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Community Structure of the Family (Scorpaenidae: Scorpionfishes) in Relation to Habitat and Depth Along the Jordanian Coast of the Gulf of Aqaba, Red Sea

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Abstract

The community structure of the fish family Scorpaenidae was investigated at nine sites along the Jordanian coast, examining various sites, depths, and habitats. The study employed a visual census technique with SCUBA diving for data collection. To present the findings, GIS maps were generated using ArcMap 10.8.1, showcasing the projected benthic cover, frequency of appearance, and relative abundance of the species. The community indices were computed using PRIMER-5 software (Primer-E 2000). The survey recorded a total of 417 scorpionfish individuals, representing seven different species, across 87 belt transects located at nine coastal sites. The average number of scorpionfish individuals per transect was approximately 4.8. Notably, three out of the seven species accounted for a significant 79.8% of all observed individuals. These dominant species were *Pterois miles*, which exhibited the highest relative abundance at 37.9%, followed by *Synanceia verrucosa* at 21.3%, and *Pterois radiata* at 5.4%. Further analysis of the data revealed that *P. miles* was most prevalent in both coral reef habitats (RA=55.6%) and sandy habitats (RA=47.0%). On the other hand, *S. verrucosa* showed the highest abundance in the seagrass habitat with a relative abundance of 53.4%. Additionally, *P. miles* was the most abundant fish species at a depth of 9 m, accounting for 46.9% of the population, while both *S. verrucosa* and *Scorpaenopsis diabolus* shared the highest relative abundance at reef flats with 44.4% each. Moreover, *P. miles* was the most commonly observed species across all sites, with a frequency of appearance (FA) of 70.1%. In the seagrass habitat, *S. verrucosa* dominated, with an FA of 88.9%. Furthermore, *P. miles* was frequently encountered at the sandy bottom and coral reef habitats, with FAs of 82.5% and 58.3% respectively. Reef flats showed an equal prevalence of both *S. verrucosa* and *P. miles*, each accounting for 50.0% of the observed scorpionfish. Cluster analysis revealed the presence of two main groups: the northern natural sites GH, HA, and PLB formed the first group, while the remaining sites constituted the second group. The species richness was found to be highest at a depth of 6 m, whereas the lowest richness was observed at reef flats. The sandy habitat exhibited the highest diversity index, while the coral reef habitats displayed the lowest diversity. This comprehensive survey provides valuable insights for decision-makers and managers, aiding them in making informed decisions to ensure the safety of beach users and visitors to Aqaba. Additionally, it contributes to public awareness regarding the potential risks posed by these fishes, thereby reducing the likelihood of injuries caused by encounters with them.

Keywords: Scorpionfish; Gulf of Aqaba; Fish mapping; Scorpaenidae

1. Introduction

The Red Sea, renowned for its unique ecological and biological characteristics, stands as a hub of marine biodiversity, harbouring a remarkable diversity of over 1,200 fish species (Golani and Bogorodsky 2010). From diminutive reef fish to sizable predatory species, these fish showcase a stunning array of colours and behaviours. Notably, Khalaf (2004) meticulously documented 507 fish species inhabiting the Jordanian coast of the Gulf of Aqaba, including 18 species from the Chondrichthyes group and 489 species from the Ostichthyes group. Numerous studies have been conducted to explore different facets of this marine biodiversity, including research on the community structure, biogeography, and assemblage composition of fish species, as well as their roles as indicators of benthic habitats (Khalaf and Kochzius 2002a, 2002b; Khalaf and Crosby 2005). Furthermore, Brokovich et al. (2006) examined the influence of various substrate variables, particularly physical complexity and live coral cover, on the richness and abundance of coral reef fish communities. The research highlighted that substrate attributes play a direct role in shaping fish community parameters, such as the species composition and food availability. Consequently, these factors significantly impact community intricacy, diversity, and richness (Roberts and Ormond 1987).

Notably, about two-thirds of venomous vertebrates in the world are venomous marine fish, including stingrays,

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scorpion, zebra, and stone fishes, as well as certain types of sharks, catfish, and blennies (Church and Hodgson 2002; Sivan 2009). Among them, the Reef Stonefish (*Synanceia verrucosa*) is frequently encountered by humans and poses a venomous threat. While the Gulf of Aqaba is home to various harmful marine organisms that can be fatal or cause severe injuries (Wahsha et al. 2021), the severity of injury typically depends on factors such as the amount of venom, individual responses, and the nature and location of the injury (Smith et al. 2016). Despite the lack of previous research on the distribution patterns of hazardous fish along the Jordanian coast, national reports indicate that numerous people visit Aqaba beaches during the summer holidays. Notably, 72% of injuries were incurred by visitors rather than locals (Mutair et al. 2006).

The primary objective of this research is to delve into the community structure and spatial distribution of scorpion fishes across various locations, depths, and habitats along the Jordanian coast of the Gulf of Aqaba.

2. Materials and Methods

2.1. Study Area:

The Gulf of Aqaba, measuring 180 km in length and up to 20 km in width, is a semi-enclosed sea distinguished by its numerous distinctive natural and physical characteristics. This geographic isolation is primarily attributed to the narrow Straits of Tiran, which have a considerable depth of approximately 260 m. While a substantial portion of the Gulf boasts significant depths exceeding 1800 m, the northern sector features a relatively shallow shelf that runs alongside major human population centers. The Jordanian coast, extending for 27 km, is bordered by a series of reefs along approximately 13 km of its shoreline. These reefs are separated by sandy bottoms, frequently adorned with lush seagrass meadows (UNEP/IUCN 1988). The Gulf's waters are renowned for their tranquil nature and exceptional clarity, allowing for high visibility. The tides in the region display minimal fluctuations, with semidiurnal and diurnal variations measuring less than one meter (Manasrah 2002).

2.2. Stud sites

The underwater habitats in various areas of Aqaba can be described as follows: The Hotel Area (HA) features a bottom with a seagrass habitat. The Al-Gandoor Area (GH) is primarily characterized by seagrass habitat. The Phosphate Loading Berth (PLB) is distinguished by a combination of seagrass and sandy habitat. The Marine Science Station (MSS) is characterized by hard coral. Barracuda Beach (BB) has a sandy bottom with corals. The Marine Park (MB) features a sandy bottom, while Sodasyat (SOD), Tala Bay Radisson (TBR), and Tala Bay Movenpick (TBM) are all characterized by a sandy bottom.

To gain deeper insights into the coastal areas, an investigation was conducted between April 2018 and May 2019. The study covered nine distinct sites along the Jordanian coast (Figure 1), each denoted by an abbreviation and the number of transects surveyed in parentheses: Hotel Area (HA: 9); Ghandoor Beach (HB: 9); Phosphate Loading Berth (PLB: 9); Marine Science Station (MSS: 12); Marine Park (MP: 9); Barracuda Beach (BB: 12); Sodasyat (SOD: 9); Tala Bay Radisson (TBR: 9); Tala Bay Movenpick (TBM: 9).

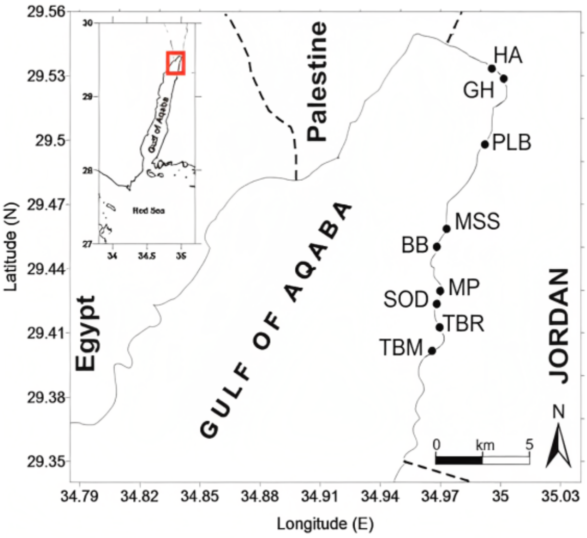

Figure 1. Locations of the study sites, which include the Hotel Area (HA), Ghandor (GH), Phosphate Loading Berth (PLB), Marine Science Station (MSS), Marine Park (MP), Barracuda Beach (BB), Sodasyat (SOD), Tala Bay Radisson (TBR), and Tala Bay Movenpick (TBM).

2.3. Visual census

Scorpion fish surveys were conducted using the visual census technique with SCUBA diving, following the protocol outlined by English et al. (1994). The survey includes three sets of replicated transects, each spanning a distance of 50 meters. These replicates were established at each of the three specific shallow depths: 3, 6, and 9 m``. The replicate transects were carefully placed in sequence, with a distance of 10–20 m between each one. In addition to the aforementioned transects, another set of three fish transects was carried out on the reef flat, at depths of less than 2 m, focusing on sites with coral reef habitats (i.e. the MSS). During the surveys, a waiting period of approximately 10 minutes was observed to allow the fish to return to their normal behavior before counting commenced. Once the waiting period was over, the observer swam along the transects and meticulously recorded all Scorpion fish sightings within a 1.5-m radius on each side of the line and 3 m above the transect. Each transect took about 20-25 minutes to complete. To assess the benthic community, the point intercept method, as modified after the work of English et al. (1994), was employed. This method involved recording the percentage of live hard and soft coral cover, seagrass, dead coral/rock, and sediment (sand). To ensure the identification of dangerous marine organisms, the guidelines established by Randall (2010), Myers (1991), and Khalaf and Disi (1997) were adhered to. By employing these rigorous methodologies and adhering to established protocols and guidelines, the scorpion fish populations and benthic communities were thoroughly and accurately studied, contributing valuable insights to marine research.

2.4. Statistical analysis and diversity calculations

The statistical analysis employed in this study follows the methods outlined by Sokal and Rohlf (1981), which were implemented using the StatView computer software.

Additionally, community indices such as the number of species (S), fish abundance (N), species richness (d), and species diversity (H´) were computed using the PRIMER-5 software developed by Primer-E (2000).

The abundance of fish species was described by two metrics: relative abundance (RA) and frequency of appearance (FA). The calculations for these metrics are as follows:

$$RA = \frac{Xi}{Ya} \times 100$$

where Xi represents the pooled average abundance of species i from each depth and site, and Ya represents the pooled average abundance of all species from each depth and site.

$$FA = \frac{Ni}{Nt} \times 100$$

where Ni denotes the number of transects in which species I was present, and Nt represents the total number of all transects.

Species diversity was evaluated using the Shannon-Weaver Diversity Index (Ludwig and Reynolds 1988):

$$H' = - \sum (pi \ln pi)$$

where pi is the proportion of all individuals counted that belonged to species i.

Species richness (d) was determined using the following formula:

$$d = S / N$$

where S is the total number of species observed, and N is the total number of individuals counted.

Cluster analysis and ANOSIM (analysis of similarities), were conducted using the PRIMER-5 software (Primer-E 2000). To examine the significant differences ($p \leq 0.05$) between (sites, depth, and habitat) concerning the number of species, species richness, and Shannon-Wiener diversity index, the group variations were measured using a One-Way Analysis of Variance (ANOVA). For presenting GIS maps related to the projected benthic cover, frequency of appearance, and relative abundance, ArcMap 10.8.1 software was utilized.

3. Results

3.1. Benthic coverage

The distribution of benthic coverage in the study area was thoroughly examined and presented in Figure 2. Among the surveyed sites, the MSS exhibited the highest proportion of live hard coral cover, accounting for an impressive 48.3%. In comparison, TBR came in second with a cover of 12.0%, while GH had the least hard coral cover, with a mere 0.4%. Hence, the MSS site stands out as a remarkable coral reef habitat. As for soft coral cover, GH led with 12.7%, closely followed by TBR with 9.8%. In terms of seagrass cover, HA, PLB, and GH were the highest, with percentages of 61.8%, 54.0%, and 45.6%, respectively. These three sites were identified as significant seagrass habitats, contributing substantially to the overall ecosystem. The sandy habitats were prominently represented in five sites, with BB having the highest sand cover at 72.7%, followed by TBR (54.9%), MP (54.5%), TBM (45.1%), and SOD (43.1%). Notably, the sand cover percentages varied across different depths, with 46.5% at 3 m depth, 45.3% at 6 m, and 44.2% at 9 m. Additionally, the distribution of hard coral cover was found to be predominantly concentrated in the reef flat, accounting for 44.7% of the coverage, followed by rocky habitats at 30.7%.

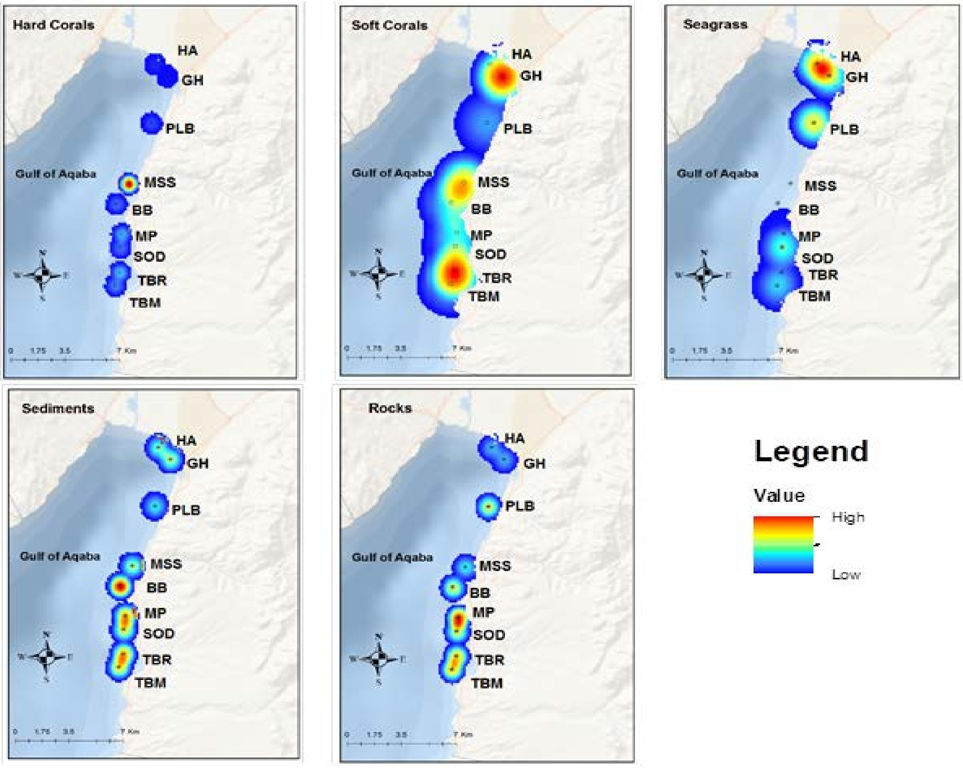

Figure 2. Distribution of Benthic Habitats; Hard Corals, Soft Corals, Seagrass, dead coral/rock and sediment at the nine sites along Gulf of Aqaba, Jordan.

3.2. Scorpion fish assemblages

A total of 417 scorpion fishes from 7 distinct species were meticulously recorded. The investigation involved the examination of 87 belt transects, which were strategically positioned at 9 diverse coastal sites spanning from the northern to the southern borders of the region. The findings revealed an average of approximately 4.8 scorpion fish individuals per transect.

3.3. Dominant Scorpion fish species at various sites

Based on the relative abundance (RA) calculations, three species were found to be the most abundant in this study. *Pterois miles* ranked first with a relative abundance of 37.9%, followed by *Synaneia verrucosa* at 21.3%, and *Pterois radiata* at 20.6%, collectively representing 79.8% of the total counted individuals. Among the nine sites studied, *P. miles* dominated at seven locations, with its RA varying from 8.6% at PLB to 60.7% at MP. *S. verrucosa* had the highest abundance at two sites, with RA ranging from 5.0% at SOD to 71.4% at PLB. Interestingly, *S. verrucosa* was not observed at the TBR and TBM sites (Figure 3).

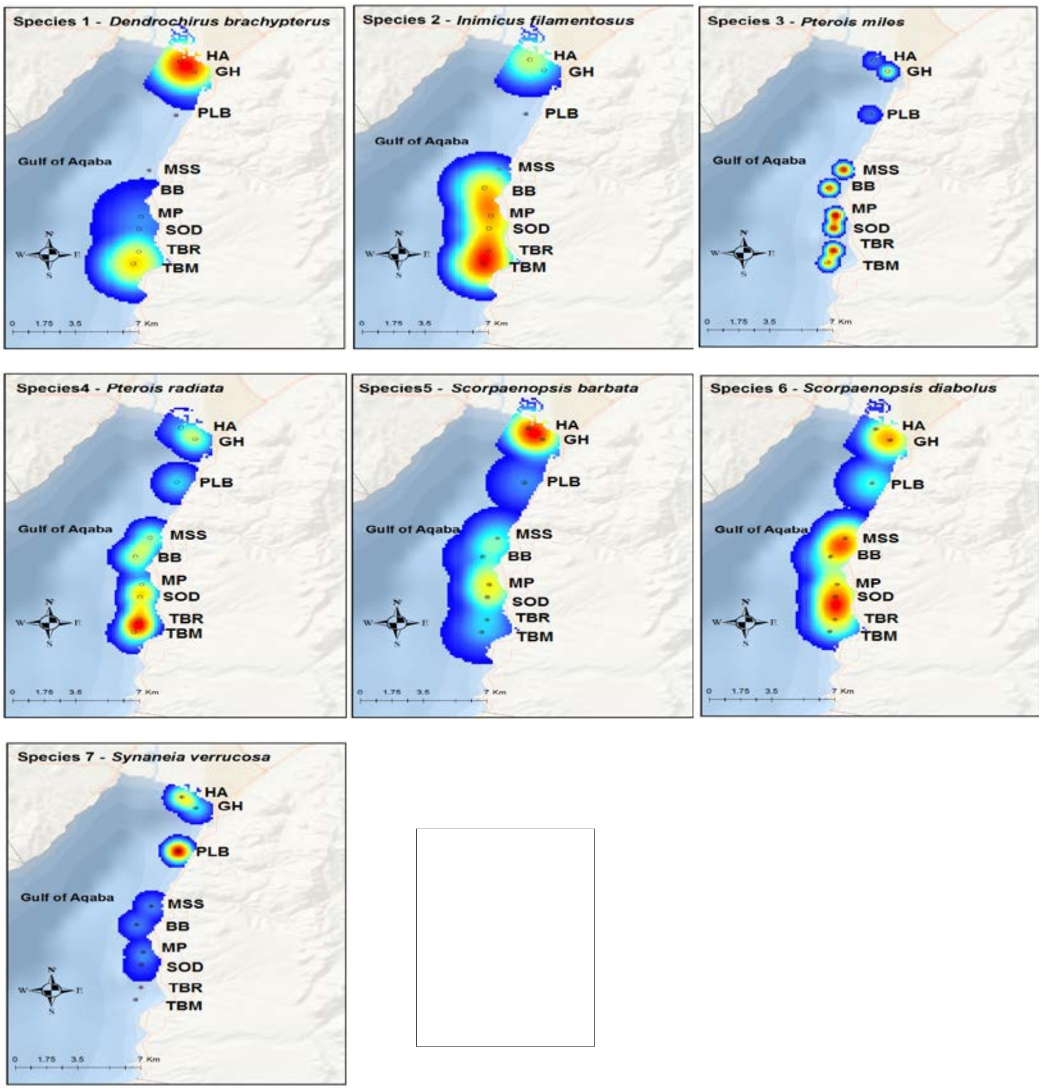

Figure 3. Projected relative abundance of seven species currently under investigation at the nine sites along Jordanian Gulf of Aqaba

3.4. Frequency of Appearance (FA)

The scorpionfish species observed on the Jordanian coast of the Gulf of Aqaba were well-documented in a study (Figure 4). Among the prevalent species, *P. miles* had the highest occurrence with a frequency of 70.1%, followed by *P. radiate* at 54.0%, and *S. verrucosa* at 41.4%. The distribution of these species varied across different locations, as indicated in Figure 3. At GH, five fish species were found to be most frequent, while three fish species were most commonly observed at HA. Additionally, two fish species were predominant at TBR, and one particular species stood out as the most common at TBM sites.

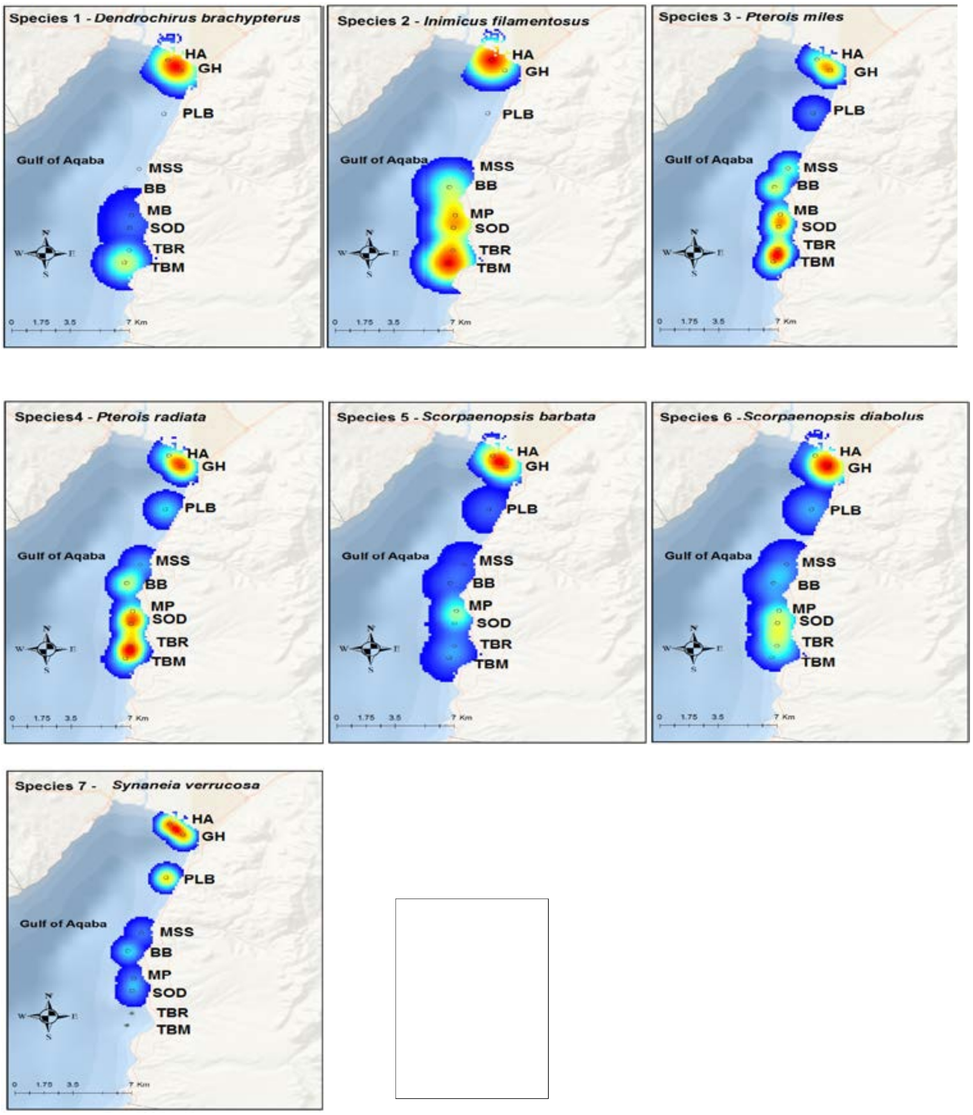

Figure 4. Projected Frequency of Appearance for the seven species under investigation at the nine sites along Jordanian Gulf of Aqaba.

3.5. Diversity Parameters

The data presented in Figure 5 displays the average values for various biodiversity measures across each site. The median number of species (S) ranged from 1.33 at the MSS site to 4.56 at the GH site. Similarly, the median number of individuals (N) varied from 1.78 at the MSS site to 10.44 at the GH site. Median species richness (d) showed a range from 0.36 at the MSS site to 1.53 at the GH site. Lastly, the Shannon-Wiener diversity index (H') exhibited a range from 0.22 at the MSS site to 1.38 at the GH site.

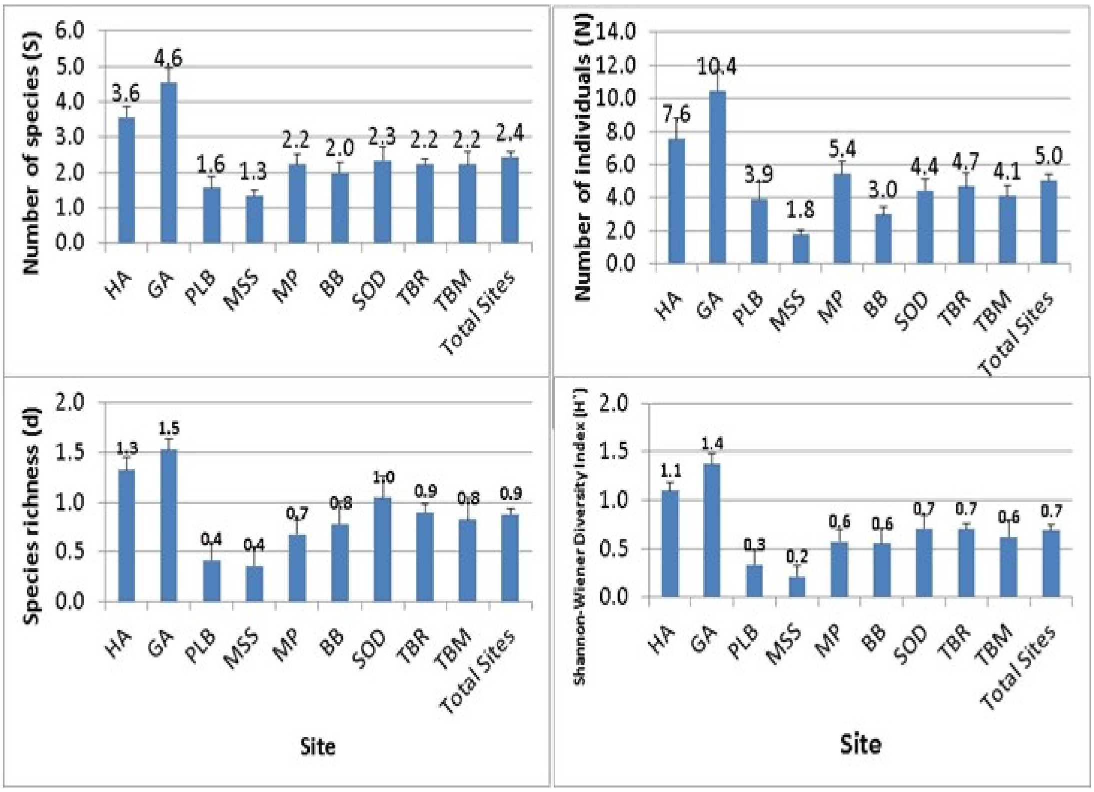

Figure 5. Average number of species (S), average number of individuals (N), average species richness (d), and average Shannon-Wiener Diversity Index (H') per 250 m^2 at different study sites situated along the Jordanian coastal waters. The study sites are identified as follows: Hotel Area (HA), Ghandor (GH), Phosphate loading berth (PLB), Marine Science Station (MSS), Marine Park (MP), Barracuda Beach (BB), Sodasyat (SOD), Tala Bay Radisson (TBR), and Tala Bay Movenpick (TBM).

3.6. Dominant Scorpionfish species by habitat

Table 1 presents the dominant scorpionfish species observed in different habitats. The data indicates that *P. miles* exhibited the highest abundance in both coral reef habitats (RA of 55.6%) and sandy habitats (RA=47.0%). On the other hand, *S. verrucosa* was found to be the most abundant scorpionfish species in seagrass habitats, with a relative abundance of 53.4%.

Table 1. Relative fish abundance (RA) data for three distinct habitat types along the Jordanian coast: seagrass (SG), coral reef, and sandy (SD) habitat. The calculation was performed per 250 m^2 transect. The number of individuals (N) in each habitat type was taken into consideration during the analysis.

Fish Species	SG	CR	Sand
D. brachypterus	13.6	0.0	7.8
I. filamentosus	1.9	0.0	1.7
P. miles	8.7	55.6	47.0
P. radiate	11.7	22.2	23.6
S. barbata	8.7	5.6	5.4
S. diabolus	1.9	5.6	3.7
S. verrucosa	53.4	11.1	10.8

3.7. Frequency of Appearance (FA)

The most common dangerous fish species found in seagrass habitats was *S. verrucosa*, constituting 88.9% of the occurrences, with *P. miles* and *P. radiata* following at 38.9% each. In contrast, the prevalent fish species in sandy habitats was *P. miles* (82.5%), while *P. radiata* followed closely at 64.9% for each species. Moreover, in coral reef environments, the dominant fish species was *P. miles*, accounting for 58.3% of the occurrences, while *P. radiata* accounted for 25.0% (Table 2)

Table 2. Frequency of appearance (FA) calculated for Seagrass (SG), Coral reef (CR) and Sandy (SD) habitats along the Jordanian coast.

Fish species	SG	CR	SD
D. brachypterus	33.3	0.0	26.3
I. filamentosus	11.1	0.0	8.8
P. miles	38.9	58.3	82.5
P. radiata	38.9	25.0	64.9
S. barbata	33.3	8.3	22.8
S. diabolus	11.1	8.3	17.5
S. verrucosa	88.9	16.7	31.6

3.8. Diversity Parameters

The seagrass habitat exhibited the highest average number of species (S=2.7), with sandy bottoms following closely behind (S=2.5), and the coral reef had the lowest number of species (S=1.2). Regarding the number of individuals, seagrass hosted the most significant population (N=5.7), while the coral reef had the lowest number of individuals (N=1.5). The species richness was at its highest in the seagrass habitat (d=1.1) and reached its lowest in the coral reef (d=0.7). Analyzing the Shannon

Diversity Index, both sandy and seagrass habitats showed the highest value (H`=0.7 each) (Figure 6).

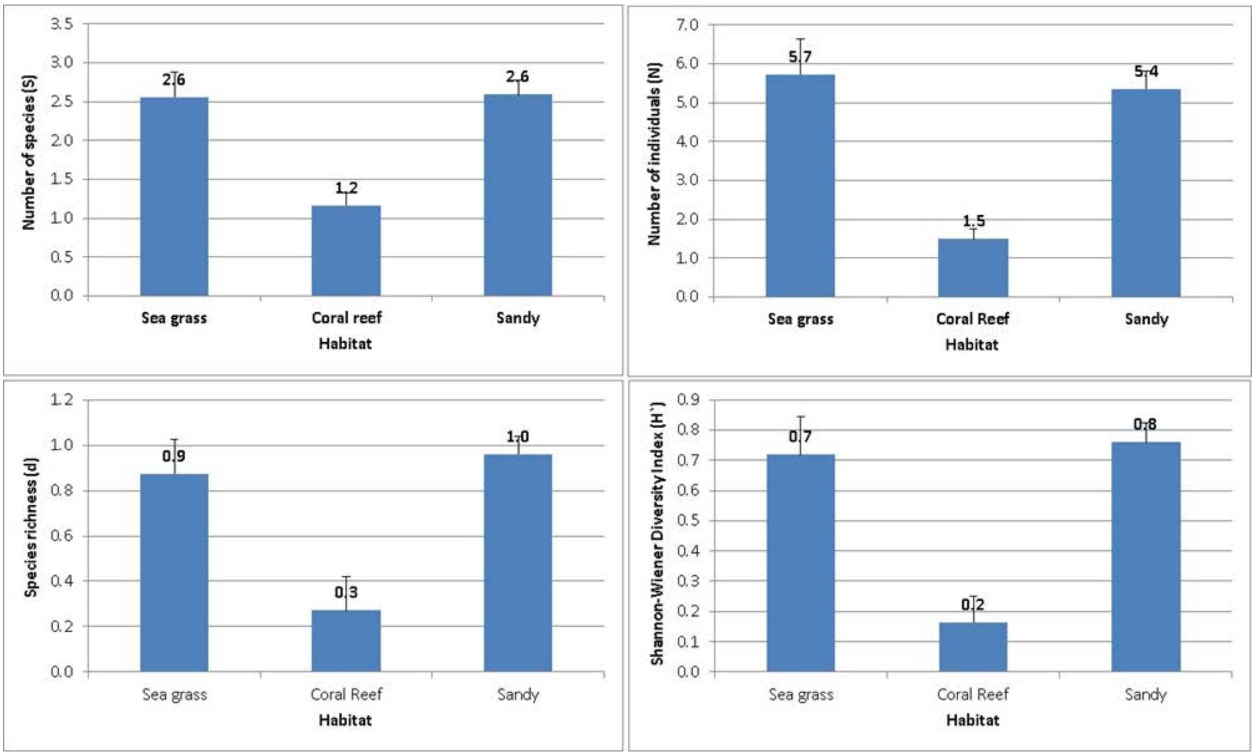

Figure 6. Average number of species (S), average number of individuals (N), average species richness (d), and average Shannon-Wiener Diversity Index (H') per 250 m^2 across different habitats along the Jordanian coast in the Gulf of Aqaba.

3.9. Dominant Scorpionfish species by depth

Table 3 displays the predominant fish species found at different depths. The distribution patterns of the fish species varied depending on the depth. Among these, *S. verrucosa* and *Scorpaenopsis diabolus* were the most abundant scorpionfish at RF, with each species accounting for 44.4% of the relative abundance (RA). On the other hand, *P. miles* dominated at 3 m, 6 m, and 9 m depths, with RAs of 36.1%, 34%, and 46.9% respectively.

Table 3. Relative fish abundance (RA) calculated at different depths along the Jordanian coast. The data incorporates the reef flat (RF), as well as depths of 3m, 6m, and 9m, which were combined in 250 m² transects.

Fish species	RF depth	3 m	6 m	9 m
D. brachypterus	0.0	12.3	8.3	6.9
I. filamentosus	0.0	0.0	3.2	1.5
P. miles	0.0	36.1	34.0	46.9
P. radiate	0.0	22.1	17.9	23.8
S. barbata	44.4	5.7	5.8	4.6
S. diabolus	11.1	2.5	3.8	3.1
S. verrucosa	44.4	21.3	26.9	13.1

3.10. Frequency of Appearance (FA)

Among the various scorpionfish species found at the reef flat, *S. Verrucosa* and *Scorpaenopsis diabolus* were the two most prevalent ones, each accounting for 50.0% of the observed occurrences. Notably, *P. miles* emerged as the dominant fish species at depths of 3 and 9 m, with a frequency of occurrence (FA) value of 74.1%. At a depth of 6 m, its FA increased further to 77.8% (Table 4).

Table 4. Frequency of appearance (FA) values computed for different depths on the reef flat (RF) of the Jordanian coast. The depths considered are 3m, 6m, and 9m.

Fish species	RF depth	3 m	6 m	9 m
D. brachypterus	0.0	29.6	25.9	22.2
I. filamentosus	0.0	0.0	18.5	7.4
P. miles	0.0	74.1	77.8	74.1
P. radiata	0.0	51.9	55.6	66.7
S. barbata	50.0	22.2	22.2	18.5
S. diabolus	16.7	11.1	22.2	11.1
S. verrucosa	50.0	48.1	48.1	25.9

3.11. Diversity parameters

When analyzing depth-related factors, it becomes evident that the fish species distribution varies significantly across different transects (Figure 7). Among the transects studied, those at a depth of 6 m stand out with the highest number of fish species per transect (S=2.70). Following this, the 3-m deep transects also exhibit considerable species richness (S=2.37), while the 9-m deep transects have a slightly lower number of species (S=2.26). On the other hand, the reef flat (RF) transects show the lowest species count (S=1.16).

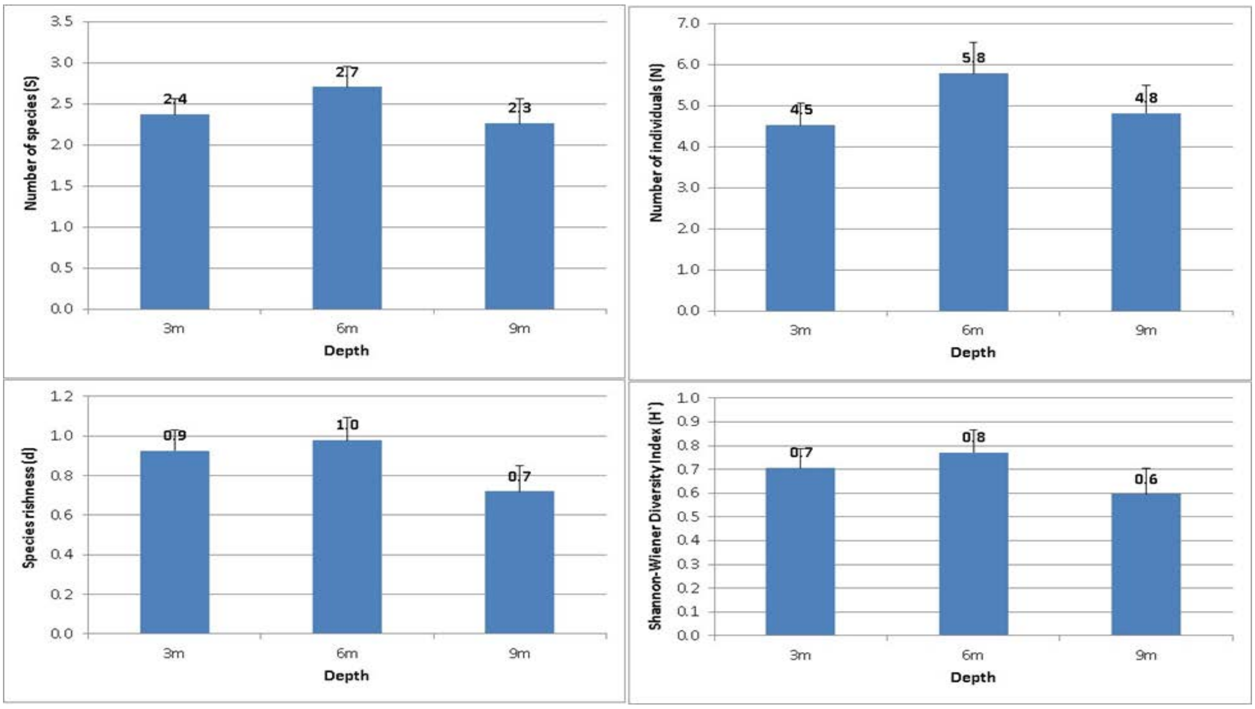

Figure 7. Average values of different ecological parameters measured per 250 m^2 at varying depths (3m, 6m, and 12m) along the Jordanian coast. These parameters include the mean number of species (S), the mean number of individuals (N), the mean species richness (d), and the mean Shannon-Wiener Diversity Index (H').

Regarding the abundance of individuals, the 6-m deep transects again come out on top, hosting the highest number of fish per transect (N=5.78). The 9-m deep transects show a substantial presence of fish (N=4.81), and the 3-m deep transects have a somewhat lower number of individuals (N=4.52). In contrast, the reef flat (RF) transects exhibit the lowest number of individuals (N=1.50).

To assess species richness, we calculated the dominance index (d) for each transect. The 6-m deep transects demonstrate the highest species richness (d=1.10), followed closely by the 3-m deep transects (d=1.04). Comparatively, the reef flat depth records the lowest species richness (d=0.91).

The Shannon-Diversity Index provides insight into the overall diversity within each transect. The 6-m deep transects display the highest diversity (H`=0.8), indicating a more balanced distribution of species. In comparison, the 3-m deep transects show slightly lower diversity (H`=0.7). The reef flat (H`=0.2), however, exhibits the lowest diversity, suggesting a less even distribution of species in this area.

Table 5 presents the statistical significance analysis for the variables S, N, d, and H` with respect to sites, depths, and habitat. The findings indicated a notable distinction between sites and habitat ($p<0.05$). However, no significant differences were observed among various depths for the variables S, N, d, and H.

Table 5. One-way ANOVA comparison test for mean number of species (S), mean fish abundance (N), species richness (d) and Shannon-Wiener Index (H`) at sites (7 sites), depths (RF, 3 m, 6 m, and 9m), and habitat (coral reef, sandy and seagrass) along the Jordanian coast.

Significance	S	N	D	H`
Between sites	< 0.0001	< 0.0001	< 0.0001	< 0.0001
Between depths	0.4274	0.3853	0.2543	0.4090
Between habitat	0.0019	0.0009	0.0019	0.0004

3.12. Site similarities

The analysis of the clusters has unveiled distinct patterns across the various sites, as depicted in Figure 8. Group A includes sites such as the Marine Science Station (MSS), Marine Park (MP), Barracuda Beach (BB), Sodasyat (SOD), Tala Bay Radisson (TBR), and Tala Bay Movenpick (TBM). These sites collectively represent the middle and southern regions of the Jordanian coastline along the Gulf of Aqaba. Conversely, Group B comprises the northern locations, including the Hotel Area (HA), Ghandor (GH), and Phosphate Loading Berth (PLB).

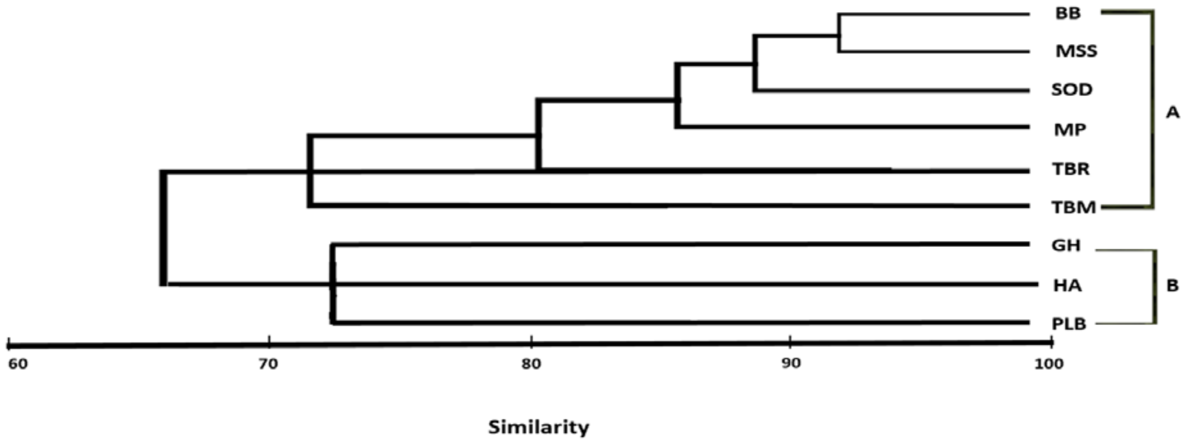

Figure 8. Dendrogram plot illustrating the comparative similarity among various sites including Hotel Area (HA), Ghandor (GH), Phosphate Loading Berth (PLB), Marine Science Station (MSS), Marine Park (MP), Barracuda Beach (BB), Sodasyat (SOD), Tala Bay Radisson (TBR), and Tala Bay Movenpick (TBM). The labels 'A' and 'B' denote distinct group clusters.

4. Discussion

Historically, research along the Jordanian coastline has predominantly been dedicated to commercial and coral reef fish, focusing on biological, ecological, and taxonomical aspects (Wahbeh and Ajiad 1987; Wahbeh 1992; Khalaf and Disi 1997; Al-Rousan et al. 2005; Khalaf and Crosby 2005; Khalaf and Krupp 2008; Krupp et al.,2009). However, there is a conspicuous absence of studies on hazardous marine creatures in this region. As beach traffic escalates due to local and international tourism, it is vital to gather precise information about these potentially dangerous animals. Moreover, the Jordanian coastline is grappling with considerable strain from rapid development and excessive exploitation of marine resources. Scorpion fishes, although not innately aggressive toward humans, can inflict harm due to human ignorance (Khalaf and Disi 1997). Thus, enhancing awareness and exercising caution in shallow waters are recommended preventative steps. Touching underwater objects while swimming or diving is strongly discouraged. The information, maps, and data derived from this research can assist policymakers in making informed decisions about beach safety and raise public awareness about the potential risks associated with dangerous Scorpion fishes. This knowledge can guide actions to lower injury risks and increase overall safety for beachgoers.

Of the globally recognized 219 scorpion fish species (Eschmeyer and Fong 2013), 19 are found in the Red Sea (Golani and Bogorodskey 2010), and 26 in the Arabian Sea. The Jordanian side of the Gulf of Aqaba hosts 14 identified species (Khalaf and Kochzius 2002a). This study adds seven species found at shallow depths across nine coastal sites to the existing knowledge of scorpion fish distribution, providing a basis for future research and conservation endeavors. The fish community distribution and abundance are largely dictated by depth and benthic habitat. The studies of Khalaf and Kochzius (2002a) have demonstrated that fish species richness is associated with substrate cover, habitat diversity, and live hard coral cover.

The statistical analysis showed distinctive differences among the sites for certain species, such as *Dendrohairus brachypterus, Pterois miles, P. radiata, S. barbatus,* and *S. verrucosa,* with *P. miles* being particularly abundant along the Jordanian coast, followed by *S. verrucosa*. This pattern may be attributed to the high prevalence of *P. miles* at seven sites and *S. verrucosa* at two sites. The habitats preferred by *P. miles* are coral reefs and sandy areas with sporadic corals, with their abundance possibly being influenced by food availability. Small fish species like *Neopomacentrus miryae, Chromis viridis*, and *Pseudanthias squamipinnis* inhabit patchy coral heads in the region. Conversely, species such as *Diplodus noct, Gerris oyena*, and *Scalopsis ghonam*, known to reside in sandy bottoms, may serve as a food source for *S. verrucosa*, which is mainly abundant at the PLB and HA sites. These sites feature sandy bottoms where *S. verrucosa* can bury itself, as noted by Khalaf and Disi (1997).

There were considerable differences in fish community structure and spatial distribution among coral reefs and seagrass beds. Coral reefs and seagrass beds surrounding Marsa Abu Dabab had fish communities typical of other inshore areas of the northern Red Sea. While some species were confined to either seagrass or coral reefs, others were widely distributed along the gradient. The settlement of larval and juvenile fish is also pivotal in determining the structure and stability of reef fish communities, with substrate type selection playing a role (Williams and Sale 1981). Many reef fish species prefer settling on live corals (Booth and Beretta 2002).

The GH site exhibited the greatest number of species, fish abundance, species richness, and species diversity, closely followed by the Hotel Area (HA). These sites were remarkably similar, sharing adjacent positions and similar habitat characteristics. Both contained small coral patches and rocks, creating ideal conditions for the species studied, as they use these features for camouflage and prey capture (Khalaf and Disi 1997). Habitat complexity accounted for 71% of the variation in species richness and 22% of total fish abundance variation, according to Gratwicke and Speight (2005).

Based on standardized and square root analysis, this study detected significant variations in the distribution patterns of scorpionfishes across different sites along the Jordanian coast of the Gulf of Aqaba. The dendrogram suggests the existence of two main clusters. The structure of dangerous marine organisms in GH and HA showed notable differences from other sites. The habitat in the northern part of the coast seemed to affect the presence of scorpionfishes. Brokovich et al. (2006) reported a strong correlation between fish assemblages and different habitat types at the northern tip of the Gulf of Aqaba, a finding echoed by Khalaf and Kochzius (2002a). While Brokovich et al. (2006) stressed the importance of depth as a critical factor impacting fish community distribution and abundance, the results from this study contradicted their findings from the western side of the Gulf of Aqaba. This discrepancy might be attributed to the lower depths surveyed in this study, ranging from the reef flat to only 9 m deep.

This study found that the highest fish abundance occurred at 3 m deep transects, whereas the lowest number of fish species and individuals were observed in the reef flat area. This could be due to the unique conditions of this habitat. The reef's flat area is exposed to various physical factors, such as wind, waves, and sunlight, which result in a complex environment. In addition to rocks, sand, or mud, these physical factors pose different challenges to the organisms inhabiting this area. Species living in such environments need to be capable of tolerating significant fluctuations in salinity and moisture and withstand the potential impact of powerful waves to survive. *P. miles* was the most abundant fish species at 3, 6, and 9 m deep transects. This fish typically inhabits coral reef areas hosting schools of small fish, which are their primary food source. However, this species is considered one of the most common fish species in the *Pterois* genus (Khalaf and Disi 1997; Khalaf and Kochzius 2002a). Significant differences were observed in fish abundance, species richness, and diversity between sites and habitats. Statistical significance for fish assemblage showed a significant difference between habitats and sites. Fishes were most abundant in the GH and HA sites, which are dominated by seagrass, with some sandy and small coral patches. On the other hand, seagrass habitats had the highest diversity of fishes, whereas sand and coral reefs had lower diversity and fish abundance. These findings were also reported by Aguilar-Perera and Appeldoorn (2008), who observed that fish assemblages in seagrass beds were more diverse than in sandy and coral reef habitats. Aguilar-Perera and Appeldoorn (2008) concluded that seagrass beds are an important habitat for a number of fish species due to the diversity of food resources and availability of hiding places.

5. Conclusions

In conclusion, this study has elucidated the community structure and distribution patterns of scorpion fishes along the Jordanian shoreline of the Gulf of Aqaba. The investigation pinpointed seven unique species of scorpion fish inhabiting various coastal locations and depths, with *Pterois miles* and *Synaneia verrucosa* standing out as the most prevalent species. Moreover, the research underscores the significant impact of specific locations and habitats on the abundance, species richness, and diversity of these fishes. Coral reef habitats were characterized by the greatest fish abundance and diversity, while seagrass habitats demonstrated superior species richness. The study has also revealed striking disparities in the community structure and spatial distribution of fish across northern locales compared to middle and southern areas. These findings offer invaluable insights for policymakers and beachgoers alike, promoting enhanced safety measures and fostering awareness regarding the potential hazards posed by these dangerous marine creatures. On the whole, this research augments the existing body of knowledge regarding scorpion fish distribution and could act as a cornerstone for future conservation endeavors in the region.

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