AN OBSERVATION OF FRACTAL INTEGRITY IN SCALE STRUCTURE OF COLORFUL GUPPY (*POECILIA RETICULATA*)

KHUSHBU VITHTHALANI, B. B. RADADIYA, V. C. SONI

Abstract: The scale structure symmetry among different color strains of guppy (*Poecilia reticulata*) was analyzed based on fractal dimension, using math base software Matlab. Fractal geometry deals with, on a basis level, repeating fractured structure that shows the similarity and similar complexity for any scale that they observed. Many facets of fractal geometry can be observed for cell structure in biological system. Different color strains of guppy including albino red, AOC bi-color and half colors were analyzed for similarity of their scale structure. Regarding to this same scale of color strain is also compared with female guppy individually. Results drawn from the statistical analysis i.e. ANOVA and t-test ($P < 0.05$) were reported to accept the null hypothesis, simulated to frame structural similarity (Fractal pattern) among colorful guppies. The study thus reveals that fractal arrangement of guppy scales generalized to conspicuous and cryptic color pattern and later may evolve to meet adaptive behavior. Thus present calculus supports the prior findings; expression of diverse color pattern among guppies is subjected to natural selection.

Keywords: Fractal, Guppy, scale, MatLAb, Natural selection.

Introduction: The conspicuous and cryptic color pattern formation in *Poecilia reticulate,* the guppies which is best explained for evolutionary aspect [1]. The color variation among fancy guppy has been found to be a great interest for their polymorphic variety. Cited literatures draw the review about expression of different gene and there by different color pigment cells, which are responsible for color variation among male guppies [2]-[3]. A color pattern is regarded as mosaic and color spot or patches of various size and shape [4]. The ample simulations have been made and proved that the chromatophore cells are responsible for color pattern [2]. Field observations defined that the pigment color as a Cryptic matches with the ground and conspicuousness is for sexual selection [1]. Regarding to these facts the skin structure with respect to color variation of fancy Guppy was patterned for the fractal arrangement in their skin structure and related fractal dimension was measured.

Skin Structure of Guppy: As shown in figure 1; the cellular layers of the guppy skin consist of an epidermis, dermis, and hypodermis. The scales are colorless while most of the skin is translucent. The Chromatophore cells which are arranged in between different skin layers are responsible for color variation among guppies. The pigmentation is observed to be in dermis [5]. The histological studies revels structural integrity forming by symmetrically arranged scale along with different chromatophore cells, made up with different pigments. Multiple Pigments (i.e. Xenthophore, Melenophore and Iridophores) were postulated previously, are contributing in Male guppy to provide mate choice [3]. This polymorphism emphasis great diversity among different strains of Guppy as physically, they are isolated. The study of these color cells shows evolutionary behavior that reflects the natural selection [1]. No Authentic technique has been listed showing interlink the geometry of structural integrity of different color cells among male Guppies.

Withstanding this review the skin color of different guppies was subjected for their structural geometry using the concept of fractals by calculating Fractal dimension. The hypothesis has been set up to stipulate the fractality and dimension symmetry of scale structure among polymorphic Guppy. The Guppies with different color strains viz solid color to combinations of half color were selected (Table 1) from authentic database [6] and blogs [7]-[8]-[9]-[10]-[11]-[12]. Different color strains of male with female; Solid complete strains to half strains were compared for their fractal dimension. As explain later the fractal dimension measures the complex symmetry forming specific patterns in structure and possibly collects the information from all possible scales [13]. Thus this recent approach may support the adaptive color changes among guppies and its evolutionary behavior.

Fractals, Fractal geometry and Fractal Dimension: Fractals are defined as a self-similar pattern and is best explained by its complexity, the fractals are creatures that maintain their complexity at different magnification. The root of Fractal was first developed by Mandelbrot [14]. The word came from Latin word *fractus*, means fractured. Many objects in nature and Biological systems follow the subtle pattern of fractals [13]. The fractal integrity is best explained by calculating its dimension, termed fractal dimension. The well-known Box counting method is used to calculate the fractal dimension [15].

Box counting method [16]: Box method or grid method is based on algorithm to calculate the fractal dimension. In theory the method involves to cover an object with definite space structure i.e. pixels. This can be calculated as N, the total no of space fills required to cover an object. Alternatively the practical method consists of implantation of grid of pixel with definite size ε. Thus algorithm can be drawn for final calculation as;

$$D = \varepsilon \overset{lim}{\longrightarrow} 0 \frac{\ln N\ (\varepsilon)}{\ln {}^{1}/_{\varepsilon}}$$

Where N (ε) is the number of square grid with ε size required to cover whole object, the formula derived from the scaling law $N(\varepsilon) = C\left({}^{1}/_{\varepsilon}\right)^{D}$

Where, D is the dimension in which one need ${}^{C}/_{\varepsilon}$ boxes of side length ε for each one of the dimension D of the object to be covered and C is the constant. Thus, the linear equation is obtained from the Scaling law,

$$\ln N(\epsilon) \quad = \quad D \ln\left(\frac{1}{\varepsilon}\right) \quad + \quad \ln C$$

The above formula stated that the constant term ε independent, is negligible when ε ⇒0, thus it's also clear that the fractal dimension only consider the wide range of scales. The linear algorithm is giving clear appearance about the pixels, needed to cover the object, which in practice should not be less than zero. In our measurement the side size ε of pixel is 448 × 336 px.

Measurement: The photographic images (Fig. 3) from authentic blogs of guppies were selected for each sample of guppy, shown in table 1.Summative sample collection was done by collecting at least ten high resolution photographs for each sample. The each photograph further modified by image analyzer software and converted into black and white image. The final images provide the counter part that was detected by FD analyzer and final calculation of FD was done by importing the images in mathematical software; MatLAb (2015a). The MatLAb considers only the counter part of black on white object or vice versa. The fractality from each scale of an object was measured in state of fractal dimension.

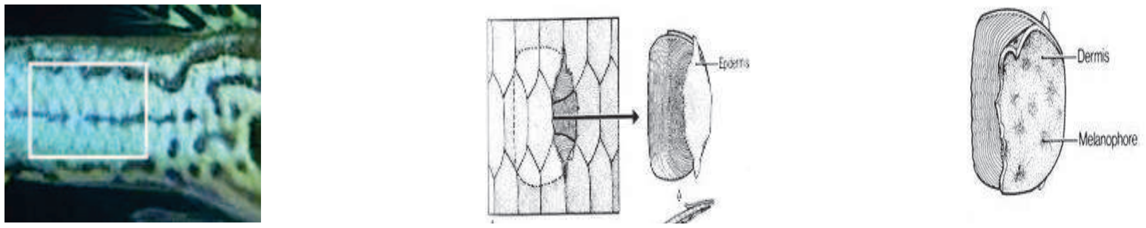
As fractal dimension is measurement of space filling details, the FD may apply in order to compare the geometrical symmetry among different color strains of guppy. The stipulated null hypothesis were checked and drawn positively from statistical analysis.

Results: The mean FD value obtained from female is 1.8555 and among different strains of male the highest FD value is 1.8675 (Yellow strain) and lowest is 1.7698 (Green); all the mixtures of bicolor express FD value around 1.80 (Except Black Yellow, FD = 1.8874). The graph (Fig. 2 a) shows the comparative account of mean FD value between different male strains and female; among the different strains of male. The peak for mean FD value of male is found to be closer or above that of female (Yellow – 1.8675). The male strains show variation in their mean FD values. The comparison was also made for half color strain with pure color. Graph (Fig 2 b) shows the mean FD value of different half black strains. With respect to mean FD value of Black color, the FD value of all half black strains is found to positively vary from of black color (Black – 1.7978).

The obtained value of fractal dimension of color structure of different guppies favors for statistical tests and fit to the null hypothesis positively. Table 3 shows the comparative results of statistical tests.

Conclusion and Discussion: The different color strains of fancy Guppy, *Poecilia reticulata* were subjected for fractal integration of pigment cells, responsible for color variation. The complex similarity of pigment cell arrangement among various Guppies can be established in terms of fractal dimension. The equality in mean FD value exhibits the reintegration of common basic self-similar pattern i.e. fractal pattern for the means of adaptation. Statistical results (Table 3) support the previous foundation i.e. different pigment cells involved in formation of color variation [3], which can be reflect in distinct mean value of fractal dimension of different color strains (Fig 2b). Statistical tests (Table 3) signify the structural geometrical symmetry of different strains of Guppy though they are found in various geographical regions. Results regarding the FD value of variety of Guppies are clearly emphasizing the complete literature of molecular, morphological and genetic studies [17]. Thus Guppies are found to having self-similar structure, which further modify among male guppies to show the cryptic or conspicuous behavior. Thus Fractal data are found to be supportive tool; to be added in complete description of color variety of fancy Guppies.

The documented results of Guppies with respect to their fractal cell structure and fractal dimension provides preliminary data. Though the fractal shows the detail expression about color cell formation in Guppies, these can't explain the complete biology behind that. Withstanding this issue the program was initiated to introduce the idea of fractal description shown by different living processes [13] and where the living organism subjected to their ecological behavior.



(a) (b) (c)

Fig. 1: (a) The skin structure of Guppy showing (b) Epidermis (c) Dermis with pigment (Melenophore) [5].

Table 1: Different color strains of male Guppies along with female

Solid Colour (Male)		Bi-colour (Male)	
AOC Bi-Color	Female	Half black AOC	Black Male
Albino red		Half Black RED	
Blue		Half Black Blue	
Green		Half Black Green	
Purple		Half Black Purple	
Yellow		Half Black yellow	
Multi		Half black Pastal	
		Red Bi-colour	
Snakeskin		Blue - Green Bi-colour	

Table 2: The mean FD value of selected samples of Guppies with their SE and SD

S. N.	Color pigment	Mean	std error	std dev	Bi color	Mean	std error	std dev
1.	Albino red	1.8263	0.01673	0.05291	AOC Bi color	1.842	0.019175	0.06064
2.	Black	1.7978	0.01403	0.04435	Blue-Green Bicolor	1.7977	0.018743	0.05927
3.	Blue	1.805	0.02146	0.06787	Red Bicolor	1.8069	0.004916	0.01555
4.	Green	1.7698	0.02164	0.06842	Half black AOC	1.8344	0.017103	0.05408
5.	Purple	1.8399	0.02267	0.0717	Half Black Blue	1.8107	0.016695	0.05279
6.	Yellow	1.8675	0.01508	0.04769	Half Black Green	1.8026	0.008374	0.02648
7.	Multi	1.835	0.01952	0.06174	Half black Pastal	1.8085	0.024036	0.07601
8.	Snakeskin	1.8097	0.02333	0.07379	Half Black Purple	1.8114	0.005877	0.01858
9.	Females	1.8556	0.01893	0.05987	Half Black Red	1.8113	0.009977	0.03155
					Half Black Yellow	1.8874	0.02594	0.08203

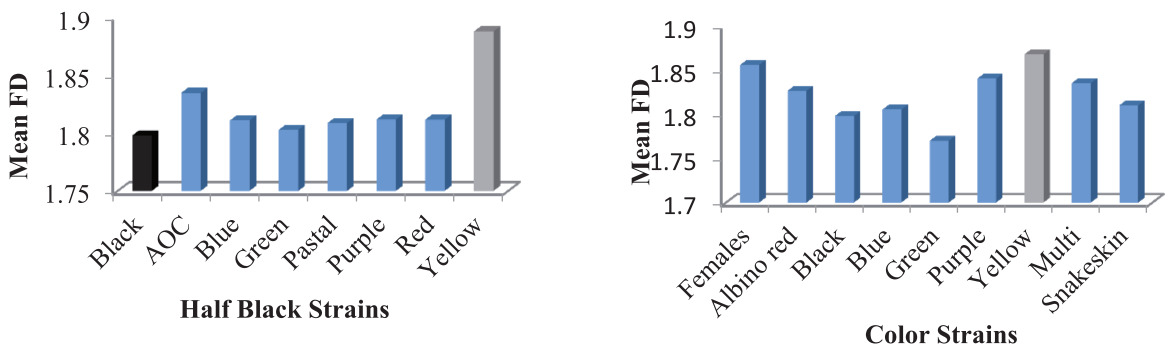


Figure 2: (a) Mean FD value of different half different strains; (b) Mean FD value of different color strains with female guppy.

Table 3: Statistical results for different color strains of Guppy

S.N.	Statistical Result	Statistical Test	P Value ($\alpha = 0.05$)	
1.	Different color Strains	ANOVA	$P < 0.05$	$\mu \neq \mu_0$
2.	Different Half-Black strains with Black strain	ANOVA	$0.05 > P = 0.01$	$\mu = \mu_0$
3.	Different strains of Blue - Green Bi- Color	ANOVA	$0.05 > P = 0.01$	$\mu = \mu_0$
4.	Female with different color strains	F- Test	$P > 0.05$	Variance are equal
5.	Female with different color strains	t - Test (Assuming Equal Variance)	$P > 0.05$	$\mu = \mu_0$
6.	Female with Black color strains	t - Test (Assuming Equal Variance)	$P < 0.05$	$\mu \neq \mu_0$

Figure 3: Plates of different color strains of Guppy *Poecilia reticulate* [6]-[10]-[11]

References:

1. *Hanchinmani, C. N, Imamsaheb, S. J,* Influence of Ga3 and Different Date of Sowing on Growth, Yield and Economics of Radish (*Raphanus Sativus*) ; Life Sciences International Research Journal , ISSN 2347-8691, Volume 2 Issue 2 (2015): Pg 130-132
2. Endler, John A.(1980). "Natural Selection on Color PAttern in Poesillia reticulata." Evolution, Vol.34, Issue I: 76-90.
3. S Desai ,Dhanshri J Gadgil, Richard V Peter, Fiza Arjuman S, Kavitha. A, ,Basavaraj S Hungund, Isolation of Tannase Producing Fungi and Partial Savitha; Life Sciences International Research Journal , ISSN 2347-8691, Volume 1 Issue 1 (2014): Pg 267-270
4. Painter, K. J. (n.d.). "Models for pigment pattern formation in the skin of Fishes." IMA Volume MAths & Apps: 59-82.
5. Verena A. Kottle, Iris Koch, Malthias Flotenmeyer, Hisashi Hashimoto.(2014). "Multiple Pigment Cell types contribute to the Black, Blue, and Orange Ornaments of MAle Guppies (Poecilia reticulata)." PLOSONE 9.1.
6. Sayali Daptardar, Dr. Unnatipadalia, Nosocomial infections: A Threat to Neonates in ICU; Life Sciences International Research Journal , ISSN 2347-8691, Volume 2 Spl Issue (2015): Pg 250-255
7. Shigery Kondo, Hideaki Shirota. (2009). "Theoritical Analysis of mechanisms that generate the pigmentation Pattern of Animals." ELSEVIER: 82-89.
8. Yew, Chris.(2005). "Skin structure of Guppy."
9. www.guppychicago.org.<http://www.guppychicago.org// guppy types>.
10. guppy.pro.com. <http://guppy.pro/swallow-solid-Black guppy/>.
11. *Khushbu H. Viththalani, Vinod C. Soni,* Fractal Dimension: A Case Study on Butterfly Wing; Life Sciences International Research Journal , ISSN 2347-8691, Volume 2 Issue 2 (2015): Pg 124-129
12. www.aquariumfish.net. <http://www.aquariumfish.net>.
13. www.guppyfish.biz.<http://www.guppyfish.biz>.
14. www.pinanguppy.myguppy.net.<http://www.pinanguppy.myguppy.net>.
15. *Prajakta Patil, Nayna Chandak,* Biosurfactant Production By Pseudomonas Sp. and Bacillus Sp. Using Peanut Shell As A Renewable Substrate and Its Applications; Life Sciences International Research Journal , ISSN 2347-8691, Volume 2 Spl Issue (2015): Pg 232-242
16. www.pinterest.com.<http://www.pineterest.com>.
17. www.tropical-fish-keeping.com.<http://tropical-fish-keeping.com/tag/common guppy>.
18. Mandelbrot, B.B. (1982). The Fractal Geometry of Nature. Freeman.
19. P. A. Joshi, K. J. Mhatre , Isolation and Optimization of Azo Dye Decolorization Activity of Bacillus SPP; Life Sciences International Research Journal , ISSN 2347-8691, Volume 2 Spl Issue (2015): Pg 256-260
20. Mandelbrot, B.B.(1977). Fractal: form, chance and dimension. WH Freeman.
21. Murray, J.D. (2002)."Use and Abuse of fractal in Mathematical Biology: I. An Introduction." third addition. Library of Congress Cataloging-in-Publication Springer-Verlag, 484-499.
22. *Barot Viral J, Acharya Mahant S, Dr. G.Thirumaran,* A Case Study on the Biodiversity of ; Life Sciences international Research Journal , ISSN 2347-8691, Volume 2 Issue 1 (2015), Pg 432-433
23. Castrejon-Pita, A.A., Sarmiento-Galan, A., Castrejon-Pita, J.R., Castrejon-Garcia, R. (2004). "Fractal Dimension in Butterflies wing: A novel approach to understand wing pattern." Journal of Mathematical Biology: 584-594.
24. Verena A. Kottler, Andrey Fadeev, Detlef Weigd and Christine Dreyer. (2013). "Pigment Pattern formation in the Guppy, Poecilia reticulata, involves the Kita and Csfıra receptor Tyrosine Kinases." Genetics 194.3: 631-646.
25. Vasanta Bhanu, Estimation of Yield Losses in Rice Due to Rodent K. ; Life Sciences International Research Journal , ISSN 2347-8691, Volume 1 Issue 1 (2014): Pg 271-273

***

Khushbu Viththalani/ Research Scholar/Department of Biology/
M & N Virani Science College/Rajkot/Gujarat/
B. B. Radadiya/Professor/Department of Biology/M & N Virani Science College/Rajkot/ Gujarat/
V. C. Soni/Retd. Professor/Department of Biosciences/Saurashtra University/Rajkot/Gujarat/