highly significant P value <0.01 *Significant <0.05

Table 4: Correlation among the gut morphometric parameters of *O. mykiss* in Table size stage

	TL	SL	WT	GL	GWT	CI	LWT	RLG	CO	RGM	ZI	HSI	GaSI
TL													
SL	0.970**												
WT	0.853**	0.850**											
GL	0.426**	0.464**	0.455**										
GWT	0.727**	0.719**	0.777**	0.431**									
CI	0.633**	0.656**	0.459**	0.534**	0.521**								
LWT	0.362*	0.403**	0.493**	0.359*	0.620**	0.293							
RLG	-0.523**	-0.466**	-0.358*	0.532**	-0.298	-0.095	-0.017						
CO	0.047	0.048	-0.084	0.315*	0.111	0.784**	0.063	0.245					
RGM	0.007	0.013	-0.102	0.047	0.525**	0.231	0.309	-0.004	0.308				
ZI	-0.311	-0.281	-0.411**	0.618**	-0.224	0.141	-0.049	0.855**	0.403**	0.157			
HSI	-0.324*	-0.282	-0.339*	0.000	-0.002	-0.055	0.633**	0.280	0.163	0.439**	0.319*		
GaSI	0.037	0.035	-0.089	0.049	0.546**	0.231	0.315*	-0.033	0.290	0.991**	0.151	0.436**	

**Highly significant P value <0.01 *Significant <0.05

Table 5: Correlation among the gut morphometric parameters of *O. mykiss* in Brood size stage

	TL	SL	WT	GL	GWT	CI	LWT	RLG	CO	RGM	ZI	HSI	GaSI
TL													
SL	0.891**												
WT	0.316*	0.471**											
GL	0.250	0.303	0.092										
GWT	0.436**	0.504**	0.341*	0.652**									
CI	0.206	0.236	0.167	0.877**	0.644**								
LWT	0.230	0.246	0.391*	-0.233	0.039	-0.252							
RLG	-0.278	-0.163	-0.093	0.859**	0.409**	0.754**	-0.351*						
CO	-0.269	-0.285	-0.090	0.704**	0.357*	0.862**	-0.374*	0.832**					
RGM	0.299	0.312*	-0.054	0.641**	0.909**	0.583**	-0.112	0.477**	0.399*				
ZI	0.080	0.070	-0.341*	0.902**	0.456**	0.746**	-0.399*	0.859**	0.700**	0.617**			
HSI	0.094	0.024	-0.099	-0.339*	-0.140	-0.378*	0.866**	-0.378*	-0.382*	-0.103	-0.293		
GaSI	0.307	0.325*	-0.066	0.662**	0.909**	0.596**	-0.128	0.493**	0.406**	0.994**	0.643**	-0.116	

**Highly significant P value <0.01 *Significant <0.05

Pearson's relation among various gut parameters of *O. mykiss* in FL stage is given in table 2. Relation between SL and TL is highly significant (r = 0.937, *p*<0.01); followed by strong correlation between SL and WT (r = 0.907, *p*<0.01) SL and GL (R = 0.846, *p*<0.01); SL and GWT (r = 0.800, *p*<0.01); SL and CI (r = 0.792, *p*<0.01); SL and RGM (r = 0.519, *p*<0.01); SL and GaSI (r = 0.516, *p*<0.01); SL and LWT (r = 0.471, *p*<0.05) and SL showed a negative correlation with RGL (r = -0.077) and a weak correlation between SL and HSI (r = 0.082). Correlation of *O. mykiss* weight with SL is (r = 0.946, *p*<0.01) is highly significant followed by GL (R = O.888, *p*<0.01); CI (r = 0.818, *p*<0.01); GWT (r = 0.805, *p*<0.01); RGM (r = 0.503, *p*<0.01); GaSI (r= 0.503, *p*<0.01) and LWT (r = 0.468, *p*<0.05) is significant and weight reflected a weak correlation with ZI (r = 0.112). RGM reflected a strong correlation with HSI (r = 0.815, p<0.01) and showed a weaker negative relationship with that of ZI (r= -0.08). Whereas ZI showed a higher correlation with RLG (r= 0.744, *p*<0.01) fallowed by CO (r = 0.643, *p*<0.01) and showed a negative relationship with HSI (r = -0.17). But HSI has a positive high significant relation with ZI (R= 0.755, *p*<0.01). GaSI showed a perfect high significant correlation with RGM (r = 1.00, *p*<0.01). Also HSI has a negative relation with GaSI (r =-.0.59). The correlation of gut morphometric parameters in YL stage of *O. mykiss* is presented in table 3. The TL was seen highly correlated with SL (r = 0.903, *p*<0.01); followed by wt (r = 0.868, *p*<0.01); GL (r = 0.672, *p*<0.01); LWT (r = 0.0.647, *p*<0.01); CI (r =0.646, *p*<0.01); GWT (r = 0.379, p<0.01). TL showed negative relation with RLG (r = -0.334); CO (r = -0.266); RGM (r= -0.421); GaSI (r = -0.421) and ZI (r = -0.119). SL showed a higher significant correlation with WT (r = 0.843, *p*<0.01); followed by GL (r = 0.695, *p*<0.01); CI (r = 0.690, *p*<0.01); LWT (r = 0.590, *p*<0.01) and GWT (r = 0.452, *p*<0.05) was significant. SL reflected negative correlation with RLG (r = -0.190); CO (r = -0.337); RGM (r= -0.325); ZI (r = -0.273) and GaSI (r = -0.325). WT of O. mykiss has a strong highly significant correlation with LWT (r = 0.724, *p*<0.01); followed by GL (r = 0.712, *p*<0.01); CI (r = 0.695, *p*<0.01); GWT (r = 0.571, p<0.01). The WT showed negative relation with RLG (r =-0.132); CO (r = -0.135); RGM (r = -0.379); ZI (r = -0.239) and GaSI (r = -0.379). GL showed higher correlation with CI (r = 0.528, *p*<0.01) followed by LWT (r = 0.619, p<0.01); GWT (r= 0.588, p<0.01); ZI (r= 0.506, *p*<0.01); RLG (r= 0.471, *p*<0.05); HSI (r= 0.362, *p*<0.05) and showed a negative relation with RGM (r= -0.39) and GaSI (r = -0.39). RGM is perfectly correlated with GaSI (r =1.00, *p*<0.01) showing high significance and with ZI showed also high significance (r = 0.430, *p*<0.01). Whereas HSI is negatively related with GaSI (r = -0.22) in YL stage.

The Pearson's relation for gut morphometric parameters in TS is given in table 4. The TL has higher significant relation with SL (r = 0.970, *p*<0.01) followed by WT (r = 0.853, p<0.01); GWT (r = 0.727, *p*<0.01); CI (r= 0.633, *p*<0.01); GL (r = 0.426, *p*<0.01) and a significant relation of TL with LWT was observed (r= 0.362, *p*<0.05). TL also showed a weaker correlation with CO (r = 0.047); RGM (r = 0.007) and GaSI (r = 0.037) followed by a negative relationship with ZI (r = -0.311) and HSI (r = 0.324). The SL is highly correlated with WT in TS stage (r = 0.850, *p*<0.01) followed by GWT (r = 0.719, *p*<0.01); CI (r = 0.656, *p*<0.01); GL (r = 0.464, *p*<0.01); LWT (r = 0.403, <0.01). SL has a negative relation with the ZI (r= -.0281) and HSI (r = -0.282). *O. mykiss* weight has a high significant relation with GWT (r= 0.777, *p*<0.01) followed by LWT (r = 0.493, *p*<0.01); CI (r= 0.459, *p*<0.01); GL (r = 0.455, *p*<0.01). Fish weight in TS stage reflected a negative relation with following parameters: RLG (r = -0.358); CO (r = -0.84); RGM (r = -0.102); HSI (r = -0.339) and GaSI (r = -0.89). Gut length in TS stage has a highly significant relation with ZI (r = 0.618, *p*<0.01) followed by CI (r = 0.534, *p*<0.01); RLG (r = 0.532, *p*<0.01); GWT (r = 0.431, *p*<0.01) and has a significant relation with WT (r = 0.359, *p*<0.05) and CO (r = 0.315, *p*<0.05).

The correlation of gut morphometry of broodsize stage is given in table 5. The relationship between TL and SL is highly significant (r = 0.891, *p*<0.01) followed by GWT which also reflected high significant relation (r = 0.436, *p*<0.01). The total length in broods also reflects significant bonding with WT (r = 0.316, *p*<0.05). TL with RLG (r = -0.278) and CO (r = -0.269) showed negative relation. SL in broods showed highly significant relation with GWT (r = 0.504, *p*<0.01) and WT (r= 0.4711, *p*<0.01) and a significant relation was seen in case of GaSI (r = 0.325, *p*<0.01) and RGM (r = 0.312, *p*<0.05). The RLG in broods has a strong connection with ZI (r = 0.859, *p*<0.01) and is highly significant followed by CO (r = 0.477, <0.01) and GaSI (r= 0.493, *p*<0.01) and RLG showed negative relation with HSI. The intestinal coefficient CO in BS stage has a highly significant relation with ZI (r = 0.700, *p*<0.01) and has a significant correlation with RGM (r = 0.399, *p*<0.05); GaSI (r = 0.406, *p*<0.05) and CO has negative relation with HSI. RGM has a strong high significant correlation with GaSI (r = 0.994, *p*<0.01) and ZI (r = 0.617, *p*<0.01). RGM has a negative relation with HSI (r = -0.103). ZI has a highly significant relation with GaSI (r = 0.643, $p<0.01$) and negative relation with HSI (r = -0.293). HSI has a negative relation with GaSI (r = -0.116). Intestinal length and eating preferences are connected, more so in iliophagous, herbivorous, and omnivorous fish species and less so in carnivorous and insectivorous fish species. The intestine, the principal organ involved in digestion, is essentially a tube where food travels, digestion takes place in an alkaline environment, and nutrient absorption happens as a result (Canan *et al.*, 2012) [3]. According to this pattern, high CO levels are linked to herbivorous species, whereas intermediate levels are linked to omnivore species and low levels are linked to carnivorous fish species (Canan *et al.*, 2012) [3]. Throughout the course of the investigation, a strong link between fish weight and gut length was seen. The anatomy of the alimentary canal is heavier in *O. mykiss* because it is an energetic fish that consumes its food with a voracious appetite. Fish weight and gut length were shown to be significantly correlated throughout the study. Due to its busy lifestyle and voracious appetite, *O. mykiss* has a heavier alimentary canal structure than other fish. This is indicated by a measure termed relative gut mass, which is primarily used to gauge the amount of digestive tract tissue in fish. Due to the rise in feeding intensity from the fry to adult stages, the RGM in our study had a strong correlation with the GaSI and a substantial relationship with the Zihlers index. According to Raiz and Naeem (2020) [11], the relative gut mass of W. aatu correlated favorably with gut weight. In all the stages of *O. mykiss* under study, RGM was also discovered to be highly associated with gut weight, and thus this is appropriate given that it generally supports this study.

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