

Research Article

Occurrence of puffer fishes (Tetraodontidae) in the eastern Mediterranean, Egyptian coast - filling in the gap

Mahmoud M.S. Farrag^{1*}, Alaa A.K. El-Haweet², El-Sayed kh A. Akel³ and Mohsen A. Moustafa¹

¹Faculty of Science, Al-Azhar University (Assiut Branch), Egypt

²College of Fisheries Technology and Aquaculture, Arab Academy for Science, Technology and Maritime transportation, Alexandria, Egypt

³National Institute of Oceanography & Fisheries (Alexandria Branch), Egypt

*Corresponding author

E-mail: m_mahrousfarrag@yahoo.com

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Abstract

The occurrence of puffer fish species along the Egyptian Mediterranean coast was evaluated using samples obtained from the commercial fishing operations during 2012 – 2015. Six species were identified: *Lagocephalus sceleratus* (Gmelin, 1789), *Lagocephalus suezensis* Clark and Gohar, 1953, *Lagocephalus guentheri* Miranda Ribeiro, 1915, *Lagocephalus lagocephalus* (Linnaeus, 1758), *Torquigener flavimaculosus* Hardy & Randall, 1983 and *Sphoeroides pachygaster* (Müller & Troschel, 1848). Of these, *L. guentheri*, *L. suezensis*, *S. pachygaster* and *T. flavimaculosus* were recorded for first time in the Egyptian Mediterranean waters. Pufferfishes were captured from sandy, rocky and muddy-bottom habitats from shallow waters to more than 150 m deep. The presence of different tropical puffer fish species in the Egyptian Mediterranean waters reflects the ongoing Lessepsian migration and expansion of its distributions, particularly for *L. sceleratus* which was the common distributed one along the coast. This study filled in a major the gap in records of species' distributions and is further evidence of the changing of biodiversity in the Mediterranean Sea, which may affect the ecosystem and the commercial fisheries. The results emphasize the need for a continuous, directed, monitoring and management plan for the detection and abundance monitoring of alien species.

Key words: Puffer fishes, bioinvasions, first records, Mediterranean Sea, Egypt

Introduction

Migration of biota from Red Sea to Mediterranean waters via Suez Canal was named Lessepsian migration (Por 1978); it is ongoing with both the positive and the negative effects (Farrag et al. 2014; Farrag 2014). However, the many exotic species in the Mediterranean Sea came from both the Red Sea and the Atlantic Ocean. They came through a variety of pathways including migration through the Suez Canal and Straits of Gibraltar, ballast water and other shipping operations, and other activities (Fricke et al. 2012; Farrag 2014). In the early 2000s, there were about 59 confirmed Lessepsian immigrant species reported out of a total of 650 fishes in the Mediterranean basin, constituting almost 10% of the population (Golani et al. 2002). By 2015, this number exceeded 90 and there could be as many as 99 confirmed Lessepsian-immigrant fishes (Evans et al. 2015;

Fanelli et al. 2015; Fricke et al. 2015). Puffer fish are among the important immigrant species within the different Mediterranean basins. They cause some negative effects to the fisheries' activities in the area partly because they are poisonous, and they can become quite abundant. The number of confirmed pufferfishes in the Mediterranean is at least 10, which includes five Lessepsian immigrants in Egyptian Mediterranean waters (Farrag 2014). Earlier reports listed six species from family "Tetraodontidae" in the Mediterranean Sea (Migratory and native): *Ephippion guttifer* (Bennett, 1831); *Lagocephalus guentheri* (previously misidentified as *Lagocephalus spadiceus* (Richardson 1845) see Matsuura et al. 2011); *Lagocephalus lagocephalus* (Linnaeus, 1758); *Lagocephalus suezensis* Clark & Gohar, 1953; *Sphoeroides pachygaster* (Müller & Troschel, 1848) and *Torquigener flavimaculosus* (Hardy & Randall, 1983) (Tortonese 1986; Golani et al. 2002).

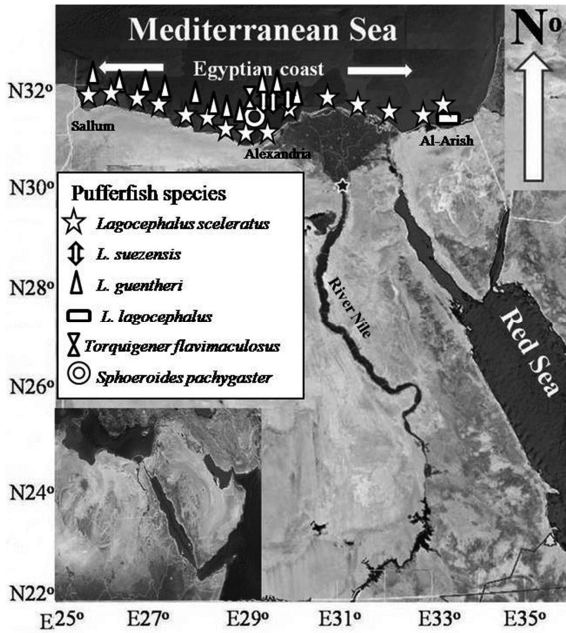


Figure 1. Map showing capture locations of pufferfish species (*Lagocephalus sceleratus*, *Lagocephalus suezensis*, *Lagocephalus guentheri*, *Lagocephalus lagocephalus*, *Torquigener flavimaculosus* and *Sphoeroides pachygaster*) by commercial harvesters and their distributions along the Mediterranean coast, Egypt. For details see supplementary Table S1.

In fact, there were seven species because *Lagocephalus sceleratus* (Gmelin, 1789), which originated in the Red Sea, was misidentified as *L. suezensis* by Mouneimne (1977) but then first confirmed by Akyol et al. (2005). The number of species increased to ten with the additions of *Sphoeroides marmoratus* (Lowe, 1838), *Sphoeroides spengleri* (Bloch, 1785), and *Tylerius spinosissimus* (Regan, 1908) (Turan et al. 2007a,b; Vacchi et al. 2007). These species appear to be well-established their new habitats in the Mediterranean Sea and, similar to the Red Sea, there have been many cases of tetrodotoxin poisoning reported in the eastern Mediterranean (Bentur et al. 2008). The Egyptian Mediterranean coast encompasses the Suez Canal, which is the main passageway for many tropical species from the Red Sea and Indo-Pacific region. Therefore the detection of such Lessepsian immigrants at locations far from the Suez Canal means it is likely that these species occur, and perhaps are established, in Egyptian waters near the Canal terminus. However, few studies have mentioned the pufferfishes in the Egyptian Mediterranean coast; the last documented works (El-Haweet et al. 2011; Halim and Rizkalla 2011) mentioned *L. sceleratus* and *L. spadiceus* with no mention of any other

species. Thus non-native species, particularly pufferfish species, still needed to be investigated with regards to occurrence, distribution, and species' diversity. The aim of the present work was to fill the gap in geographic distributions of pufferfishes and to describe the species composition of the pufferfish assemblage currently present in the Egyptian Mediterranean waters.

Materials and methods

The study area extended along the Egyptian Mediterranean coast from El-Arish (34°12'36"E; 31°15'00"N) to El-Sallum (25°08'42"E; 31°60'00"N). The puffer fish samples were collected opportunistically from the catch of commercial boats using different fishing gears along the coast, from 2012 until 2015 (Figure 1 and supplementary Table S1). The initial identification of specimens was done using the identification keys of Whitehead et al. (1986) supplemented by Matsuura et al. (2011) and Froese and Pauly (2015).

Results

The pufferfishes in this study were collected by a variety different fishing gears along the coast. *Lagocephalus sceleratus* was caught by long lines, bottom trawl, trammel and gill nets from many substrates (sandy, rocky and muddy bottom) along the whole coast of Egypt at depths from 5–150 m (Figure 1). *L. guentheri* was mainly caught east off Alexandria from El-Maadia to Matrouh by bottom trawl and long lines on sandy and rocky bottom, with few individuals collected as deep as 50 m. *L. suezensis* was mainly caught by bottom trawls on sandy bottoms in water <40 m deep from El-Maadia to Sidi-kiririnu the area of Alexandria. A single specimen of *L. lagocephalus* was caught from at the eastern edge of the study area at Al-Arish. A few individuals of *Sphoeroides pachygaster* were caught from sandy bottom habitat by bottom trawls at a depth >150m off Alexandria. *Torquigener flavimaculosus* was caught mainly by bottom trawl off Alexandria at depths <40m.

The six pufferfishes (Family Tetraodontidae) captured in the Egyptian Mediterranean waters share a number of morphological features, they have no pelvic fins, the belly is white, and the body is completely smooth without scales, spines, or bony plates. The six species have a single dorsal fin; two large teeth in each jaw (forming a beak like dental plate); and lack spiny rays in the

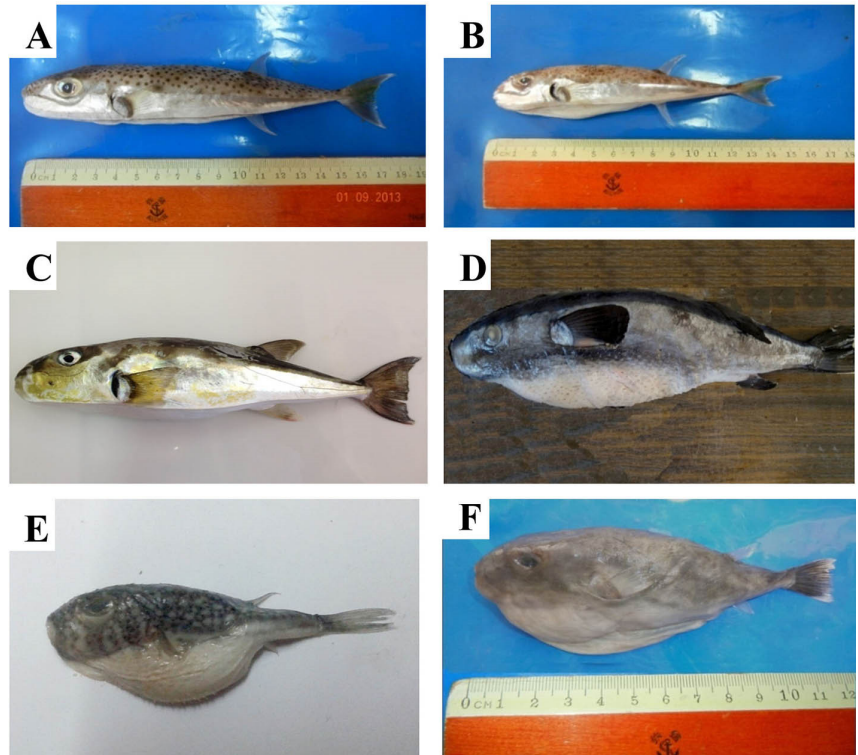


Figure 2. Images of the six puffer fish species: (A) *Lagocephalus sceleratus*; (B) *L. suezensis*; (C) *L. guentheri*; (D) *L. lagocephalus*; (E) *Torquigener flavimaculosus*; and (F) *Sphoeroides pachygaster* collected from Egyptian waters of the Mediterranean Sea. Photographs by Mahmoud M.S. Farrag.

fins. The gill opening consists of a single slit in front of the pectoral fins. The specific characters for each species were as follows:

(A) *Lagocephalus sceleratus* (Gmelin, 1789) Silver-cheeked toad fish. The body is elongated, somewhat compressed laterally and inflatable; two lateral lines, grey to greenish colour with regular black spots above; dorsal and ventral small spinules extending dorsally to origin of the dorsal fin, and ventrally to before the cloacae. A wide silver band is located on the lower parts of the flanks from the mouth to the caudal fin with silver blotch in front and below of eye. The base of pectoral fin is black, and it has a wide base. The dorsal and anal fins are opposite each other and the caudal fin is lunate (Figure 2 A). It is native to the Indo-Pacific basin, including the Red Sea.

(B) *Lagocephalus suezensis* Clark & Gohar, 1953; Tetraodon-lièvre de Suez. It is similar to *L. sceleratus* in its characteristics having two lateral lines; dorsal and ventral small spinules extending dorsally to origin of the dorsal fin, and ventrally to before the cloacae. A wide silver band is located on the lower parts of the flanks from the mouth to the caudal fin with silver blotch in front and below of eye but this species

can be distinguished by smaller length than *L. sceleratus*; the presence of a raised skin fold along lower side of caudal peduncle; spots are found irregularly shaped of brown to grey in various sizes dorsally, as opposed to the equal-sized black spots on the back of *L. sceleratus* (Figure 2B). Similar to *L. sceleratus*, *L. suezensis* is native to the Indo-Pacific basin, including the Red Sea.

(C) *Lagocephalus guentheri* Miranda-Ribeiro, 1915, Diamond back puffer fish. The body is relatively elongate with a somewhat box-shaped, broad, head; two lateral lines with no spots. Color is yellow- brownish or sometimes dark green yellowish with dark bands over the back, the first band between the eyes, the second above the gill opening, the third above the posterior part of the pectoral fin, the fourth encircling the dorsal-fin base, and a couple of small dark markings on the dorsal side of the caudal peduncle. Lunate caudal fin with the extended middle rays slightly to posterior with dusky to dark brownish color or many times black with the dorsal and ventral white tips as opposed to *L. spadiceus* where the dorsal two thirds of the caudal fin is dark yellow and the ventral one third is white (Matsuura et al. 2011). Large lateral silver band extended from mouth to base of

caudal fin that slightly covered by yellow layer, while the pectoral and anal fins pale, head and belly with trough spinules extending posteriorly to the lower jaw and slightly to before the anus. Eyes are large rounded with an orbital edge at lower part; dorsal small spinules forming a rhomboidal or elliptical patch; starting anteriorly between the nasal organ and ending at the region dorsal to the posterior part of the pectoral fin and donot reach the dorsal fin origin as distinguishable character from similar species *L. lunaris* (Figure 2 C). It is native to the Indian Ocean from Pakistan to South Africa.

(D) *Lagocephalus lagocephalus* (Linnaeus, 1758), the Oceanic puffer fish was represented by single specimen of 45 cm total length. Body is elongated, somewhat compressed laterally and inflatable, two lateral lines. Colour is a dark blue above with no spots; large lateral silver band on the flanks extended from mouth to caudal fin; a silver blotch in front of eyes; belly with small spinules. Pectoral, dorsal and anal fins are dark located far posteriorly (Figure 2 D).It apparently is native to tropical and subtropical waters of the Atlantic, Indian, and Pacific Oceans.

(E) *Torquigener flavimaculosus* Hardy & Randall, 1983; yellow spotted puffer fish; body is elongated with two lateral lines and no spots and silver bands, compressed laterally and inflatable, terminal mouth; dorsal and anal fins are elongated and pointed, rounded pectoral fin with wide base. The skin had numerous longitudinal pleats, presence of small spinules on the belly and head, on the gill opening, these spinules did not reach the dorsal fin; eye is encircled by dorsal lateral line; caudal fin is truncate. Colour is slightly brownish with irregular grey-whitish spots dorsally and white below; a mid-lateral line of well-distinguished yellow-orange spots, followed by a pale yellow zone, separating the dorsal, colored, surface from the white ventral surface; scattered brown spots on caudal fin, dorsal lightly spotted with white, anal and pectorals fins are transparent; vertical yellow-brown bands on cheek, separated by irregular white bands (Figure 2 E). It is native to western Indian Ocean from east Africa to the Persian Gulf and includes the Red Sea.

(F) *Sphoeroides pachygaster* (Müller and Troschel, 1848) blunthead puffer; body is inflatable with one lateral line on each side convoluted; no dorsal and ventral spinules; large head with rounded snout; body is greyish on dorsal surface in color with faint brownish spots on flanks, belly whitish pale grey; dorsal fin placed behind

midpoint and opposite the similar-shaped anal fin. Caudal fin is truncated with base dark; eyes big and oval with a flat interorbital space. (Figure 2 F). *Sphoeroides pachygaster* is circum-globally distributed in tropical and temperate seas except the Pacific coasts of the Americas.

Discussion

The detection of non-native species in the Mediterranean Sea has increased considerably with time. There are > 900 alien species in the Mediterranean Sea (Zenetos et al. 2012), with some of the invaders from the Red Sea becoming very successful colonizers (Oral 2010). Some of these alien species now constitute an important share of the commercial catch, e.g., *Nemipterus japonicus* (Bloch, 1791) by El-Haweet (2013) and an *Etrumeus* species formerly identified as *E. teres* (De Kay, 1842) by Farrag et al. (2014), however it could be *E. golanii* DiBattista, Randall & Bowen, 2012 or *E. sadina* (Mitchill, 1814) due to high similarity or change in its identification. Invasions of non-native species in the ocean can profoundly reshape indigenous communities, impact conservation strategies, and affect human health and the economy (Rilov and Crooks 2009). The establishment of so many non-indigenous species in the Eastern Mediterranean suggests conditions are suitable for growth, reproduction, and survival of tropical species, offering the aliens various advantages when competing with native species as water temperatures rise (IUCN 2008; Bernardi et al. 2010). Six non-native pufferfish species were identified in Egyptian waters in this study but not all of them were widespread. Of these six, only *L. lagocephalus* and *S. pachygaster* were not Lessepsian migrants.

Lagocephalus sceleratus (Gmelin, 1789) was widespread and abundant in the present study. This Lessepsian migrant, was first detected in the Mediterranean waters as misidentified specimens of *L. suzezensis* from Lebanon (Mouneimne 1977). While first recorded from Turkish water by Filiz and Er (2004), the first confirmed record may be one captured in February 2003 in the Go kova Bay, Aegean Sea, Turkey (Akyol et al. 2005). *L. sceleratus* quickly spread north and west along the coasts of Mediterranean basin (Bilecenoglu et al. 2006), was reported in 2004 from Jaffa along the Israeli coast (Golani and Levy 2005); and offshore from Rhodes in 2005 (Corsini et al. 2006) and Malta in 2014 (Deidun et al. 2015). To the west of the Suez Canal, it was recorded from Egyptian waters in 2007 (El-Haweet et al. 2011),

in Libyan and Tunisian waters in 2010 (Jribi and Bradai 2012; Milazzo et al. 2012). In the central area, this species was recorded from parts of Sicily during 2013 and 2014 (Azzurro et al. 2014a; Tiralongo and Tibullo 2014). By 2012, *L. sceleratus* had reached the Adriatic Sea (Šprem et al. 2014). The species was recorded first from Algeria in 2013 and shortly afterwards from the coasts of Spain (Izquierdo-Muñoz and Izquierdo-Gomez 2014; Kara et al. 2015). Thus in the brief period since first being detected, *L. sceleratus* has spread to almost all parts of the Mediterranean basin. Due to potential ecological and economic impacts of this rapid expansion, further study and monitoring clearly is warranted (Bariche et al. 2004; IUCN 2008; Oral 2010). In Egyptian waters, the stock status of this important species was evaluated by Farrag et al. (2015) who concluded this Lessepsian migrant is well-established and, despite prohibition under Egyptian law, this poisonous species is being sold in various markets.

The second most abundant Lessepsian migrant in our study was *Lagocephalus suezensis*. While this study is first confirmation for Egyptian Mediterranean waters, it was first recorded in the Mediterranean Sea in 1977 from the Lebanon coast (where it was misidentified as *L. sceleratus* by Mouneimné (1977)), then recorded from Israel (Golani 1996), followed by Turkey (Bilecenoglu et al. 2002), Syria (Saad 2005), Rhodes (Corsini et al. 2005), and Libya (Ben-Abdallah et al. 2011). The distribution of this species mainly in eastern part of Mediterranean Sea reflects a slow rate of expansion compared to that of *L. sceleratus*.

There have been nomenclature issues with *Lagocephalus guentheri*, which complicates assessing its rate of spread in the Mediterranean Sea. Initially, it was considered as a synonym of the Atlantic species *L. laevigatus* (Linnaeus, 1766) (Shipp 1974). However, it was shown to be the same species as found in South Africa (Smith 1986) and the Red Sea (Matsuura et al. 2011). Within the Mediterranean Sea, this species was difficult to distinguish from *L. spadiceus* (Richardson, 1845) and *L. gloveri* Abe and Tabeta, 1983. However, Abe (1987) re-described the holotype of *L. guentheri* and confirmed that no specimens had been collected from the Atlantic. The description of Matsuura et al. (2011) demonstrates clear differences between *L. guentheri* and *L. spadiceus*, and the specimens in this study conformed to the characteristics *L. guentheri*. Given the taxonomic issues, this study likely represents the first confirmed record for *L. guentheri* in the Mediterranean Sea.

Lagocephalus lagocephalus occurs in the Atlantic Ocean from the British Isles to South Africa (Tortonese 1986). The first Mediterranean records were from Tunisia (Chakroun 1966) and then it was reported several times in Adriatic waters (Dulčić and Pallaoro 2006; Lipej and Dulčić 2010; Tsiamis et al. 2015). Tsiamis et al. (2015) suggest the sporadic records indicate *L. lagocephalus* has not become established in the Adriatic Sea. Zava et al. (2005) mentioned that the number of oceanic pufferfish specimens has been increasing since 1999 for Sicilian waters (western Ionian Sea); and also this species was observed several times during 2007 to 2012 along the Calabrian coast of the Central Mediterranean (Nicolaidou et al. 2012). The distribution of such species in the north and west Mediterranean Sea are consistent with an Atlantic origin of this species. The capture of a single specimen in this study may well represent a single stray or it may have occurred several times as suggested by Tsiamis et al. (2015); however, it is not widespread or abundant.

Torquigener flavimaculosus is a Lessepsian migrant first recorded in Haifa Bay, Israel, (Golani 1987). It subsequently was detected in Turkish waters (Bilecenoglu 2003, 2005; Erguden and Gurlek 2010; Tsiamis et al. 2015), Greek waters (Corsini-Foka et al. 2006; Zenetos et al. 2008) and but not in Syrian waters until 2009 (Sabour et al. 2014) – possibly the result of differences in sampling efforts. To date, the distribution of this species reflects the typical north and east spread of Lessepsian migrants to the Mediterranean. The capture of *T. flavimaculosus* in the Egyptian waters off Alexandria, a first record, suggests a western spread is occurring and countries such as Libya, Tunisia, and Algeria may soon be colonized if it is not already present.

The blunt head puffer *Sphoeroides pachygaster* was recorded in the Mediterranean basin for the first time from Balearic Islands off the Spanish coast in 1979 (Oliver 1981), and this species has since been recorded numerous locations in Mediterranean basin, e.g., Italy (Arculeo et al. 1994); Greece (Zachariou-Mamalinga and Corsini 1994); Israel (Golani 1996); in 2004 from the Gulf of Gabes, Tunisia (Bradai 2000; Psomadakis et al. 2008); Turkey (Eryilmaz et al. 2003); Algeria (Hemida et al. 2009); and from waters off Piran, Northern Adriatic (Lipej and Mavric 2013). Most of records were in the western and central Mediterranean and these findings strongly support the hypothesis of its immigration to the Mediterranean from the Atlantic Ocean via Gibraltar Strait (Golani et al. 2002). The specimen described in

this work was captured in waters off of Alexandria, which consistent with the continuing expansion of *S. pachygaster* from west to east in the Mediterranean Sea. This species lives in deeper water than the other species we captured (Ligas et al. 2007; Hemida et al. 2009; this study).

The present study documents the occurrence of six non-native pufferfishes in Egyptian waters of the Mediterranean Sea, four Lessepsian immigrants (*L. sceleratus*; *L. suzezensis* and *L. guentheri*, *T. flavimaculosus*) and two have of Atlantic origin. The Lessepsian species appear to be well established, particularly *Lagocephalus sceleratus*, consistent with the hypothesis that ongoing Lessepsian colonization of the Mediterranean Sea is being aided by the tropicalization of the region (Galil and Zenetos 2002). The records presented here fills in a major information gap – records for pufferfishes in Egyptian waters largely were lacking, particularly for four species (*L. suzezensis*, *L. guentheri*, *T. flavimaculosus* and *S. pachygaster*) that are recorded for the first time. A possible earlier record for *L. suzezensis* was based solely on an otolith (Tuset et al. 2012) with no picture or specimen description; hence, this study is either the first confirmation or second record in Egyptian waters. In spite of mentioning *L. spadiceus* in Egypt before (El-Haweet et al. 2011), the taxonomic confusion around the identity of *L. spadiceus* in the Mediterranean (Matsuura et al. 2011) means the present record for *L. guentheri* may be the first confirmed record for the Mediterranean Sea and previous records (specimens) of *L. spadiceus* that need to be re-examined because of misidentification possibility. These findings demonstrate the need for continuous monitoring on a broad scale to detect the presence/absence of another pufferfish *L. spadiceus* with confirmatory characteristics and to detect new other immigrants due to the importance of this phenomenon in the continuing alteration of the structure and functioning of the greater Mediterranean ecosystem. Moreover, the recent expansion of the Suez Canal may increase the speed at which non-native species from the Indo-Pacific region colonize the Mediterranean Sea.

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Supplementary material

The following supplementary material is available for this article:

Table S1. Date and locations of records of collection of puffer fish species in Egyptian waters.

This material is available as part of online article from:

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