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Differences in some cranial bones between two Cyprinidae species, Common carp *Cyprinus carpio* (Linnaeus, 1758) and Crucian Carp *Carassius carassius* (Linnaeus, 1758) Collected from Tigris River, Iraq

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Abstract

The present study attempts to identify some of the differences between the skull bones of two species *Cyprinus carpio* and *Carassius carassius*, which belong to the Cyprinidae family. The study is a taxonomic diagnostic study between the two species which are considered local fish abundant in the Iraqi aquatic environment

Keywords: Biometrics; Carp; Comparison; Skull; Symmetry

1. Introduction

There is an extent of convergence between fish species and races in terms of the general structure of the skeleton, especially skull bones, which differ from one species to another and from one sex to another. The skull bones and cranial bones of the same fish family, of different sexes, are similar. They differ according to different families in terms of shape and division of cranial bones as stated by [1]. The study of the characteristics of fish bones gives valuable information which is employed in classifying fish and studying the genetic relationships between fish as agreed upon by researchers in their most important studies by Keivany and Nelson, 1998, 2004, 2006; Diogo and Bills 2006; Keivany 2014a, b, c, d [2-9].

Bogutskaya NG et.al, [10] and others show that the development of fish skull is closely related to the development and growth of fish bones. Several research studies and morphological studies have shown this close relationship for many fish families that researchers have diagnosed, especially the Cyprinidae family as Takeuchi and Hosoya 2011 and Nasri et al. 2016 [11-12].

Hilton EJ [13] argues that the function of the skull is to protect the brain and the delicate sensory organs. It is divided into two parts: the nerve skull, which includes the brain, nerves, and sensory organs; the second part which includes the bones of the face and jaw, as it is also confirmed by Jalili P et.al, [14]. The shape of fish skull is affected firstly by genetics and secondly by the type and nature of the food, in addition to the quality of the water, as it is explained by Cooper WJ et.al, [15].

Fish skeleton is very complex and has a highly efficient articular movement ability as demonstrated by Ferry-Graham LA et.al, [16]. The study of bones in general and the study of the skull bones in particular give a clear idea of the formation of fish body and the characteristic of this formation; each species needs certain type of formation which varies according to the types of fish species. The skeleton of vertebrates in general has attracted many specialists in comparative anatomy as stated by Goethe JW [17] and confirmed by Tatsuya Hirasawa et.al, [18].

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To understand fish taxonomic relationships, fish physiological characteristics must be understood, fish bones, the comparative anatomy of species within the same family, and species of different fish families must be studied. This is what many researchers have argued by Ramaswami,1951 and Howes,1982 and Bogutskaya,1994 and Mafakheri et al, 2014 [19-22].

2. Material and methods

Ten heads of both species *C. carpio* and *C. carassius* were collected and isolated. The heads were cooked at the boiling point for five minutes only and put in cold water immediately after cooking to stop cooking process. They were soaked for 15 minutes in cold water. The tissues, muscles, the caps of gills and the rest of the tissues and organs that are not included in the study were removed using forceps and a scalpel. Then, the skulls were washed well and calmly with running water and kept in a dilute formaldehyde solution at a concentration of 10% for a period of one week only.

The bones were removed from a 10% dilute formaldehyde solution and the skulls were washed with clean running water for five minutes. Then, they were kept in a dilute ethyl alcohol solution at a concentration of 70% for a week to get rid of the fat and water remaining in the bones. Then, they were left to dry at room temperature on blotting paper for another week to prepare them for shooting and making the rest of the required biometrics. This method of preparing bones is similar to the method conducted by Taylor WR et.al, [23].

3. Results and discussion

The general linear model for this study was shown in Table (1)

Table 1 General linear model for the study

Output Created		**18-MAR-2021 07:49:46**
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Input	Data	D:\tasks\MHD Inad statistical analysis\New folder\Untitled1 - Copy.sav
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	N of Rows in Working Data File	18
Missing Value Handling	Definition of Missing	User-defined missing values are treated as missing.
	Cases Used	Statistics are based on all cases with valid data for all variables in the model.
Syntax		GLM Skull_Length Skull_Width Skull_High Eye_Lenght Eye_deepth Weight BY Type /METHOD=SSTYPE (3) /INTERCEPT=INCLUDE /POSTHOC=Type (DUNCAN) /PLOT=PROFILE(Type) /EMMEANS=TABLES(OVERALL) /EMMEANS=TABLES(Type) /PRINT=DESCRIPTIVE /CRITERIA=ALPHA (0.05) /DESIGN= Type.
Resources	Processor Time	00:00:01.75
	Elapsed Time	00:00:01.66

Table (2) shows the statistical description of the two species of the study

Table 2 The statistical description of C.carassius and C. carpio

	Type	Mean	Std. Deviation	N
Skull Length	Common Carp	4.344	0.2404	9
	Crasses fish	4.122	0.3833	9
	Total	4.233	0.3308	18
Skull Width	Common Carp	2.333	0.1323	9
	Crasses fish	1.989	0.1833	9
	Total	2.161	0.2355	18
Skull High	Common Carp	1.467	0.1803	9
	Crasses fish	1.656	0.1424	9
	Total	1.561	0.1852	18
Eye_Lenght	Common Carp	1.544	0.2506	9
	Crasses fish	1.244	0.1333	9
	Total	1.394	0.2485	18
Eye_deepth	Common Carp	0.711	0.1054	9
	Crasses fish	0.644	0.1236	9
	Total	0.678	0.1166	18
Weight	Common Carp	2.690	0.4100	9
	Crasses fish	2.060	0.0860	9
	Total	2.380	0.4350	18

Table (3) shows the test of effects in this study subjects

Table 3 testing effects in subjects

Source	Dependent Variable	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	Skull_Length	0.222[a]	1	0.222	2.171	0.160
	Skull_Width	0.534[b]	1	0.534	20.891	0.000
	Skull_High	0.161[c]	1	0.161	6.084	0.025
	Eye_Lenght	0.405[d]	1	0.405	10.055	0.006
	Eye_deepth	0.020[e]	1	0.020	1.516	0.236
	Weight	1.805[f]	1	1.805	20.539	0.000
Intercept	Skull_Length	322.580	1	322.580	3151.392	0.000
	Skull_Width	84.067	1	84.067	3289.587	0.000
	Skull_High	43.867	1	43.867	1662.337	0.000
	Eye_Lenght	35.001	1	35.001	868.979	0.000
	Eye_deepth	8.269	1	8.269	626.695	0.000
	Weight	101.769	1	101.769	1158.018	0.000

Type	Skull_Length	0.222	1	0.222	2.171	0.160
	Skull_Width	0.534	1	0.534	20.891	0.000
	Skull_High	0.161	1	0.161	6.084	0.025
	Eye_Lenght	0.405	1	0.405	10.055	0.006
	Eye_deepth	0.020	1	0.020	1.516	0.236
	Weight	1.805	1	1.805	20.539	0.000
Error	Skull_Length	1.638	16	0.102		
	Skull_Width	0.409	16	0.026		
	Skull_High	0.422	16	0.026		
	Eye_Lenght	0.644	16	0.040		
	Eye_deepth	0.211	16	0.013		
	Weight	1.406	16	0.088		
Total	Skull_Length	324.440	18			
	Skull_Width	85.010	18			
	Skull_High	44.450	18			
	Eye_Lenght	36.050	18			
	Eye_deepth	8.500	18			
	Weight	104.980	18			
Corrected Total	Skull_Length	1.860	17			
	Skull_Width	0.943	17			
	Skull_High	0.583	17			
	Eye_Lenght	1.049	17			
	Eye_deepth	0.231	17			
	Weight	3.211	17			

a. R Squared = .119 (Adjusted R Squared = .064); b. R Squared = .566 (Adjusted R Squared = .539); c. R Squared = .276 (Adjusted R Squared = .230) d. R Squared = .386 (Adjusted R Squared = .348); e. R Squared = .087 (Adjusted R Squared = .029); f. R Squared = .562 (Adjusted R Squared = .535)

Figures (1 & 2) shows the phenotypic differences and the external shape of the two studied species

Figure 1 *Cyprinus carpio*

Figure 2 *Carassius carassius*

Table (4) shows the correlations between the studied traits of the two species identified in this study

Table 4 Correlations between the studied traits of the two species

		Skull_ Length	Skull_ Width	Skull_ High	Eye_ Lenght	Eye_ deepth	Weight
Skull_ Length	Pearson Correlation	1	0.833**	0.070	0.446	0.447	0.517*
	Sig. (2-tailed)		0.000	0.781	0.063	.063	0.028
	N	18	18	18	18	18	18
Skull_ Width	Pearson Correlation	0.833**	1	-0.131	0.569*	0.374	0.727**
	Sig. (2-tailed)	.000		0.604	0.014	0.127	0.001
	N	18	18	18	18	18	18
Skull_ High	Pearson Correlation	0.070	-0.131	1	-0.580*	-0.179	-0.457
	Sig. (2-tailed)	0.781	0.604		0.012	0.478	0.056
	N	18	18	18	18	18	18
Eye_ Length	Pearson Correlation	0.446	0.569*	-0.580*	1	0.584*	0.402
	Sig. (2-tailed)	0.063	0.014	0.012		0.011	0.098
	N	18	18	18	18	18	18
Eye_ deepth	Pearson Correlation	0.447	0.374	-0.179	0.584*	1	0.210
	Sig. (2-tailed)	0.063	0.127	0.478	0.011		0.402
	N	18	18	18	18	18	18
Weight	Pearson Correlation	0.517*	0.727**	-0.457	0.402	0.210	1
	Sig. (2-tailed)	0.028	0.001	0.056	0.098	0.402	
	N	18	18	18	18	18	18

**. Correlation is significant at the 0.01 level (2-tailed)

*. Correlation is significant at the 0.05 level (2-tailed).

The bones were cleaned according to the method described in the methods of work that approximate those of Taylor WR et.al, [23]. Biological measurements of each species were taken and a comparison was made between these measurements. The total length of *C. carpio* skull (SL.) exceeded the average total length of the ten bone models (4,34 cm), whereas the average total length of the bones of *C. carassius* of ten models was (4.17 cm). The total length of the bones and these differences can be clearly identified from the figures (3, 4, 5).

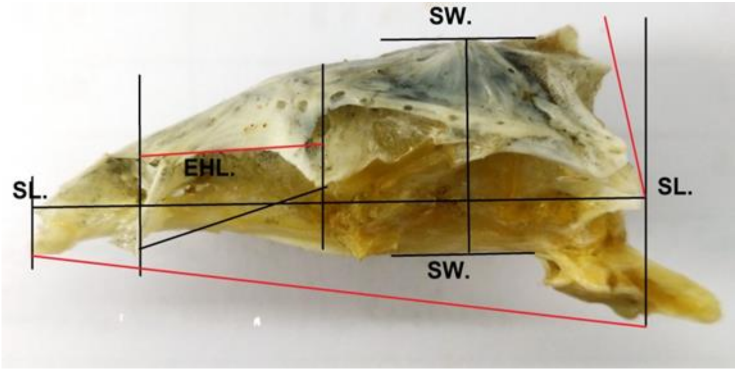

Figure 3 *C. carpio* skull from the side

Figure 4 *C. carassius* from the side

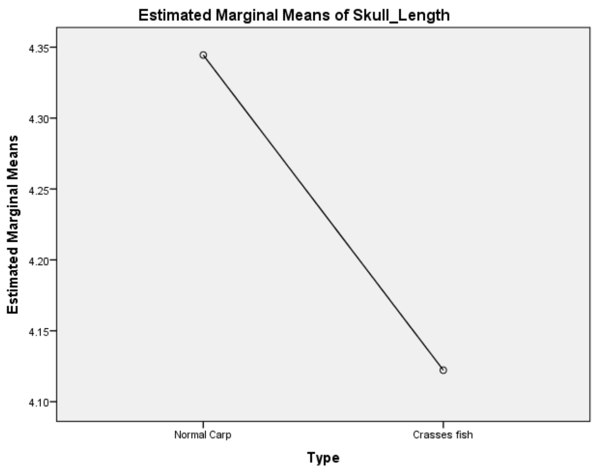

Figure 5 Linear relationship of the superiority of the *C. carpio* skull length over the *C. carassius*

The two figures show a lateral view of the bones of *C. carpio* and *C. carassius*. The average width of the skull bones (SW.) *C. carpio* is (2.33 cm), whereas in *C. carassius* is (2 cm). These differences in the skull bones total length and width, which varies from one species to another as figures (6, 7, 8) indicate, can be traced back to the origins of the species or types, their behavior, the type of food, the depth of the water where the species is found and the impact of water pressure on fish according to different areas of the depths of the water, which affects the behavior, nutrition of the species and the different biological modifications acquired by different species of fish. Yet, there may be similar biological modifications within the same family, especially in behavior, type of food, and method of feeding and the presence or absence of teeth of both maxillary and pharyngeal types [1].

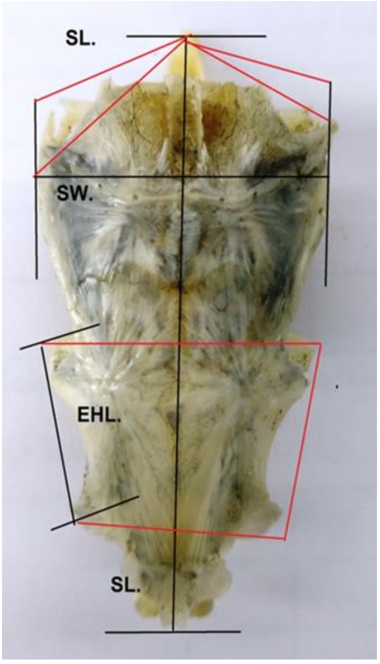

Figure 6 *C. carassius* skull from above

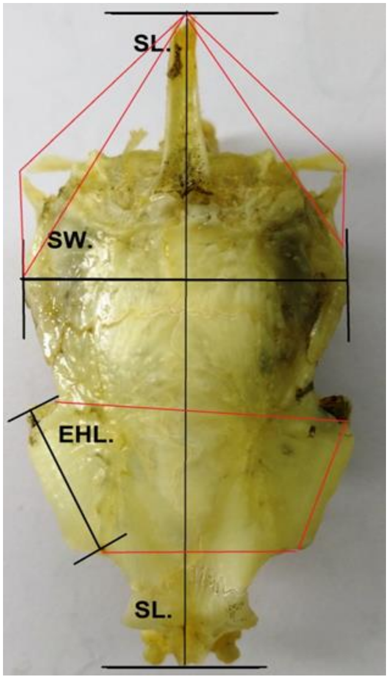

Figure 7 *C. carpio* skull from above

In order to clarify the comparison between the bones of fish species, we must first understand the stages of evolution of these species and their environment, as confirmed by Hilton EJ et.al, [13]. The skull shape and head bones, especially the jaws, are related to the food system for each species, the method of feeding, and the area of the species presence in the water column. Fugi R et.al, [24] sheds lights on the differences between fish of surface nutrition and fish of bottom and middle nutrition in skull shape, jaws and the front of the head. This is an explanation of the differences between the two species: *C. carpio* and *C. carassius* and of the way they are fed, which differs from one species to another, as illustrated by figures (9, 10, 11). Skull bones from the bottom of both species studied in this paper with some measurements marked: (SL.) denotes the total skull length, (SW.) denotes the width of the skull, (EHL.) denotes the length of the eye socket from the outside and (EHW.) denotes the depth of the eye socket.

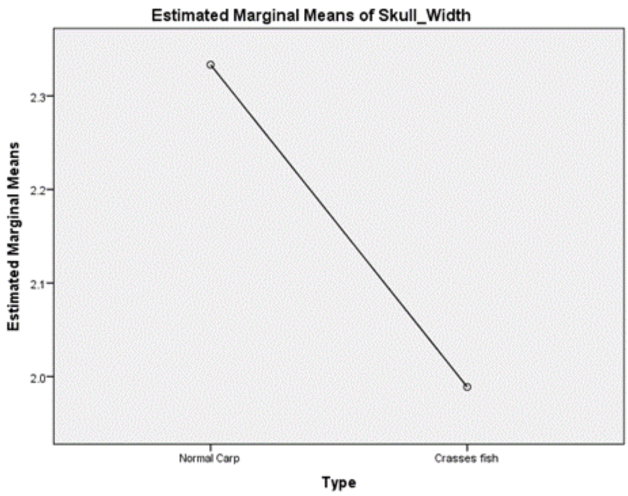

Figure 8 Linear relationship of skull width superiority of *C. carpio***.**

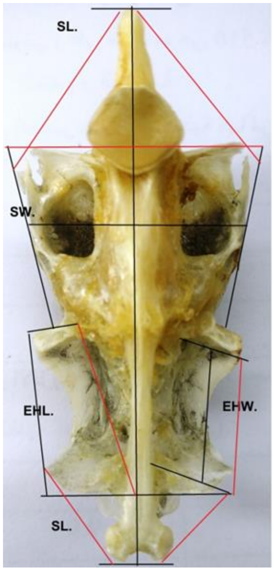

Figure 9 *C. carpio* skull from the bottom

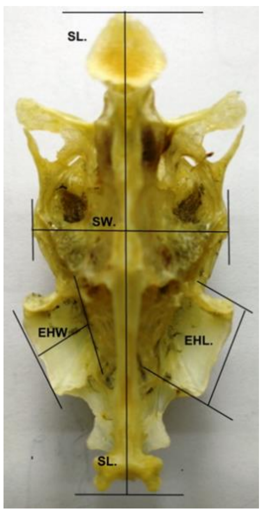

Figure 10 *C. carassius* skull from the bottom

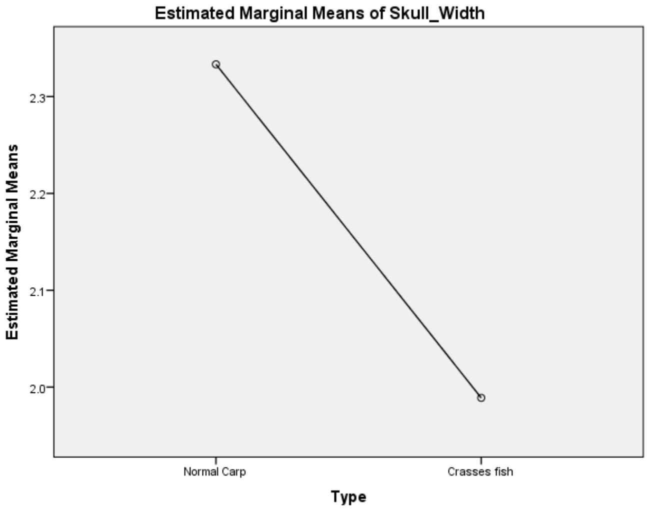

Figure 11 Linear relationship of skull width superiority of *C. carpio*

We find some biological characteristics such as eye socket length (EHL.), Eye socket depth (EHW.) and skull height (SH.) which differ in *C. carpio* and *C. carassius*. In a way, the average eye-socket depth of carp is (0, 71 cm), whereas in crocus is (0.64 cm). However, *C. carassius* surpasses *C. carpio* in the average height of the skull bones in *C.carpio* (1.46 cm), unlike *C. carassius* (1, 67 cm), as illustrated in Figure (12). The length of the eye socket in *C. carpio* is (1, 54 cm) but in *C. carassius* is (1, 22 cm).

Despite the thin look of skull bones in fish, it is one of the strongest bones in terms of formation and cohesion just like the skull bones in all other vertebrates, as explained by Herbing et al,1996 and Koumoundouros et al,2000 and Löffler et al,2008 [25],[26],[27]. The bones of fish skull provide great protection for the brain and delicate sensory organs; they also play an essential part in respiration and nutrition.

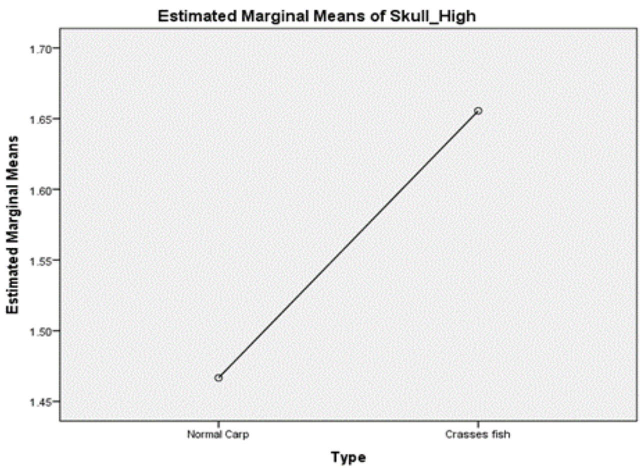

Figure 12 Linear relationship of cranial height and carp crocus superiority

The present study suggests making a comparison between the weight of the skull bones of the two species *C. carpio* and *C. carassius*. Physiological and morphological studies have not addressed the weight of the bones of the species and compared their results to identify the features and composition of the fish species bones that certainly differ from one species to another is especially that the bone tissue may differ from one species to another according to the genes in the formation of bones, the environmental elements affecting the development and the nature of body formation in the water, as well as the type and nature of the food that provide the bodies of different species with many elements that may be not available for all species. There is also the effect of the heavy elements in the water and the extent of deposition of these elements in the bodies of fish. There are differences found between the skull bones of *C. carpio* and *C. carassius* in weight. The average weight of the skull bones of the *C. carpio* ten models is (2.69 g), whereas the average weight of the skull bones of *C. carassius* is (2.08 g). We note here that the skull bones of carp fish are heavier than the bones of the *C. carassius*. This gives an impression of the reason of the heaviness of the skull bones which varies from one species to another which stresses the importance of detecting the environment of each species, the feeding pattern and the amount of metabolism. This is consistent with what is proposed by Jogeir T et.al, [28]. Jogeir showed that the active moving fish with a low-fat content in the nature of their body composition have low levels of the concentrations of calcium Ca and phosphorous elements P, unlike the less active fish species with a high fat content in their bodies. The concentrations of these two elements increase, which gives weight to the bones of these species.

RF Lee et.al, [29] showed, when studied the percentage of lipids in the bones of two species of fish *Peprilus simillimus* and *Anoplopoma fimbria*, that their bones and even the skull were full of fat. The proportion of fat in the bones of these two species were (68-60% of dry weight) respectively, which reflects the weight of the bones and the skull of these two species. Although this study is concerned with marine species from different families; yet, two species of freshwater fish belonging to the same family are tackled, namely *C. carpio* and *C. carassius. C. carpio* skull weight bigger than *C. carassius* skull weight, as in Figure (13).

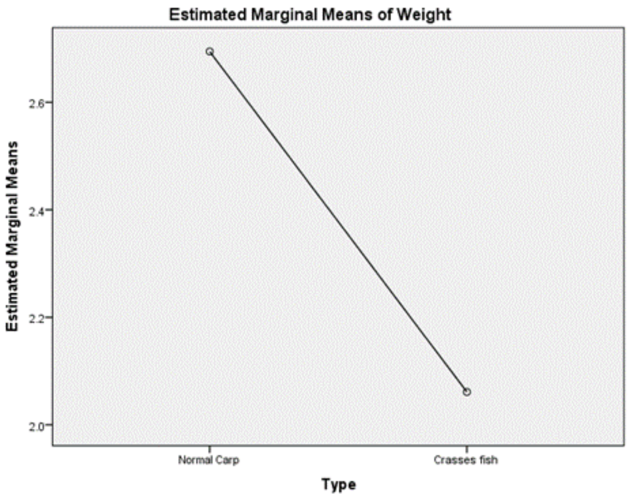

Figure 13 Linear relationship of skull and the *C. carpio* superiority

The studies have not touched upon the differences in mouth depth of fish species, but. They only study mouth length and width in two states: when the mouth is opened and closed. Besides, they have tackled the relationship between mouth length and width and the total length of fish.

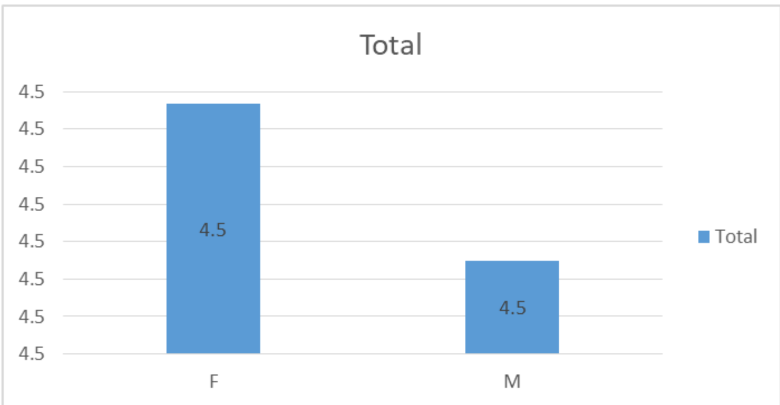

Figure 14 Mouth depth in the two sexes of *C. carpio*

Kyritsi S et.al, [30] suggests studying the depth of mouth in different species. There are differences between sexes within the same species studied. Analysis of variance revealed significant differences at the level ($p < 0.05$) between *C. carpio* and *C. carassius* species in the mouth depth and gender, X-axis shows mouth depth and Y-axis shows gender in all figures. Mouth depth in females was superior to males in *C. carpio*, as Figure (14) shows, whereas mouth depth in males of *C.*

carassius was bigger than mouth depth in females, as Figure (15) shows. Differences in depth of mouth in the two species were significant in general, and they were in favor of males, as shown in Figure (16).

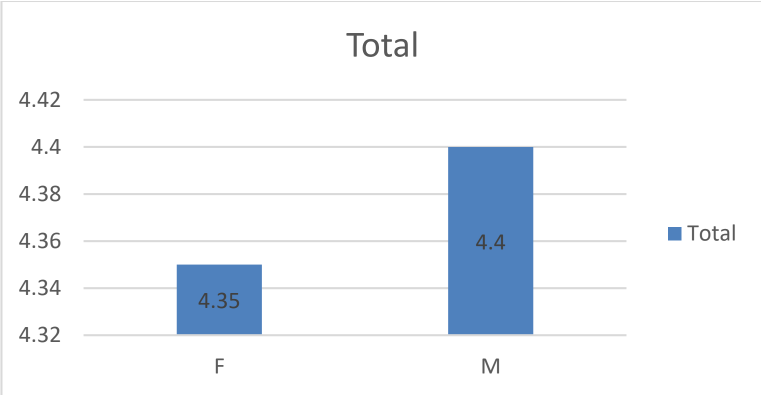

Figure 15 Mouth depth in the two sexes of *C. carassius*

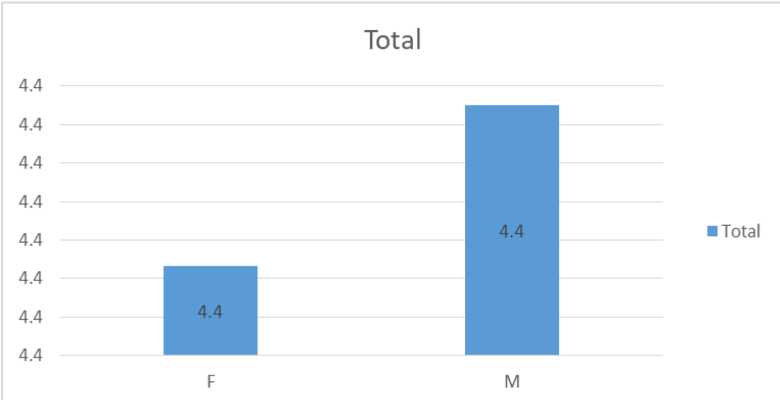

Figure 16 Mouth depth in the two fish species

Mouth depth can give information regarding feeding pattern, the feeding style followed by the species, the size of prey, and the preferred food type by species [31]. Mouth size, shape and dimensions also determine many characteristics of fish species, including feeding pattern, preferred prey types by each species, the relationship between predator and prey, the type of organisms present in the food of these fish, as well as the type and size of the fishing hook that follows the type in fisheries [32],[33].

4. Conclusion

The species *C. carpio* and *C. carassius*, are identical with respect to the family. The analysis of variance shows that there are significant differences at the level of (p <0.05) between the two studied species. The results of the analyzes of *C. carpio* are superior to *C. Carassius*, except in the skull-height where *C. Carassius* is superior to *C. carpio*, which gives an impression of the differences between species, even within the same family and even within the same species.

Recommendations

Deep studies should be conducted in the shape and composition of bones and the nature of their construction of different fish species, different families and within the same family and the same type to determine the importance of the nature of the formation of those bones. This will help to clarify the structure of the bodies of different species. Research and study of mouth depth of species is essential since it gives important and vital indicators of the nature of the different foods consumed by different species, the relationship of fish with their prey and the behavior of those fish with prey. Studies should focus on the characteristic of mouth depth that differs in the gender within the same species. This will enable us to know the extent of development and adaptation in fish species to simulate various aquatic environments.

Compliance with ethical standards

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Disclosure of conflict of interest

There was no conflict of interest in this study.

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