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Comparative studies on the gill rakers of some marine fishes with different feeding habits

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ABSTRACT

The present study aimed to compare between gill rakers of some marine fishes with different feeding habits. A total of 78 specimens in 13 species belonged to 6 fish families: Sparidae (*Sparus aurata*, *Diplodus noct*, *Rhapdosargus haffara* and *Boops boops*); Family: Mugilidae (*Mugil cephalus, Mugil capito* and *Liza aurata*); Family: Siganidae (*Siganus rivulatus* and *Siganus luridus*); Family: Synodontidae (*Saurida undosquamis* and *Synodus saurus*); Family: Clupeidae (*Herklotsichthys quadrimaculatus*) and Family: Carangidae (*Caranx sexfasciatus*) were collected by irregular visits from land fish market in different localities of Egyptian Mediterranean Sea and Suez Gulf; during the period from March, 2014 to November, 2014.

Results showed that, the first gill arch formed of one piece, consisting of two limbs (upper and lower limbs). The gill arch carried two rows of gill rakers on its concave border and two rows of gill filaments on its convex one. The gill rakers in the anterior row (oral row) are longer, more in number and more developed than that of the posterior row (aboral row).

The gill arch in family Sparidae is bow-like shape. The anterior gill rakers on the first gill arch of most sparid species are short, conical in shape adapted to carnivorous feeding. The gill arch of fish species in Mugilidae is mostly crescent-shaped and rarely bow-shaped. The anterior gill rakers on the first gill arch are long and great in number adapted to detritus feeding. The gill arch in family Synodontidae is V shaped. The anterior gill rakers on the first gill arch appeared as clusters of small tooth patches adapted to piscivores feeding. The gill arch in family Siganidae is hook-like shape. The anterior gill rakers on the first gill arch were needle spine in shape with secondary projections adapted to herbivorous feeding. The gill arch in fish species of Clupeidae is V like shape. Gill rakers are well developed and arranged in only one row. They are numerous and elongated adapted to seizing food items in the plankton feeding. The gill arch in fish species of Carangidae is bow-like shape. Gill rakers are moderate in length and number adapted to carnivorous feeding.

According to the different feeding habits, the results showed that, the highest average length of the first gill arch (mm) is recorded in carnivore and piscivore fish. The maximum averages number and the length of the anterior gill rakers are recorded in detritivore fish and plankitivore fish. The highest percentages of the anterior gill raker length /gill arch length ratio (%) are recorded in plankitivore fish and detritivore fish.

Results showed that, the maximum inter raker space (µm) and the inter raker space/gill arch length (%) is recorded in carnivore fish. The maximum breadth at the raker base (µm) in the anterior row of rakers is recorded in piscivore fish. The highest breadth at the raker base/gill arch length (%) in the anterior row of rakers is recorded in carnivore, piscivore and planktivore fish. The highest posterior gill raker length (µm) and the posterior gill raker length /gill arch length ratio (%) are recorded in detritivore fish.

In conclusion: The morphological characters of the gill rakers in the first gill arch were differ in species studied according to different feeding habits. So that, can be used in determine the fish family and feeding habits.

Key words: Sparidae; Mugilidae; Synodontidae; Siganidae; Clupeidae; carangid; gill rakers; feeding habits; carnivore; detritivore; piscivore; herbivore; plankitivore.

INTRODUCTION

Among fish, diversity of the food resources leads to the evolution of various adaptive characters in the pharynx, which plays an indispensable role in the retention, maneuvering and transport of food for swallowing. The pharynx, in teleost, was characterized by the presence of gill arches. These gill arches were located at the boundary between the pharyngeal cavity and the opercular chamber on either side of the head. The gill arches in general were equipped with gill rakers toward their pharyngeal side and were considered to play an important role in feeding[1 - 3].

The gill arches may be equipped with projections called gill rakers, which aid in food gathering. In the same manner, the gill-rakers are also specialized in relation to the food and feeding habits. They may be small and few in number in fish that consume large prey. While, the plankton feeders usually have elongated, numerous and variously lamellated or ornamented gill rakers, forming an extensive straining sieve[4]. The gill rakers allow the solid food to go to gullet and only water is allowed to pass through gills to outside[5].

Little studies were available on the analyzed gill rakers and their adaptations related to feeding in species with the same feeding habit[6] or related gill rakers to species identification[7].

Therefore, the present study aimed to describe the differences between some families of marine fish species in the morphological features of gill rakers; in addition to the correlation with food and feeding habits.

MATERIAL AND METHODS

1. Specimens collection:

A total of 78 specimens belongs to six families: Sparidae (7 of *Sparus aurata*, 5 of *Diplodus noct*, 5 of *Rhapdosargus haffara* and 12 of *Boops boops*); Family: Mugilidae (4 of *Mugil cephalus*, 7 of *Mugil capito* and 9 of *Liza aurata*); Family: Siganidae (5 of *Siganus rivulatus* and 7 of *Siganus luridus*); Family: Synodontidae (4 of *Saurida undosquamis* and 4 of *Synodus saurus*); Family: Clupeidae (4 of *Herklotsichthys quadrimaculatus*) and Family: Carangidae (5 of *Caranx sexfasciatus*) were collected by irregular visitors from land fish market in different localities of Egyptian Mediterranean Sea and Suez Gulf; during the period from March, 2014 to November, 2014 (Table, 1). Fishes were freshly examined and preserved in 10% formalin solution and transported to laboratory of Marine Biology, Zoology Department, Faculty of Science, Al-Azhar University, Nasr City, Cairo, Egypt for latter examinations. In the laboratory, fishes were identified[8 - 10]. Standard and total lengths were measured to the nearest millimetres and recorded.

2. Staining of gill arch:

In the laboratory, after carefully dissection, operculum was removed, the first gill arch in the left side of the fish was cut off from the rest of the gill; and immersed in 70% ethyl alcohol + 3% Alizarin red for 24 hours, then it washed in 1% KOH for 2 hours.

3. Examination and measurements:

The gill arches were microscopically examined and the number of gill rakers was counted under a dissecting microscope. The digital photographic images were taken using a digital camera mounted on a dissecting microscope. From the digitalised images, the numbers of gill rakers on the anterior row of the first gill arch were recorded and the following measurements were made using the Image Pro Plus Program:

1. The length of anterior gill rakers (L_R) from the tip to base of the longest and the 4 neighboring rakers (um).
2. The breadth (L_B) at the base of the longest and the 4 neighboring rakers (μm).

3. The inter-raker space (I_R) between examined gill rakers, as the distance (μm) between the edge of each gill raker and the edge of the next gill raker.
4. The length of posterior gill rakers (LP) at the first gill arch the longest and the 4 neighboring rakers (if possible) were measured in um.

4- Statistical analysis:

Statistical analysis (ANOVA test) and graphics of data was conducted by using Microsoft Excel under windows programs.

Table (1): List of examined fish species and notes on their specimen numbers, feeding habits and sampling sites.

Order	Family	Species (Scientific name)	Notes		Sampling site
			No.	Feeding habits	
Perciformes	Sparidae	***Sparus aurata***	**7**	Carnivore	Suez Gulf
		Diplodus noct	**5**	Carnivore	Suez Gulf
		Rhapdosargus haffara	**5**	Carnivore	Suez Gulf
		Boops boops	**12**	Plankton feeder	Mediterranean Sea
	Mugilidae	***Mugil cephalus***	**4**	Detritus feeder	Mediterranean Sea
		Mugil capito	**7**	Detritus feeder	Mediterranean Sea
		Liza aurata	**9**	Detritus feeder	Mediterranean Sea
	Siganidae	***Siganus rivulatus***	**5**	Herbivore	Mediterranean Sea
		Siganus luridus	**7**	Herbivore	Mediterranean Sea
	Carangidae	***Caranx sexfasciatus***	**5**	Carnivore	Suez Gulf
Aulopiformes	Synodontidae	***Saurida undosquamis***	**4**	Piscivoure	Mediterranean Sea
		Synodus saurus	**4**	Piscivoure	Mediterranean Sea
Clupeiformes	Clupeidae	***Herklotsichthys quadrimaculatus***	**4**	Plankton feeder	Suez Gulf

RESULTS

1. Morphology of gill arch:

Family Sparidae is represented in the present study by four species (*Sparus aurata, Diplodus noct*, *Rhapdosargus haffara and Boops boops*). The gill arch is bow-like shape; formed of one piece. It is displayed semilunar in shape, consisting of two limbs (upper and lower limbs). The gill arch carried two rows of gill rakers on its concave border and two rows of gill filaments on its convex one. The anterior row (oral row) and posterior (aboral row) of gill rakers varied in length and shape in the first gill arch; having long and more developed rakers in the first row and short with less developed in the second one. The gill rakers in the anterior row of first gill arch in most species of family Sparidae (s*parus aurata*, *Diplodus noct*, *Rhapdosargus haffara* are short, conical in shape and elongated thick slightly pointed end strips with triangular base in *Boops boops* (Fig. 1A).

Family Mugilidae is represented in the present study by three species comprise (*Mugil cephalus, Mugil capito and Liza aurata*. The gill arches of Mugilidae have crescent-shaped (in *Mugil cephalus* and *Mugil capito*) or bow-shaped (in *Liza aurata*). Each gill arch is formed of one piece, consisting of two limbs (upper and lower limbs). The gill arch carried gill rakers on its concave border and gill filaments on its convex one. Gill rakers are arranged in two rows, the anterior row of the first gill arch is characterized by having long and great numbers of rakers, which are short and less in numbers on the posterior one (Fig. 1B).

Family Synodontidae is represented in this study by two species (*Saurida undosquamis* and *Synodus saurus*). All species in this family are piscivores. Gill arches have V shaped and carried two rows of gill rakers on its concave border and gill filaments on its convex one. Gill rakers in synodontid fish are actually appeared as clusters of small tooth patches on the epi-, cerrato-, and basi-branchials (Fig. 1C).

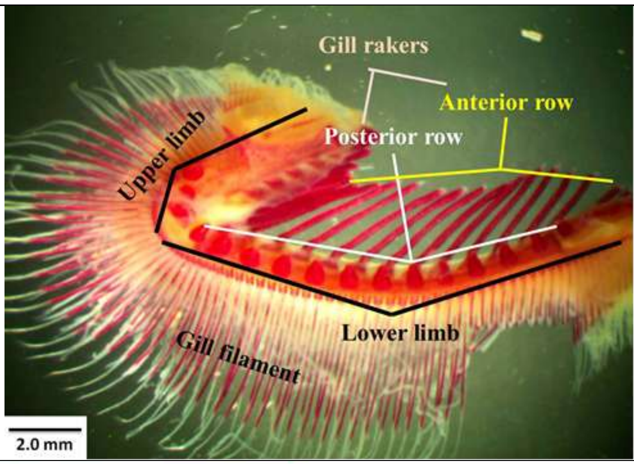
Family Siganidae is represented by two species (*Siganus rivulats* and *Siganus luridus*). These species of family siganidae are herbivores; they have a hook-like shape gill arch supported by two rows of gill rakers which extended antero-medially from the arch. The arch is slightly convex laterally and slightly concave medially. Rakers of the anterior row on first gill arch are more numerous, needle spine in shape with secondary projections and more developed than the posterior row of rakers (Figure, 2A).

Clupeid fishes are plankton-feeder fish, generally characterized with numerous and elongated gill rakers. This family is represented in this study by only *Herklotsichthys quadrimaculatus*. The gill arch has the V like shape. Each gill arch consists of one piece contains 2 limbs (upper and lower limbs). Each gill arch carried well developed gill rakers arranged in one row (anterior row of gill rakers); where the posterior one is absent. Rakers serve in straining water current entering pharyngeal cavity for seizing food items (Fig. 2B).

Carangid fish species are pelagic carnivores, feeding mainly on crustaceans and fishes. This family is represented in this study by *Caranx sexfasciatus*. The gill arch is formed of one piece and has the bow-like shape. Gill rakers are moderate in length and number to long and numerous, their number decreasing with growth (Fig. 2C).

Comparative studies on the gill rakers of some marine fishes with different feeding habits

A



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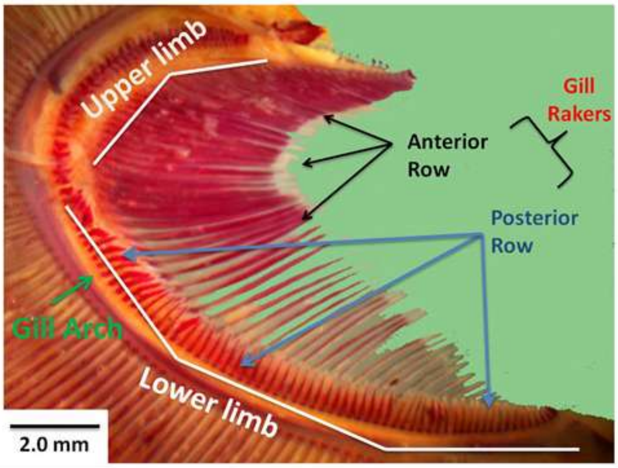

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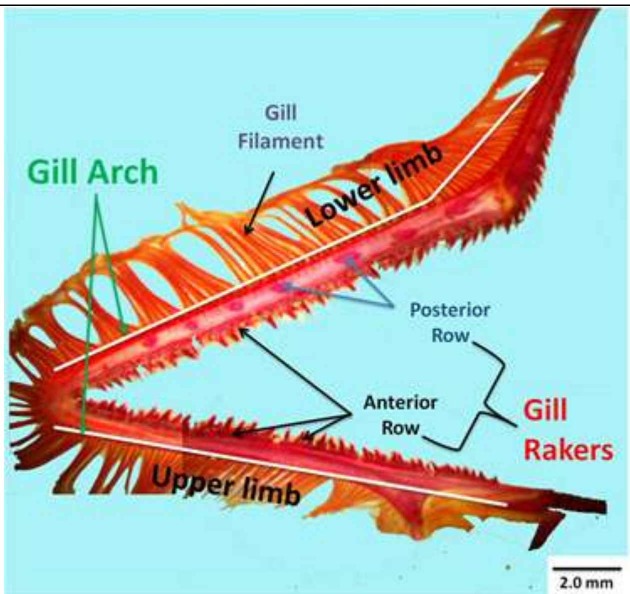
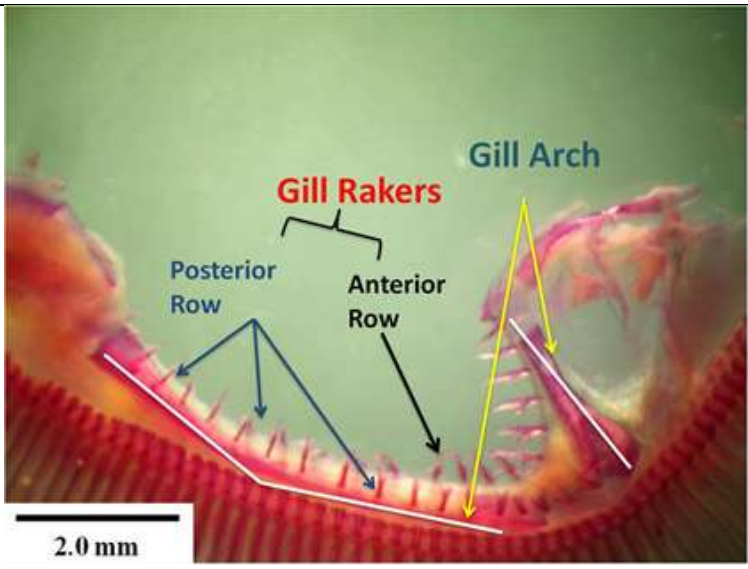


Fig. (1): A photomicrograph of the first gill arch, showing the general morphology and structure of the first gill in fish representing species of family. A- Sparidae, B-Mugilidae and C- Synodontidae.

A



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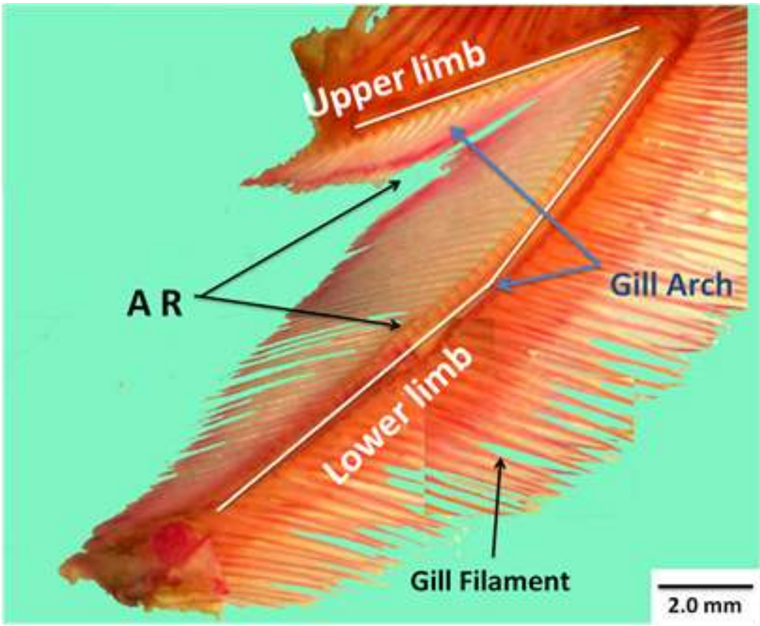

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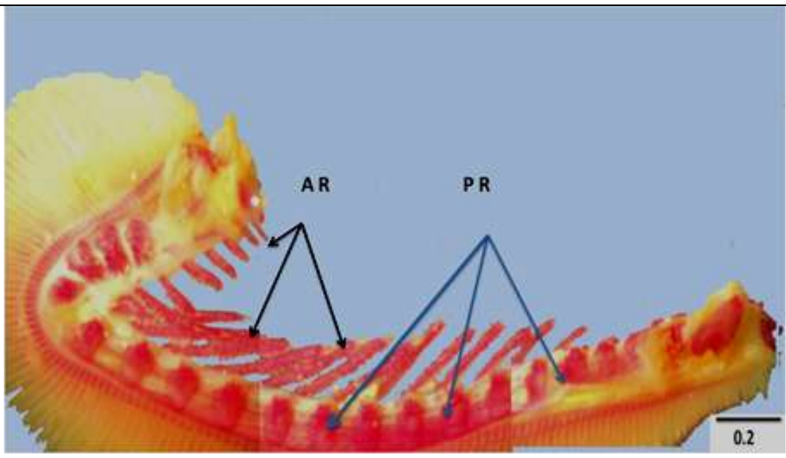

Fig. (2): A photomicrograph of the first gill arch, showing the general morphology and structure of the first gill in fish representing species of family. A- Siganidae, B-Clupeidae and C-Carangidae.

2. Gill rakers - feeding habits relationship:

Results showed that, according to the feeding habits, fish species can be classified into: carnivore fish (*Sparus aurata, Diplodus noct, Rhapdosargus haffara* and *Caranx sexfasciatus*); piscivore fish (*Saurida undosquamis* and *Synodus saurus*); detretivore fish (*Mugil cephalus*, *Mugil capito* and *Liza aurata*); herbivore fish (*Siganus rivulats* and *Siganus luridus*) and plankitivore fish (*Boops boops* and *Herklotsichthys quadrimaculatus*).

According to the different feeding habits, the results showed that, the highest average length of the first gill arch (mm) is recorded in carnivore and piscivore fish. It gradually decreased in plankitivore and detritivore fish and reached to its lowest average in herbivore fish (Table 2 and Fig. 3). The differences in gill arch length are statistically significant ($P < 0.05$) except between the detritivore fish species which is non-significant (Table 3).

The results showed that the maximum average number of the anterior gill rakers, in relation to the different feeding habits, is recorded in detritivore fish and plankitivore fish. It clearly decreased in carnivore, piscivore and herbivore fish (Table 2 and Fig. 4). The differences in the anterior gill rakers number are statistically highly significant ($P < 0.01$) between the different feeding habits and between the different species of each feeding habit, except between the detritivore fish species which is non-significant (Table 3).

The highest length of anterior gill raker (µm) in fish species with different feeding habits is recorded in detritivore fish followed by planktivore fish and some carnivore fish. While, the lowest anterior gill raker length is occurred in herbivore fish, piscivore fish and some carnivore fish (Table 2 and Fig. 5). The differences in the anterior gill rakers length are statistically significant ($P < 0.05$) between the different feeding habits and between the different species of each feeding habit (Table 3).

The anterior gill raker length /gill arch length ratio (%) in fish species with different feeding habits showed that, the highest percentages are recorded in plankitivore fish and detritivore fish. It gradually decreased in carnivore fish and herbivore fish; reaching to its lowest percentages in piscivore fish (Table 2 and Fig. 6).

The maximum space between the anterior gill rakers (µm) in fish species with different feeding habits is recorded in carnivore fish and it clearly decreased in fish species of other feeding habits (Table 2 and Fig. 7). The differences in the inter rakers space are statistically highly significant ($P < 0.01$) between the different feeding habits and between the different species of each feeding habit (Table 3).

The inter raker space/gill arch length (%) in the anterior row of rakers in fish species with different feeding habits showed that, the highest percentages are recorded in carnivore fish. It gradually decreased in herbivorous and plankitivore fish, reaching to its lowest percentages in piscivore and detritivore fish (Table 2 and Fig. 8).

The maximum breadth at the raker base (µm) in the anterior row of rakers in fish species, according to the different feeding habits, is recorded in piscivore fish. It gradually decreased in carnivore, planktivore, detritivore fish and reaching to its lowest values in herbivore fish (Table 2 and Fig. 9). The differences in the breadth at the raker base in the anterior row of rakers are statistically highly significant ($P < 0.01$) between the different feeding habits and between the different species of each feeding habit (Table 3).

The highest breadth at the raker base/gill arch length (%) in the anterior row of rakers in fish species with different feeding habits is recorded in in carnivore fish, piscivore fish and planktivore fish. The lowest values are recorded in detritivore fish and herbivore fish (Table 2 and Fig. 10).

The highest length of posterior gill raker (µm) in fish species with different feeding habits is recorded in detritivore fish followed by some carnivore fish. While, the lowest posterior gill raker length is recorded in piscivore fish, herbivore fish and some carnivore fish

(Table 2 and Fig. 11). The differences in the posterior gill rakers length are statistically non-significant except between piscivore and herbivore fish species which are highly significant (P< 0.01) (Table 3).

The posterior gill raker length /gill arch length ratio (%) in fish species with different feeding habits showed that, the relatively highest percentages are recorded in detritivore fish, herbivore fish and carnivore fish. It gradually decreased in plankitivore fish and reached to its lowest percentage in piscivore fish (Table 2 and Fig. 12).

DISCUSSION

In the present study, the gill rakers in most species of family Sparidae such as s*parus aurata*, *Diplodus noct*, *Rhapdosargus haffara* are short, conical in shape and pointed to binding the preys to the oesophagus. These findings are in conformity with those of the carnivorous fish described[11 - 14]**.** But, the gill rakers in *Boops boops* are elongated thick slightly pointed end strips with triangular base modified to sorting of plankton. Similar observations are detected[4]**.** He mentioned that, the gill arches may be equipped with projections called gill rakers, which aid in food gathering. In the same manner, the gill-rakers are also specialized in relation to the food and feeding habits. They may be small and few in number in fish that consume large prey. While, the plankton feeders usually have elongated, numerous and variously lamellated or ornamented gill rakers, forming an extensive straining sieve.

Carangids are pelagic carnivores, feeding mainly on crustaceans and fishes. The gill arches are formed of one piece and have bow-shape. In the present work, gill rakers on the anterior row of *Caranx sexfasciatus* exist as elongated thick strips rakers with triangular base, which bent inward and their length increases in the middle portion of the gill arch. This result is in agreement with Fischer and Whitehead[15]**.** They mentioned that, gill rakers are mostly moderate-sized, occasionally either stumps or very long.

In the present study, the gill arches of Mugilidae are crescent-shaped (e.g. *Mugil cephalus* and *Mugil capito)* or bow-shaped (e.g. *Liza aurata)*. The gill arches lack of angle of curvature or display an acute angle of curvature in the middle of the gill arches. These observations may be attributed to the degree to the pharynx expansion in filter-feeding mullets, *Mugil cephalus* [16]**.** The gill rakers of the anterior row on the first gill arch are long and numerous. This structure is adapted to the feeding habits in different species of mullets (muddy skeeper). Long and numerous of gill rakers, may be related to mechanical sieving of mud. Similar observations at the same family are recorded[17 - 18]**.**

In the present study, the gill arches of family: Synodontidae are V shaped. It may be attributed to help the fish in swallowing the large food by backward direction in the pharyngeal cavity. Gill rakers in synodontids are actually clusters of small tooth patches adapted to piscivores feeder. This result is coinciding with Carpenter [19]. He mentioned that, gill rakers in synodontid fish are rudimentary or minute and spine-like.

In the present study, the top surface of the gill rakers in rabbit fish consists of a relatively smooth, thin ridge at its distal end. Regular arrays of secondary projections, either spiny or smooth extended from the underside of each raker. They look like a spine with broad bases and more or less tapering ends. This structure in rakers is adapted to vegeterians feeder. The siganid fish is herbivorous; progress from feeding on zoo- and phytoplankton as larvae to finer algae as small juveniles and to coarser seaweeds and encrusting algae, and occasionally sea grasses, as adults[20]**.**

Table (2): Averages of some measurements and ratios of gill rakers on the first gill arch of studied fish species of different feeding habits.

Food category	Fish species	L_A (mm)	RC	L_R (µm)	L_R/L_A (%)	I_S (µm)	I_S/L_A (%)	L_B (µm)	L_B/L_A (%)	L_P (µm)	L_P/L_A (%)
Carnivorous	*S. aurata*	18	15	851.2	0.47	766.7	0.43	469.3	0.26	398.8	0.22
	D. noct	15	22	1178.9	0.79	348.6	0.23	416.8	0.28	442.6	0.30
	R. haffara	33	16	2477.7	0.75	1143.3	0.35	1368.6	0.41	1127.2	0.34
	C. sexfasciatus	32	28	4727.6	1.4	643.7	0.20	1011.8	0.32	1051.6	0.47
	Mean ±SD	24.50 ± 9.33	20 ± 6	2308.86 ± 758.85	0.87 ±0.42	725.57 ±329.14	44.85 ±32.94	816.63 ±455.81	0.31 ± 0.06	755.06 ±538.43	0.33 ±0.10
Piscivorous	*S. undosquamis*	37	24	560.6	0.15	317.6	0.09	1664.3	0.45	276.95	0.07
	S. saurus	32.3	38	449.7	0.13	270.93	0.08	551.55	0.17	548.55	0.17
	Mean ±SD	34.65 ± 3.32	31 ± 10	505.14 ± 78.37	0.14 ± 0.01	294.27 ± 33.00	58.45 ±2.53	1170 ±786.83	0.31 ± 0.19	412.75 ±192.05	0.12 ± 0.06
Detritivorous	*M. cephalus*	35.7	145	5703.9	1.60	220.39	0.06	419.7	0.12	1437.4	0.40
	M. capito	40.3	147	6842.8	1.70	328.8	0.08	633.2	0.16	1395.6	0.35
	L. aurata	39.5	162	6590.0	1.67	172.1	0.04	435.3	0.11	1610.3	0.41
		38.50 ± 2.46	151 ± 9.29	6378.94 ± 98.04	1.65 ± 0.05	240 ± 80.24	3.76 ± 1.100	496.02 ±119.00	0.12 ± 0.02	1481.11 ±113.84	0.38 ± 0.03
Herbivorous	*S. rivulatus*	14	24	838.4	0.60	346.5	0.25	254.1	0.18	439.49	0.31
	S. luridus	11.5	21	910.8	0.79	302.2	0.26	142.8	0.12	467.38	0.41
	Mean ±SD	12.75 ± 1.77	23 ± 2	874.61 ± 51.15	0.69 ± 0.13	324.37 ± 31.35	37.26 ± 5.76	198.45 ± 78.66	0.15 ± 0.04	453.44 ± 19.72	0.36 ± 0.06
Planktivorous	*B. boops*	20	25.0	4175.6	2.09	372.6	0.19	756.9	0.38	587.8	0.29
	H. quadrimaculatus	30.7	105	4710.9	1.53	107.0	0.03	446.9	1.21	0.00	0.00
	Mean ±SD	25.35 ± 7.57	65 ± 56.57	4443.29 ± 378.56	1.81 ± 0.39	239.82 ± 87.77	0.11 ± 0.10	601.95 ±219.14	0.26 ± 0.16	293.9 ±415.63	0.15 ± 0.20

L_A: length of gill arch; RC: Gill rakers counts; L_R: length of gill rakers in anterior row; I_S: Inter raker space of anterior row; L_B: length of breadth at the base of anterior rakers and **L_P: Length of gill rakers in posterior row.**

Table (3): Statistical analysis of variance results of some measurements of gill rakers on the first gill arch, between fish species of each feeding habit and between the different feeding habits.

Measurements		Carnivores Fish species	Piscivores Fish species	Detritivores Fish species	Herbivores Fish species	Planktivores Fish species	Total feeding habits
L_A	F-	281.14	4.04	0.99	34.09	134.73	**127.07**
	P-	1.63E-16 **	0.07 *	0.39 NS	0.0001 **	3.99E-07 **	**3.15E-16 ****
RC	F-	441.71	80.81	0.36	27.76	1449.77	**430.18**
	P-	1.94E-18 **	4.18E-06 **	0.54 NS	0.0003 **	3.72E-12 **	**1.19E-22 ****
L_R	F-	347.28	6.69	11.10	16.49	12.99	**1445.44**
	P-	3.85E-36 **	0.015 *	0.0001 **	0.0003 **	0.001 **	**1.88E-66 ****
I_S	F-	35.33	7.82	13.41	9.84	241.90	**270.15**
	P-	5.98E-13 **	0.009 **	3.13E-05 **	0.003 **	2.63E-15 **	**9.45E-42 ****
L_B	F-	157.83	335.67	13.05	153.34	195.80	**348.37**
	P-	2.75E-27 **	3.99E-17 **	3.90E-05 **	7.07E-13 **	3.66E-14 **	**2.12E-45 ****
L_P	F-	0.99	2567.45	2.13	3.99	25189.95	**1.00**
	P-	0.40 NS	4.34E-29 **	0.13 NS	0.055 NS	6.47E-43 **	**0.41 NS**

L_A: length of gill arch; RC: Gill rakers counts; L_R: length of gill rakers in anterior row; I_S: Inter raker space of anterior row; L_B: length of breadth at the base of anterior rakers; L_p: Length of gill rakers in posterior row; F- and P- value: the result data of statistical analysis of variance (ANOVA); NS: non-significant; *: significant and **: highly significant.

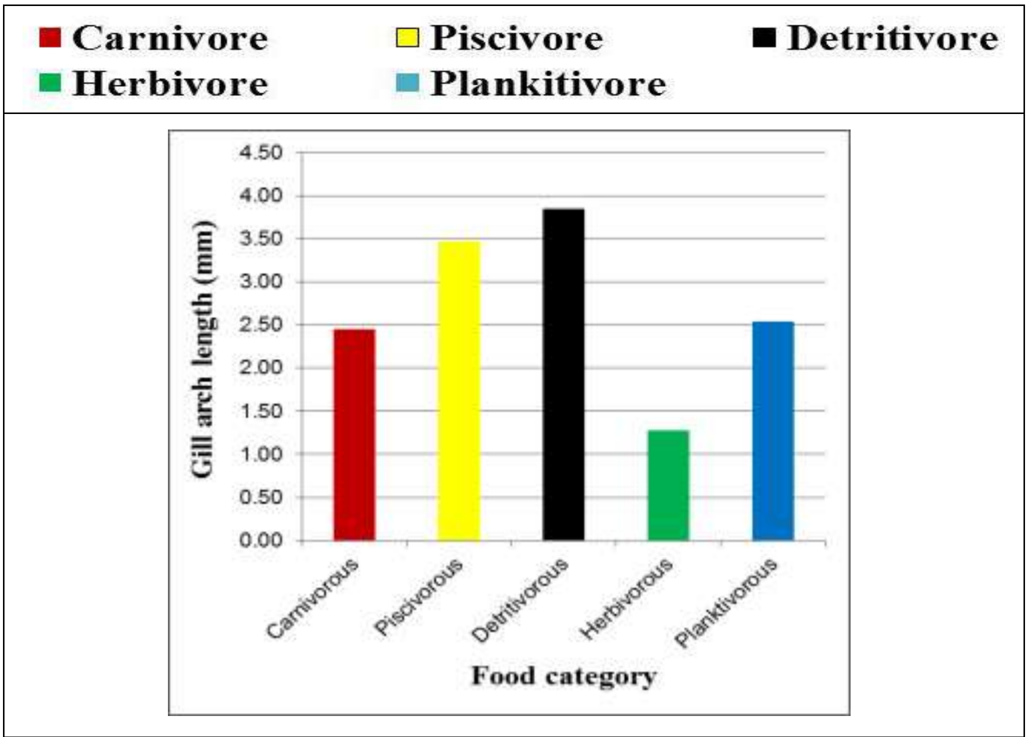

Figure (3): A histogram of the first gill arch length (average, mm) in fish species with different feeding habits.

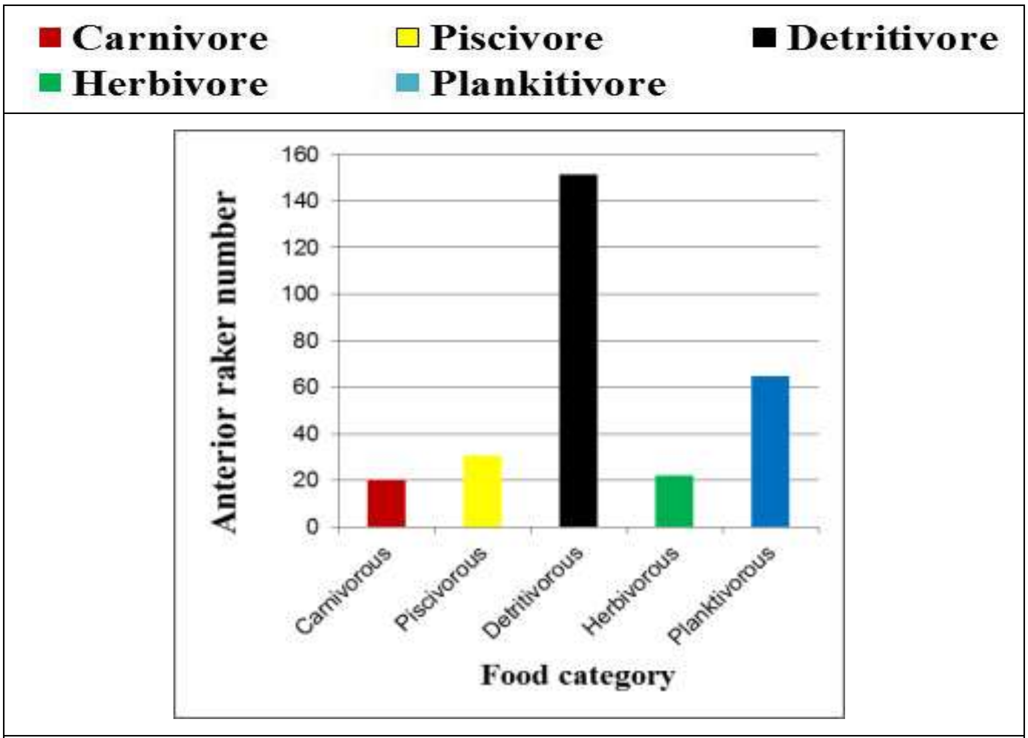

Figure (4): A histogram of the anterior gill raker number in fish species with different feeding habits.

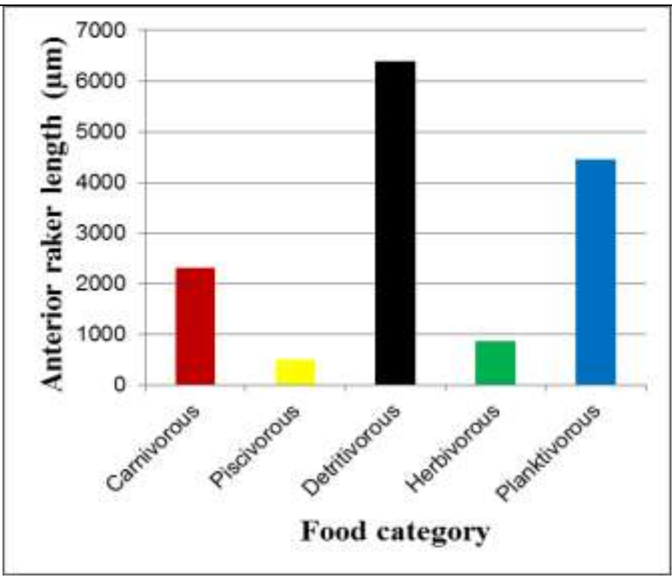

Figure (5): A histogram of the anterior gill raker length (µm) in fish species with different feeding habits.

Carnivore	Piscivore	Detritivore
Herbivore	Plankitivore	

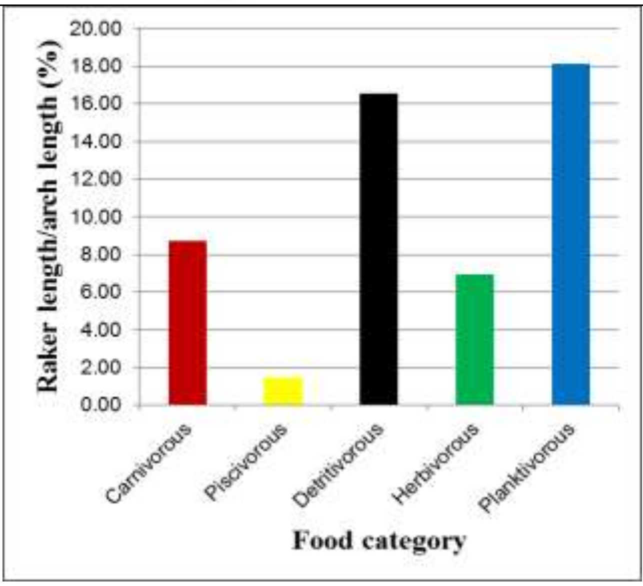

Figure (6): A histogram of the anterior gill raker length /gill arch length (%)in fish species with different feeding habits.

Carnivore	Piscivore	Detritivore
Herbivore	Plankitivore	

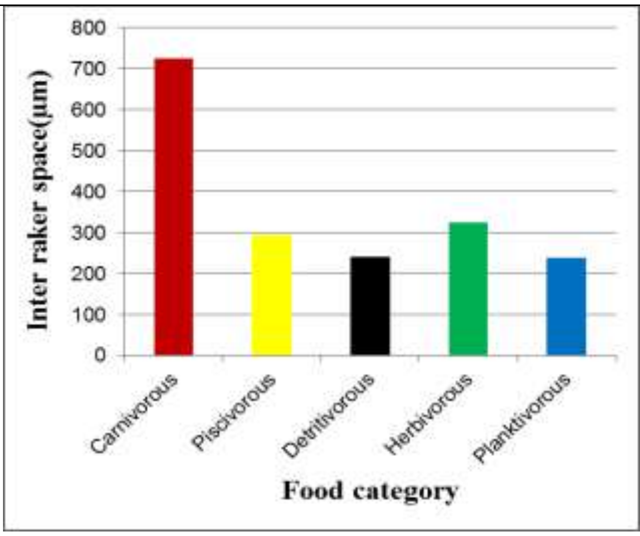

Figure (7): A histogram of the inter raker space (µm) in the anterior row of rakers in fish species with different feeding habits.

■ Carnivore □ Piscivore ■ Detritivore
■ Herbivore ■ Plankitivore

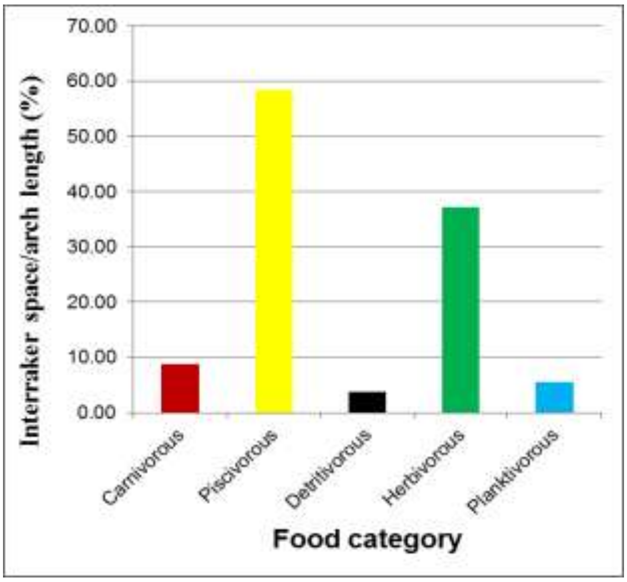

Figure (8): A histogram of the inter raker space /gill arch length (%) in the anterior row of rakers in fish species with different feeding habits.

■ Carnivore □ Piscivore ■ Detritivore
■ Herbivore ■ Plankitivore

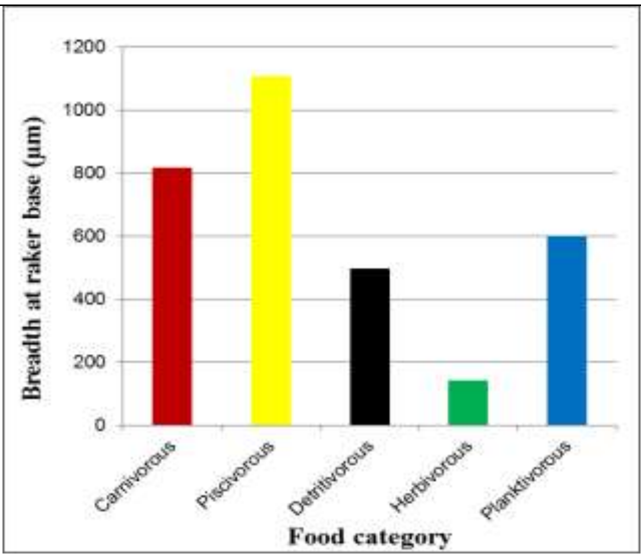

Figure (9): A histogram of breadth at the raker base (µm) in the anterior row of rakers in fish species with different feeding habits.

■ Carnivore ■ Piscivore ■ Detritivore
■ Herbivore ■ Plankitivore

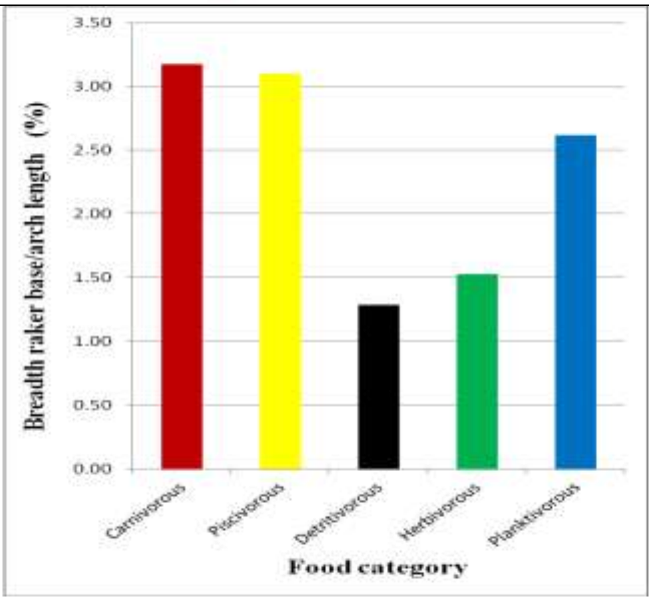

Figure (10): A histogram of breadth at the raker base /gill arch length (%) in the anterior row of rakers in fish species with different feeding habits.

■ Carnivore ■ Piscivore ■ Detritivore
■ Herbivore ■ Plankitivore

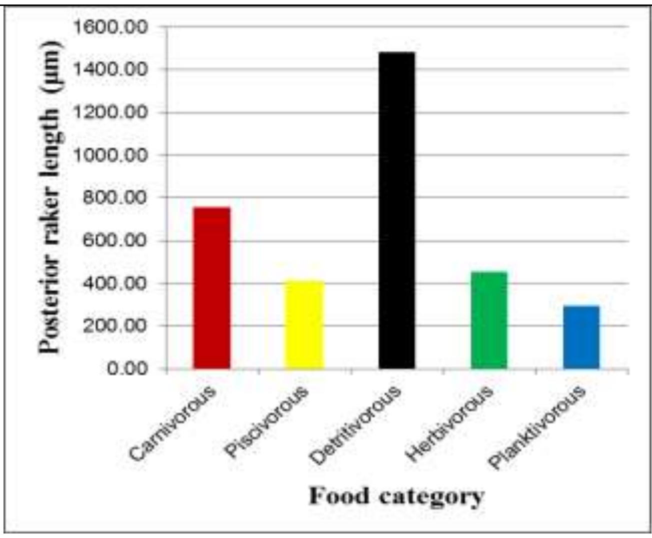

Figure (11): A histogram of posterior gill raker length (µm) in fish species with different feeding habits.

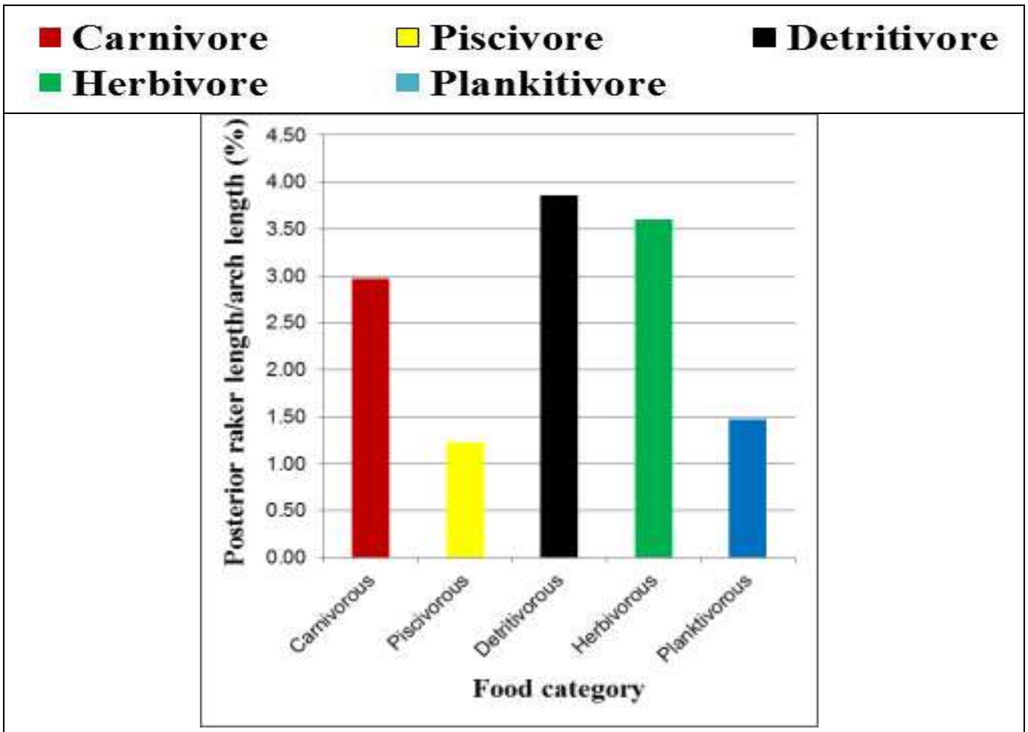

Figure (12): A histogram of posterior gill raker length /gill arch length (%) in fish species with different feeding habits.

DISCUSSION

In the present study, the gill arches of family: Synodontidae are V shaped. It may be attributed to help the fish in swallowing the large food by backward direction in the pharyngeal cavity. Gill rakers in synodontids are actually clusters of small tooth patches adapted to piscivores feeder. This result is coinciding with **Carpenter [19].** He mentioned that, gill rakers in synodontid fish are rudimentary or minute and spine-like.

In the present study, the top surface of the gill rakers in rabbit fish consists of a relatively smooth, thin ridge at its distal end. Regular arrays of secondary projections, either spiny or smooth extended from the underside of each raker. They look like a spine with broad bases and more or less tapering ends. This structure in rakers is adapted to vegeterians feeder. The siganid fish is herbivorous; progress from feeding on zoo- and phytoplankton as larvae to finer algae as small juveniles and to coarser seaweeds and encrusting algae, and occasionally sea grasses, as adults **[20].**

In the present study, gill arches in family Clupeidae have the V shape appearance. Each arch carries well developed rakers arranged in one row. Clupeid fish are generally characterized with numerous and elongated rakers. These rakers carries numerous, fine spinules adapted to filtering of plankton. Rakers serve in straining water current entering pharyngeal cavity for seizing food items. The rakers on the first gill arch account for almost 60% of the whole filtering area. The observed particle retention capabilities of the fish when filter-feeding are lower than those expected on the basis of the estimated spaces between the rakers **[21].**

In the present study, the highest length of anterior gill raker is recorded in detritivore fish followed by planktivore fish and the lowest occurred in piscivore and carnivore fish. The role of the gill raker apparatus is related to prey retention efficiency, where the gill rakers function as a cross-flow filter **[22 - 23].** An increasing number of gill rakers enhance crossflow filtering and the closely spaced gill rakers also limit the escape possibilities of small prey. Accordingly, a high number of long gill rakers are common in planktivorous fish species and morphs, whereas benthic species and morphs usually display a lower number of short gill rakers **[24 - 25].**

In the present study, the detritivore and plankitivore fish recorded the maximum average number and the minimum space between the anterior gill rakers. There may be a trend for species with increase in number and smaller distances between the gill rakers and denticles of pharyngeal pads to have a preference for, or to be able to ingest smaller particles **[26].**

On the other hand, in all studied species, the posterior rakers of the first gill arch are shorter and less in numbers compared to those on the anterior row. Similar observations are recorded **[27 - 28]** in other species, and are related to respiratory (gasseous exchange) and osmoregulatory (ion exchange) functions **[28],** as well as filter feeding mechanism **[21].**

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دراسات مقارنة على الأسنان الخيشومية لبعض الأسماك البحرية مع إختلاف العادات الغذائية

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المستخلص

يهدف هذا البحث إلى توضيح الإختلافات المورفولوجية للأسنان الخيشومية فى بعض الأسماك البحرية وربطها بنوعية الغذاء. وقد تمت الدراسه على 13 نوع من الأسماك البحرية تتبع 6 عائلات وهى: عائلة الشراغيش (الدنيس العادى: سبارس أيوراتا، الدنيس أبونقطة: دبلودس نقط، الحفارة: رابدوسارجس حفارة والموزة: بوبس بوبس)، عائلة البورى (البورى الأصيل: ميوجل سيفالس، الطوبارة: ميوجل كابيتو والدهبانة: ليزا أيوراتا)، عائلة ملتحمة الأسنان أو أسماك المكرونة (سيوريدا أندوسكوامس وسينودس سيورس)، عائلة السيجان (سيجانس رفيولاتس وسيجانس لوريدس)، عائلة الصابوغيات أو أسماك السردين (هيركلوتسكسس كوادريماكيولاتس) وعائلة البياض (كارانكس سكسفاشياتس). تم تجميع الأسماك في زيارات غير منتظمة من مناطق مختلفة على سواحل البحر المتوسط وخليج السويس في الفترة ما بين مارس 2014 وحتى نوفمبر 2014م.

أوضحت النتائج أن القوس الخيشومي الأول مكون من قطعه واحدة وله طرفان علوى وسفلى ويحمل صفين من الأسنان الخيشومية على الجانب المقعر وصفين من الخيوط الخيشومية على الجانب المحدب. الأسنان الخيشومية فى الصف الأمامي من القوس الخيشومي الأول كانت طويلة وكثيرة العدد ومتطورة عن الأسنان الخيشومية فى الصف الخلفى. كما أظهرت النتائج أن القوس الخيشومي فى أنواع عائلة الشراغيش على شكل قوس. الأسنان الخيشومية فى الصف الأمامي من القوس الخيشومي الأول كانت قصيرة، عريضة ومخروطية الشكل لكى تتوائم مع الأسماك التى تتغذى تغذية لاحمة. كما أوضحت النتائج أن القوس الخيشومي فى أنواع عائلة البورى يكون هلالى الشكل فى أسماك البورى الأصيل والطوبارة وعلى شكل قوس فى أسماك الدهبانه. وظهرت الأسنان الخيشومية فى الصف الأمامي من القوس الخيشومي الأول طويلة، كثيرة العدد. كما ظهر سطحها مزود بحواف رفيعه ناعمه ذو نهاية عريضة. وهذا التركيب يتوائم مع الأسماك التى تتغذى على ترشيح كميه كبيرة من المواد العضوية القاعية المتحللة.

أتضح من النتائج أن القوس الخيشومي فى أنواع عائلة ملتحمة الأسنان (أسماك المكرونة) على شكل حرف V. الصف الأمامي من القوس الخيشومي الأول عبارة عن كتل تنتهى بأشواك رفيعة ومدببة. وهذا التركيب يتوائم مع الأسماك اللاحمه التي تتغذى على الأسماك. كما أتضح أن القوس الخيشومي فى أنواع عائلة السيجان يكون خطافى الشكل. الأسنان الخيشومية فى الصف الأمامي من القوس الخيشومي الأول عبارة عن أشواك إبرية الشكل ذو قاعدة عريضة

وتحمل زوائد ثانوية ناعمة تمتد على الجانب الخلفى للأسنان الخيشومية. وهذا التركيب يتوائم مع الأسماك التى تتغذى على الطحالب والحشائش.

أوضحت النتائج أن القوس الخيشومي فى أنواع عائلة الصابوغيات (أسماك السردين) يكون على شكل حرف V ويحمل أسنان خيشومية متطورة تترتب فى صف واحد فقط. الأسنان الخيشومية فى هذا الصف طويلة مخروطية ذو حافة مستدقة. تعمل هذه الأسنان على تصفية الماء لتلتقط الغذاء. وهذا التركيب يتوائم مع الأسماك التى تتغذى على الهائمات.

أوضحت النتائج أن القوس الخيشومي فى أنواع عائلة البياض يكون على شكل قوس. الأسنان الخيشومية فى الصف الأمامي من القوس الخيشومي الأول عبارة عن أشرطة طويلة وسميكة ذو قاعدة مثلثة وتحمل العديد من الشويكات المثلثية الشكل ذو حافة مستدقة. وهذا التركيب يتوائم مع الأسماك التى تتغذى على اللاحمات.

مما سبق يتضح إن الا ختلاف في الأسنان الخيشومية يرتبط بالعادات الغذائية حيث وجد أن أعلى أطوال للقوس الخيشومي سجلت فى الأسماك أكلة الدبال وآكلات الأسماك. بينما سجلت النتائج أكثر أعداد للأسنان الخيشومية الأمامية وأطول الأسنان الخيشومية الأمامية والخلفية في الأسماك آكلة الدبال. كما سجلت أعلى نسبة فى طول الصف الأمامى للأسنان الخيشومية / طول القوس الخيشومى فى الأسماك التى تتغذى على الهائمات والأسماك آكلة الدبال. وأيضا سجلت أعلى قيمة فى المسافات البينية فى الصف الأمامى للأسنان الخيشومية ونسبتها على طول القوس الخيشومى فى الأسماك التى تتغذى على اللاحمات. بينما سجلت أعلى قيمة فى عرض قاعدة الصف الأمامى للأسنان الخيشومية ونسبتها على طول القوس الخيشومى فى الأسماك آكلة الأسماك وكذلك الأسماك اللاحمة.

ونخلص من هذه الدراسة إلى أن التراكيب المورفولوجية للأسنان الخيشومية في الصف الأمامي للقوس الخيشومي الأول إختلفت فى الأسماك محل الدراسة بإختلاف الغذاء والعادات الغذائية.

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