Alqalam Journal of Medical and Applied Sciences. 2026;9(8):2372-2379
https://doi.org/10.54361/ajmas.269808

Research article

Histopathological Changes in Black Scorpionfish (Scorpaena porcus) from the Tripoli Coast, Libya: A Three-Season Baseline Study

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Abstract
The Mediterranean Sea experiences pronounced seasonal temperature changes and varied seafloor topography. Within this environment, the coastal waters of Tripoli, Libya, create physiological challenges for resident fish. This study aims to describe seasonal histopathological alterations of vital tissues (liver, kidney, muscle, and gill) in S. porcus collected from the Tripoli coast and discuss their potential relationship to environmental conditions. A total of 25 specimens of black scorpionfish (Scorpaena porcus) were randomly collected from the Tripoli coast across three distinct seasons. The specimens were dissected to extract the liver, kidney, gills, and dorsal muscle tissues for histological analysis. Histopathological analysis revealed seasonal differences in tissue lesions. The liver revealed moderate-to-severe vascular dilation, mild activation of Melanomacrophage centers (MMCs), and unidentified parasitic cysts. The kidney showed degenerative alterations in the renal tubular epithelium, focal interstitial fibrosis, granuloma-like structures, and frequent activation of Melanomacrophage centers (MMCs). Most gill and muscle tissues retained normal histological architecture in the majority of examined specimens. Integrating histopathological biomarkers provides a cost-effective, reliable baseline for monitoring deep-water benthic health and evaluating the long-term ecological trajectory of the Libyan coastline.
Keywords. *Scorpaena PORCUS,* Melanomacrophage CENTERS (Mmcs), Seasonal VARIATION, Granuloma.

Introduction

The Mediterranean Sea experiences pronounced seasonal temperature variations and varied seafloor topography [1]. Coastal waters off Tripoli, Libya, create physiological challenges for resident fish [2]. In this region, seasonal changes create varying environmental stress levels that necessitate robust adaptive mechanisms for survival [3,4]. The depth range of 30–50 meters represents a significant ecological transition zone, where light attenuation, hydrostatic pressure, and thermal gradients begin to stabilize relative to the more volatile shallow-water environments [5]. However, even at 12 km from the shoreline, these offshore habitats remain susceptible to the Mediterranean's pronounced seasonal shifts, which drive fluctuations in environmental variables and biological productivity throughout the water column [6, 7, 4]. During winter and spring, increased vertical mixing and nutrient upwelling often alter the water column's physicochemical properties, affecting metabolic homeostasis [8, 9, 10]. Conversely, summer months are marked by thermal stratification and potential declines in dissolved oxygen, forcing teleost fish to undergo significant metabolic and respiratory adaptations to survive hypoxic or hyperthermic stress [9, 10].
The black scorpionfish (*Scorpaena porcus*) ranks among the most abundant and economically vital species of the Scorpaenidae family in the Mediterranean Sea [11, 12]. The black Scorpionfish (*Scorpaena porcus*) inhabits benthic environments characterized by rocky or mixed rocky-sandy substrates. Within the Mediterranean basin, it exhibits a broad bathymetric distribution ranging from shallow waters to the bathyal zone, typically occurring between 20 and 200 m. They reside and hunt at depths up to 50 meters and beyond in rocky and heavily vegetated habitats [13]. Interestingly, it has been recorded at depths of up to 800 m [12].
Over 1000 teleost species inhabit temperate and tropical seas and belong to the Scorpaeniformes [14]. Since it targets disproportionately large prey, *Scorpaena porcus* acts as a macrophagic carnivore. Moreover, it preys on small fish, crabs, and other invertebrates [15]. Histopathological examination is commonly used in fish health research. It serves as a reliable indicator of a polluted aquatic environment [16]. Furthermore, it is applied as a critical early warning system for disease detection, providing insight into the underlying mechanisms of physiological stress responses [17]. The Liver, kidney, spleen, gills, and skin are frequently used in histopathological examination of fish [18]. On the other hand, gills represent the first organ in direct contact with the aquatic environment and are sensitive to changes in water quality. Therefore, gills are used as the primary indicators of aquatic environment pollution [19]. At the same time, the liver plays a crucial role in detoxification and systemic homeostasis as the primary site for the metabolic processing of xenobiotics [20]. However, the function of the kidneys is to regulate body fluid and remove waste products [21], whereas the analysis of muscle tissue provides insight into energetic trade-offs and protein turnover, reflecting the fish's ability to maintain growth and locomotion under varying conditions [22].
In fish, the biological processes, including reproductive cycles and metabolic rates, exhibit significant seasonal variation, often in synchrony with fluctuating environmental parameters, particularly temperature [23]. Most previous investigations in the Tripoli region have focused on general well-being, often disregarding how seasonal fluctuations might exacerbate or mask the effects of environmental pollutants [14, 4]. While the importance of histological monitoring is well established

Received: *01-06-2026 -* ***Accepted:*** *29-07-2026 -* ***Published:*** *05-08-2026*

https://doi.org/10.54361/ajmas.269701

[24, 25], there is a significant lack of research on the effects of seasonal environmental variables on the vital organs of *S. porcus*, particularly along the Libyan coastline. Therefore, this preliminary study provides the first comprehensive seasonal histological examination of *Scorpaena* species, a key commercial fish in Libya, to investigate how environmental stressors impact the health of the vital organs. By quantifying these histological changes in samples from the Tripoli coast, this research elucidates the adaptive capacity of *Scorpaena* and provides critical insights into the resilience of the Libyan marine ecosystem.

Materials and Methods

Study Area and Sample Collection

A total of 25 fresh Scorpionfish (*Scorpaena porcus*) samples were randomly collected from the Tripoli Coast by local fishermen, along the 12 km offshore line at a depth of 50 m.
Specimens were collected using standardized bottom longline and gillnet techniques, selected specifically to minimize capture-related stress and ensure the integrity of the samples for subsequent analysis. Sampling was conducted across three distinct seasons: 8 in Winter (December - February), 8 in Spring (March - May), and 9 in Summer (June - August). The fish samples were kept on ice inside an icebox until they were transported to the Pathology laboratory at the Faculty of Veterinary Medicine, Tripoli University, Libya.

Biometric Measurements

Upon collection, each specimen was immediately transferred to the laboratory, where biometric data were recorded. The total length was measured to the nearest centimeter, and total body weight was determined using an electronic scale to the nearest 0.1 gram, with lengths ranging from 14.5 cm to 24.0 cm (with one exceptional specimen at 29.1 cm) and body weights ranging from 59.0 g to 211.0 g.

Tissue Sampling and Histological Processing

The specimens were dissected to extract the liver, kidney, gills, and dorsal muscle tissues. Tissue samples were immediately fixed in a 10% neutral-buffered formalin solution for 24 hours. Following fixation, the tissues were dehydrated in a graded ethanol series, cleared in xylene, and embedded in paraffin wax. Thin sections (5 μm thick) were cut using a rotary microtome and stained with standard hematoxylin and eosin (H&E) according to the method described by Carleton *et al*. (1980). Finally, the stained sections were examined under a light microscope to evaluate histopathological alterations:
a-Vascular alterations, including congestion, hemorrhage, and dilation of blood vessels.
b-Inflammatory responses, including inflammatory cell infiltrations, granuloma-like structure formation, and interstitial fibrosis.
c-Immunological markers based on activation and frequency of melanomacrophage centers (MMCs).
d-Epithelial changes, including lamellar fusion, hyperplasia, and necrosis in the gill filaments.

Results

Biometric Data and Specimen Distribution

Winter Collection (Samples 1–8): Included the largest and heaviest specimens (e.g., Sample 1 at 24 cm, 211 g), which exhibited the most complex internal organ pathology.
Spring Collection (Samples 9–16): Ranged between 15.0 cm and 25.0 cm, showing persistent MMCs activation in the kidney and frequent gill lesions.
Summer Collection (Samples 17–25): Ranged from 14.5 cm to 20.1 cm, exhibiting a higher frequency of gill pathological changes alongside kidney and liver MMCs activation.
Statistical comparison of lesion prevalence across seasons was not performed due to the small sample size (n=8-9 per season). The following results are presented descriptively.

Histopathological Findings by Organ

Liver Tissues

Histologically, the liver revealed moderate to severe dilation and congestion of blood vessels and sinusoids in 92% of the examined specimens (Figure1 A and B). Mild activation of Melanomacrophage centers (MMCs) was observed in 40% of samples (Figure1 C), particularly during the spring and summer months, while multiple cysts of an unidentified parasite were observed in 36% of specimens (Figure 1 D).

Received: 01-05-2026 - **Accepted**: 26-06-2026 - **Published**: 01-07-2026

https://doi.org/10.54361/ajmas.269701

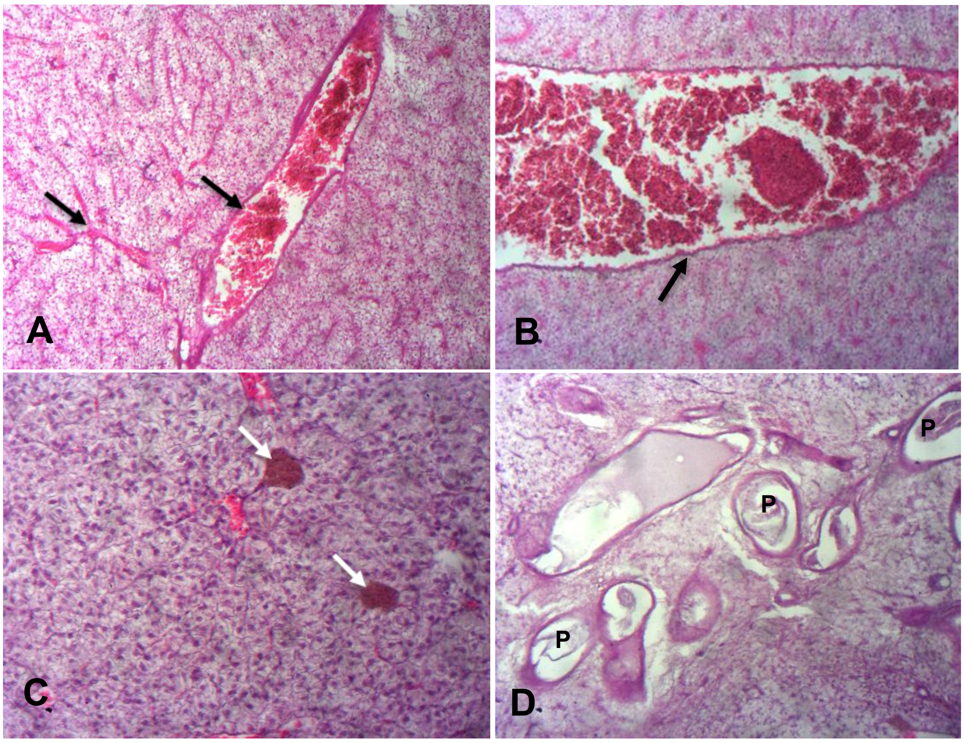

Figure 1. Photomicrographs of the liver tissue of black scorpion fish showing (A, B) moderate to severe dilation and congestion of blood vessels and sinusoids (black arrows) ;(C) mild activation of Melanomacrophage centers (MMCs) (white arrows); (D) cysts of unidentified parasite in hepatic tissue (P) (incidental finding) (H&E stain: A, B &D x 50, C x100).

Kidney Tissues

Microscopic examination of the kidney tissue revealed degenerative changes in the epithelium of some renal tubules, focal areas of interstitial fibrosis, granuloma-like structure formation, and mild vascular congestion with hemorrhage in 28% of specimens, most notably in samples from the Winter collection (Figure 2 A, B, and C). The activation of Melanomacrophage centers (MMCs) was the most common renal finding, present in 76% of examined samples (Winter, Spring, and Summer collections) (Figure 2 B and C).

***Received**: 01-05-2026 - **Accepted**: 26-06-2026 - **Published**: 01-07-2026*

https://doi.org/10.54361/ajmas.269701

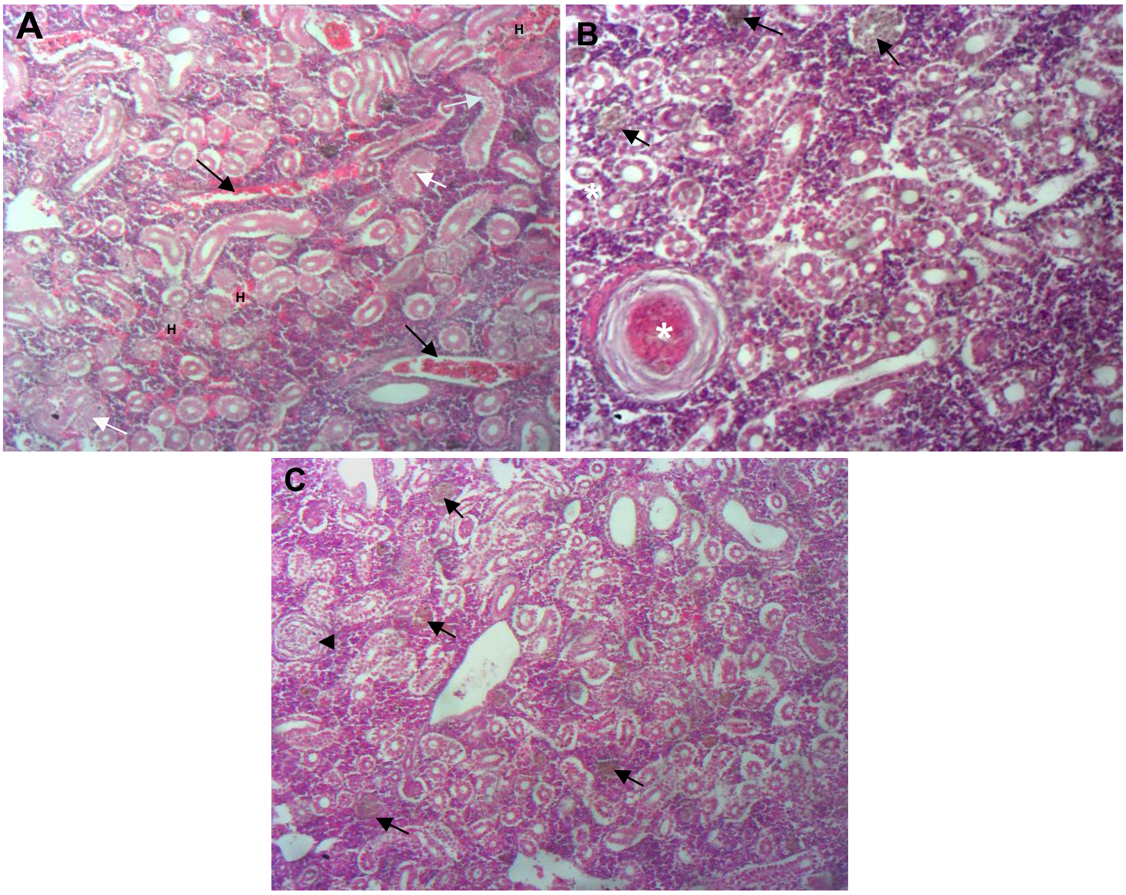

Figure 2. Photomicrographs of the kidney tissue of black scorpion fish showing (A) mild congestion of blood vessels (black arrows), hemorrhages (H) and degenerative changes of the renal tubular epithelium (white arrows); (B, C) activation of Melanomacrophage centers (MMCs) (black arrows), focal interstitial fibrosis (arrow-head). and granuloma like structure formation (asterisk) (H&E stain: A&C x 50, B x 100).

Gills Tissues

The majority of specimens exhibited normal gill architecture with well-defined primary and secondary lamellae (Figure 3A). However, mild pathological changes, such as vascular congestion, epithelial thickening, and fusion of secondary lamellae, were observed in some areas of 32% of specimens, with a higher prevalence in the summer months (Figure 3B and C).

***Received**: 01-05-2026 - **Accepted**: 26-06-2026 - **Published**: 01-07-2026*

https://doi.org/10.54361/ajmas.269701

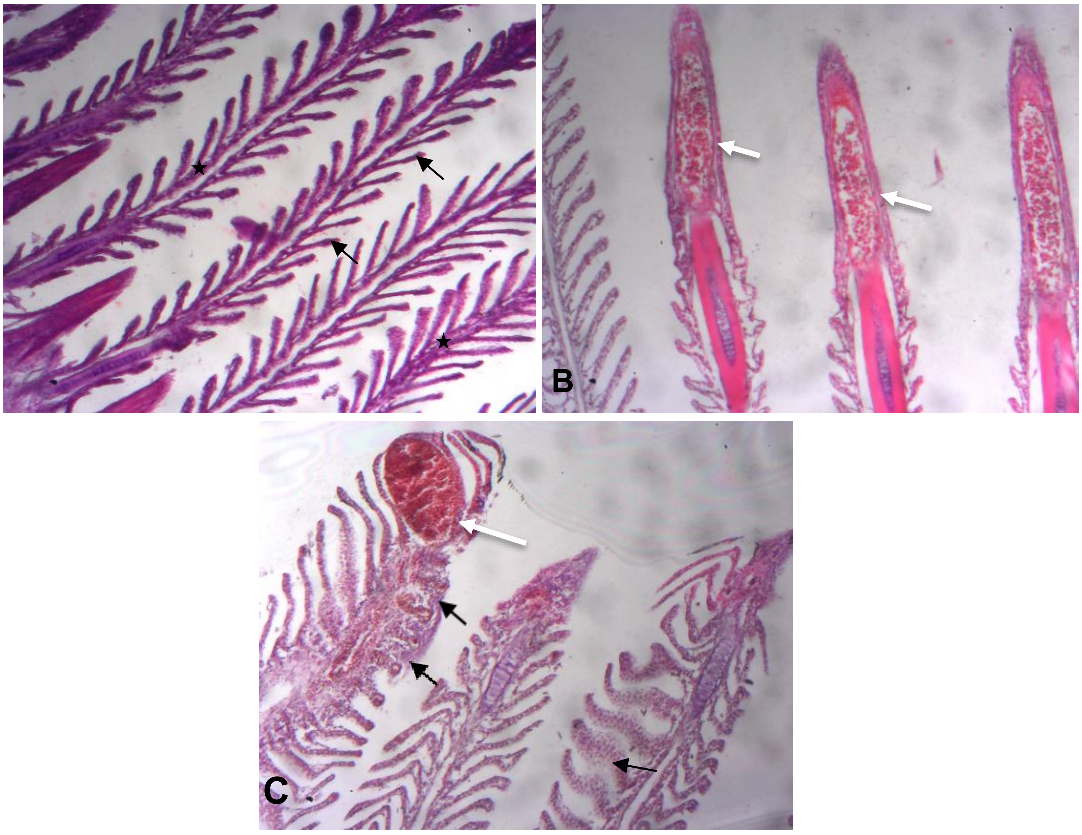

Figure 3. Photomicrographs of the gills of black scorpion fish showing (A) normal histological structure, with well-organized primary filaments (asterisks) and secondary lamellae (black arrows); (B and C) dilation and congestion of blood vessels within primary filaments and secondary lamellae (white arrows); (C) areas of epithelial thickening and fusion of secondary lamellae (black arrows) (H&E stain: Ax50,B&C x100).

Muscle Tissues

All examined muscle tissues exhibited a completely normal architecture with well-organized, distinct muscle fibers and striations, indicating no structural atrophy (Figure 4).

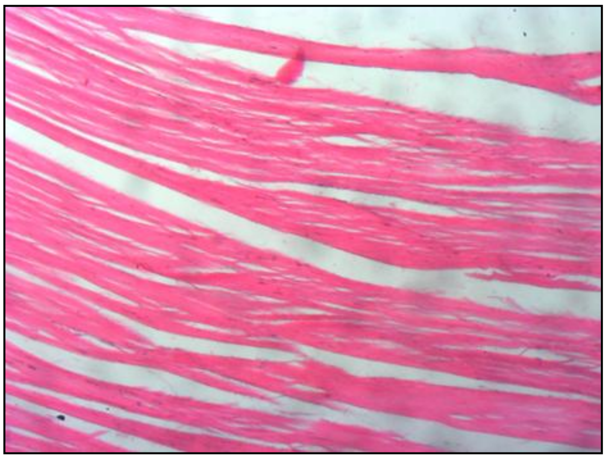

Figure 4. Photomicrograph of the skeletal muscles of black scorpion fish illustrating normal tissue architecture (H&E stain: x 50).

Discussion

The coastal environment of Tripoli, Libya, faces severe ecological pressure from rapid urbanization, industrial growth, and the continuous discharge of untreated municipal wastewater [24]. To evaluate the biological consequences of these environmental stressors, histopathological alterations in vital fish organs are widely recognized as powerful tools in environmental monitoring [27]. This preliminary investigation demonstrates that the black scorpionfish (Scorpaena porcus), sampled at the 12 km offshore line and a depth of 50 m along the Tripoli coast, exhibits histopathological patterns that are consistent with responses to environmental stressors documented in other studies that measured pollutants. However, without concurrent pollutant data, causation cannot be established in this study.

Received: *01-05-2026* - ***Accepted***: *26-06-2026* - ***Published***: *01-07-2026*

https://doi.org/10.54361/ajmas.269701

While the black scorpionfish (Scorpaena porcus has been documented across a broad depth range (20- 200 m) [13], this study specifically sampled at 50m to target the offshore benthic zone potentially impacted by coastal discharges. However, the specific causative agents were not identified in the current study.

The histopathological evaluation of the black scorpionfish (*Scorpaena porcus*) reveals distinct seasonal variations in tissue responses. The Winter collection yielded the largest and heaviest specimens, presenting the most severe renal pathologies. Seasonal variation in the type and severity of histopathological lesions has been reported in other fish species [27,28]. However, the specific lesion patterns observed in this study diverge from the summer peaks reported by Santos et al. [28]. This difference may reflect confounding by fish size/age or species-specific responses. In contrast, the findings of this study are inconsistent with those reported by Kostić et al. [20], who found no significant statistically seasonal differences in histopathological lesions. This variation suggests a cumulative bioaccumulation effect in older fish.

As benthic organisms, *Scorpaena porcus* serve as historical recorders of their environment [29, 30, 31]. The histopathological alterations observed, specifically the presence of granulomas and fibrosis within the renal tissue, directly reflect this cumulative exposure. The current findings revealed that the liver exhibited moderate-to-severe dilation and congestion of blood vessels and sinusoids in 92% of specimens. The present results are partially consistent with those reported by Eissa et al. [15] and other histopathological studies conducted on the Tripoli coast [25,40]. Similar renal tubular degeneration, vascular alterations, interstitial fibrosis, activation of (MMCs), and unidentified parasitic cysts have also been described in *Trachurus trachurus* and Mugil cephalus [24, 25].

The histopathological findings in the kidneys (granuloma and progressive fibrosis) are consistent with patterns reported in fish exposed to chemical stressors [32, 33]. However, without concurrent water-quality data, we cannot definitively attribute these lesions to specific pollutants. These results generate hypotheses for future studies that incorporate chemical analysis. In response to this toxicological burden, the activation of MMCs serves as a vital physiological defense mechanism [34, 35, 36]. Their sustained activation across all three seasons indicates that the stressors are not seasonal flushes but persistent features of the benthic environment. These structural alterations suggest that contaminants originating from Tripoli’s coastal discharges reach the 50 m depth contour [37].

The majority of specimens displayed normal gill architecture. The present results are consistent with those reported by Mohammed et al. [38], who recorded predominantly normal gill architecture in *Lagocephalus sceleratus* fish collected from the same Libyan coasts. Therefore, the predominance of normal gill structure may reflect an adaptive defensive response. In fact, in the Mediterranean Sea, summer months bring elevated water temperatures and lower dissolved oxygen levels, which exacerbate the toxicity of trace elements [39]. Regarding muscle tissue in the current study, the present results agree with the findings of Shahid et al., which documented normal histological architecture in Nile tilapia (*Oreochromis niloticus*) sampled from Pakistan's Chenab River. Fish muscle tissue often remains structurally intact and normal even when other metabolic or respiratory organs show signs of environmental stress due to a combination of metabolic depression, enhanced anaerobic capacity, and protective blood flow redistribution [41].

Conclusion

This preliminary study demonstrates that the black scorpionfish (Scorpaena porcus) at the 12 km offshore line and 50 m depth off the Tripoli coast shows histopathological patterns which are consistent with responses to environmental stressors documented in other studies; however, no causative agents were identified. The findings reveal that although the muscular architecture and overall gill structure remain intact, the excretory and metabolic organs are subject to persistent sublethal stress. Specifically, the high prevalence of hepatic vascular congestion (92%) and renal MMCs activation (76%), along with structural lesions such as interstitial fibrosis, suggests a sustained response to environmental contaminants accumulating at the 50 m depth contour. These results confirm that the offshore zone is not insulated from the anthropogenic footprint of Tripoli’s urban and industrial discharges. The activation of these defense mechanisms highlights the utility of S. porcus as a biological sentinel. Ultimately, integrating histopathological biomarkers provides a cost-effective, reliable baseline for monitoring deep-water benthic health and evaluating the long-term ecological trajectory of the Libyan coastline.

Limitations of the Study

This study presents a baseline analysis of *Scorpaena porcus* along the Tripoli coast, though several limitations constrain the broader interpretation of the findings. First, the limited sample size (N=25) may affect statistical power and generalizability to the wider Mediterranean population. Second, the absence of autumn data prevents a complete annual assessment of seasonal biological variations. Third, the localized sampling within a 12 km stretch at a 50 m depth restricts the applicability of the results to other ecological zones or bathymetric profiles. Finally, potential biases may arise from the selectivity of commercial fishing gear, and the notable size range of specimens (14.5–29.1 cm) introduces biological heterogeneity, likely reflecting multiple age cohorts. Future research is required to validate these findings with larger, more temporally and spatially diverse cohorts.

***Received**: 01-05-2026 - **Accepted**: 26-06-2026 - **Published**: 01-07-2026*

Ethical Statement

Fish specimens were obtained from commercial catches by local fishermen using standard bottom longline and gillnet methods. No live animals were subjected to any experimental procedures or additional stress. The study was conducted in accordance with the ethical guidelines of the Faculty of Veterinary Medicine, University of Tripoli, Libya.

Acknowledgements

Special thanks to the local fishermen at the Tripoli Port for their invaluable cooperation and assistance during sample collection.

Conflict of interest

The authors declare no conflict of interest.

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***Received**: 01-05-2026 - **Accepted**: 26-06-2026 - **Published**: 01-07-2026*

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Received*: 01-05-2026 -* ***Accepted****: 26-06-2026 -* ***Published****: 01-07-2026*