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Stock differentiation of the greater lizardfish *Saurida tumbil* (Teleostei: Synodontidae) collected along the western coast of the Arabian Gulf and Sea of Oman using meristic characters

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Abstract

Meristic variation among stocks of greater lizardfish *Saurida tumbil* through the western coasts of the Arabian Gulf and Sea of Oman was examined using meristic characters. Statistical analysis of meristic traits proposed that there is constrained migration of populations of greater lizardfish along the western coast of the Arabian Gulf and Sea of Oman. Overlapping of the two samples from the northern part of the Arabian Gulf (Iraq-Kuwait waters), three samples from the middle region of the Arabian Gulf (Bahrain-Qatar-Saudi Arabia) and two samples from the southern part of the Arabian Gulf/Sea of Oman (United Arab Emirates–Sultanate of Oman) suggested that there are three self-recruiting populations in the studied area. Inspection of the role of each meristic trait variable to Canonical discriminant analysis showed that changes among samples appeared to be linked with the pattern of distribution of water temperature and configuration of current in both the Arabian Gulf and Sea of Oman areas.

KEYWORDS
greater lizardfish, management, meristic, population, stock identification

1 | INTRODUCTION

Arabian Gulf and Sea of Oman are among the important marine extensions of the Indian Ocean. By way of the Strait of Hormuz, the Arabian Gulf is connected to the Sea of Oman, which is bounded by Iran on its north coast and United Arab Emirates (UAE) and Sultanate of Oman on its south coast (Al-Abdulrazzak *et al*., 2015; Al-Abdulrazzak & Pauly, 2014; Hamza & Munawar, 2009; Sadighzadeh *et al*., 2014; Valinassab *et al*., 2006).

The Arabian Gulf maintains extremely productive coastal ecosystems (Sale *et al*., 2011; Sheppard *et al*., 2010) that provide sustenance for vital commercial fisheries (Al-Abdulrazzak *et al*., 2015), but with less biological diversity than the neighbouring Indian Ocean because of its extreme habitat settings (Sale *et al*., 2011). On the contrary, the Sea of Oman provides a wealth of good fisheries to the two countries bordering it, Iran and Oman, the latter being considered as one of the largest fish producers in the western Indian Ocean (Carpenter *et al*., 1997).

The greater lizardfish is a marine species that occasionally lives in association with reefs (Riede, 2004) at depths shallower to 700 m (Goldshmidt *et al*., 1996), but usually found at a depth range 20–60 m (FAO-FIGIS, 2005). It is distributed in the Indo-Pacific region from the Red Sea and east coast of Africa west and eastward to the Arabian Gulf, Sea of Oman, Southeast Asia and Australia (Russell & Houston, 1989). It reaches a maximum total length of 600 mm, with a reported age of 7 years (Shindo, 1972). Its diet comprises fishes, crustaceans and squids (Sommer *et al*., 1996). This lizardfish is considered one of the most commercially important species in its geographical distribution and in Iraq in particular, where the percentage of the total landings reached 46.666% in 1999–2000 (Mohamed *et al*., 2005).

An adequate level of separation may cause a marked morphological and genetic distinction within a species, which may be decipherable as a source for racial separation and management of discrete populations (Turan, 2004). Meristic counts have long been used successfully in showing the fish population structure (Haddon & Willis, 1995;

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Silva, 2003; Villaluz & Maccrimmon, 1988). Disparity in these traits was presumed to be totally genetic in early studies (Heincke, 1898; McQuinn, 1997); nonetheless, it is now not certain whether both environmental and genetic factors might cause such changes (Cabral *et al*., 2003; Robinson & Wilson, 1996). In spite of the introduction of biochemical and molecular facilities, the morphological disparity between populations endures having a vital role in fish stock investigations, which are represented by meristic traits, which are part of the fish phenology (Dwivedi & Dubey, 2013; Murta *et al*., 2008; Swain & Foote, 1999; Turan, 2004; Turan *et al*., 2006) that are fixed in embryos or larvae (Turan, 2004).

It has been shown that the fishing effort is dissimilar between the adjacent seas. For example, the occurrence of *Trachurus mediterraneus* is significantly higher in the Black Sea and lower in the northeastern Mediterranean Sea (DIE, 2001). Therefore, the assessment of the movement of individuals between the neighbouring coastal areas would be imperative for fisheries management.

Currently, there are no data of greater lizardfish structure among fishing areas of the Arabian Gulf and Sea of Oman using morphometric and meristic characters except for that of Mohanchander *et al*. (2019) from the Cochin coasts, India. In that study, morphometric characters were used to separate *Saurida tumbil* from its congener *Saurida pseudotumbil*, and such usage revealed its validity.

The goal of the present study is to explore the population structure of *S. tumbil* based on meristic traits subjected to canonical discriminant analysis.

2 | MATERIALS AND METHODS

Greater lizardfish were collected during the spawning season (April–July) (Abaszadeh *et al*., 2013; Rahimibashar *et al*., 2012) from Iraq (Khor al-Aumaia, 29° 46′ 30.69″ N, 48° 42′ 13.46″ E) (173 individuals, 190–275.8 mm L_T), Kuwait (Kuwait Bay, 29° 23′ 58.75″ N, 48° 04′ 40.54″ E) (198 individuals, 195–381.5 mm L_T), Bahrain (Quamis, 25° 54′ 42.96″ N, 50° 42′ 24.79″ E) (128 individuals, 190.6–391.4 mm L_T), Qatar (Al-Shamal, 26° 18′ 31.89″ N, 51° 15′ 58.46″ E) (143 individuals, 196.4–354.3 mm L_T), Saudi Arabia (Jubail city coasts, 27° 14′ 28.22″ N, 50° 27′ 45.32″ E) (212 individuals, 189.6–391.4 mm L_T), UAE (Dubai, 25° 23′ 53.11″ N, 55° 01′ 16.63″ E) (173 individuals, 190.2–396.7 mm L_T) and Sultanate of Oman (Sohar, 24° 31′ 11.80″ N, 57° 12′ 00.65″ E) (175 individuals, 197.1–344.9 mm L_T) (Figure 1). Therefore, Reist's (1985) recommendation that at least 25 specimens be used for meristic analyses was fulfilled. In all localities, fishes were collected by a bottom trawler equipped with a 40 mm mesh-sized codend trawl net during the period 2014–2015. This vessel operated in the Arabian Gulf and Sea of Oman fishing at depths ranging from 300 to 700 m over 1.5–2.0 nautical miles at a speed of *c*. 3 knots, 0.5 h tows. Therefore, samples were collected *c*. 6 h after capture, but were kept in a good condition by deep freezing and defrosted just before being examined in the laboratory. Four meristic characters were counted, such as: dorsal (D), anal (A) and pectoral (P) fin ray counts and number of the lateral line (LL) scales. Fin ray counts of the dorsal and anal fins followed that of Hubbs and Lagler (1949). The most posterior dorsal and anal fin rays were counted as one ray based on having a common origin. The other meristic characters of the fish appeared to be conservative and showed no spatial variation.

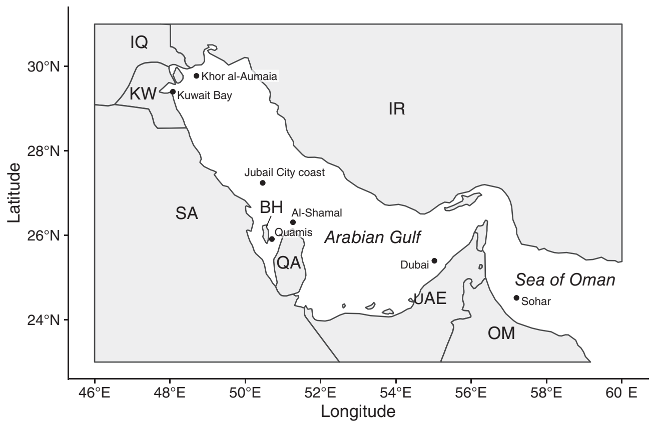

FIGURE 1 Map showing localities where samples of *Saurida tumbil* were collected from the western coast of the Arabian Gulf

The boxplot by variable and country was made to compare and determine the distribution of each meristic variable and the total length. Comparisons were done by Kruskal–Wallis analysis because normality was not achieved in any case. This test is the non-parametric equivalent of the one-way ANOVA and is used when the normality assumption is violated. A discriminant analysis (SPSS ver. 25.0) on the meristic data by country sample was run to assess the efficacy of the latter in classification. Later, a Mann–Whitney *U*-test was used to compare two independent samples or geographic zones of different sample sizes. Finally, a discriminant analysis (SPSS ver. 25.0) on the meristic data by country sample was run to assess the efficacy of the latter in classification. The percentage of correct classification using cross-validation analysis was recorded.

2.1 | Ethical statement

This work is based on commercial fish species, and the specimens were collected from a commercial catch. Therefore, ethical aspects are not applicable.

3 | RESULTS

Table 1 presents the mean (±S.D.), minimum and maximum values for total length (cm) and each of the meristic measurements. At first sight, the meristic values for Iraq and Kuwait coincide as well as do those for Saudi Arabia, Bahrain and Qatar, and finally UAE and Oman. The same pattern can be observed in Figure 2 where it is clear that the three zones are formed for the four meristic traits analysed. The results of the analysis showed that the localities examined are falling into three main groups. The first one formed by the localities of

TABLE 1 Sample size, mean ± standard deviation, minimum and maximum values of total length (L_T) and meristic characteristics of *Saurida tumbil* specimens collected along the coast of the Arabian Gulf and the Sea of Oman

Country	*N*	Total length (cm)		Dorsal fin ray count		Anal fin ray count		Pectoral fin ray count		Lateral line scales count	
		Mean ± s.d.	Min–max	Mean ± s.d.	Min–max	Mean ± s.d.	Min–max	Mean ± s.d.	Min–max	Mean ± s.d.	Min–max
Iraq	173	25.1 ± 2.83	19.1–27.6	12.6 ± 0.47	12–13	12.1 ± 0.33	12–13	15.1 ± 0.31	15–16	55.4 ± 0.62	55–57
Kuwait	198	23.5 ± 6.91	16.0–38.2	12.9 ± 0.40	12–14	12.6 ± 0.50	12–13	15.2 ± 0.43	15–16	55.6 ± 0.76	55–57
Saudi Arabia	212	28.6 ± 5.85	19.0–39.1	11.9 ± 0.29	11–12	10.9 ± 0.34	10–11	13.7 ± 0.44	13–14	52.8 ± 0.39	52–53
Bahrain	128	22.5 ± 2.90	19.1–34.0	11.8 ± 0.43	11–12	10.7 ± 0.46	10–11	13.8 ± 0.39	13–14	52.7 ± 0.46	52–53
Qatar	143	27.8 ± 5.20	19.6–35.4	11.7 ± 0.44	11–12	10.6 ± 0.50	10–11	13.6 ± 0.49	13–14	52.7 ± 0.50	52–53
United Arab Emirates	173	24.9 ± 4.72	19.0–35.4	10.8 ± 0.37	10–11	9.8 ± 0.42	9–10	12.7 ± 0.46	12–13	50.8 ± 0.36	50–51
Oman	175	26.2 ± 4.37	19.7–34.5	9.9 ± 0.33	9–10	9.8 ± 0.41	9–10	12.3 ± 0.65	11–13	50.5 ± 0.68	49–51

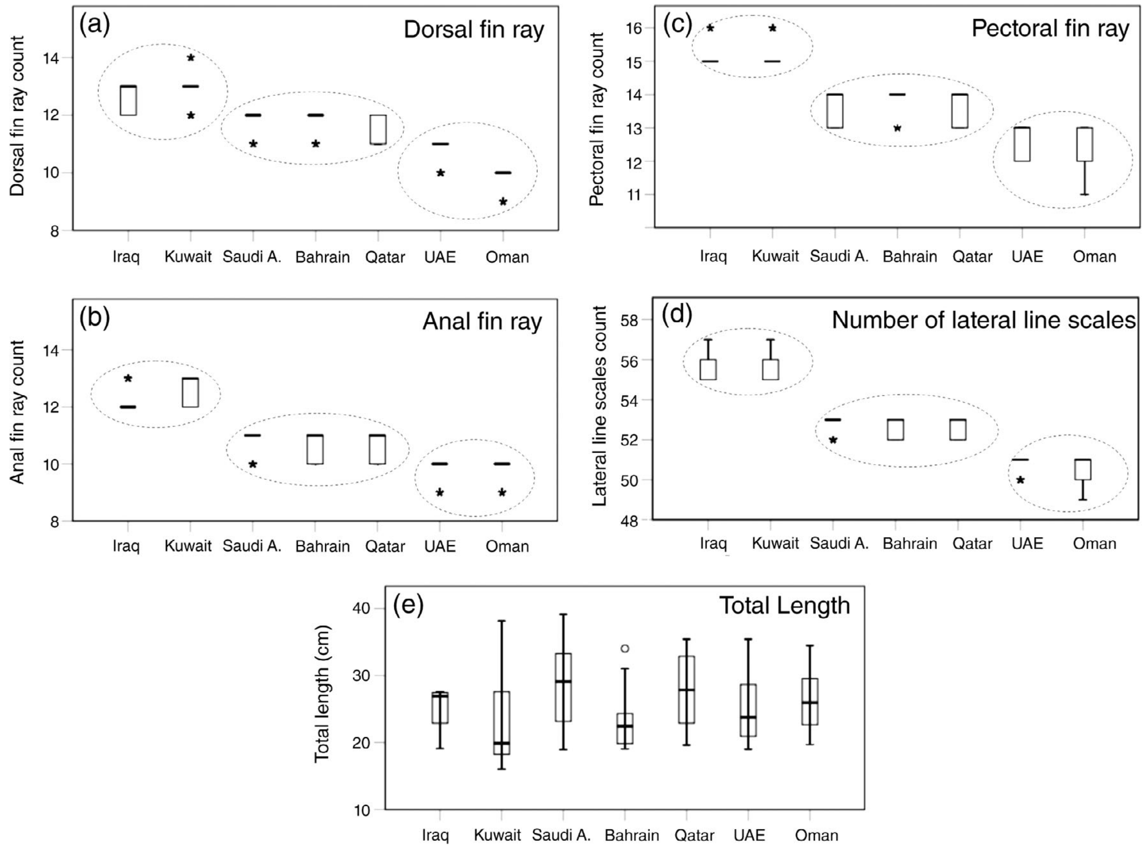

FIGURE 2 Mean ± standard error and standard deviation of four meristic variables and total length (cm) for: (a) dorsal fin ray count; (b) anal fin ray count; (c) pectoral fin ray count; (d) number of lateral line scales and (e) total length (cm)

Iraq and Kuwait; the second one formed by Saudi Arabia, Bahrain and Qatar; and the third by UAE and Oman (Figure 2: zones included by dotted lines). It is important to mention that size (L_T = total length) was significantly different between locations but, unlike meristic, showed no pattern of association by zones.

Because the aggrupation was clear, the meristic differences were analysed by the zones mentioned adding the specimens from Iraq and Kuwait as zone 1; Saudi Arabia, Bahrain and Qatar as zone 2 and the other two countries as zone 3.

Significant differences between zones were detected for all meristic variables: χ^2 (2 g.l.) = 987.826, $P < 0.001$ for Dorsal fin ray count; χ^2 (2 g.l.) = 1024.033, $P < 0.001$ for Anal fin ray count; χ^2 (2 g.l.) = 1042.045, $P < 0.001$ for Pectoral fin ray count and χ^2 (2 g.l.) = 1109.401, $P < 0.001$ for the number of lateral line scales. Mann–Whitney *U*-test showed significant differences between zones 1 and 2 ($Z = -22.764$, $P < 0.001$ for D; $Z = -26.433$, $P < 0.001$ for A; $Z = -26.695$, $P < 0.001$ for P and $Z = -26.448$, $P < 0.001$ for L) and zones 2 and 3 ($Z = -24.590$, $P < 0.001$ for D; $Z = -21.650$, $P < 0.001$ for A; $Z = -22.500$, $P < 0.001$ for P and *Z*

TABLE 2 Cross-validated classification results from the analysis of the meristic measures (dorsal, anal and pectoral fin ray counts and number of the lateral line scales) of 1202 specimens for seven locations: (1) Iraq; (2) Kuwait; (3) Saudi Arabia; (4) Bahrain; (5) Qatar; (6) United Arab Emirates (UAE); (7) Oman

		Predicted group membership							
Locations		Iraq	Kuwait	Saudi Arabia	Bahrain	Qatar	UAE	Oman	Total
%	Iraq	91.9	8.1	0	0	0	0	0	100.0
	Kuwait	32.8	67.2	0	0	0	0	0	100.0
	Saudi Arabia	0	0	59.4	23.6	17.0	0	0	100.0
	Bahrain	0	0	34.4	38.3	27.3	0	0	100.0
	Qatar	0	0	34.3	21.7	44.1	0	0	100.0
	UAE	0	0	0	0	0	83.8	16.2	100.0
	Oman	0	0	0	0	0	0	100.0	100.0

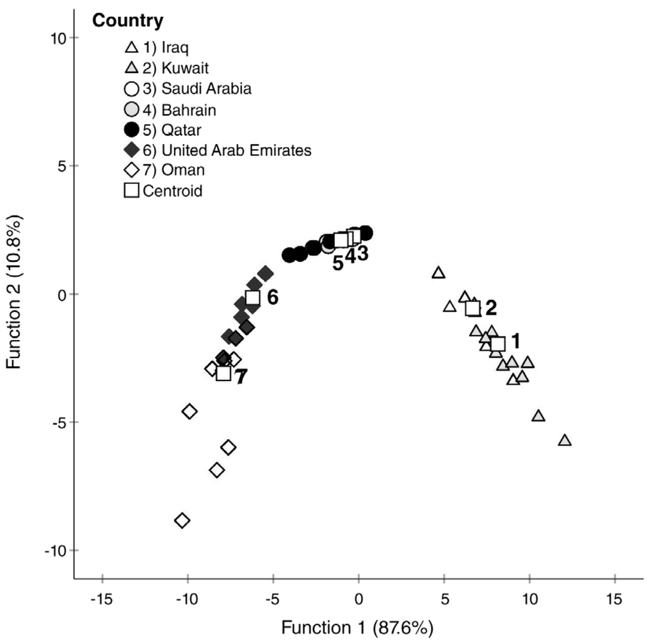

FIGURE 3 Scatter plot of the discriminant function scores from the analysis of meristic measures (dorsal, anal and pectoral fin ray counts and number of the lateral line scales) for seven different locations: (1) Iraq; (2) Kuwait; (3) Saudi Arabia; (4) Bahrain; (5) Qatar; (6) United Arab Emirates; (7) Oman. Centroids by country and figures by population: rectangles for Iraq and Kuwait; circles for Saudi Arabia, Bahrain and Qatar and diamonds for United Arab Emirates and Oman

= –26.180, $P < 0.001$ for L) for all meristic variables. For the analysis of meristic data, the first canonical discriminant function explained 87.6% of the total among-location variance, whereas the second accounted for 10.8% (Wilks' $\lambda = 0.004$, $P < 0.001$). These seven locations fall into three groups separated from each other in the four meristic characters: dorsal, pectoral and anal fin rays counts and the number of scales on the lateral line. The discriminant analysis correctly classified 70.7% of the locations for the seven locations (Table 2). The best classification rate of 100% was obtained for Oman followed by the ones from Iraq (91.9%). Meanwhile the locations Saudi Arabia, Bahrain and Qatar showed the lower classifications values: 59.4, 38.3 and 44.1%, respectively. Therefore, misclassifications were more common among Saudi Arabia, Bahrain and Qatar (Figure 3). Clearly three groups were formed, the first one with locations from Iraq and Kuwait, the second with the locations from Saudi Arabia, Bahrain and Qatar and the third with UAE and Omar locations.

4 | DISCUSSION

Meristic characters showed significant phenotypic heterogeneity among the Arabian Gulf and Sea of Oman samples, through non-parametric analysis and meristic comparisons by Kruskal–Wallis. The results suggest the presence of three distinct populations of *S. tumbil* in the area studied. The discrepancy may suggest a link between the deviation degree of meristic characters and geographic distance, signifying that migration among populations of the Arabian Gulf and Sea of Oman may be restricted. The notable environmental changes between the localities are water temperature and currents (Reynolds, 1993; Swift & Bower, 2003; Xue & Eltahir, 2015). The northern Gulf can uphold a minor cyclonic circulation, whereas the southward coastal currents occur between the head of the Gulf and Qatar and extend to the east of Qatar and north of UAE with an outflow through the southern part of the Strait (Xue & Eltahir, 2015). Modelling advocates that strong, northwest winds in the winter and spring yield southeast-flowing surface currents along both coasts in the northern gulf, restrict cyclonic circulation to the southern Gulf and shift the surface current through the Strait to the south side of the channel (Lardner *et al*., 1993). Moreover, river discharge from both the Shatt-Al-Arab and the Iranian rivers is diverted into currents flowing southward along both the Arabian and Iranian coasts (Lardner *et al*., 1993; Reynolds, 1993) that reduce their immediate impact on water mass formation in the central portions of the Gulf.

The inflow current along the Iranian coast is declining by Shamal winds in the winter, but in the summer it reinforces and spreads virtually to the head of the Arabian Gulf (Reynolds, 1993). Runoff from Shatt Al-Arab in the northwest Gulf upholds a cyclonic circulation there that would or else by anti-cyclonic. A southward coastal jet occurs between the head of the Gulf and Qatar, and extends to east of Qatar, depending on the wind.

The mean wintertime surface current pattern in the southern Arabian Gulf is the most broadly recognized current design. A southward coastal flow is present along the whole southern coast of the Arabian Gulf. The flow festers east of Qatar, where high evaporation and sinking form a dense, bottom flow to the north-west and out of the Strait of Hormuz (Reynolds, 1993).

Flow at the north end can be easterly or westerly, clockwise or counterclockwise circulation, and to the south of the low-energy area will move northerly or southerly (Lardner *et al*., 1993). Outflow from the Shatt Al-Arab is carried by the counterclockwise circulation in a westerly direction and down the Kuwait and Saudi Arabian coast.

Circulation in the Gulf of Oman is dominated by a clockwise gyre in the west and a counterclockwise gyre in the east. The interface between the two counter-rotating gyres is a region of upwelling along the Iranian coast (Reynolds, 1993).

Remarkably warm water temperatures through the water column distinguish the western approach to the Strait of Hormuz in summer. The unusual settings are geographically limited to the region spreading westward from the eastern side of Strait of Hormuz to the south-western coast of the gulf. To the east of this region, little change occurs at 50 m depth in either temperature or salinity between June and July. To the west of this region, water temperature at 50 m depth increases between June and July in the area opposite to the coasts of UAE, but salinity and density do not change significantly (Swift & Bower, 2003). Johns and Olson (1998) found that the vertical temperature profile detected at their mooring in the channel west of the Strait becomes much warmer in summer. Swift and Bower (2003) suggested that the appearance of unusually warm temperatures throughout the water column in the western approach to the Strait concurs with fast warming of the sea surface. Warming of the sea surface impacts the Gulf as a whole throughout the spring and summer (Reynolds, 1993).

Mohanchander *et al*. (2019) used similar statistical analyses to compare some morphometric characters of *S. tumbil* and *S. pseudotumbil* collected from the Cochin coasts in India. In that study, morphometric characters were used to separate *S. tumbil* from its congener *S. pseudotumbil*, and such usage revealed its validity.

The discriminant analysis successfully identified three main populations of *S. tumbil* inhabiting the west coasts of the Arabian Gulf and the Sea of Oman, a northwest population, located in the north and north-west of the Arabian Gulf area comprising samples from Iraqi and Kuwaiti waters. The middle population, located near the middle of the Arabian Gulf's western coast, comprised samples from the Saudi/Persian, Qatari and Bahraini waters. The southeast population comprised samples from UAE and Sultanate of Oman. The robust meristic differentiation of the north, middle and southern populations of *S. tumbil* in the Arabian Gulf and Sea of Oman showed that spatial differences on stocks based on meristic characters are true and may be a self-recruiting population or sub-species of the greater lizardfish *S. tumbil* in these marine water bodies. The dispersion of free larvae may be the main factor, but water temperature (as well as other factors) is a secondary factor that will act when the larvae arrives on a region.

Water temperature may play a significant role in the grouping of *S. tumbil* populations. During the spawning season, which may last from May/June to August/September depending on the locality, water temperatures can vary in the seven localities studied: Iraq, Khor al-Aumaia 19.2–27.0°C (Al-Mahdi *et al*., 2009); Kuwait Bay 20–28°C (Chen *et al*., 2009), Bahrain, Quamis 29–30.2°C (Ali, 2014; Swift & Bower, 2003), Qatar, Al-Shamal 28–31°C (Beltagy, 1983), Saudi Arabia, Jubail City coast 21.5–35.9°C (Al-Thukair *et al*., 2007), UAE, Dubai coasts 29.2–32.9°C (Cavalcante *et al*., 2011) and Oman, Sohar coast 28–32.7°C (Piontkovski & Chiffings, 2014; Zaki *et al*., 2012). Swift and Bower (2003) and Xue and Eltahir (2015) have suggested that there is an increasing cline in water temperatures in the Arabian Gulf from north-west to south-east. The values of the meristic characters examined in this study coincide with the increasing cline in water temperature towards Strait of Hormuz (Table 1). According to the results (Table 1), specimens of *S. tumbil* showed higher values for meristic characters in the north and north-west area of the Gulf because of the lower water temperature, whereas intermediate values were recorded in the middle Gulf, where Bahrain, Qatar and Saudi Arabia are located. The lowest values were observed at two localities: UAE in the south-west coast of the Gulf and at the Omani coast on the Sea of Oman. This could be because of the increasing pattern of water temperature from north to the south of the Gulf.

The other factor that appears to cause such groupings in the population is the pattern of water currents in the Arabian Gulf. Reynolds (1993) suggested that water currents entering the Arabian Gulf move northward along the eastern (Iranian) side of the Gulf. On reaching the north, the current starts to move southwards along the western coast of the Gulf. In the middle of the Gulf, in Bahrain, Qatar and Saudi Arabia, this current moves across the Gulf. Such a change in the direction of the water current may cause an environmental uniqueness in the waters off Bahrain, Qatar and Saudi Arabia and in turn separate the populations of *S. tumbil* from those in the north and in the south of the Gulf.

Turan (2004) suggested that meristic traits might be more influenced by local environmental factors, which increases their differences on a small geographic scale.

The three major clusters of *S. tumbil* in the Arabian Gulf and Sea of Oman may reflect a constant diversity as suggested by meristic analyses. This could support the existence of three populations of greater lizard fish *S. tumbil*. Until now, the configuration of high inter-sample disparity might designate reproductive isolation between local populations in the Arabian Gulf and Sea of Oman, which needs a genetic validation. A more detailed study is required to determine this.

Until now, *S. tumbil* has been considered as a single stock in the Arabian Gulf and the Sea of Oman. From a fisheries management perspective, the existing meristic analyses propose that there might be some population restructuring of greater lizardfish along the western coasts of the Arabian Gulf and the Sea of Oman, where three major populations are recognized: northern (Iraq–Kuwait waters), middle (Bahrain–Qatar–Saudi Arabia waters) and southern (UAE–Sultanate of Oman, Sea of Oman waters, these being parts of the Arabian Gulf/Sea of Oman). The controlling inferences depend on the degree to which such configuring continues over time. Steady changes, shown by regular analyses, between two groups of fish might show their temporal and spatial integrity (Turan, 2004). Endurance would deserve distinct administration, because any exhaustion in one of these three populations is unlikely to be recompensed by movements of individuals of *S. tumbil* from other stocks, at least at an adequately quick rate.

For a steady documentation of stock selection, methods should be selected because dissimilar ways may yield diverse results (Fournier *et al*., 1984; Shaw *et al*., 1999). The outcome from this work must be correlated with data obtained from other phenotypic and genetic investigations to approve stock uniqueness. For instance, otolith chemistry is progressively used as a natural marker that reveals changes in the chemical configurations of the individual's environment and evaluate comparative contribution of the different breeding areas to assorted adult populations (Campana & Thorrold, 2001; Rooker *et al*., 2003). As a recommendation, molecular study should be performed to support the finding of this investigation.

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CONFLICTS OF INTEREST

The authors declare that they have no conflicts of interest.

AUTHOR CONTRIBUTIONS

L.A.J. developed the research idea and wrote manuscripts with input from all authors; J.M.A. collected some samples and analysed data; A.L.I. analysed data and drew graphs.

DATA AVAILABILITY STATEMENT

The data underlying this article will be shared on reasonable request to the corresponding author.

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