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Morphological adaptations of digestive tract according to food and feeding habits of the lizardfish, *Synodus variegatus*, inhabiting Red Sea waters, Hurghada, Egypt

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ABSTRACT

This study is concerned with the morphological adaptations of the digestive tract with respect to food and feeding habits of lizardfish *Synodus variegatus*. 75 fish specimens were seasonally collected from Hurghada, the Red Sea, Egypt. Results showed that the greatest value of feeding activity of *S. variegatus* was recorded in summer (82.26%) and the lowest value (24.14%) occurred in winter. While in autumn and spring, the feeding activity was moderate, with 44.50% and 47.26%, respectively. This species was proved to be a piscivorous and crepuscular feed, consuming a large variety of small fishes. *Atherinomorus lacunosus*, *Herklotsichthys quadrimaculatus*, *Cephalopholis hemistiktos*, *Lethrinus mahsena*, *Parupeneus forsskali* and *Siganus rivulatus* formed the major food items consumed. *S. variegatus* has a reptile-like head to facilitate capturing the prey. Jaw's teeth are canine and slightly curved towards the inner part of the mouth. Buccal teeth are canine shaped and arranged in a line on vomerine and palatine in addition to five rows on ectopterygoid of both sides in the roof of the buccal cavity. They specialized in capturing and holding the prey and preventing its escape from the mouth cavity. The pharyngeal teeth are placed in rows and bent in shape. They are specialized in food cutting and masticating. Gill arch is V-shaped; it may be attributed to help in swallowing large prey. The front row gill rakers of the first-gill arch is short, straight, and ended by thin pointed spines adapted for food gathering and binding prey to the entry esophagus. Esophagus in *S. variegatus* is a short muscular narrow and distensible tube suitable for conducting food. Its stomach has a great distensibility giving a bag shape to allow catching relatively enormous prey. The intestine is a short, simple tube. In conclusion, the morphological features of the mouth, teeth, gill rakers, esophagus, stomach and intestine of lizardfish *S. variegatus* were subjected to various and significant modifications according to food and feeding habits to enrich the available data on the species.

INTRODUCTION

The Red Sea coast is a very important part in Egyptian fisheries, both for great total catch and for the numerous economically remarkable species. Coral reefs community plays a role of great importance in the marine environment. They provide many marine organisms with food, shelter and breeding ground. For many countries, coral reefs are considered an important food source for humans; it provides a considerable amount of seafood specially fishes **(Alevizon, 1994; Mohamed, 1999** and **Bhat, 2004)**.

The piscivorous coral reef fishes are those which feed primarily or wholly on other fishes. Predation prevents populations from achieving levels of inter-species competition. There are three different basic hunting strategies used by such predators, each involving a variety of physical adaptations and behaviors. Piscivorous can be defined as chase, ambush and stalking. Ambush predators rely on disguise and immobility to hunt like lizardfish (**Lieske & Myers, 1999).** There are 40 species of lizardfish (Family: Synodontidae); 31 species belong to genus *synodus* that all were in the Atlantic Ocean. Others are distributed in the Indian Ocean and Indo-Pacific. Nine species of synodontid fish occur in the shallow Red Sea reefs such as *S. variegatus*. Lizardfish were named for their reptile-like heads **(Randall, 1983** and **Rahimibashar *et al*., 2012).**

Knowledge of the natural animal foods is vital for understanding the dietary habits and nutritional requirements of the species and is also essential in basic community analysis for studies of food webs, tropho-dynamics, resource sharing and ecological energy networks. On the other hand, the food and dietary habits of the fish are significant for cultivating a group of fish in ponds or impoundments, so that their competition for food is minimal **(Rao & Durga Prasad, 2002; Khalaf- Allah, 2013; Shalaby, 2017** and **Alabssawy *et al*., 2019).**

The adaptations of the digestive organs of the fish to their natural diet are particularly obvious in the shape, size, structure, abundance and limitation of the microscopic parts like teeth, mucous cells, taste buds, digestive glands and the muscular envelope of the esophagus, stomach and intestine in the fish. All of these features are subject to various and significant variations and many modifications that conform to food and dietary habits **(Dasgupta, 2000; Khalaf- Allah, 2013; Shalaby, 2017** and **Alabssawy *et al*., 2019).**

Few studies on adaptations of the digestive system of coral reef fish to food and feeding habits in the Egyptian Red Sea were recorded by **Al-Hussini (1947)** on some teleosts living in the Hurghada, Red Sea; **Gohar & Latif (1959)** on some scarid and labrid fish; **Azab *et al*. (1998)** on sole fish, *Solea solea* and goat fish, *Parupeneus forsskali*; **Khalaf - Allah (2012 & 2013)** on therapon fish, *Terapon jarbua* and the broomtail wrasse, *Cheilinus lunulatus*; **Shalaby (2017)** on rabbit fish, *Siganus rivulatus*, cornet fish, *Fistularia commersonii*, yellow striped goat fish, *Mulloidichthys flavolineatus* and needle fish, *Tylosurus choram*, and **Alabssawy *et al*. (2019)** on lizardfish, *S. variegatus.* However, information on the morphological structures of digestive tract in lizardfish, *S. variegatus* adapted to food and dietary habits is very little.

Therefore, the present study pointed to provide description of the morphological adaptations of digestive system according to food and feeding habits of lizardfish, *S. variegatus* inhabiting Hurghada, Red Sea, Egypt.

MATERIALS AND METHODS

1. Specimens collection:

A total of 75 specimens of lizardfish, *S. variegatus* (14 – 25cm in total length) **(Fig. 1)** were seasonally collected from Hurghada, Red Sea, during the period from January to December, 2021. Longlines fishing nets were the principle method used to collect the fish. The fish were examined fresh, fixed in a formalin solution (10%), and transported to the marine biology laboratory, Zoology Department, Faculty of Science, Al-Azhar University, Cairo, Egypt for further examinations. In lab, fish were identified taxonomically, according to **Randall (1983)** and the following studies were carried out.

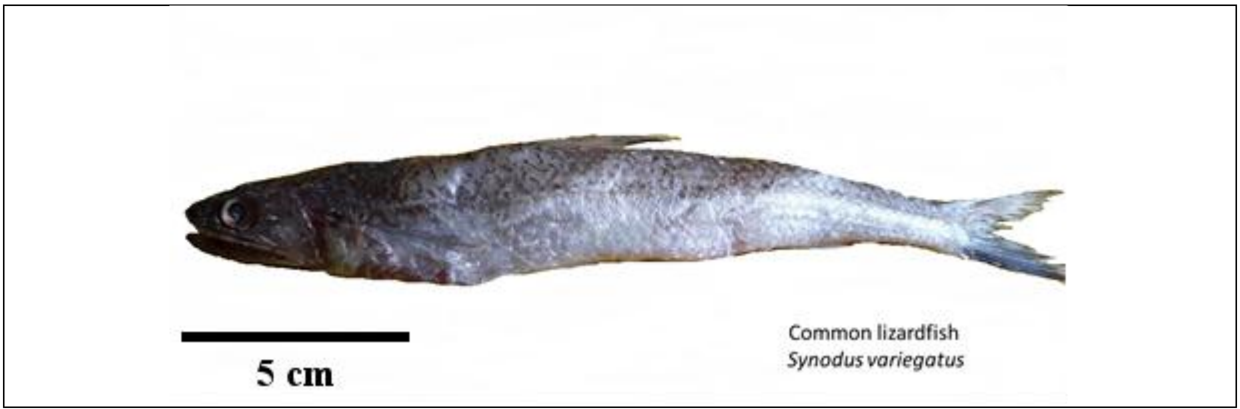

Fig. (1). Light photograph of lizardfish, *Synodus variegatus*, collected from Hurghada, Red Sea, Egypt.

2. Food and feeding habits:

2.1. Feeding activity:

To investigate feeding activity, all the stomachs examined were firstly assessed. The evaluation was based on the visual estimates of the distension of the stomachs and the relative quantity of food they contained. The stomachs examined were categorized into five classes, according to the following style used by **Geevarghese (1976):**

1. Empty: The stomach contained particularly nothing and the wall was evident.
2. Poor: The stomach contained little food, but distension of the wall was not evident.
3. Medium: The stomach was nearly half full and the wall was slightly distended.
4. Good: The stomach was almost full and the distension of wall was quite evident.
5. Heavy: The stomach was gorged with food and the wall was fully distended.

The proportion of the above five groups of stomachs gage was counted. The percent of heavy, good, and medium stomachs which was actually reflective of good condition seasonally was determined to estimate the feeding activity.

2.2. Food composition:

To analysis food composition, the point assessment method **(Hynes, 1950)** was executed. Each stomach was split and washed with water and its contents were dispersed into a Petri dish and examined under a low-power binocular microscope. Food items were identified taxonomically, as far as possible up to genera used by **Randall (1983)** and **Lieske & Myers (2004)**. The Percent of each item was calculated and graphically represented for each fish category.

3. Morphology of digestive tube:

For studying the dentition, after dissection of the head, upper and lower jaws, pharyngeal pads and first gill arch were carefully isolated. They embedded in 3% KOH, with adding a drop of 1% Alizarin red stain for 5 days and transferred into 70% ethyl alcohol, then photographed and described. Esophagus, stomach and intestine were segregated neatly from the body cavity and stored in 70% ethyl alcohol, then pictured and described.

RESULTS

1. Food and feeding habits:

1.1. Seasonal variation in the feeding intensity:

The percent of heavy, good and medium stomachs of *S. variegates* which was actually reflecting good condition seasonally, was recorded to estimate the actively fed and the rest poorly fed.

Results in **Table (1)** demonstrate that, the percentages of actively fed and non-actively fed diverse considerably from season to season. The highest number of empty and poor stomachs was reported during the winter (75.86%) and the lowest (17.74%) occurred during the summer. While in autumn and spring, the non-actively fed is moderately, being 55.50% in the former and 52.74% in the latter. On the other hand, the highest value of feeding activity was reported during the summer (82.26%) and lowest (24.14%) occurred within the winter. While in autumn and spring, feeding activity is moderately, being 44.50% in the former and 47.26% in the latter **(Fig. 2 & 3).**

1.2. Seasonal variation in the food items:

Data in **Table (2)** showed that, *S. variegatus* is basically piscivorous and consumed a broad range of small fishes. *Atherinomorus lacunosus*, *Herklotsichthys quadrimaculatus*, *Cephalopholis hemistiktos*, *Lethrinus mahsena*, *Parupeneus forsskali* and *Siganus rivulatus* were the major food items which the fish consumed. *Tylosurus choram* and *Abudafduf sexfasciatus* are consumed sporadically.

There are quantitative differences of the food items during different seasons. As already stated, small fishes are invariably consumed during seasons. The lowest value of *Atherinomorus lacunosus* was recorded during summer (12%) and spring (12.66%), it gradually increases during autumn (44.88%) and extended to its highest number during winter (52%). The highest number of *Herklotsichthys quadrimaculatus* and *Cephalopholis hemistiktos* were reported during winter and lowest occurred in summer, being 17.56% and 20.44% in the former and 11.23% and 3.10% in the latter. It was completely absent through autumn and spring. On the other hand, the highest number of *Siganus rivulatus* was reported during spring (50%) and lowest occurred through autumn (25.80%). the highest number of *Abudafduf sexfasciatus* was reported through autumn (10%) and lowest occurred through spring (5.92%). *Siganus rivulatus* and *Abudafduf sexfasciatus* were entirely absent during winter and summer **(Table, 2** and **Fig. 4).**

The highest value of *Lethrinus mahsena* was recorded during summer (20.64%) and lowest reported through autumn (10.44%). It was completely absent through winter and spring. The highest number of *Parupeneus forsskali* was reported through spring (22.34%) and lowest occurred through summer (13%). It was completely absent during autumn and winter. While, *Tylosurus choram* (27.30%) was consumes by the fish during summer only. The un-identified fish is consumed by the fish during autumn, winter, spring and summer by low value and limit range, being 8.88%, 10%, 9.08%and 12.73% respectively **(Table, 2** and **Fig. 4).**

Table (1): Percentage of feeding intensity in the lizardfish, *Synodus variegates*, collected from Hurghada, Red Sea, Egypt

Feeding Intensity		Seasons			
		Autumn	Winter	Spring	Summer
Non actively fed	Empty stomachs	22	41.38	34.24	4.70
	Poor stomachs	33.50	34.48	18.50	13.04
Actively fed	Medium stomachs	20.54	10.34	14.18	21.39
	Good stomachs	19.96	6.90	11.58	17.39
	Heavy stomachs	4	6.90	21.50	43.48
Non actively fed		**55.50**	**75.86**	**52.74**	**17.74**
Actively fed		**44.50**	**24.14**	**47.26**	**82.26**
Total		**100**	**100**	**100**	**100**

Table (2): Feeding intensity (%) and food items of the lizardfish, *Synodus variegates*, collected from Hurghada, Red Sea, Egypt

Food items	Seasons			
	Autumn	Winter	Spring	Summer
Atherinomorus lacunosus	44.88	52	12.66	12
Herklotsichthys quadrimaculatus	0.00	17.56	0.00	11.23
Siganus rivulatus	25.80	0.00	50	0.00
Cephalopholis hemistiktos	0.00	20.44	0.00	3.10
Lethrinus mahsena	10.44	0.00	0.00	20.64
Parupeneus forsskali	0.00	0.00	22.34	13
Abudafduf sexfasciatus	10	0.00	5.92	0.00
Tylosurus choram	0.00	0.00	0.00	27.30
Un-identified	8.88	10	9.08	12.73
Total	**100**	**100**	**100**	**100**

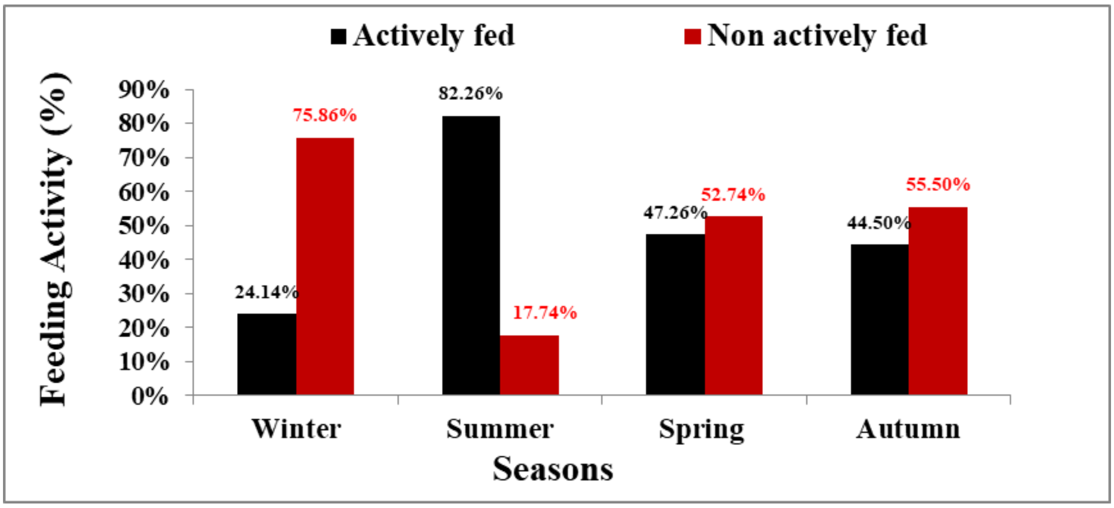

Fig. (2): Seasonal variations of the percentages of feeding activity of common lizardfish, *Synodus variegatus*, collected from Hurghada, Red Sea, Egypt

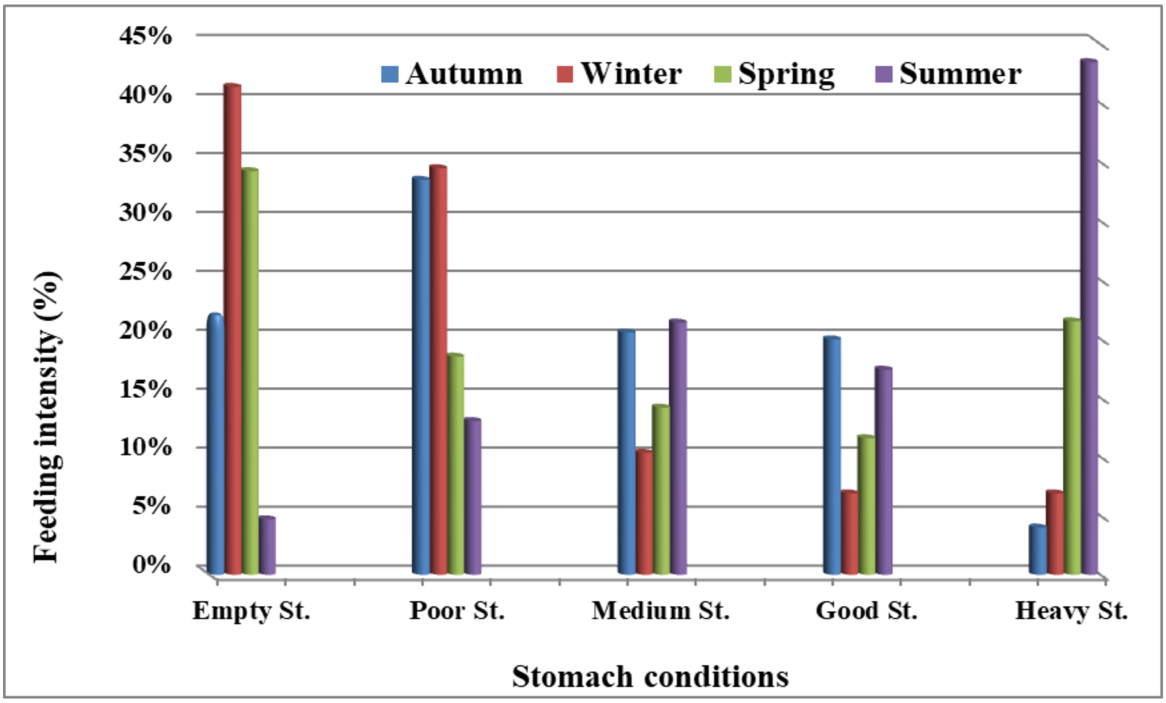

Fig. (3): Seasonal variations of the percentages of feeding intensity of common lizardfish, *Synodus variegatus*, collected from Hurghada, Red Sea, Egypt

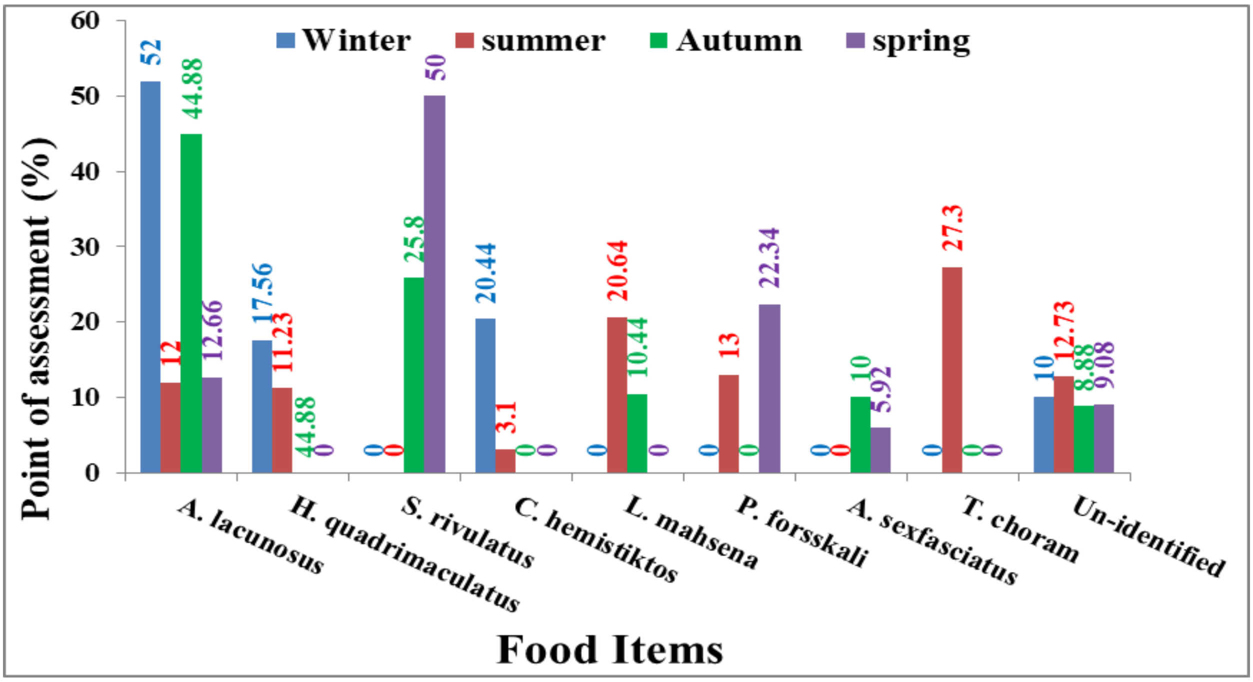

Fig. 4: Seasonal variations in the percentages of various food items in the stomachs of common lizardfish, *Synodus variegatus*, collected from Hurghada, Red Sea, Egypt

2. Morphology of the digestive tract:

2.1. The jaws teeth:

The mouth of *S. variegatus* is large, terminal in position and is bounded by the upper and lower jaws, usually with prominent lips. Each jaw beset with two outer uni-serial canine teeth. The teeth are large in number and size, conical in shape, pointed and slightly curved towards the inside mouth. It was separated by some shorter teeth in the upper jaw **(Fig. 5).**

2.2. The buccal teeth:

Buccal teeth of *S. variegatus* are found on vomer, palatine and ectopterygoid bones in the roof of buccal cavity. Vomerine and palatine teeth on two sides of the roof are arranged in line, large in number and small in size. They are canine, strong and pointed tiny teeth. Ectopterygoid teeth on two sides of the roof are line like shape. These teeth are canine in shape and arranged in five rows; three central rows are small in size and emarginated by relatively long two rows **(Fig. 5).**

2.3. The Pharyngeal teeth:

The pharyngeal pads of *S. variegatus* are triangular in shape; large size in the upper and small size in the lower pharyngeal pads. Teeth are arranged in rows, pointed, sharp and curved in shape. The teeth in the upper pharyngeal pad are overlapped together with the position of the teeth in the lower one **(Fig. 5)**.

2.4. Gill rakers:

Gill arches of *S. variegates* have V shaped and carried two rows of gill rakers on its concave border and gill filaments on its convex one. Gill rakers are found in patches (clusters); ended by thin pointed spines. These rakers are short, straight and a large number in the central area of the arch; then they curved and decreased in size towards the terminal ends of the gill arch. The rakers on the posterior row are fewer in number, formed of small patches, have no spines and depressed in shape **(Fig. 5).**

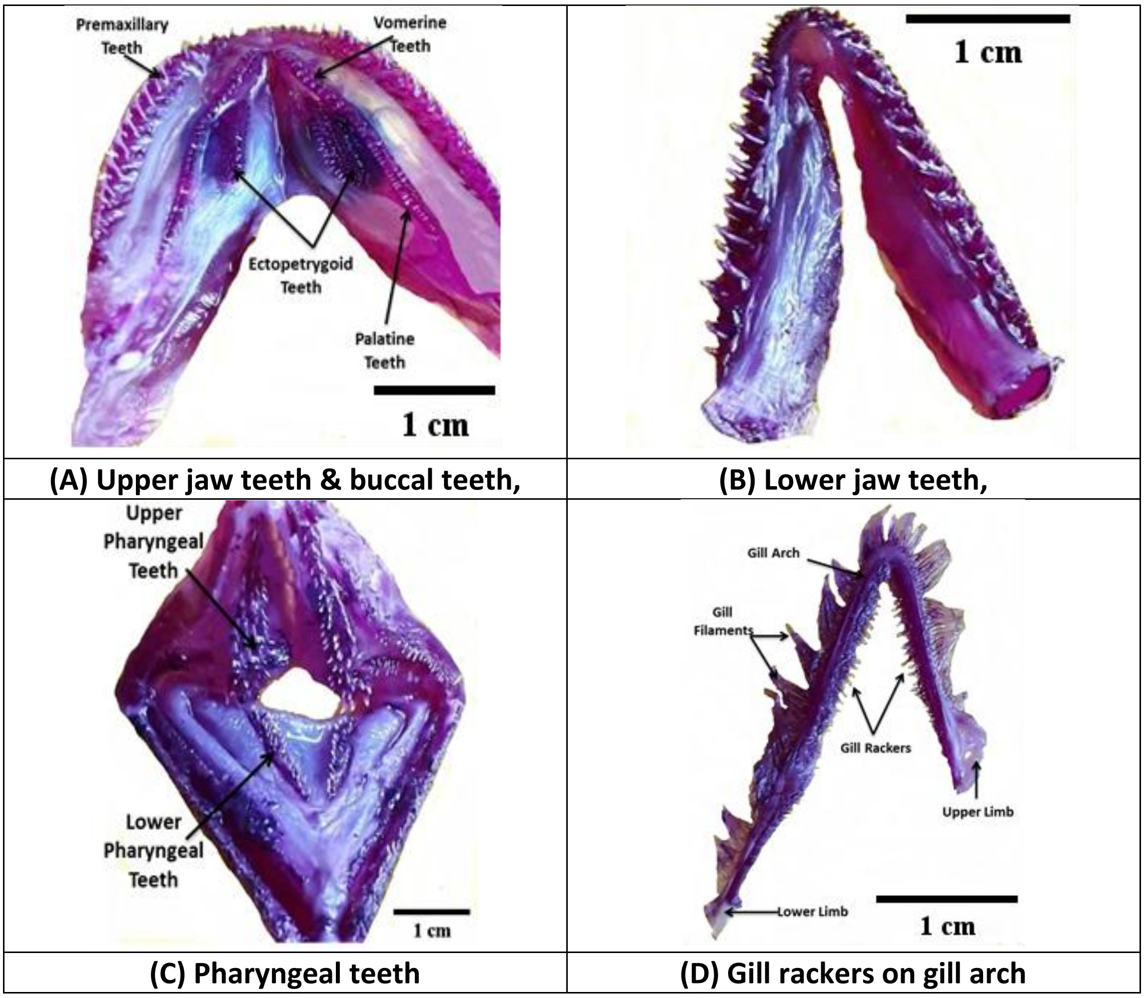

Fig. (5). Light photographs of (A) Upper jaw teeth & buccal teeth, (B) Lower jaw teeth, (C) Pharyngeal teeth and (D) Gill arch of lizardfish, *Synodus variegatus*, collected from Hurghada, Red Sea, Egypt.

2.5. Esophagus:

The esophagus of lizardfish, *S. variegatus* is a short muscular distensible tube. It extends backwards from the pharynx, few millimeters from the pharyngeal teeth pads and immediately passes through the transverse septum, ventral to the swim-bladder to open in the anterior section of the stomach. There is no sharp line of separation between the esophagus and stomach, except some alteration in the grade of mucosal folds **(Fig. 6).**

2.6. Stomach:

The lizardfish, *S. variegatus* stomach wall has a large distensibility giving the bag-like shape to help these fishes to pick relatively big prey. Generally, the stomach is divided into the proximal cardiac, the mid fundic and the distal pyloric zones. The three parts all together created the carrot root-form stomach. The cardiac and pyloric parts continuous with the esophagus; composed a large bend and linked on the lesser torsion towards the free back end to create the fundic part. The boundaries among the three regions will hardly be recognized **(Fig. 6).**

2.7. Intestine:

The lizardfish, *S. variegatus* intestine consist of a short simple tube. It extends from the pylorus forward as a narrow tube. It can be divided into a thicker descending part (anterior intestine), which pass into backward without additional convolution to the slot creating a finer descending part (mid intestine) and a terminal one (posterior intestine). The wall of the intestinal region is thicker with differences in the diameter of each part **(Fig. 6).**

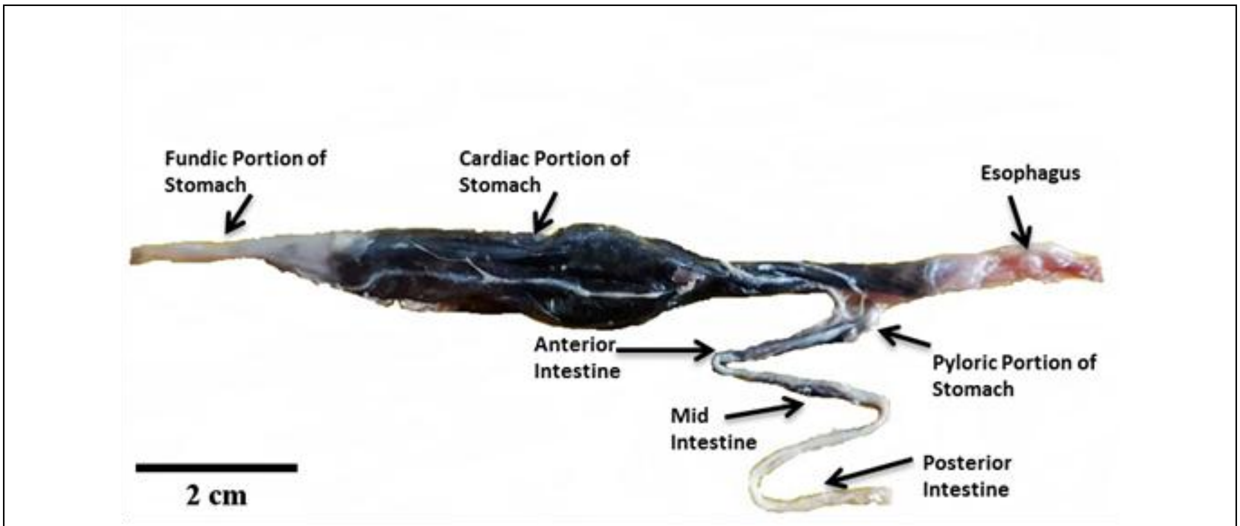

Fig. (6). Light photograph of tubular part of the digestive tract of lizardfish, *Synodus variegatus*, collected from Hurghada, Red Sea, Egypt.

DISCUSSION

The importance of understanding of the food and dietary habits of fish in studying their biology is well established. It helps determine the distribution of a fish population which critical to effective in fisheries management **(Rao & Durga Prasad, 2002).**

In the present study, feeding intensity of *S. variegatus* indicated that, fish have alternated their feeding activity throughout the seasons. The highest number of feeding activity was reported within summer and lowest occurred within winter. The lowest ratio of feeding activity throughout winter may be due to the influence of low temperature of water on the abundance of diet in nature. Similar results were observed by **Khalaf-Allah (2009).**

The lizardfish, *S. variegatus* was a piscivorous, more voracious habit and consumed a broad range of small fish. It feeds by sight and appeared to be crepuscular feeders. They can be differentiating between the favorite food items and the unfavorable ones. The contents of fish stomachs reflect the relative intensity of food items seasonally and the ability of the fish to use of the available feed based on their needs. Comparable notations were monitored by **Carpenter (2002)**.

The digestive tract adaptations of the fish to their food are particularly obvious in the shape of dentitions, gill rankers, esophagus, stomachs, intestine and the gut length **(Dasgupta, 2000; Al-Abdulhadi, 2005; Khalaf-Allah, 2013; Shalaby, 2017** and **Alabssawy *et al*., 2019).**

The current study, the mouth open of *S. variegatus* was reptile like head to easy capture of preys (small fish) that venture near. It was voracious predators **(Randall, 1983; De Bruin *et al*., 1995** and **Carpenter, 2002)**.

In the present study, jaws teeth were canine, conical in shape, pointed and slightly curved towards the inside mouth. Buccal teeth were canine in shape and arranged in line on Vomerine and palatine and arranged in five rows on ectopterygoid of two sides in the roof of the buccal cavity. They specialized in capturing and holding the prey and prohibiting its fleeing out of the buccal cavity. These modifications are in conformity with those of the described piscivorous fish **(Bond, (1996; Shalaby, 2017** and **Alabssawy *et al*., 2019).**

In the present study, the pharyngeal pads were triangular in shape; large size in the upper and small size in the lower pharyngeal pads. Teeth are arranged in rows pointed, sharp and curved in shape. They were specialized for cutting and masticating the food. The same conclusion were revealed in piscivorous fish, *Tylosurus choram* (**Shalaby, 2017)**

In the current study, gill arch in *S. variegatus* was V-shape, may be attributed to help the fish in swallowing the large prey by backward direction in the pharyngeal cavity. The gill rakers at the frontal line of the first gill arch were found in patches, short, strait and ended by thin pointed spines adapted for food gathering and binding the preys to entry the esophagus. These modifications are in conformity with those of the described piscivorous fish **(Carpenter, 2002** and **Mousa *et al*., 2016).**

In the current study, in the piscivorous fish, *S. variegatus* esophagus is a distensible muscular tube short and narrow. The large distensibility of the esophagus is adaptation for feeding. So a relatively large object can be swallowed**.** In this respect, the esophagus of these fish resembles the esophagus of piscivorous fish, *Tylosurus choram* (**Shalaby, 2017).** Comparable notations were monitored by previous authors in some carnivorous fish including *Moron labrax* **(Shehata, 1997a),** *Lates niloticus* **(Albattal, 2002),** *Clarias gariepinus* and *Bagrus bajad* **(Hussein, 2004),** *Mylio cuvieri* and *Tilapia spilurus* **(Al-Abdulhadi, 2005),** *T. puta*, *L. mormyrus* and *C. lunulatus* **(Khalaf-Allah, 2009** and **2013)** and *Synodus variegatus* **Alabssawy *et al*. (2019).**

From the present results, the piscivorous fish, *S. variegatus* stomach wall has a large distensibility giving the bag-like shape to help these fishes to pick relatively big prey. This conclusion was not confirmed in all piscivorous fish. **Shalaby (2017)** indicated that the piscivorous fish stomach of (*Tylosurus choram*) is of the pseudo-gaster or fake stomach.

In this study, the lizardfish, *S. variegatus* intestine consist of a short simple tube. It runs from the pylorus forward as a narrow tube. Outside, the intestine is not differentiated into varied distinct parts because there is no delineation among them. Internally, however, the intestine can be divided into three parts: anterior, mid and posterior intestine. These results from this work are very similar to those reported in other carnivorous fishes **(Shehata, 1997b; Dasgupta, 2002 & 2004; El-Bakary, 2007; Khalaf-Allah, 2009 & 2013; Hassan, 2013; El-Deeb *et al*., 2016** and **Alabssawy *et al*., 2019).**

CONCLUSION

In conclusion, the morphological features of mouth, teeth, gill rakers, esophagus, stomach and intestine of lizardfish, *S. variegatus* are subjected to diverse significant variations and many modifications in accordance with the food and feeding habits, in order to understand the associated functional mechanisms of the digestive physiology of fish.

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