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An investigation on growth of scales in *Heniochus acuminatus* (Linnaeus, 1758)

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Abstract
The present investigation concerns with the growth of scales of *Heniochus acuminatus*. In this study, nine body regions of fish were selected. Scales of selected regions were collected and slides were prepared after proper cleaning and dehydration of scales. Each slide was studied under the microscope and different scale parameters were measured and counted. The results of regression analysis of different parameters show that all scale parameters were moderately (r=0.51-0.69) to strongly correlated ($r \geq 0.80$) with scale length and scale width. All results were found to be highly significant at α=1% (p<0.01). From the results of this study, it can be concluded that all scale parameters were correlated with each other and these scale parameters also growing in their size or numbers with the growth in scale length and scale width in *H. acuminatus*.

Keywords: Scale growth, regression analysis, *Heniochus acuminatus*, Pakistan

1. Introduction
Heniochus acuminatus belongs to order Perciformes, family Chaetodontidae. In Pakistan, known as Pari or Rani-koi in Sindhi language and Dateera in Balochi language [1]. They are reef-associated fishes and also reported from brackish areas, from 2-178m depth. They are Indo-Pacific and reported from East Africa, Persian Gulf, Society Islands, Japan. Common length is about 15cm TL [2]. Body strongly compressed, white with two wide black bands. Dorsal fin having XI-XII spines and 24-27 soft rays. Fourth dorsal spine is elongate and forms a long filament. Anal fin with III spines and 15-18 soft rays [1]. *H. acuminatus* is a popular aquarium fish but less value as food fish [3].
Teleost fishes have flexible, calcified plates called the scales. These scales provide protection, reduced the fraction and also store the minerals and nutrients for fish [4]. According to Johal *et al*. (2014) [5] morphometric study of fish scales could be helpful in taxonomy and phylogeny of fishes. Further, Johal (2015) [6] confirms the authenticity of the studies on scale type, scale morphology and morphometry, arrangement of scales in fish identification. However, there is no published work accessible on the growth of scales of *Heniochus acuminatus.* Therefore, to fill this space of information, this study provides the basic information about the growth of scale parameters in relation to their scale length and scale width.

2. Materials and Methods
2.1 Collection of fish sample
The sample of *Heniochus acuminatus* (18.5cm TL) was collected from the commercial catch of Karachi fish harbour (24.84 ^{0}N, 66.97 ^{0}E), Pakistan.

2.2 Collection of scale samples
To study the variations in scales and the growth of different parameters of scale, body of fish was divided into nine regions and a total of 109 scales were collected from these regions (Figure 1).

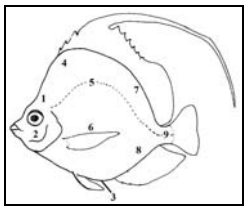

Fig 1: Showing nine body regions selected for scale collection. (Modified from Fisher & Bianchi, 1984) [3]

2.3 Preparation of scale slides

Scale slides were prepared after Musarrat-ul-Ain *et al.* (2016) [7]. Fish scales of each selected body region were placed in 10% NaOH for 2mins and the mucous and dirt particles on scale surface were removed with the help of a soft brush. Clean scales were dehydrated with different grades of Alcohol (30%, 50% and 70%). Scales were placed on a glass slide and covered with another glass slide and the edges were bound with masking tape. Each slide was labeled with their respective body region. Prepared slides were studied under microscope and different parameters of scales were measured or counted.

2.4 Selected scale parameters for study

Six scale parameters were selected to study the growth of scales (Figure 2).

TLS= length of scale
WDS= width of scale
Rs= distance from focus to outer margin of scale
HRS= number of ctenii in horizontal row
VRS= number of ctenii in vertical row
RDS= number of radii

2.5 Statistical analysis of data

Firstly, all data was entered in MS Excel 2016 and then statistical analysis of data was carried out with the help of Statistical software Minitab 17 [8].

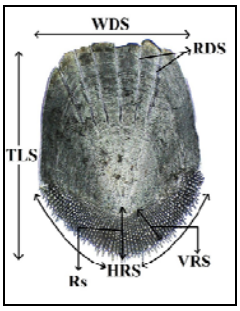

Fig 2: Showing selected parameters of scales of *Heniochus acuminatus*.
TLS= scale length, WDS= scale width, Rs= distance from focus to outer margin, HRS= horizontal row of ctenii, VRS= vertical row of ctenii, RDS= radii

3. Results and Discussions

The results of regression analysis of scale length (TLS) and selected scale parameters (*i.e.*, WDS, Rs, HRS, VRS and RDS) of *Heniochus acuminatus* are presented in Table 1. The results of present study show the strong correlation (r≥0.80) between scale length (TLS) and scale width (WDS). This strong correlation between scale length (TLS) and scale width (WDS) specify that the growth of length (TLS) is strongly related to the growth of scale width (WDS). While, the results show moderate correlation (r=0.51-0.69) for the growth of scale length (TLS) and growth of distance from the focus to the outer margin of scale (Rs), number of ctenii in vertical row (VRS) and the number of radii (RDS). However, the results of present investigation illustrate high correlation (r=0.70-0.79) between the growth of scale length (TLS) and the growth of number of ctenii in horizontal row (HRS). All results are found highly significant (p<0.01), which confirms that all selected parameters of scales (*i.e.*, WDS, Rs, HRS, VRS and RDS) grows significantly in their size or numbers with the growth of scale (TLS).

The results for the regression analysis of scale width (WDS) and selected scale parameters (*i.e.*, Rs, HRS, VRS and RDS) of *H. acuminatus* are shown in Table 2. The results of present study demonstrate a moderate correlation (r=0.51-0.69) between the growth of scale width (WDS) and the growth of distance from the focus to the outer margin of scale (Rs) and the number of radii (RDS). Whereas, the relationship between the growth of scale width (WDS) and the growth of number of ctenii in horizontal row (HRS) observed as strong relation (r≥0.80). While, the growth of scale width (WDS) and the growth in number of ctenii in vertical row (VRS) found highly correlated (r=0.70-0.79). The p-value of each relationship was obtained less than the specified level of significance (p<0.01) which approves that all selected parameters of scales (*i.e.*, Rs, HRS, VRS and RDS) grows significantly in their size or numbers with the growth of width (WDS).

Previously, several scientists have worked on deferent aspects of fish scales, such as; Ikoma *et al.* (2003) [9] have defined the microstructure, mechanical and biomimetic properties of fish scales. Sire and Akimenko (2004) [10] described the scale structure, its origin and the formation of scales. Jawad and Al-Jufaili (2007) [11] studied the morphology of fish scales helpful in fish taxonomy. Saddozai *et al.* (2015) [12] found weak correlations between fish length and scale length of *Cirrhinus mrigala.* Kanwal *et al.* (2015) [13] studied weak correlation between fish size and scale size while, moderate correlation was observed between scale length and scale width in *Labeo rohita.* Though, the results of present investigation show the moderate to strong correlations between the selected scale parameters of *Heniochus acuminatus* and represent that the growth of scale parameters are related to each other.

Table 1: Regression analysis between scale length (TLS) and different selected scale parameters of *Heniochus acuminatus*.

						Significance of correlation			
X	**Y**	**a**	**b**	**r**	**r^2**	**S.E (b)**	**t-test**	**p-value**	**CT**
TLS	WDS	0.184	0.853	0.819	67.08	0.0578	14.77	0.000 [a]	***
TLS	Rs	0.918	0.1345	0.541	29.3	0.0202	6.66	0.000 [a]	*
TLS	HRS	23.65	7.714	0.728	53.03	0.702	10.99	0.000 [a]	**
TLS	VRS	4.57	1.797	0.66	43.52	0.198	9.08	0.000 [a]	*
TLS	RDS	1.123	1.067	0.554	30.66	0.155	6.88	0.000 [a]	*

[a] shows highly significant (p<0.01), *** shows strong correlation (r≥0.80), ** shows high correlation (r=0.70-0.79), * shows moderate correlation (r=0.51-0.69).

Table 2: Regression analysis between scale width (WDS) and different selected scale parameters of *Heniochus acuminatus*.

						Significance of correlation			
X	**Y**	**a**	**b**	**r**	**r^2**	**S.E (b)**	**t-test**	**p-value**	**CT**
WDS	Rs	0.9693	0.1414	0.593	35.13	0.0186	7.61	0.000 [a]	*
WDS	HRS	22.49	8.941	0.879	77.29	0.469	19.08	0.000 [a]	***
WDS	VRS	5.442	1.853	0.708	50.2	0.178	10.38	0.000 [a]	**
WDS	RDS	1.242	1.181	0.638	40..71	0.138	8.57	0.000 [a]	*

[a] shows highly significant (p<0.01), *** shows strong correlation (r≥0.80), ** shows high correlation (r=0.70-0.79), * shows moderate correlation (r=0.51-0.69).

4. Conclusions

It is concluded from the results of present investigation that growth of all scale parameters are correlated with each other. Scale parameter (*i.e*., Rs, HRS, VRS and RDS) grows in their size or numbers with the growth of scale length (TLS) and scale width (WDS) in *Heniochus acuminatus*.

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