American Research Journal of Earth Science

Volume 3, Issue 1, 1-4 Pages
Research Article | Open Access
ISSN (Online)- 2642-3022
DOI : 10.21694/2642-3022.23001

AMERICAN RESEARCH JOURNALS
An Academic Publishing House

The Diversity of Cichlid Fishes

Yuntong Chu[1], Dr. Andrew John Conith[2]

[1]Canterbury School, New Milford, United States of America.
[2]Department of Biology, University of Massachusetts Amherst | UMass Amherst.

ABSTRACT

Introduction: *Cichlids are a large group of freshwater fish. They are deep-bodied and have one nostril on each side of the head and rounded tails. The lateral line is discontinuous, and there are three or more anal spines. They usually do not grow longer than ~30 cm (12 inches). In many species, the rear edges of the dorsal and anal fins are pointed and the pelvic fins are elongated. Most cichlids are found in sub-tropical America, South America, mainland Africa, Madagascar, and southern Asia. Scientists estimate that there are at least 1,350 species worldwide, and possibly hundreds more new species yet to be described. Cichlids occupy a wide range of aquatic habitats, and where water temperatures are greater than about 68℉ (20℃). Cichlids exhibit a great diversity of feeding adaptations and consume numerous food types: phytoplankton, zooplankton, soft bottom deposits, benthic algae, higher plants, insects, molluscs, fish scales and fins, fish eggs and larvae, among others. Specialization of the jaws and dentition have allowed cichlid species to occupy a wide range of habitats and feed on a diversity of food types. The diversity of cichlids may be the result of a phenomenon called adaptive radiation. In order to adapt to their surroundings and quickly prey on new food sources, their body and head of cichlids exhibit extremely diverse morphologies, which allow them to achieve great success in specific diets in specific habitats.*

Objective: *Because the cichlid's varied head shape is related to a number of factors, I chose one of the possible factors – diet. Based on the cichlid's diet, my goal was to work out how the length, width, and depth of the cichlid head associate with diet?*

Methods: *In order to achieve the goal, I first placed eighteen landmarks on different types of cichlids' CT scans by using MeshLab. Then I used numerous statistical analyses to assess differences between and among groups and to examine possible associations between diet and head shape and extract linear measurements from the landmarks(i.e., a t-test, analysis of variance (ANOVA) and a Tukey honest significant difference (HSD) test, and a linear regression). I used a t-test to understand if the means of two populations are different. I combined ANOVA and Tukey HSD to understand if there is a difference in means among multiple groups. And regression is used to examine correlations between two continuous (i.e., number) variables. All of these steps can be shown on the R programming language.*

Results: *I observed differences between cichlid groups in their head lengths. The Utaka sand dwelling group typically exhibited longer heads relative to the Mbuna rock dwellers. The ANOVA revealed differences in head width between cichlids based on their diets ($P = 0.0125$), and a Tukey HSD test later revealed these differences were driven by the insect dietary group, in which cichlids exhibited much wider heads than both the plant and zooplankton groupings ($P = 0.018$ and $P = 0.043$ respectively). There was a strong correlation ($r^2 = 0.85$) between the height of the skull crest (where feeding muscles attach) and the height of the skull bar (which resists feeding forces), $P < 0.001$. Typically, cichlids that eat insects exhibit larger crests and bars compared to cichlids that eat plants and zooplankton. The figures below enhance the results.*

Conclusions: *According to the data, cichlids with mostly carnivorous diets of fish, insects, or plankton will require longer heads because fast prey will need to be chased down and quickly captured. Secondly, cichlids with mostly herbivorous diets will require wider heads because a shorter head allows the cichlid to get closer to the algae and pluck relatively more algae from rocks.*

KEYWORDS: *Diversity of Cichlid Fishes, Adaptive radiation, Cichlids' diet, CT scans, Linear measurements, t-test, ANOVA test, Tukey HSD, p-value.*

INTRODUCTION

Cichlids are a large group of freshwater fish. Cichlids are found in sub-tropical America, South America, mainland Africa, Madagascar, and southern Asia. They are well-known due to a huge number of species across these regions and their colorful body patterns, making them a favorite of the aquarium trade (Conith 2022). There are more than 1000 cichlid species, and the majority of species are African, appearing in great diversity in the major African lakes (Britannica 2017). Most cichlid species are found in three large lakes in East Africa: Lake Malawi, Lake Victoria and Lake Tanganyika. Lake Malawi alone contains more than 500 species. Scientists estimate that there are at least 1,350 species worldwide, and possibly hundreds more new species yet to be described. (Britannica 2017).

HABITATS AND DIET

Cichlids occupy a wide range of aquatic habitats: from open water to shallow areas in lakes, rivers, streams and swamps; also mud, sand, rock or vegetated bottoms; and where water temperatures are greater than about 68°F (20°C) (Cichlid 2022). Cichlids are rather deep-bodied and have one nostril (rather than the usual two) on each side of the head. The lateral line is discontinuous, and there are three or more anal spines. They generally have rounded tails and, though sizable for aquarium fishes, usually do not grow longer than ~ 30 cm (12 inches) (Britannica 2017). In many species, the rear edges of the dorsal and anal fins are pointed and the pelvic fins are elongated. Cichlids exhibit a great diversity of feeding adaptations and exploit numerous food types: phytoplankton, zooplankton, soft bottom deposits, benthic algae, higher plants, insects, molluscs, fish scales and fins, fish eggs and larvae, among others. Specialization of the jaws and dentition have allowed cichlid species to occupy a wide range of habitats and feed on a diversity of food types (Cichlid 2022).

The diversity of cichlids may be the result of a phenomenon called adaptive radiation. As cichlid species occupy new habitats, they undergo multiple adaptive radiations to adapt to their surroundings and quickly prey on new food sources. The result of this adaptive radiation could lead to the emergence of a new species with a changed head and body shape that best enables them to exploit the resources in their new environment and survive to the next generation. As a result, both the body and head of cichlids exhibit extremely diverse morphologies, which may allow them to achieve great success in specific diets in specific habitats. A typical factor that affects cichlid skull changes is diet. Cichlids typically specialize in several different prey species, such as fish, insects, snails, plants or fruits.

HYPOTHESIS

How do length, width, and depth of the cichlid head associate with diet?

I predict that those cichlids with diets such as fish, insects, or plankton (i.e., small, typically evasive prey) will require longer heads, those cichlids with diets such as plants (i.e., algae that is attached to rocks) will require wider heads, and those cichlids with diets such as fish and insects will require longer and wider heads.

METHODOLOGY

First, I placed eighteen landmarks on CT scans by using Mesh Lab. After I extracted linear measurements from the landmarks, I used numerous statistical analyses to assess differences between and among groups and to examine possible associations between diet and head shape (i.e., a *t*-test, analysis of variance (ANOVA) and a Tukey honest significant difference (HSD) test, and a linear regression). I use a *t*-test to understand if the means of two populations are different. I combine ANOVA and Tukey HSD to understand if there is a difference in means among multiple groups. And regression is used to examine correlations between two continuous (i.e., number) variables.

Here are the steps for these methods. Scripts can be run using the *R* programming language.

```
#T-Test

cichlid = read.csv("CichlidMeasurementFinal.csv")

cichlid$Clade = as.factor(cichlid$Clade) t.test

(cichlid$Length~cichlid$Clade)

boxplot(cichlid$Length~cichlid$Clade)

#ANOVA and TukeyHSD

cichlid = read.csv("CichlidMeasurementFinal.csv")

Fit1 = aov(cichlid$Width~cichlid$Diet)

summary(Fit1)

TukeyHSD(Fit1)

boxplot(cichlid$Width~cichlid$Diet)

#Linear Regression

cichlid = read.csv("CichlidMeasurementFinal.csv")

Fit2 = lm(cichlid$SCHeight~cichlid$PSHeight)

summary(Fit2)

MyCol = c("blue","black","green","red")

cichlid$Diet = as.factor(cichlid$Diet)

#Fish=blue, Insects=black, Plants=green, zooplankton=red

plot(cichlid$SCHeight~cichlid$PSHeight, pch=19,

col=MyCol[unclass(cichlid$Diet)],

xlab="Parasphenoid Height (mm)", ylab="Skull Crest Height (mm)")

abline(Fit2)
```

RESULTS

I observed differences between cichlid groups in their head lengths (P-value = 0.002923, Figure 1), the Utaka sand dwelling group typically exhibited longer heads relative to the Mbuna rock dwellers. The ANOVA revealed differences in head width between cichlids based on their diets (P = 0.0125), a Tukey HSD test later revealed these differences were driven by the insect dietary group, in which cichlids exhibited much wider heads than both the plant and zooplankton groupings (P = 0.018 and P = 0.043 respectively, Figure 2). There was a strong and tight relationship (r^2 = 0.85) between the height of the skull crest (where feeding muscles attach) and the height of the skull bar (which resists feeding forces), P <0.001. Typically the cichlids that eat insects exhibit larger crests and bars compared to the cichlids that eat plants and zooplankton (Figure 3).

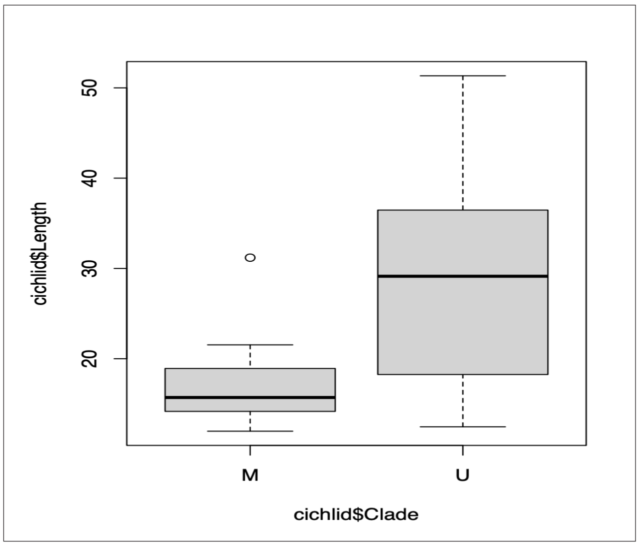

Figure 1. Box and whisker plot comparing cichlid head lengths between groups. Clade groupings: M = Mbuna (rock dwellers), U = Utaka (sand dwellers). Solid black line denotes median value, box denotes 75% quartiles, whiskers denote data range. Single circles denote statistical outliers. *T*-test revealed differences between groups.

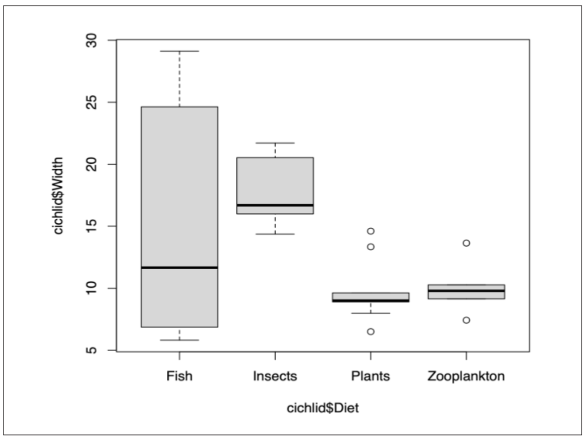

Figure 2. Box and whisker plot to assess differences in diet and skull width. Solid black line denotes median value, box denotes 75% quartiles, whiskers denote data range. ANOVA test revealed differences among groups.

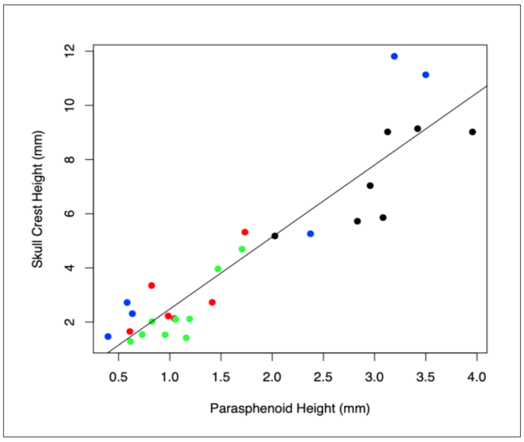

Figure 3. Linear regression of skull crest height against parasphenoid height. Color codes, Blue = fish eaters, Black = insect eaters, Green = plant eaters, Red = zooplankton eaters).

CONCLUSION

According to the data, cichlids with diets such as fish, insects, or plankton will require long, narrow heads because fast prey will need to be chased down and quickly captured. This face and head shape allows the cichlid to swim through the water more quickly and capture prey more easily.

Secondly, cichlids with diets such as plants will require shorter heads. This is because a short, wide head allows the cichlid to get closer to the algae and pluck relatively more algae from the rock.

Taken together, over many generations cichlids have changed their head shape to better enable them to take advantage of a more diverse array of diets. This has enabled the group to occupy many ecological niches and contributed to the evolutionary success of the group.

REFERENCES

1. Conith, A. 2022. pers. Comm.
2. Britannica, The Editors of Encyclopedia. “cichlid”. *Encyclopedia Britannica*, 6 Sep. 2017, https://www.britannica.com/animal/cichlid. Accessed 25 June 2022.
3. “Cichlid.” *Georgia Aquarium*, 8 June 2022, www.georgiaaquarium.org/animal/cichlid/#:~:text=The%20cichlids%20comprise%20a%20large,Lake%20Victoria%20and%20Lake%20Tanganyika.
4. “Adaptive radiation of cichlid fish.” George F. Turner, 26 July 2007, https://www.cell.com/current-biology/pdf/S0960-9822(07)01704-6.pdf.
5. Salzburger, Walter. “Understanding Explosive Diversification through Cichlid Fish Genomics.” *Nature News*, Nature Publishing Group, 15 Aug. 2018, www.nature.com/articles/s41576-018-0043-9.
6. Gammerdinger WJ, Kocher TD. Unusual Diversity of Sex Chromosomes in African Cichlid Fishes. *Genes*. 2018; 9(10):480. https://doi.org/10.3390/genes9100480.

APPENDIX A

Data:

1	SpeciesID	Clade	Diet	Length	Width	Depth	SCHeight	PSHeight	PSLength	CentroidSize
2	Abactochromis_l	M	Insects	31.19292255	15.34687423	17.35770094	5.855594404	3.082743559	18.59891692	43.21870322
3	Chindongo_belli	M	Plants	16.07822482	9.00570716	7.643593112	1.415229951	1.160478636	8.702925576	23.89425655
4	Cynotilapia_afra	M	Zooplankton	15.60624252	9.313172568	8.971150267	2.127563914	1.045351364	8.942272619	23.39711151
5	Gephyrochromis	M	Plants	21.53781084	13.33720182	12.64835831	3.960129084	1.470849516	12.00899493	33.49885879
6	Iodotropheus_sp	M	Plants	15.80977383	9.628742436	8.897178567	2.112021829	1.194193964	8.574309235	24.85183205
7	Labeotropheus_	M	Plants	19.84085858	14.60986428	13.74223985	4.690257501	1.705632183	10.15512182	33.51443653
8	Labeotropheus_	M	Plants	14.12610392	8.98188542	7.324198636	1.536452066	0.730430276	7.742548096	21.43730682
9	Labidochromis_c	M	Plants	11.97398669	6.504792094	6.294646667	1.27844555	0.615920687	6.438255797	18.31739301
10	Maylandia_konir	M	Plants	14.20866849	9.024547008	8.225833389	2.094901046	1.057985718	7.962948115	21.45207914
11	Melanochromis_	M	Plants	14.68265839	7.979243134	7.188292032	1.528786456	0.954749294	8.024112911	21.17357675
12	Melanochromis_	M	Zooplankton	18.00661116	9.144205371	8.991979513	2.22159502	0.984179849	10.77424905	26.20376347
13	Metriaclima_mbe	M	Plants	14.11581949	8.90262282	8.152231776	2.014330266	0.826600501	7.560619017	21.65160559
14	Alticorpus_menta	U	Fish	49.12944404	24.62948845	30.40066479	11.81184592	3.193143114	30.17180337	71.18244933
15	Aulonocara_koni	U	Zooplankton	13.15128648	7.423350974	7.205950435	1.649628413	0.610090718	6.911029675	20.21553521
16	Aulonocara_stua	U	Zooplankton	20.15147452	10.2714192	11.49177226	2.725263457	1.41422682	12.01896629	29.84504588
17	Buccochromis_n	U	Fish	12.46049882	6.859591585	6.111957702	1.463251778	0.396228423	6.900971761	19.36294198
18	Cheilochromis_e	U	Insects	34.65870088	21.71007976	24.00490785	9.019052586	3.95620447	19.87220412	54.08698413
19	Chilotilapia_rhoa	U	Insects	21.96263423	14.37113213	16.03446288	5.177336059	2.026186364	12.00385392	37.82075952
20	Copadichromis_l	U	Zooplankton	20.65415061	10.2720102	10.32220396	3.346693708	0.82219823	11.28996748	28.12369245
21	Dimidiochromis_	U	Fish	15.23358819	5.811322141	7.616376444	2.719426358	0.583089222	9.422833848	20.74942072
22	Exochochromis_	U	Fish	16.35468489	8.179877412	7.351507152	2.30836989	0.634352096	9.804530443	23.32549784
23	Hemitaeniochror	U	Fish	51.33365138	29.11763707	28.61324326	11.12899478	3.499342293	32.01196631	73.82404009
24	Lethrinops_lethri	U	Insects	43.80673145	19.539833	26.00452625	9.139297191	3.420471098	28.00575482	59.96213379
25	Lichnochromis_a	U	Insects	36.88382713	16.6418202	18.12966653	5.721592543	2.832092583	24.2266489	50.08337421
26	Mchenga_cyclic	U	Zooplankton	25.37406766	13.63866815	14.95308542	5.317601029	1.733758174	14.8273352	36.82727327
27	Mylochromis_lat	U	Insects	34.01048432	16.69250324	19.63223603	7.03443439	2.95717778	21.57640713	46.62076217
28	Naevochromis_c	U	Insects	36.04042775	21.52525699	23.61929845	9.020876928	3.127304178	22.46868983	54.67727481
29	Nimbochromis_li	U	Fish	32.89368038	15.14430027	15.13711227	5.259233874	2.37387227	21.06975642	45.17615911

Citation:Yuntong Chu, Dr. Andrew John Conith, "The Diversity of Cichlid Fishes", American Research Journal of Earth Science, Vol 3, no. 1, 2023, pp. 1-4.