Alqalam Journal of Medical and Applied Sciences. 2025;8(1):327-332
https://doi.org/10.54361/ajmas.258146

Original article

Feeding Habits and Diet of *Torquigener flavimaculosus* (Hardy & Randall in 1983) along the Tobruk Coast in the Mediterranean Sea, Eastern Libya

Ayiman Bouhuweesh[1]*, Abdallah Belhassan[1], Ayiman Bilhassan[2]

[1]*Department of Marine Biology, Faculty of Science, University of Omar Al-Mukhtar, Al-Bayda, Libya*
[2]*Department of Zoology, Faculty of Science, University of Derna, Al Guba, Derna, Libya*
Corresponding Email. *Eman.othman558@omu.edu.ly*

Abstract
This study looked at the eating habits of 161 *Torquigener flavimaculosus* fish (from the Tetraodontidae family) living along the Tobruk Mediterranean coast. The research was done every month from January to December 2022. It focused on what the fish ate throughout the year, how their diet changed each month, how their diet varied with their size, and how much they ate. *T. flavimaculosus* eats many types of prey, including Polychaete worms (47.9%), snails (Gastropoda) (17.5%), clams (Bivalvia) (16.4%), Crustaceans (4.9%), sea urchins and starfish (Echinodermata) (4.2%), fish (3.4%), and other foods (5.7%). Polychaete worms, snails, and clams were eaten all year and by all size groups of *T. flavimaculosus*. The study found that as the fish grew bigger, they ate more polychaete worms, snails, and clams, but less crustaceans and sea urchins. Fish item appeared in the diet of *T. flavimaculosus* when they reached 13.5-14.4 cm in size (2.1%), and other food items were found in fish measuring 12.5 to 14.4 cm (0.7% to 3.6% repectivey). The fish *T. flavimaculosus* was very active in eating during spring (67.2%) and autumn (82.4%). However, they ate much less in winter (36.1%) and summer (44.5%).
Keywords. Feeding Habits, *Torquigener Flavimaculosus*, Tobruk Coast, Mediterranean Sea, Eastern Libya.

Introduction

The Eastern Mediterranean today has a large number of exotic species, primarily due to the Suez Canal [12]. This is because the canal, which was constructed by humans, links the Mediterranean Sea, which is colder, with the Red Sea, which is warmer. There has been a 40% increase in foreign species reports in the Eastern Mediterranean during the past ten years [35]. Around the world, puffer fish come in about 200 varieties [29]; [11]. The *Torquigener* [32] group includes 29 of these species, all of which have Indo-Pacific origins.

The western Indian Ocean is home to a species of puffer fish called the yellow spotted puffer, or *Torquigener flavimaculosus* [18]. This fish inhabits regions as far south as Madagascar and as far north as the Persian Gulf and the Red Sea. At depths of 3 to 57 meters, it is typically found close to coral reefs. It can reach a length of 13.0 cm and consumes small aquatic life, such as marine invertebrates. The yellow-spotted puffer's body can swell when it senses danger, and it has a spherical head with a blunt nose and two big, beak-like teeth in each jaw. Its side fins are broad at the sides, and it has tiny fins on the rear and close to the tail. The Suez Canal allowed this species to enter the Mediterranean Sea [16]. It was initially found in 1987 in Israel's Haifa Bay [14] . Later, it was found in Egypt (9), Syria, Greece, Turkey, and Libya [1]. *Torquigener flavimaculosus* is actually the same species as *T. hyselogeneion*, according to recent studies on its genes and appearance [5]. Tetrodotoxin (TTX), a poison that is lethal to humans, is present in extremely high concentrations in *T. flavimaculosus*. According to [3], pufferfish with TTX levels more than 2.2 µg/g are deemed unsafe to consume, and *T. flavimaculosus* had TTX levels beyond this threshold is deadly to humans. According to [3], pufferfish with TTX levels more than 2.2 µg/g are deemed unsafe to consume, and *T. flavimaculosus* had TTX levels beyond this threshold. According to [21], the fish's body is abundant in toxins, with over 15 µg/g found in its muscles, 5 µg/g in its reproductive organs, 12 µg/g in its intestines, 7 µg/g in its liver, and 35 µg/g in its skin. It is an extremely dangerous invasive species as a result. The majority of research in the Mediterranean focuses on various aspects of this fish, including its geographic range [15]; [4]; [34]; [1], growth and reproduction [22], size and weight [7], diet and position in the food chain [6], population studies [23], and levels of toxins [21].

Understanding the diet and feeding habits of fish is essential to determining the locations of fish populations. An analysis of previous studies demonstrates that this data is essential for efficient fishery management and is a fundamental component of every fisheries research program [28]. Utilizing samples captured in various regions of the Mediterranean Sea, numerous research has examined the diet and feeding patterns of the fish species **Torquigener flavimaculosus** [5,6,29]. However, because there are no publications on the eating habits of *Torquigener flavimaculosus* in Libyan waters, this species has not been investigated as much in the Libyan portion of the Mediterranean. Therefore, the purpose of this study was to provide a comprehensive and understandable description of the feeding habits of *Torquigener flavimaculosus* along the coast of Tobruk in the eastern Libyan Mediterranean Sea. The food chain and the interactions between

Received: *28-12-2024* - ***Accepted***: *13-02-2025* - ***Published***: *20-02-2025*

various species in the water environment of the region under study may be better understood with the use of this knowledge.

Methods

Samples were collected on the Mediterranean Sea shore of Tobruk, which is situated in eastern Libya at 32° 4′ 40.8″ N, 23° 58′ 58.8″ E. Samples were taken between January and December of 2022 (Fig. 1). The study included 161 *Torquigener flavimaculosus* fish. Each fish's total weight was recorded in grams, and its total length (TL) was measured in centimeters.

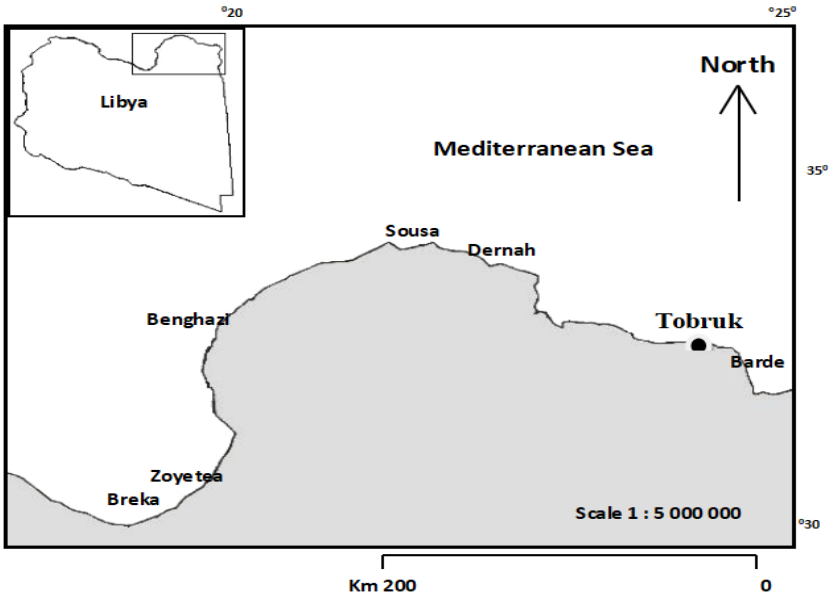

Figure 1. Map showing the collection site, Tobrok coast in the eastern Libyan Mediterranean coast

The contents of each stomach were scraped out after it was cut open lengthwise and put in a little Petri plate with some water. Using the technique outlined by [24], the stomach's fullness was assessed by looking at it and classified as empty, trace, quarter full, half full, three-quarters full, or entirely full. During the study, the months and seasons were associated with the kinds of food and the amount of food consumed by the fish. Fresh samples' stomach contents were removed and viewed under a microscope. Using guidance and references, the prey items were categorized and assigned to the most particular group [10,13,16]. We employed specific computations, such as the percentage of numerical abundance (%N = number of a specific prey / total number of prey × 100), to examine the diet and eating patterns of the two species [20].

Results

Annual diet composition

A large selection of food was offered. However, the main foods eaten by *Torquigener flavimaculosus* (see Fig. 2) were polychaeta (a type of worm), gastropoda (snails), bivalvia (clams), crustaceans (like crabs), echinodermata (such as starfish), fish, and other items (like digested food). Polychaeta made up 47.9% of the diet by volume, followed by gastropoda at 17.5%, bivalvia at 16.4%, crustaceans at 4.9%, echinodermata at 4.2%, and fish at 3.4% (for example, *Lithognathus mormyrus*). Other food items, such as fish parts, scales, small amounts of sea grass, and digested food, made up 5.7% of the diet.

Variations in food composition every month:

Food items were discovered throughout the year during the survey. Throughout the year, *Torquigener flavimaculosus's* primary food sources, comprising 81.8% of the diet, were polychaeta, gastropoda, and bivalvia (see Table 1). The monthly dietary changes of 161 stomachs of *T. flavimaculosus* that were obtained from the shore of Tobruk are displayed in Table 1. Each month, bivalvia, gastropoda, and polychaeta were found. However, echinodermata and fish were absent in January and February, crustacea were absent in November and December, and other food items were lacking in April and August.

Received*: 28-12-2024 -* ***Accepted****: 13-02-2025 -* ***Published****: 20-02-2025*

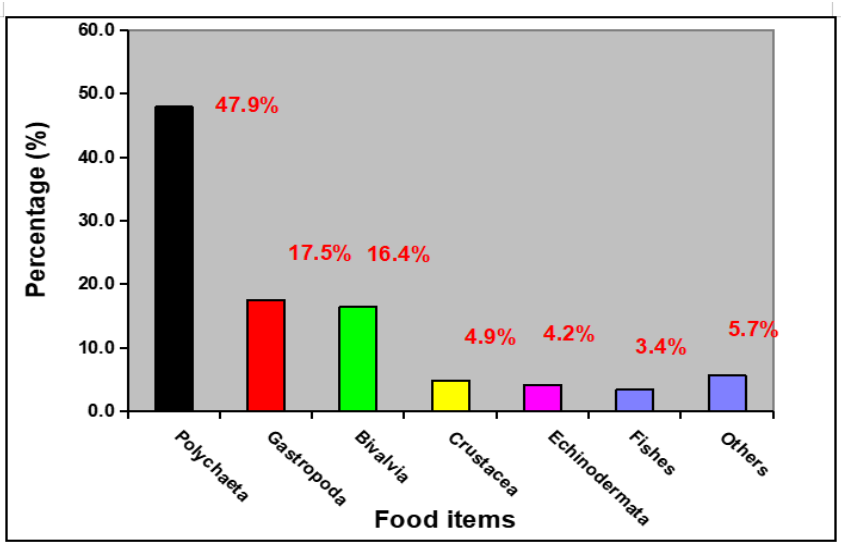

Figure 2. Torquigener flavimaculosus diet composition from January to December 2022 in the Tobruk shore in eastern Libya

Table 1. From January to December 2022, 161 Torquigener flavimaculosus from the Tobruk shore in eastern Libya showed monthly changes in their diet composition

Months	No.	Food items						
		Polychaeta	Gastropoda	Bivalvia	Crustacea	Echinodermata	Fishes	Others
Jan	10	59.9	19.8	11.8	4.5	A	A	4.1
Feb.	8	51.8	16.2	15.7	10.4	A	A	5.9
Mar.	11	50.7	15.8	20.4	3.1	5.8	1.5	2.8
Apr.	12	48.6	15.1	20.7	7.8	6.7	1.1	A
May	8	44.6	32.6	7.2	8.4	5.4	1.5	0.3
Jun.	20	40.1	32.7	10.7	7.1	4.1	4.3	1.1
Jul.	26	44.3	15.7	11.9	2.8	7.8	5.4	12.2
Aug.	32	40.6	23.3	20.9	4.4	4.2	6.6	A
Sep.	7	51.5	12.3	21.6	4.8	2.7	3.2	3.9
Oct.	8	50.7	11.2	19.8	5.3	5.3	6.9	0.7
Nov.	9	49.9	5.1	21.4	A	4.5	5.1	14.1
Dec.	10	41.7	10.6	14.5	A	4.4	5.3	23.5
%	161	47.9	17.5	16.4	4.9	4.2	3.4	5.7

Data shown as a percentage, (A) No food was consumed during the month

The correlation between fish size and feeding behavior

Based on size, the population of *Torquigener flavimaculosus* was split into 7 groups, each of which was separated by 0.9 cm and ranged in size from 8.5 cm to 15.4 cm (see Table 2). While smaller fish preferred to consume smaller prey, larger fish tended to devour larger prey. Bivalvia, echinodermata, gastropoda, and polychaeta were present in all size groups of *Torquigener flavimaculosus*. As the fish in this study grew larger, their diets contained more polychaeta, gastropoda, and bivalvia, but their diets had fewer crustacea and echinodermata. The 13.5–14.4 cm group consumed fish (2.1%), while the 12.5–14.4 cm groups consumed other foods at 0.7% and 3.6%, respectively.

Table 2. The food makeup of 161 Torquigener flavimaculosus from the Tobruk shore in eastern Libya across various size classes from January to December 2022.

Size groups (cm)	No.	Food items						
		Polychaeta	Gastropoda	Bivalvia	Crustacea	Echinodermata	Fishes	Others
8.5-9.4	22	41.8	12.3	13.1	14.7	16.1	B	B
9.5-10.4	25	43.9	13.3	21.9	13.3	6.6	B	B
10.5-11.4	31	44.4	17.3	21.6	10.3	6.5	B	B
11.5-12.4	16	49.5	18.4	18.9	8.8	4.3	B	B
12.5-13.4	23	52.9	19.9	18.9	7.3	0.2	B	0.7
13.5-14.4	12	52.9	20.2	19.3	0.3	1.6	2.1	3.6
14.5-15.4	32	55.9	23.5	19.5	B	1.1	B	B

(B) No food in size categories occurred; data shown as a percentage

Received*: 28-12-2024 -* ***Accepted****: 13-02-2025 -* ***Published****: 20-02-2025*

Intensity of feeding

About 57.6% (±14.6) of the *Torquigener flavimaculosus* animals under study had stomachs that were half full, nearly full, or full of food (group b%). However, 42.5% (±11.8) of the specimens had empty stomachs, stomachs with only signs of food, or stomachs that were a quarter full (group a%) (Table 3). The seasons with the highest feeding activity were spring (67.2%) and fall (82.4%). On the other hand, *T. flavimaculosus* showed the lowest feeding rates throughout the winter (36.1%) and summer (44.5%) (Table 4).

Table 3. From January to December 2022, 161 Torquigener flavimaculosus from the Tobruk shore in eastern Libya showed monthly fluctuations in feeding activity.

		The degree of distension of the stomach							
Months	No.of fish	Empty	Trace	1/4	a %	1/2	3/4	Full	b %
Jan. (2022)	10	5.3	22.4	33.5	61.2	13.9	10.1	14.8	38.8
Feb.	8	21.2	22.7	26.3	70.2	8.7	A	21.1	29.8
Mar.	11	25.5	A	A	25.5	24.0	27.1	23.3	74.4
Apr.	12	20.0	12.0	2.3	34.3	11.3	11.2	43.2	65.7
May	8	21.3	9.9	7.4	38.6	9.4	26.0	26.0	61.4
Jun.	20	11.2	13.6	16.1	40.9	25.0	14.1	20.1	59.2
Jul.	26	33.1	22.6	11.6	67.3	32.8	A	A	32.8
Aug.	32	9.3	5.0	44.2	58.5	1.5	40.0	A	41.5
Sep.	7	15.9	A	A	15.9	13.9	20.0	50.1	84.0
Oct.	8	23.2	2.2	A	25.4	15.4	15.1	44.1	74.6
Nov.	9	11.4	A	A	11.4	13.1	48.3	27.2	88.6
Dec.	10	22.3	21.1	16.8	60.2	16.0	10.2	13.6	39.8
Average	161				42.5±11.8				57.6±14.6

Data shown as a percentage (A) = No food was consumed throughout the month

Table 4. The feeding strength of 161 Torquigener flavimaculosus from the Tobruk coast in eastern Libya varied seasonally between January and December of 2022.

Seasons	**No. of fish**	**The degree of distension of the stomach**							
		Empty	Trace	1/4	%	1/2	3/4	Full	%
Winter	28	16.3	22.1	25.5	63.9	12.9	6.8	16.5	36.1
Spring	31	22.3	7.3	3.2	32.8	14.9	21.4	30.8	67.2
Summer	78	17.9	13.7	24.0	55.6	19.8	18.0	6.7	44.5
Autumn	24	16.8	0.7	B	17.6	14.1	27.8	40.5	82.4

Information presented as a percentage B There was no in-season food.

Discussion

According to this study, *T. flavimaculosus* consumes a variety of prey, such as fish, echinoderms, bivalves, crustaceans, polychaetes, and gastropods. This is consistent with [5] findings. Generally, as fish grow, their need for food and their ability to find it also increase [19]. In our study, we observed that as *T. flavimaculosus* grew larger, they ate more polychaetes, gastropods, and bivalves, but fewer crustaceans and echinoderms. However, our findings differ from some studies in the Mediterranean. For instance, *T. flavimaculosus* captured in Cyprus, according to [29], mostly consumed small invertebrates, particularly the invading gastropod (*Cerithium scabridum*), as well as crustaceans like sea urchins and hermit crabs. Puffer fish may consume hard-shelled animals like snails, clams, barnacles, and crabs because of their powerful, regrowing teeth [27]. In order to capture small creatures that are lurking in the sandy ocean floor, smaller puffer fish also employ water jets from their mouths. They may have evolved the ability to puff up in order to increase the effectiveness of this hunting technique [31]. Therefore, it should come as no surprise that tiny snails like as *Trochus turbinatus*, *Bittium reticulatum*, and Cerithium scabridum make up the majority of the stomachs of *T. hypselogeneion*. The stomach study reveals that *T. flavimaculous* can break down the hard shells of barnacles, snails, crabs, and other shellfish, which is interesting because many of them were discovered to be half digested. It probably has a better chance of surviving as a predator because it can consume both soft and hard prey. It may even aid in the management of the invasive *Cerithium scabridum* snail population. However, it is doubtful that this has a significant effect on the ecology as a whole because these snails are so small and already widely distributed throughout the Eastern Mediterranean [29]. When blood from speared lionfish or dead crabs from lost fishing nets were present, *T. hypselogeneion* occasionally displayed aggressive and competitive feeding behavior, according to observations made of them in their natural environments in Turkey and Cyprus. *T. hypselogeneion* was described as an omnivore by [6] due to

Received*: 28-12-2024 -* ***Accepted****: 13-02-2025 -* ***Published****: 20-02-2025*

the presence of plant fragments in 7 out of 104 stomachs (6.7%). Less than 3% of stomachs in a prior study had plant material, which may have been inadvertently consumed with live animals attached. Because Siganidae (invasive rabbit fish) heavily graze the area, several forms of algae often thrive for a few months in the spring before going extinct for the remainder of the year [26]. The samples that were gathered here were taken in the spring. Additionally, the region is home to year-round colonies of seagrass, or Posidonia oceanica, which coexists with *T. hypselogeneion* in the same habitat. As a result, *T. hypselogeneion* may be better described as a generalist feeder. Seasons have a small impact on *T. hypselogeneion's* eating patterns. Before and after the summer spawning season, this fish consumes plenty of food throughout the spring and fall [17]; [25]; [8]; [2]; [33]; [22]. Fish require extra energy to support reproduction during the spawning season [11].

Conclusion

This study shows that *T. hypselogeneion* is somewhat selective in its diet. It mainly eats polychaetes, along with some gastropods, bivalves, crustaceans, echinoderms, fish, and other prey. Therefore, *T. hypselogeneion* in the Libyan Mediterranean waters is a specialized carnivore that prefers benthic invertebrates.

Acknowledgments

The authors express their gratitude to God for granting us success in this study. We appreciate everyone's assistance in collecting samples from fishermen. I want to express my gratitude to my colleagues at Omar Al-Mukhtar University's College of Science in Libya for their assistance and support in completing this scientific article.

Conflicts of Interest

Authors declare no conflicts of interest.

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Received*: 28-12-2024 -* ***Accepted****: 13-02-2025 -* ***Published****: 20-02-2025*

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المستخلص

تمت دراسة العادات الغذائية لـ 161 عينة من سمكة أبو نفاخ الصفراء (العائلة: Tetraodontidae)، التي تسكن ساحل البحر الأبيض المتوسط في طبرق، شهريًا في الفترة من يناير إلى ديسمبر 2022. تم دراسة النظام الغذائي السنوي، والتغيرات الشهرية في تكوين النظام الغذائي، وتنوع النظام الغذائي وتمت دراسة شدة التغذية. وقد وجد ان سمكة أبو نفاخ الصفراء تتغذى على مجموعة واسعة من أنواع الفرائس: الديدان عديدة الاشواك بنسبة (47.9%)، مكمل بأحادية المصراع (17.5%)، ثنائية المصراع (16.4%)، القشريات (4.9%)، الجلد شوكيات (4.2%)، الاسماك (3.4%) وغيرها من طعام مهضوم او فرائس غير معرفه لتهالك انسجتها بنسبة (5.7). وقد تم العثور على الديدان متعددة الأشواك واحادية المصراع وثنائية المصراع على مدار السنة وفي جميع المجموعات الطولية لسمكة أبو نفاخ الصفراء. في الدراسة الحالية، زادت التغذيه على الديدان عديدة الاشواك وأحادية وثنائية المصراع مع زيادة اطوال السمكه بينما تقل القشريات والجلدشوكيات مع زيادة حجم الأسماك. وكانت أنشطة التغذية عالية خلال فصل الربيع (67.2%) وعالية جدا خلال موسم الخريف (82.4%) لسمكة أبو نفاخ الصفراء وكانت أنشطة التغذية ضعيفه جدًا خلال الشتاء (36.1%) والصيف (44.5%) والخريف.

Received*: 28-12-2024 -* ***Accepted****: 13-02-2025 -* ***Published****: 20-02-2025*