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Checklist of Alien Fish Species in the Turkish Marine Ichthyofauna for Science and Policy Support

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Research Article

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Abstract

The objective of the present study was to update and consolidate the marine fish (bony and elasmobranch) checklist of Turkey based on supporting evidence. The species that came with natural and/or unnatural distribution routes into Turkish marine waters are included in the list. The current number of alien fish species was 100 belonging to 57 families recorded in the Turkish Seas. The highest number of species were found in the Tetradontidae and Gobiidae families. The Mediterranean coast of Türkiye consisted of the highest number of species (89 species), followed by the Aegean Sea with 55 species, the Marmara Sea with 12 species, and the Black Sea with 3 species. Considering the abundance status, 16.0% of the total alien fish species were considered very common, 34.0% common, 24.0% rare, 15.0% very rare, and 11.0% only one specimen of a species has been so far recorded. Only 17 species (17%) of the 100 alien fish species have economic value in terms of fishing in Turkey. Moreover, 22 species (22%) are poisonous, venomous, or sting. According to their origins, 87% of the alien fish species are of Indo-Pacific origin, 12% Tropical Atlantic origin, and 1% North-west Pacific origin. The entry routes of alien fish species found in the Turkish seas are generally via the Suez Canal with a rate of 81%, followed by species passing through the Strait of Gibraltar with a rate of 11%. The species that come through the other entry routes are at a rate of 5% by ship transportation, 2% by Aquarium activities, and 1% by Aquaculture activities. Considering the habitat preference of these alien species, 43% are pelagic species, 14% are benthic species, 14% are rocky area species, 13% are shallow water and reef species, 11% are demersal species and 5% are other habitats, which are mainly distributed in the 0-100 m depth range.

Keywords: *Non-indigenous species, Turkish marine waters, distribution, introduction pathways*

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Introduction

During the last decades, the marine biodiversity of the Mediterranean Sea is experiencing significant changes due to the penetration of alien species via ballast waters, fouling, aquaculture, aquarium release, accidental introduction, the influx from the Suez Canal, and Gibraltar Strait, etc.

Turkish marine waters are divided into four seas, the Mediterranean Sea at the south, the Aegean Sea at the west, the Marmara Sea at the north-west, and the Black Sea at the north with different hydrographic regimes and ecological characters. The number of alien species in Turkish marine waters has been considerably increased since the first arrival in 1943 (Erazi 1943). Therefore, it is very important to provide updated information on the occurrence and spatial distribution of alien species, pathways of introduction, spread rates, bio-ecology, etc. in these waters for ecologists and policymakers which enable to analysis of the demographic rates of alien populations in relation to environmental characteristics, assess their interaction with native biota, project their large-scale impact, and generate prevention measures (Zenetos, 2006; Golani & Fricke 2018;Turan et al., 2018; Uyan et al., 2024).

There has been a dilemma about alien species terminology that no definite consensus on the definition of alien species has been reached (Gozlan et al. 2010). Despite attempts to achieve common definitions, difficulties remain unsolved due to a combination of ecological and political perspectives to identify native or non-native status (Colautti & MacIsaac, 2004; Copp et al. 2005; Gozlan et al. 2010; Iannone 2021). The basis of the differences in the definitions lies in how the event is handled by different scientists. Before declaring the definition of alien species, it is better to mention the geological history of the Mediterranean Sea.

The Mediterranean Sea is the result of the formation of the Tethys Ocean which was divided by the Pangea into the Laurasia continent to the North and the Gondwana continent to the South and connected the Mediterranean connection with the Atlantic Ocean to the Indo-Pacific Ocean (Metcalfe 2003). During the Cretaceous period (130 myr BP), the connection with the Indo-Pacific Ocean was interrupted. Subsequently, around 45 myr BP (Eocene), the original Tethys became smaller as a consequence of African and Eurasian plate collisions. Twenty-five myr BP (Miocene), the African plate made contact with the Eurasian plate, dividing the Tethys Sea into two parts: the ancestor of the Mediterranean Sea in the South and the so-called Paratethys in the North-East. Both seas underwent significant reductions and the Paratethys remnants formed the Black, the Caspian, and the Aral Seas. The narrow Isthmus of Suez, separating the Mediterranean from the Indo-Pacific, was formed and the connection with the Indian Ocean was interrupted (around 13 myr BP, Miocene). During the Miocene (6–7 myr BP), the connection (the Gibraltar Strait) with the Atlantic Ocean was closed as a consequence of a collision between Africa and the south-western segment Eurasian plate. The Mediterranean at that time becomes a closed sea. Around 5 myr BP (Pliocene), the Strait of Gibraltar opened once again, allowing the waters of the Atlantic Ocean to flood the Mediterranean, repopulating it exclusively with species of Atlantic origin (Bianchi 2007).

During the Quaternary, the alternation of glacial periods with warm interglacial periods allowed the influx into the Mediterranean of Atlantic species of boreal or subtropical origin (Bianchi et al. 2000). On the other side, the Mediterranean Sea is experiencing an important influx of Red Sea species after the artificial opening of the Suez Canal in 1869. Therefore, as the Strait of Gibraltar naturally re-opened during the Pliocene (5 myr BP), and allowed the species of the Atlantic Ocean to influx to the Mediterranean, with the re-opening of the Suez Canal in 1869 by the artificial way, species of Indo-Pacific origin repopulated the Mediterranean Sea. The biodiversity of the present-day Mediterranean Sea is directly linked to that of its Mesozoic ancestor Tethys. Therefore, the endemic marine species in the Mediterranean either consist of rare paleo-endemism of Tethyan origin or more frequent neo-endemism of Pliocene origin.

In this framework, as brought out by Por (Por 1978, 2009), the current Mediterranean settlement of the tropical species coming from the Suez Canal can be considered as re-colonization by Tethyan descendants rather than an invasion by Indo-Pacific species as happened during the Pliocene with the natural opening of the Strait of Gibraltar, letting influx of the species of the Atlantic Ocean to the Mediterranean. Therefore, the alien species definition, considering the Atlantic species as a part of the Mediterranean and the Indo-Pacific as alien, is not compatible with the geological history of the Mediterranean Sea. Therefore, in the definition given by IUCN (IUCN 2000): “Alien species (non-native, non-indigenous, foreign, exotic) means a species, subspecies, or lower taxon occurring outside of its natural range (past or present) and dispersal potential (i.e. outside the range it occupies naturally or could not occupy without direct or indirect introduction or care by humans) and includes any part, gametes or propagule of such species that might survive and subsequently reproduce”, the Indo-Pacific species in the Mediterranean should be considered as natural range as Atlantics due to the geological history of the Mediterranean Sea or, both Atlantic and Indo-Pacific species in the Mediterranean should be considered as outside of its natural range.

We in the present work consider alien species as species encroaching in habitats in which they were not present before, the first available record to a continent, to a country, to a biogeographic zone can be assessed from an ecological point of view as alien. Clearly, any definition of alien species in this regard calls for arbitrary limits and a measure of pragmatism, especially when the definition is driven by requirements for policy formulation.

The objective of the present study was to update and consolidate the marine fish (bony and elasmobranch) checklist of Turkey, based on supporting evidence that would allow to confirm, question, or reject the presence of each analyzed species. Along with the updated checklist, annotations to modify the original lists were included as well as comments for fish species that present taxonomic or systematic problems.

Material and Methods

In the present study, we consider the first alien bony and elasmobranch fish species given by Erazi (1943) as the first record of alien species in Turkish marine waters, after which the species that came with natural and/or unnatural distribution routes are included in the list. Therefore, this study covers the fish species that penetrated Turkish marine waters since 1943 which is considered as alien species (exotic, lessepsian, non-native, non-indigenous). The preliminary reference documents of native species considered for Turkish marine waters are based on the list given by Aksiray (1954, 1987). The species not given in the marine species list of Turkey by Aksiray (1954, 1987) are considered as alien for Turkish marine waters.

The geographical area concerned in this study includes the Turkish coasts of the Mediterranean Sea, the Aegean Sea, the Marmara Sea, and the Black Sea. East of the Dalaman Creek (36°42′N-28°43′E) is considered the border of the Turkish coasts of the Mediterranean Sea.

Only the first occurrence of a given species in the Mediterranean, Aegean, Marmara, and Black Sea Coasts of Turkey is given with its literature in the list. The second, third and fourth occurrence of a species for each sea is not considered here. Only the first extension reports from one sea to another for a species such as from the Aegean Sea to the Marmara Sea, and Black Sea ext. are given in the checklist. The records of species from the Aegean Sea coast of Turkey as a first occurrence were started from Muğla coasts since this coast is the entrance or gate of the Aegean Sea. Besides the literature, new extensions of species in the current study were also included in the checklist.

Turkish coasts have been converted into a vector map of interlocking hexagon cells (a side length of 10 km), with an area of approximately 260 km2. All recorded fish coordinates (exclusively those associated with exact coordinates or regions; unpublished data and grey literature are not included) were plotted using the QGIS software. An additional colored density map of the recorded fish coordinates was also conducted.

The alien species identification was carried out according to Erazi (1943), Aksiray (1987), Turan et al. (2007), and CIESM (2024). The taxonomic classification of the species was made according to Eschmeyer's Catalog of Fishes (Fricke et al. 2021). In this study, habitat status, depth ranges, and origins of alien species are given based on CIESM (2024) and the Fishbase database (Froese & Pauly 2024).

Invasiveness, harmless, establishment, and abundance status were determined according to CIESM (2024) and also the other literature (Zenetos et al. 2005; Streftaris & Zenetos, 2006; Golani 2010; Golani & Fricke 2018; Golani et al. 2021a), project reports (TAGEM-09/AR-GE/11 and TAGEM-16/AR-GE/21) and personal observations in the field. Genetic analysis used to clarify the controversy on the phylogenetic status of species was conducted using the MEGA X software (Kumar et al. 2018). QGIS and R studio were used for graphical visulasation and mapping of alien species records.

Results

In the study, 100 alien fish species belonging to 57 families recorded in the Turkish Seas were given so far (Figure 1). The highest number of species (6 species) was found in the Tetradontidae and Gobiidae families which is followed by the Serranidae and Apogonidae families with 5 species, respectively (Figure 1).

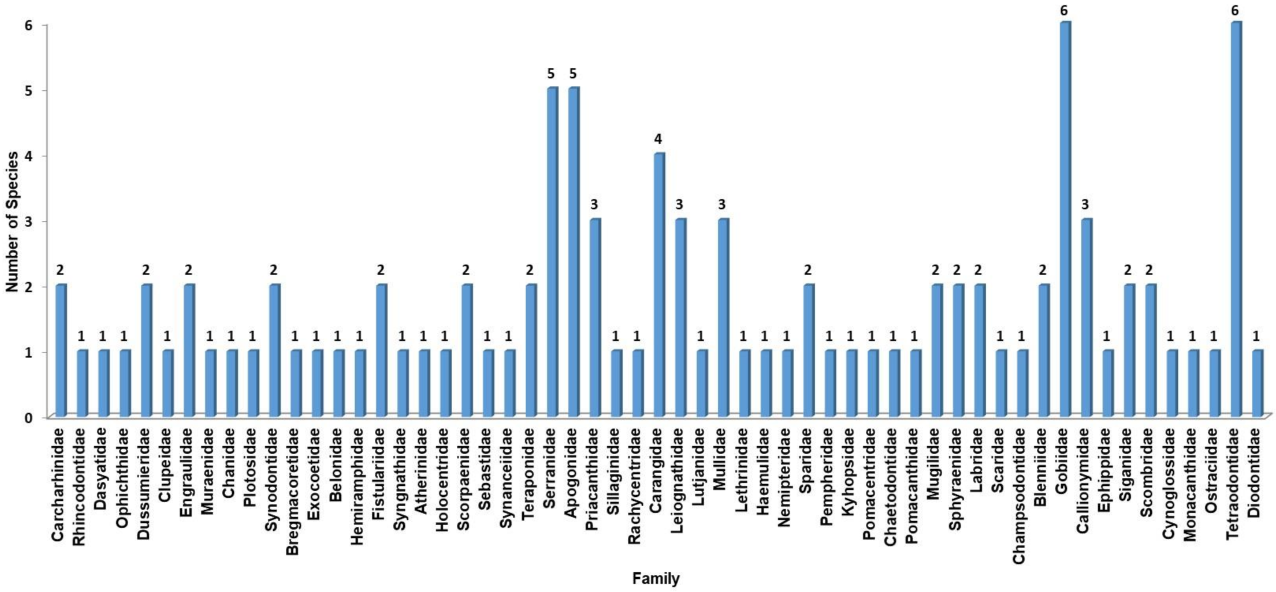

Figure 1. Number of alien species for each family distributed in Turkish coastal waters.

In Table 1, 89 species were recorded from the Mediterranean coast of Turkey, 56 species were recorded from the Aegean Sea, 12 species were recorded from the Marmara Sea, and only 3 species from the Black Sea.

Table 1. Checklist of alien fish species from marine waters of Turkey (TA, Tropical-Atlantic; IP, Indo-Pacific; NP, Northwest Pacific; R, Red Sea). Only the first entry for each species from Turkish marine waters was colored, and the corresponding reference reported the occurrence/extension is given in the relevant cells.

Family	Species	Mediterranean Sea	Aegean Sea	Marmara Sea	Black Sea	Origin
Carcharhinidae	*Carcharhinus altimus* (Springer, 1950)	Başusta and Erdem (2000)	-	-	-	A
	Carcharhinus falciformis (Bibron in Müller and Henle, 1839)	Kabasakal and Bilecenoglu (2020)	-	-	-	A
Rhincodontidae	*Rhincodon typus* Smith, 1828	Turan et al. (2021)	-	-	-	A
Dasyatidae	*Himantura uarnak* (Forsskål, 1775)	Ben Tuvia (1966)	-	-	-	P
Ophichthidae	*Pisodonophis semicinctus* (Richardson, 1848)	Yağlıoğlu and Ayas (2016)	Bilecenoğlu et al. (2009)	-	-	A
Dussumieridae	*Dussumieria elopsoides* (Bleeker, 1849)	Ben-Tuvia (1953)	-	-	-	P
	Etrumeus golanii DiBatistta, Randall and Bowen, 2012	Başusta et al. (1997)	Okuş et al. (2004)			P
Clupeidae	*Herklotsichthys punctatus* (Rüppell, 1837)	Whitehead et al. (1984-1986)	-	-	-	P
Engraulidae	*Stolephorus insularis* Hardenberg, 1933	Dalyan et al. (2014)	-	-	-	P

	Encrasicholina gloria Hata and Motomora, 2016	Çiftçi et al. (2017)	-	-	-	P
Muraenidae	*Enchelycore anatina* (Lowe, 1838)	Yokes *et. al.* (2002)	Okuş et al. (2004)	-	-	A
Chanidae	*Chanos chanos* (Forsskål, 1775)	Özvarol and Gökoğlu (2012)	-	-	-	P
Plotosidae	*Plotosus lineatus* (Thunberg, 1787)	Doğdu et al. (2016)	-	-	-	P
Synodontidae	*Saurida lessepsianus* Russell, Golani and Tikochinski, 2015	Ben-Tuvia (1966)	Ben-Tuvia (1973)	-	-	P
	Synodus randalli Cressey, 1981	Turan and Doğdu (2023)	-	-	-	P
Bregmacoretidae	*Bregmaceros nectobanus*Whitley, 1941	Yilmaz et al. (2004)	Filiz et al. (2007)	-	-	P
Exocoetidae	*Parexocoetus mento* (Valenciennes, 1837)	Ben-Tuvia (1966)	Ben-Tuvia (1966)	-	-	P
Belonidae	*Ablennes hians* (Valenciennes, 1846)	Irmak and Özden (2023)	-	-	-	P
Hemiramphidae	*Hemiramphus far* (Forsskål, 1775)	Kosswig (1950)	Kosswig (1950)	-	-	P
Fistulariidae	*Fistularia commersonii* (Rüppell, 1835)	Bilecenoğlu et al. (2002a)	Bilecenoğlu et al. (2002b)	-	-	P
	Fistularia petimba Lacepède, 1803	Ünlüoğlu et al. (2017)	Cerim et al. (2021)	Uyan and Turan (2021)	-	P
Syngnathidae	*Hippocampus fuscus* Rüppell 1838	Gökoğlu et al. (2004)	-	-	-	P
Atherinidae	*Atherinomorus forskalii* (Rüppell, 1838)	Kosswig (1950)	Geldiay (1969)	-	-	P
Holocentridae	*Sargocentron rubrum* (Forsskål, 1775)	Kosswig (1950)	Kosswig (1950)	Artüz and Golani (2018)	-	P
Scorpaenidae	*Pterois miles*(Bennett, 1828)	Turan et al. (2014a)	Turan and Öztürk (2015)	-	-	P
	Pterois volitans (Linnaeus, 1758)	Gürlek et al. (2016a)	-	-	-	A
Sebastidae	*Sebastes schlegelii* Hilgendorf, 1880	-	-	Karadurmuş et al. (2024)	Yağlıoğlu et al. (2023)	P
Synanceiidae	*Synanceia verrucosa* Bloch and Schneider, 1801	Bilecenoğlu (2012)	-	-	-	P
Teraponidae	*Pelates quadrilineatus* (Bloch, 1790)	Mater and Kaya (1987)	-	-	-	P
	Terapon puta Cuvier, 1829	Manaşirli and Mavruk (2021)	-	-	-	P
Serranidae	*Cephalopholis taeniops* (Valenciennes, 1828)	Özcan et al. (2020)	Engin *et.al.* (2016)	-	-	A
	Epinephelus aerolatus (Forsskål, 1775)	Ergüden et al. (2023)	-	-	-	P
	Epinephelus coioides (Hamilton, 1822)	Gökoğlu and Özvarol, (2015)	-	-	-	P

	Epinephelus fasciatus (Forsskal, 1775)	Gökoğlu and Biçer (2022)	-	-	-	P
	Paranthias furcifer (Valenciennes, 1828)	-	Yapıcı and Sevingel (2020)	-	-	P
Apogonidae	*Apogonichthyoides pharaonis* (Bellotti, 1874)	Mater and Kaya (1987)	Okuş et al. (2004)	-	-	P
	Cheilodipterus novemstriatus (Rüppell, 1838)	Turan et al. (2015)	Gülşahin and Yapıcı (2023)	-	-	P
	Jaydia queketti (Gilchrist, 1903)	Eryılmaz and Dalyan (2006)	Filiz et al. (2012)	-	-	P
	Jaydia smithi Kotthaus, 1970	Goren et al. (2009)	-	-	-	P
	Ostorhinhus fasciatus (White, 1790)	Turan et al. (2010)	Bilecenoğlu et al. (2013)	-	-	P
Priacanthidae	*Priacanthus hamrur* (Forsskål, 1775)	Ergüden et al. (2018)	-	-	-	P
	Priacanthus prolixus Starnes, 1988	Gürlek et al. (2017)	-	-	-	P
	Priacanthus sagittarus Starnes, 1988	Gökoğlu and Teker (2018)	-	-	-	P
Sillaginidae	*Sillago suezensis* Golani, Fricke and Tikochinski, 2014	Gücü et al. (1994)	Bilecenoğlu (2004)	-	-	P
Rachycentridae	*Rachycentron canadum* (Linnaeus, 1766)	-	Akyol and Ünal (2013)	-	-	P
Carangidae	*Alepes djedaba* (Forsskål, 1775)	Akyüz (1957)	Geldiay (1969)	Artüz and Kubanç (2014)	Turan et al. (2017a)	P
	Decapterus russelli (Rüppell, 1830)	Sakinan and Örek (2011)	-	-	-	P
	Trachurus indicus Nekrasov, 1966	Dalyan and Eryılmaz (2009)	-	-	-	P
	Seriola fasciata (Bloch, 1793)	Özvarol and Gökoğlu (2014)	Yapıcı and Filiz (2020)	-	-	A
Leiognathidae	*Equulites klunzingeri* (Steindachner, 1898)	Erazi (1943)	Ben-Tuvia (1966)	-	-	P
	Equulites leuciscus (Günther, 1860)	Kebapcioglu and Cinbilgel (2022)	-	-	-	P
	Equuilites popei (Whitley, 1932)	Yokes et al. (2015)	-	-	-	P
Lutjanidae	*Lutjanus argentimaculatus* (Forsskål, 1775)	Ergüden et al. (2023)	Akyol (2019)	-	-	P
Mullidae	*Parupeneus forsskali* (Fourmanoir and Gueze, 1976)	Çinar et al. (2006)	Yapıcı and Filiz (2017)	-	-	P
	Upeneus moluccensis (Bleeker, 1855)	Kosswig (1950)	Kosswig (1956)	Artüz and Fricke (2019)	-	P
	Upeneus pori Ben-Tuvia and Golani, 1989	Kosswig (1950)	Akyol et al. (2006)	-	-	P

Lethrinidae	*Monotaxis grandoculis* (Forsskål, 1775)	Bilecenoğlu (2007)	-	-	-	P
Haemulidae	*Pomadasys stridens* (Forsskål, 1775)	Bilecenoğlu et al. (2009)	Akyol and Ünal (2016)	-	-	P
Nemipteridae	*Nemipterus randalli* Russell, 1986	Bilecenoğlu (2008)	Gülşahin and Kara (2013)	-	-	P
Sparidae	*Acanthopagrus bifasciatus* (Forsskål, 1775)	-	Şensurat-Genç et al. (2020)	-	-	P
	Argyrops filamentosus (Valenciennes, 1830)	Gürlek et al. (2016b)	-	-	-	P
Pempheridae	*Pempheris rhomboidea* Kossmann and Rauber, 1877	Gücü et al. (1994)	Akyol et al. (2017)	Yapici and Sevingel (2020)	-	P
Kyhopsidae	*Kyphosus incisor* (Cuvier 1831)	Kiyağa et al. (2019)	-	-	-	A
Pomacentridae	*Abudefduf cf saxatilis/vaigiensis*	-	Bilecenoğlu (2016)	-	-	A
Chaetodontidae	*Heniochus intermedius* Steindachner, 1893	Gökoğlu et al. (2003)	-	-	-	P
Pomacanthidae	*Pomacanthus imperator* (Bloch, 1787)	Gürlek et al. (2019)	-	-	-	P
Mugilidae	*Planiliza carinata* (Valenciennes, 1836)	Kosswig (1956)	Geldiay (1969)	-	-	P
	Planiliza haematocheilus (Temminck and Schlegel, 1845)	-	Kaya et al. (1998)	Ünsal (1992)	Ünsal (1992)	P
Sphyraenidae	*Sphyraena chrysotaenia* Klunzinger, 1884	Akyüz (1957)	Geldiay (1969)	-	-	P
	Sphyraena flaviacauda Rüppell, 1838	Bilecenoğlu et al. (2002a)	-	-	-	P
Labridae	*Pteragogus trispilus* Randall, 2013	Taşkavak et al. (2000)	Bilecenoğlu et al. (2002b)	-	-	P
	Bodianus speciosus (Bowdich, 1825)	-	Filiz et al. (2019)	-	-	A
Scaridae	*Scarus ghobban* Forsskål, 1775	Turan et al. (2014b)	-	-	-	P
Champsodontidae	*Champsodon nudivittis* (Ogilby, 1895)	Çiçek and Bilecenoğlu (2009)	Filiz et al. (2014)	Tuncer and Dalyan et al. (2021)	-	P
Blenniidae	*Petroscirtes ancylodon* Rüppell, 1838	Taşkavak et al. (2000)	-	-	-	P
	Parablennius thysanius (Jordan and Seale, 1907)	Özbek et al. (2014)	-	-	-	P
Gobiidae	*Cryptocentrus caeruleopunctatus* (Rüppel, 1830)	Ergüden et al. (2022)	-	-	-	P
	Hazeus ingressus Engin, Larson, Irmak, 2018	-	Engin et al. (2018)	-	-	P
	Oxyurichtys keiensis (Smith, 1938)	Özden et al. (2022)	-	-	-	P

	Oxyurichthys petersii (Klunzinger, 1871)	Kaya et al. (1992)	Benli et al. (1999)	-	-	P
	Vanderhorstia mertensi Klausewitz, 1974	Bilecenoğlu et al. (2008)	Çinar et al. (2011)	-	-	P
	Trypauchen vagina (Bloch and Schneider, 1801)	Akamca et al. (2011)	-	-	-	P
Callionymidae	*Callionymus filamentosus* Valenciennes, 1837	Gücü et al. (1994)	Bilecenoğlu et al. (2014)	-	-	P
	Diplogrammus randalli Fricke, 1983	-	Seyhan et al. (2017)	-	-	P
	Synchiropus sechellensis Regan, 1908	Gökoğlu et al. (2014)	-	-	-	P
Ephippidae	*Platax teira* (Forsskål, 1775)	-	Bilecenoğlu and Kaya (2006)	-	-	P
Siganidae	*Siganus luridus* (Rüppell, 1829)	Fischer (1973)	Ben-Tuvia (1973)	-	-	P
	Siganus rivulatus Forsskål, 1775	Kosswig (1950)	Tortonese (1947)	Artüz and Koç (2012)	-	P
Scombridae	*Scomberomorus commerson* Lacepède, 1800	Fischer et al. (1987)	Buhan et al. (1997)	-	-	P
	Acanthocybium solandri (Cuvier, 1832)	Gökoğlu et al. (2024)	-	-	-	P
Cynoglossidae	*Cynoglossus sinusarabici* (Chabanaud, 1913)	Akyüz (1957)	Bilecenoğlu et al. (2014)	-	-	P
Monacanthidae	*Stephanolepis diaspros* Fraser-Brunner, 1940	Kosswig (1950)	Kosswig (1950)	Bilecenoğlu et al. (2013)	-	P
Ostraciidae	*Ostracion cubicus* Linnaeus, 1758	Gökoğlu and Korun. (2017)	-	-	-	P
Tetraodontidae	*Lagocephalus guentheri* (Richardson, 1844)	Ergüden et al. (2017)	Akyol and Aydın (2016)	-	-	P
	Lagocephalus spadiceus (Richardson, 1845)	Kosswig (1950)	Ben Tuvia (1966)	Tuncer et al. (2008)	-	P
	Lagocephalus sceleratus (Gmelin, 1789)	Bilecenoğlu et al. (2006)	Akyol et al. (2005)	Irmak and Altınağac (2015)	-	P
	Lagocephalus suezensis Clark and Gohar, 1953	Avşar and Cicek (1999)	Bilecenoğlu et al. (2002a)	-	-	P
	Sphoeroides pachygaster (Müller and Troschel, 1848)	Mater and Bilecenoğlu (1999)	Eryilmaz et al. (2003)	-	-	A
	Torquigener flavimaculosus Hardy and Randall, 1983	Bilecenoglu (2003)	Bilecenoğlu et al. (2014)	-	-	P
	Tylerius spinosissimus (Regan, 1908)	Turan and Yağlıoğlu (2011)	-	-	-	P

Diodontidae	*Cyclichthys spilostylus* (Leis and Randall, 1982)	Ergüden et al. (2012)	-	-	-	P

On the other hand, the first entry of alien fish species to the Turkish Seas and their abundance status are given in Table 2. Considering the abundance status of 100 species, 16% were considered very common, 34% common, 24% rare, 15% very rare, and 11% only one specimen of a species has been so far recorded (Table 2).

Table 2. Alien species recorded in Turkish seas and their abundance status.

Family	Species	First entry to Turkish Seas	Abundance
Carcharhinidae	*Carcharhinus altimus* (Springer, 1950)	1994-1996	Rare
	Carcharhinus falciformis (Bibron in Müller and Henle, 1839)	2020	Rare
Rhincodontidae	*Rhincodon typus* Smith 1828	2021	Very rare
Dasyatidae	*Himantura uarnak* (Forsskål, 1775)	1966	Common
Ophichthidae	*Pisodonophis semicinctus* (Richardson, 1848)	2009	Very rare
Dussumieridae	*Dussumieria elopsoides* (Bleeker, 1849)	1952	Very common
	Etrumeus golanii DiBatistta, Randall and Bowen, 2012	1997	Very common
Clupeidae	*Herklotsichthys punctatus* (Rüppell, 1837)	1984	Common
Engraulidae	*Stolephorus insularis* Hardenberg, 1933	2011	Rare
	Encrasicholina gloria Hata and Motomora, 2016	2014	Rare
Muraenidae	*Enchelycore anatina* (Lowe, 1838)	2002	Common
Chanidae	*Chanos chanos* (Forsskål, 1775)	2012	Single specimen
Plotosidae	*Plotosus lineatus* (Thunberg, 1787)	2016	Very common
Synodontidae	*Saurida lessepsianus* (Russell, Golani and Tikochinski, 2015)	1966	Very common
	Synodus randalli Cressey, 1981	2023	Rare
Bregmacoretidae	*Bregmaceros nectobanus* Whitley, 1941	2004	Common
Exocoetidae	*Parexocoetus mento* (Valenciennes, 1846)	1966	Common
Belonidae	*Ablennes hians* (Valenciennes, 1846)	2021	Rare
Hemiramphidae	*Hemiramphus far* (Forsskål, 1775)	1942	Common
Fistulariidae	*Fistularia commersonii* (Rüppell, 1835)	2002	Common
	Fistularia petimba Lacepède, 1803	2016	Common
Syngnathidae	*Hippocampus fuscus* Rüppell 1838	2003	Rare
Atherinidae	*Atherinomorus forskali* (Rüppell, 1838)	1950	Rare
Holocentridae	*Sargocentron rubrum* (Forsskål, 1775)	1949	Common
Scorpaenidae	*Pterois miles* (Bennett, 1828)	2014	Common
	Pterois volitans (Linnaeus, 1758)	2016	Rare
Sebastidae	*Sebastes schlegelii* Hilgendorf, 1880	2022	Common
Synanceiidae	*Synanceia verrucosa* Bloch & Schneider, 1801	2011	Very rare
Teraponidae	*Pelates quadrilineatus* (Bloch, 1790)	1983	Common
	Terapon puta Cuvier, 1829	2020	Rare
Serranidae	*Cephalopholis taeinops* (Valenciennes, 1828)	2015	Very rare
	Epinephelus aerolatus (Forsskål, 1775)	2022	Rare

	Epinephelus coioides (Hamilton, 1822)	2014	Rare
	Epinephelus fasciatus (Forsskal, 1775)	2021	Single specimen
	Paranthias furcifer (Valenciennes, 1828)	2019	Single specimen
Apogonidae	*Apogonichthyoides pharaonis* (Bellotti, 1874)	1983	Common
	Cheilodipterus novemstriatus (Rüppell, 1838)	2014	Very Common
	Jaydia queketti (Gilchrist, 1903)	2004	Common
	Jaydia smithi Kotthaus, 1970	2008	Common
	Ostorhinhus fasciatus (White, 1790)	2010	Common
Priacanthidae	*Priacanthus hamrur* (Forsskål, 1775)	2017	Rare
	Priacanthus prolixus Starnes, 1988	2016	Single specimen
	Priacanthus sagittarus Starnes, 1988	2017	Rare
Sillaginidae	*Sillago suezensis* Golani, Fricke and Tikochinski, 2014	1983	Common
Rachycentridae	*Rachycentron canadum* (Linnaeus, 1766)	2013	Single specimen
Carangidae	*Alepes djedaba* (Forsskål, 1775)	1952	Common
	Decapterus russelli (Rüppell, 1830)	2008	Common
	Trachurus indicus Nekrasov, 1966	2004	Rare
	Seriola fasciata (Bloch, 1793)	2014	Very rare
Leiognathidae	*Equuilites klunzingeri* (Steindachner, 1898)	1942	Very common
	Equulites leuciscus (Günther, 1860)	2021	Common
	Equuilites popei (Whitley, 1932)	2014	Rare
Lutjanidae	*Lutjanus argentimaculatus* (Forsskål, 1775)	2018	Rare
Mullidae	*Parupeneus forsskali* (Fourmanoir & Gueze, 1976)	2004	Common
	Upeneus moluccensis (Bleeker, 1855)	1942	Common
	Upenus pori Ben-Tuvia & Golani, 1989	1942	Common
Lethrinidae	*Monotaxis grandoculis* (Forsskål, 1775)	2007	Single specimen
Haemulidae	*Pomadasys stridens* (Forsskål, 1775)	2009	Very common
Nemipteridae	*Nemipterus randalli* Russell, 1986	2007	Very common
Sparidae	*Acanthopagrus bifasciatus* (Forsskål, 1775)	2018	Single specimen
	Argyrops filamentosus (Valenciennes, 1830)	2015	Single specimen
Pempheridae	*Pempheris rhomboidea* Kossmann & Rauber, 1877	1983	Very common
Kyhopsidae	*Kyphosus incisor* (Cuvier, 1831)	2018	Single specimen
Pomacentridae	*Abudefduf cf saxatilis/vaigiensis*	2016	Very rare
Chaetodontidae	*Heniochus intermedius* Steindachner, 1893	2002	Rare
Pomacanthidae	*Pomacanthus imperator* (Bloch, 1787)	2019	Rare
Mugilidae	*Planiliza carinata* (Valenciennes, 1836)	1955	Common
	Planiliza haematocheilus (Temminck & Schlegel, 1845)	1992	Very rare
Sphyraenidae	*Sphyraena chrysotaenia* Klunzinger, 1884	1955	Very common
	Sphyraena flaviacauda Rüppell, 1838	2001	Rare
Labridae	*Pteragogus trispilus* Randall, 2013	1998	Rare
	Bodianus speciosus (Bowdich, 1825)	2018	Very rare
Scaridae	*Scarus ghobban* Forsskål, 1775	2013	Common
Champsodontidae	*Champsodon nudivittis* (Ogilby, 1895)	2008	Common

Blenniidae	*Petroscirtes ancylodon* Rüppell, 1838	1997	Very rare
	Parablennius thysanius (Jordan & Seale, 1907)	2013	Very rare
Gobiidae	*Cryptocentrus caeruleopunctatus* (Rüppel, 1830)	2021	Common
	Hazeus ingressus Engin, Larson, Irmak, 2018	2015	Very rare
	Oxyurichtys keiensis (Smith, 1938)	2018	Very rare
	Oxyurichthys petersi (Klunzinger, 1871)	1991	Common
	Vanderhorstia mertensi Klausewitz, 1974	2008	Common
	Trypauchen vagina (Bloch & Schneider, 1801)	2010	Rare
Callionymidae	*Callionymus filamentosus* Valenciennes, 1837	1983	Common
	Diplogrammus randalli Fricke, 1983	2016	Very rare
	Synchiropus sechellensis Regan, 1908	2014	Rare
Ephippidae	*Platax teira* (Forsskål, 1775)	2006	Very rare
Siganidae	*Siganus luridus* (Rüppell, 1829)	1973	Very common
	Siganus rivulatus Forsskål, 1775	1942	Very common
Scombridae	*Scomberomorus commerson* Lacepède, 1800	1981	Common
	Acanthocybium solandri (Cuvier, 1832)	2024	Rare
Cynoglossidae	*Cynoglossus sinusarabici* (Chabanaud, 1913)	1955	Common
Monacanthidae	*Stephanolepis diaspros* Fraser-Brunner, 1940	1949	Very common
Ostraciidae	*Ostracion cubicus* Linnaeus, 1758	2017	Single specimen
Tetraodontidae	*Lagocephalus guentheri* (Richardson, 1844)	2015	Very Common
	Lagocephalus sceleratus (Gmelin, 1789)	2003	Very common
	Lagocephalus suezensis Clark & Gohar, 1953	1999	Very common
	Sphoeroides pachygaster (Müller & Troschel, 1848)	2001	Common
	Torquigener flavimaculosus Hardy & Randall, 1983	2002	Common
	Tylerius spinosissimus (Regan, 1908)	2010	Very rare
Diodontidae	*Cyclichthys spilostylus* (Leis & Randall, 1982)	2011	Single specimen

Commercial value, harm status, establishment, and invasive status of recorded alien fish species in Turkish seas are given in Table 3. Only 17 species (17%) of the 100 species have economic value in terms of fishing in Turkey. Regarding their establishment, 60 species (60%) are established, and 31 species (31%) have the potential to be invasive. Moreover, considering the potential harmful of these fish species, 22 species (22%) are poisonous, venomous, or sting (Table 3).

Table 3. Commercial value, harm status, establishment, and invasive status of alien fish species in Turkish seas.

Species	Commercial	Harmless	Established	Invasive
Carcharhinus altimus	No	No	Yes	No
Carcharhinus falciformis	No	No	Yes	No
Rhincodon typus	No	Yes	No	No
Himantura uarnak	No	No	Yes	No
Pisodonophis semicinctus	No	Yes	No	No
Dussumieria elopsoides	Yes	Yes	Yes	Yes

Etrumeus golanii	Yes	Yes	Yes	Yes
Herklotsichthys punctatus	No	Yes	Yes	No
Stolephorus insularis	No	Yes	No	No
Encrasicholina gloria	No	Yes	No	No
Enchelycore anatina	No	No	Yes	Yes
Chanos chanos	No	Yes	No	No
Plotosus lineatus	No	No	Yes	Yes
Saurida lessepsianus	Yes	Yes	Yes	Yes
Synodus randalli	No	Yes	No	No
Bregmaceros nectobanus	No	Yes	Yes	No
Parexocoetus mento	No	Yes	Yes	No
Ablennes hians	No	Yes	No	No
Hemiramphus far	Yes	Yes	Yes	No
Fistularia commersonii	No	Yes	Yes	Yes
Fistularia petimba	No	Yes	Yes	Yes
Hippocampus fuscus	No	Yes	Yes	No
Atherinomorus forskali	No	Yes	Yes	Yes
Sargocentron rubrum	No	Yes	Yes	Yes
Pterois miles	No	No	Yes	Yes
Pterois volitans	No	No	Yes	Yes
Sebastes schlegelii	No	Yes	Yes	Yes
Synanceia verrucosa	No	No	No	No
Pelates quadrilineatus	No	Yes	Yes	No
Terapon puta	No	Yes	No	No
Cephalopholis taeniops	No	Yes	No	No
Epinephelus aerolatus	No	Yes	No	No
Epinephelus coioides	No	Yes	No	No
Epinephelus fasciatus	No	Yes	No	No
Paranthias furcifer	No	Yes	No	No
Apogonichthyoides pharaonis	No	Yes	Yes	No
Cheilodipterus novemstriatus	No	Yes	Yes	Yes
jaydia queketti	No	Yes	Yes	No
Jaydia smithi	No	Yes	Yes	No
Ostorhinhus fasciatus	No	Yes	Yes	No
Priacanthus hamrur	No	Yes	No	No
Priacanthus prolixus	No	Yes	No	No
Priacanthus sagittarus	No	Yes	No	No
Sillago suezensis	Yes	Yes	Yes	No

Rachycentron canadum	No	No	No	No
Alepes djedaba	No	Yes	Yes	Yes
Decapterus russelli	Yes	Yes	Yes	No
Trachurus indicus	Yes	Yes	Yes	No
Seriola fasciata	No	Yes	No	No
Equuilites klunzingeri	No	Yes	Yes	Yes
Equulites leuciscus	No	Yes	Yes	Yes
Equuilites popei	No	Yes	Yes	Yes
Lutjanus argentimaculatus	No	Yes	No	No
Parupeneus forsskali	No	Yes	Yes	Yes
Upeneus moluccensis	Yes	Yes	Yes	Yes
Upenus pori	Yes	Yes	Yes	Yes
Monotaxis grandoculis	No	Yes	No	No
Pomadasys stridens	No	Yes	Yes	Yes
Nemipterus randalli	Yes	Yes	Yes	Yes
Acanthopagrus bifasciatus	No	Yes	No	No
Argyrops filamentosus	No	Yes	No	No
Pempheris rhomboidea	No	Yes	Yes	No
Kyphosus incisor	No	Yes	No	No
Abudefduf cf saxatilis/vaigiensis	No	Yes	No	No
Heniochus intermedius	No	Yes	No	No
Pomacanthus imperator	No	Yes	No	No
Planiliza carinata	Yes	Yes	Yes	No
Planiliza haematocheilus	Yes	Yes	No	Yes
Sphyraena chrysotaenia	Yes	Yes	Yes	Yes
Sphyraena flaviacauda	No	Yes	No	No
Pteragogus trispilus	No	Yes	Yes	No
Bodianus speciosus	No	Yes	No	No
Scarus ghobban	No	Yes	No	No
Champsodon nudivittis	No	Yes	Yes	Yes
Petroscirtes ancylodon	No	Yes	Yes	No
Parablennius thysanius	No	Yes	No	No
Cryptocentrus caeruleopunctatus	No	Yes	Yes	Yes
Hazeus ingressus	No	Yes	No	No
Oxyurichtys keiensis	No	Yes	No	No
Oxyurichthys petersi	No	Yes	Yes	No
Vanderhorstia mertensi	No	Yes	Yes	No
Trypauchen vagina	No	Yes	Yes	No

Callionymus filamentosus	No	No	Yes	No
Diplogrammus randalli	No	No	No	No
Synchiropus sechellensis	No	No	Yes	No
Platax teira	No	Yes	No	No
Siganus luridus	Yes	No	Yes	Yes
Siganus rivulatus	Yes	No	Yes	Yes
Scomberomorus commerson	Yes	Yes	Yes	No
Cynoglossus sinusarabici	No	Yes	Yes	No
Stephanolepis diaspros	No	Yes	Yes	No
Ostracion cubicus	No	No	No	No
Lagocephalus guentheri	No	No	Yes	Yes
Lagocephalus sceleratus	No	No	Yes	Yes
Lagocephalus suezensis	No	No	Yes	Yes
Sphoeroides pachygaster	No	No	Yes	No
Torquigener flavimaculosus	No	No	Yes	Yes
Tylerius spinosissimus	No	No	No	No
Cyclichthys spilostylus	No	No	No	No
Acanthocybium solandri	Yes	No	No	No

The distribution of the first occurrence of alien fish species in each Turkish Sea, comprising Turkish coastal waters of the Mediterranean, Aegean, Marmara, and Black Sea in the colored density map indicated (Figure 2) that the Iskenderun Bay seems to be a hot spot region for alien species in Turkish marine waters.

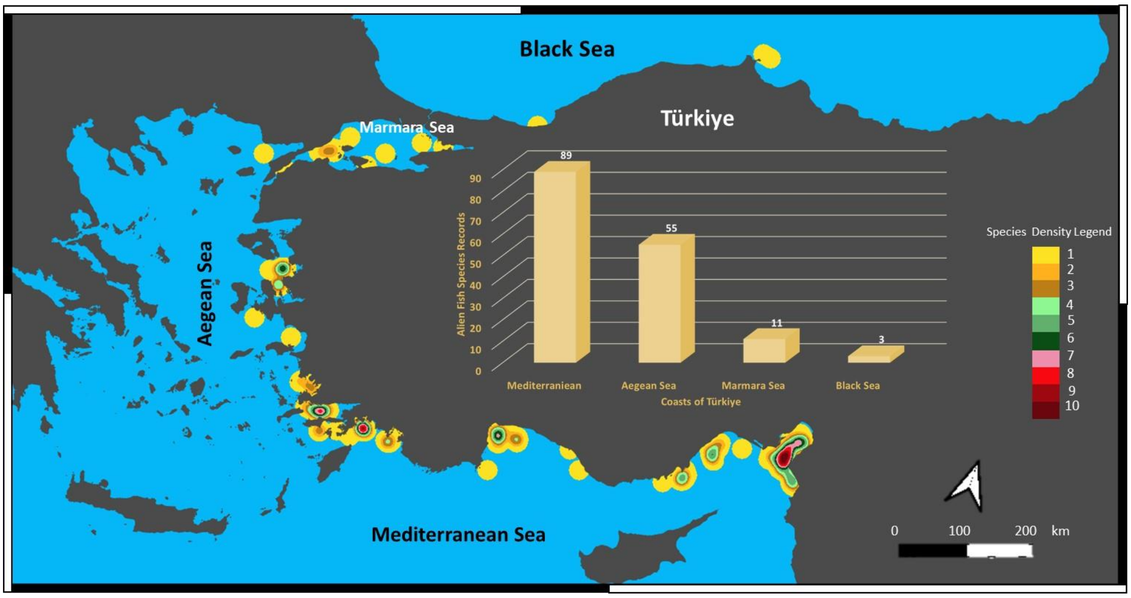

Figure 2. Colored density map, showing the distribution of first occurrence of alien fish species in each Turkish Sea, comprising Turkish coastal waters of the Mediterranean, Aegean, Marmara and Black Sea. Bar chart gives the number of species recorded from each sea. Colour scale legend gives the number of species.

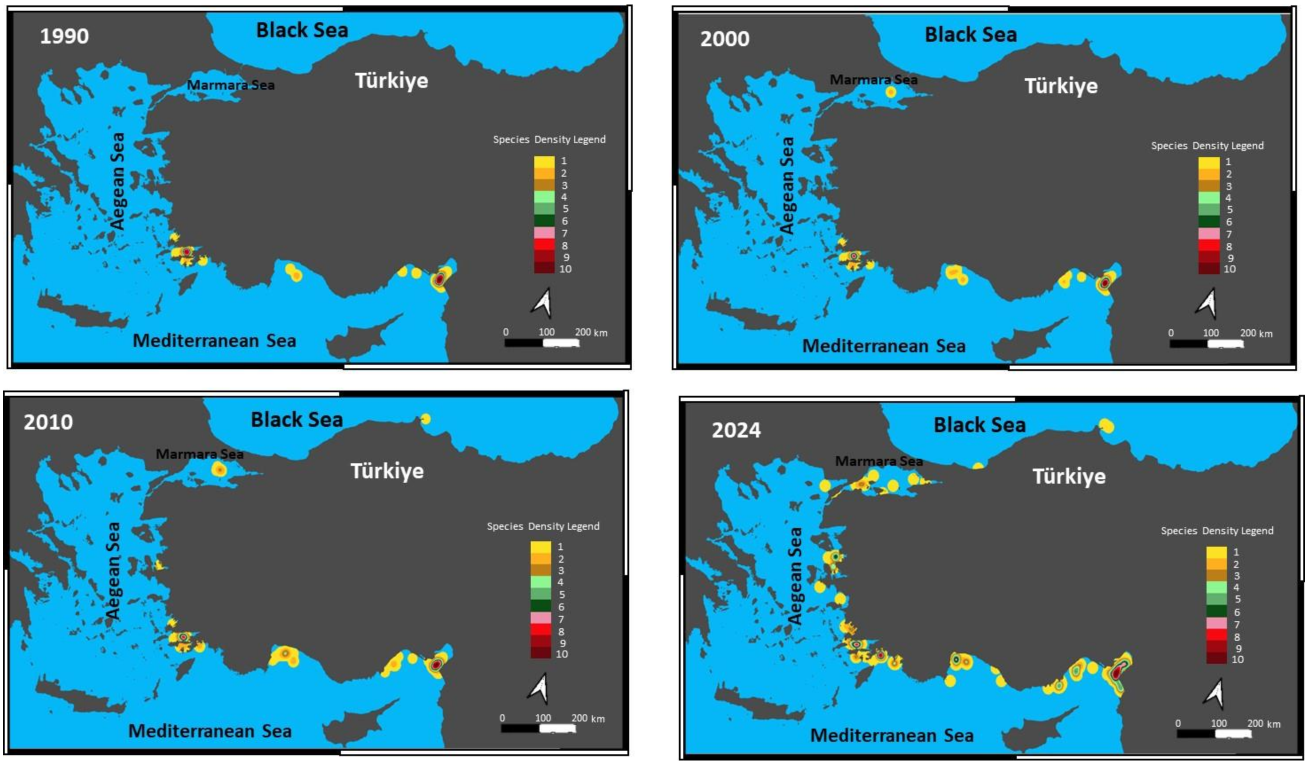

Figure 3. Colour density map showing historical increase (in decades) of the distribution of alien fish species in Turkish Marine waters, including bony, Elasmobranch and jawless species, along Turkish coasts. Colour scale legend gives the number of species.

Considering the ratio of recorded alien fish species in Turkish seas according to their origins, 87% of the alien fish species are of Indo-Pacific origin, 12% are of Tropical Atlantic origin and 1% are of North-West Pacific origin (Figure 4.A). As seen, Indo-Pacific-originated species are highly dominant in Turkish marine waters.

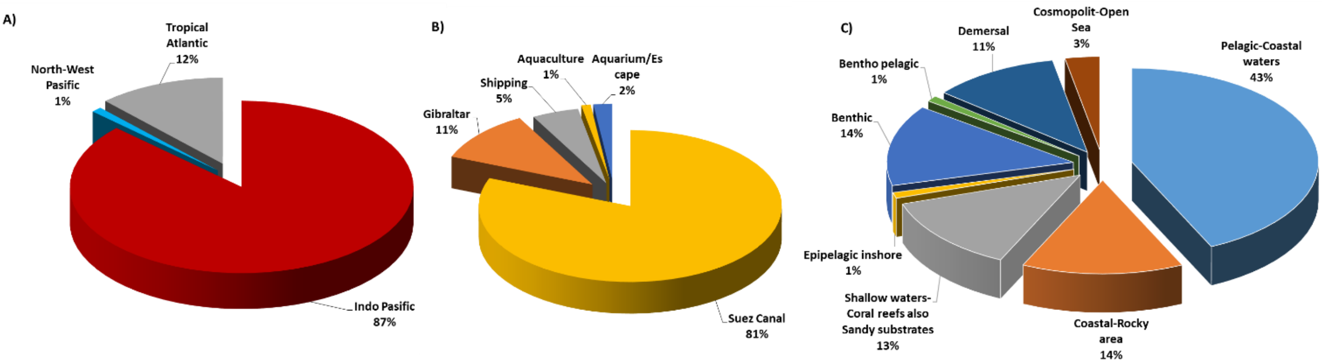

Figure 4. Rates of distribution of alien fish species recorded in Turkish coastal waters by origin (A), entry pathways (B), and habitat preference (C).

The entry routes of alien fish species found in the Turkish seas are generally via the Suez Canal with a rate of 81%, followed by species passing through the Strait of Gibraltar with a rate of 11%. The species that come through the other entry routes are at a rate of 5% by ship transportation, 2% by Aquarium activities, and 1% by Aquaculture activities (Figure 4.B).

Considering the habitat preference of these alien species, 43% are pelagic species, 14% are benthic species, 14% are rocky area species, 13% are shallow water, reef, and species, and 11% are demersal species (Figure 3.C). While one species is distributed as bento-pelagic at a rate of 1%, one species is distributed as epipelagic at a rate of 1%, and the shark species, *Carcharhinus altimus, C. falciformis* and *Rhincodon typus* are distributed as a Cosmopolitan with a rate of 3% (Figure 4.C).

The geographic proximity of the first occurrence of each species in the Mediterranean Sea to the Suez Canal and the Strait of Gibraltar was measured (only for the species given in Table 1). The geographic proximity of first occurrence location of the alien species faound in Türkiye to the Suez Canal and the Strait of Gibraltar demonstrated that the Suez Canal is main cause in the number of alien species in the Turkish marine waters (Figure 5). Among these species, the occurrence of *Planiliza haematocheilus* is known to be via Aquaculture (Ünsal, 1992), and *Sebastes schlegelii* is tought to be via ballast waters in the Black Sea (Yağlıoğlu et al., 2023).

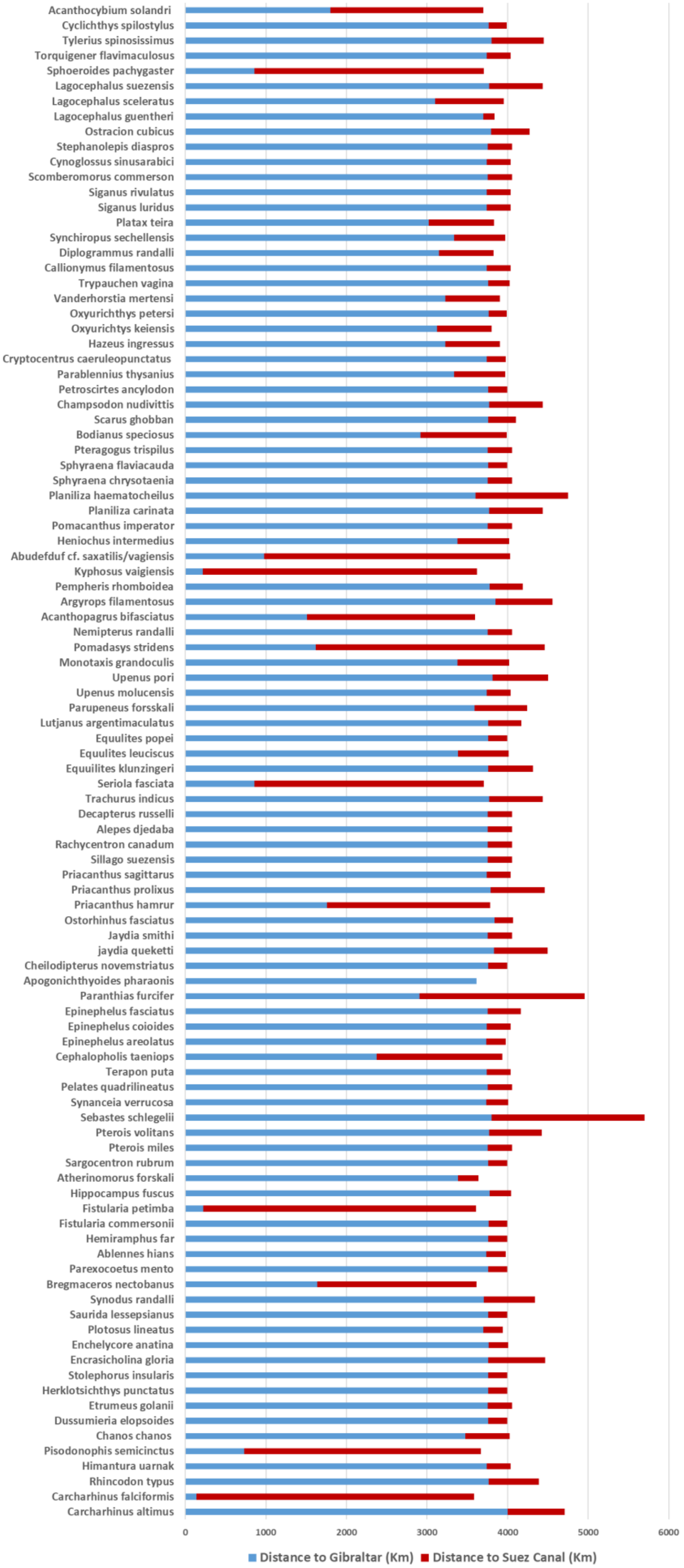

Figure 5. The geographic proximity of first occurence of alien species in the Mediterranean to the Suez Canal and Gibraltar (only for the species given in Table 1).

When the depth distribution of alien species in Turkish seas are examined; 52 species are distributed in the 0-50 m depth range, and 22 species in the 50-100 m depth range, indicating that 73 species are mostly found in the 0-100 m depth range. A total of 26 species prefer living at deeper depths between 150 and 500 m (Figure 6).

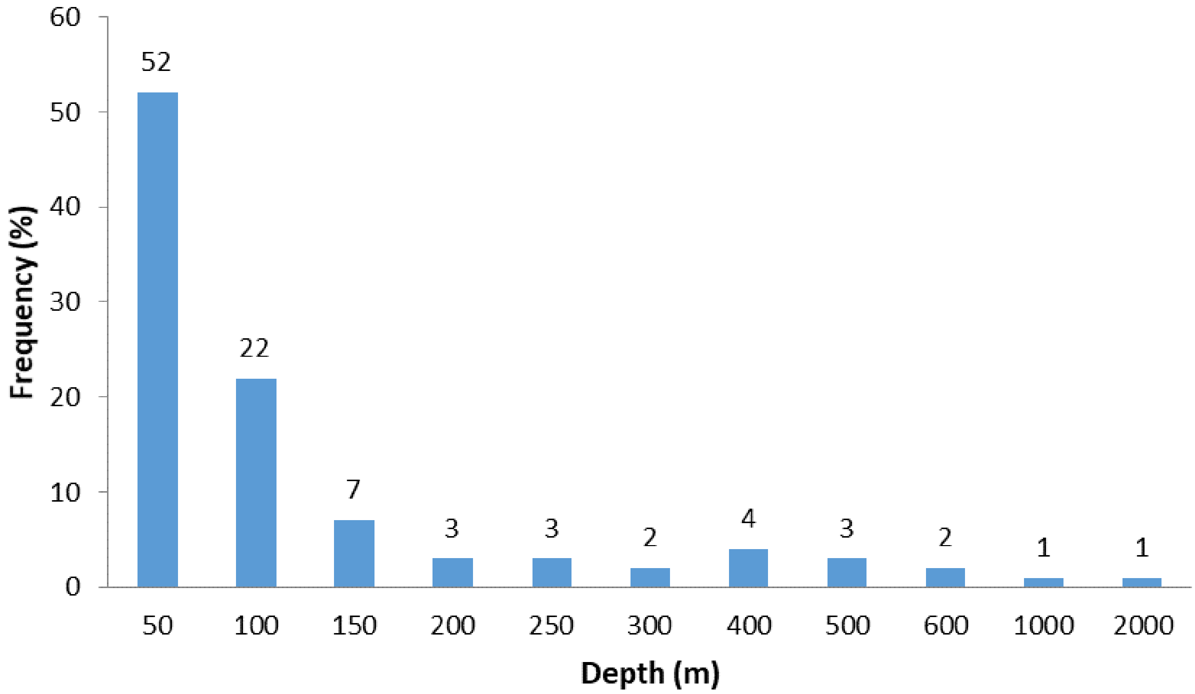

Figure 6. Depth distribution of alien fish species in Turkish coastal waters.

The alien fish species and numbers that entered the Turkish seas from the 1940s to 2020s are given in Figure 7, indicating that the number of recorded species highly increased between 1980 and 2010 years (Figure 7).

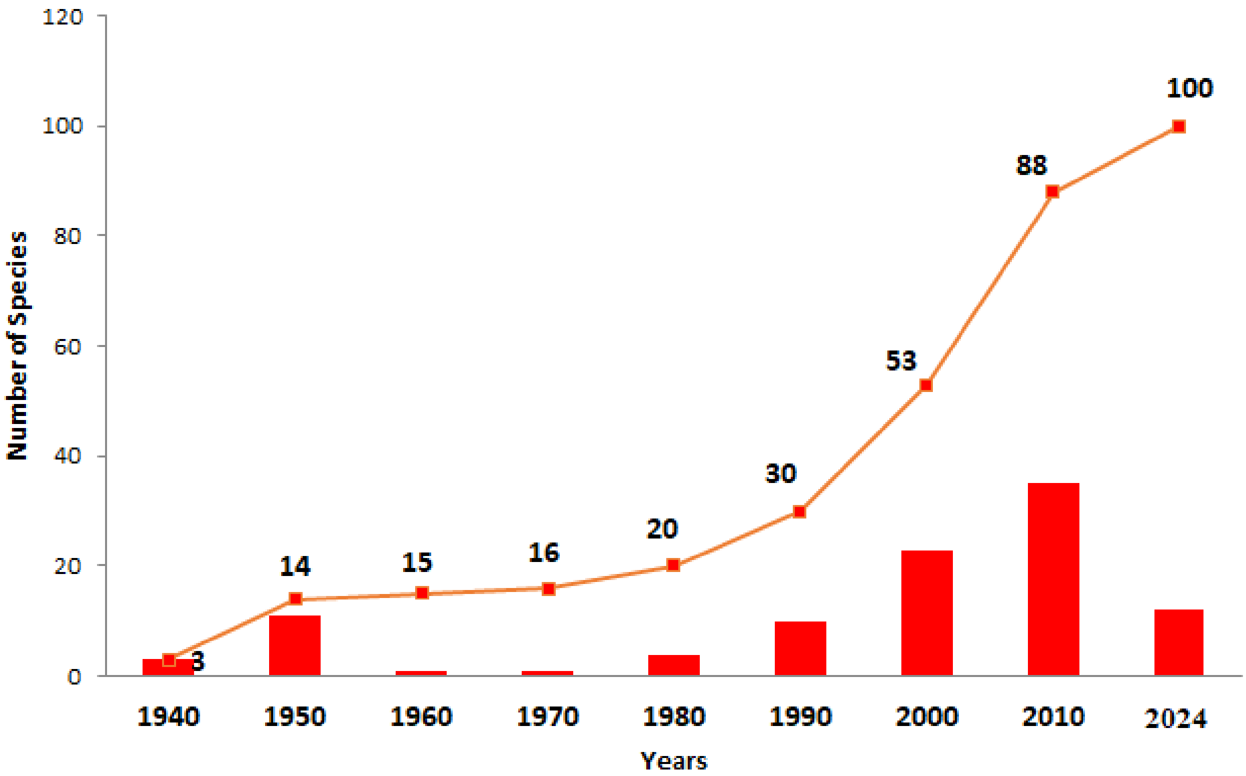

Figure 7. Time-series data of cumulative increase alien fish species in Turkish Marine waters (solid line indicates cumulative increase; bars indicate the total number of alien species recorded in Turkish marine waters).

Discussion

The Mediterranean part of the Turkish coastal waters with 88 alien species much more affected by alien species. Especially the Tetradontidae family with the highest number of species and the Scorpaenidae family with two lionfish species are having important effects in terms of native species as well as fishery and tourism in Turkey. Moreover, 51.0% of the reported alien species have a common distribution but 16.1% of them have economic value in terms of fishing in Turkey. Therefore, a relatively very low number of alien species are economically considered which points out the economic loss of Turkish fishery as well as native habitats. Besides, another downside of this invasion is that 23.0% of the alien species (22 species) are poisonous, venomous, or sting which generates extra problems and costs.

The distribution of the first occurrence of alien fish species in each Turkish Sea in the Hexagonal grid and colored density map indicated that Iskenderun Bay seems to be a hot spot region for alien fish species (Figure 2). After entering the Suez Canal, alien fish species are heading northward to Israel, Lebanon, Syria, and Turkey as a main alien pathway in the Mediterranean, consequently, the Iskenderun Bay is the first entry point of the alien migration in Turkish marine waters.

Considering the ratio of recorded alien fish species in Turkish seas according to their origins, 88% of the alien fish species are of Indo-Pacific origin, and the entry routes of alien fish species found in the Turkish seas are generally via the Suez Canal which seems to be related to the geographic proximity of Turkey to Suez Canal (Figure 4). Moreover, the eastern Mediterranean is warming at a rate far above the global average (Lewis et al.,, 2019), therefore, the tropical species that arrived through the Suez Canal are extending their distribution in the Mediterranean in line with the rising temperatures.

A central focus of alien species ecology is understanding what factors explain the distribution and abundance of alien species along with their range. This is a key issue to control the alien species and mitigate their effects. Considering the habitat preference and depth distribution of the alien species, 44% are pelagic species, and 26% are shallow water, rocky, and reef species, which are distributed in the 0-100 m depth range. These results indicate that habitat preferences of future invaders will usually be in the shallow water, rocky, and reef. Therefore, any mitigation measures on the prevention and control of alien species in shallow water, rocky and reefs that minimize their settlement persistence will shape the settlement of alien species or their decisions at settlement.

Although the number of recorded species, which highly increased between the 1980s and 2010s years, flattened out in the last decade even after the construction of the second canal between the Red Sea and the Mediterranean by the Egyptian government as an alternative to the Suez Canal. This recession can be related to the reduced number of the Red Sea and Indo-Pacific species that can live in the subtropical Mediterranean. From now on, the entrance of the Red Sea and Indo-Pacific species may depend on the process of tropicalization of the Mediterranean Sea. Besides climate change, the other driving factors such as ballast waters and shipping are not much effective in the entrance of alien fish species (Turan et al.,, 2016). Since fish species do not have a chance to live in ballast water for a long time like other living groups, there are no clear species that is thought to have entered the Turkish seas with ballast waters. For example, even it is not clear, only 3 species (*Abudefduf cf. saxatilis/vaigiensis/troschelii*, *Bodianus speciosus*, *Parablennius thysanius*) are thought to be entered by ballast water in Turkish marine waters (Özbek et al.,, 2014; Bilecenoğlu , 2016; Filiz et al.,, 2019).

Terapon puta, reported from Iskenderun Bay by Manaşirli and Mavruk (2021) as a new record for Turkey, and *Kyphosus vaigiensis* registered by Kıyağa et al., (2019) for the first time from the Iskenderun Bay, eastern Mediterranean coast of Turkey, are included in the current checklist, which was not included by Çınar et al., (2021).

Moreover, we used the Hexagonal grid map to show the number of alien species in the Turkish marine waters. The pattern of distribution of alien species using a 15x15 km square grid given by Çınar et al., (2021) in Figures 4, 5, and 6 was completely wrong and does not represent the correct distribution of alien species in Turkish marine waters. For example, in Figure 5, the number of alien fish species in Iskenderun Bay exceeds 500 species when you count each colored grid in the Iskenderun Bay according to the given legend.

Evidence needed cases

Platax teira caught by spare fishing at 12 m in Bodrum was reported by Bilecenoglu and Kaya (2006) from the Aegean coast of Türkiye about 18 years ago. However, this species has not been found or reported anywhere else in the Mediterranean, which is thought to have been penetrated the sea with aquarium activities (Zenetos et al., 2016). Çınar et al., (2021) state that *P. teira* came via the Suez Canal, but there is no concrete evidence that it may have arrived via the Suez Canal as there is only one record (Bilecenoglu and Kaya 2006) of this species. Therefore, the existence of this species is still a question mark for both the Aegean coasts of Türkiye and the eastern Mediterranean Sea.

Bilecenoğlu (2007) reported *Monotaxis grandoculis* with underwater photography from Antalya Bay, which was not fully photographed (the tail of the fish is not in the picture), and no other individuals of *M. grandoculis* have been found in the Mediterranean Sea for 17 years. Moreover, this record is still not included in the Exotic Fish Species list (CIESM Atlas of Exotic Species in the Mediterranean) prepared by the Mediterranean Science Commission (CIESM 2024). The existence of *M. grandoculis*, which needs confirmation, still poses a question mark for both the Mediterranean coasts of Türkiye and the eastern Mediterranean Sea. *Abudefduf saxatilis* is Tropical Atlantic-originated species and its existence is a question mark in Turkish marine waters. A single individual of *A. saxatilis* was reported with an underwater photograph by Bilecenoglu (2016) from Çandarlı Bay in 2016. Dragičević et al., (2021) stated that *A. saxatilis* is very similar to the Indo-Pacific originated *A. vaigiensis* species, and the existence of this species in the Mediterranean Sea is still in doubt. Tsadok et al., (2005) stated that Abudefduf species can be distinguished with genetic studies. Quenouille et al., (2011) stated that *A. saxatilis* and *A. vaigiensis* shifted to sympatricism after allopatric speciation for the last 4 million years. Although it is scientifically very difficult to distinguish these species, interestingly, Bilecenoğlu (2016) recorded *A. saxatilis* for Turkish marine waters in terms of several taxonomic characters and color descriptions based only on underwater photography. Çınar et al., (2021) determined this species as A*budefduf cf. saxatilis/vaigiensis/troschelii* for the Turkish coast. This statement also indicates that this species still needs confirmation. As a result, nowadays in the new registration studies given for a species, the identification of a species based on only underwater photographs without catching the individual of the species, and without performing both morphological and genetic studies when needed leads to erroneous results. Unfortunately, these erroneous activities cause information pollution and extra work in the scientific community. For this reason, it would be more convenient for researchers to avoid making new record publications based on only underwater photographs.

Himantura leoparda was reported by Yucel et al., (2017) from the Mediterranean coast of Türkiye. However, this species has not been found or reported anywhere else in the Mediterranean. Golani et al., (2021b) stated that this species was probably misidentified and that this species is known synonym in the Mediterranean as *Himantura uarnak*. Therefore, *H. leoparda* was excluded from the checklist.

Hata and Motomura (2016) reported for the first time the existence of a new anchovy species, *Encrasicholina gloria*, from the Persian Gulf, Red Sea and Mediterranean, with their taxonomic and systematic study. Golani et al., (2021b), in the second edition of Atlas of Exotic Fishes in the Mediterranean, previously published by Çiftçi et al., (2017) reported that *Encrasicholina punctifer* from the Mediterranean coast of Türkiye was *E. gloria* and that this anchovy species was misidentified. Also, Golani et al., (2021b) stated that previously reported from the Mediterranean coast of Türkiye, *Kyhopsus vaigiensis* is a synonym for *K. incisor* and was misidentified by Kıyağa et al., (2019).

Lagocephalus spadiceus and *L. guentheri* are argued to be the same species, and the valid ones are debated to be *L. guentheri* in the Mediterranean. *L. spadiceus* and *L. guentheri* were reported as close to each other in genetic studies (Turan et al., 2017b; Vella et al., 2017; Giusti et al., 2019; Huang et al., 2020). The genetic studies based on one region of mtDNA suggest a close relationship, but not complete similarity. We collected available GenBank sequences deposited from all over the world and conducted a phylogenetic analysis to clarify the current controversy (Figure 8).

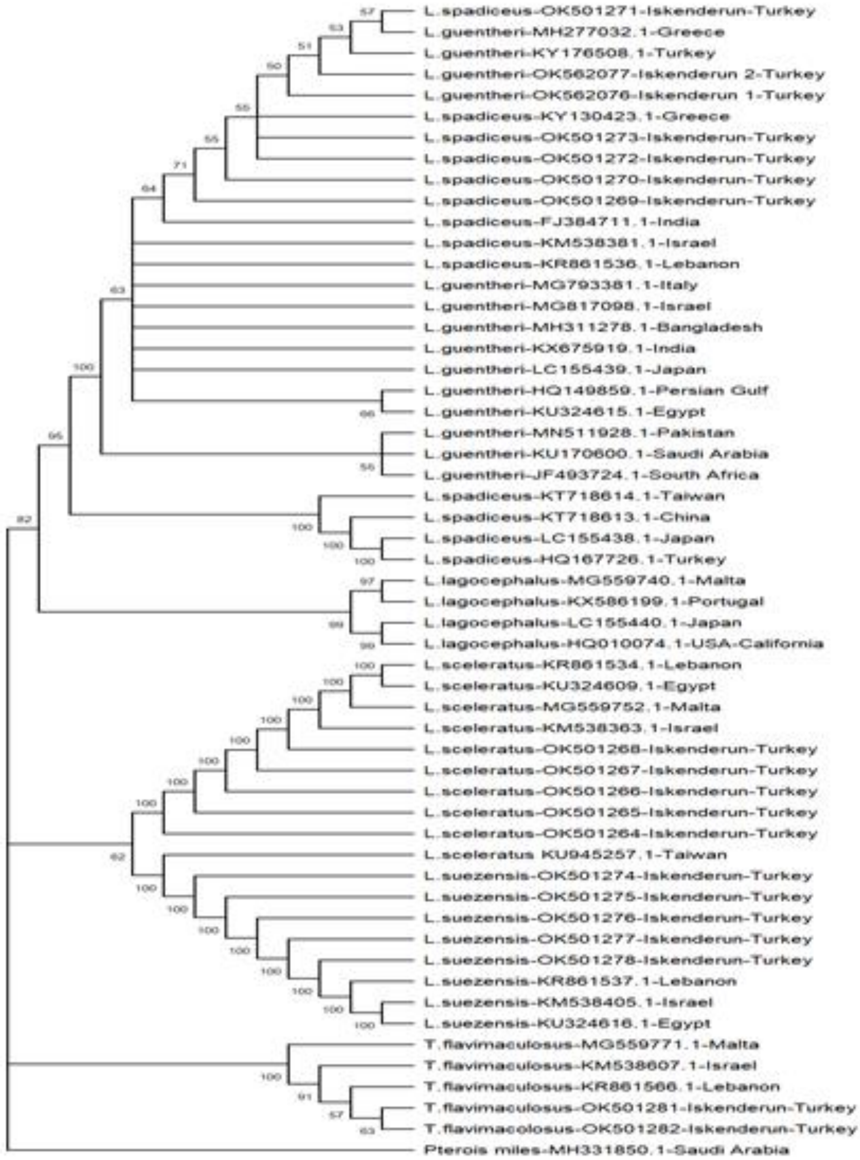

Figure 8. NJ tree based on COI sequences of pufferfishes. The bootstrap values (50% cut-off) were shown on nodes. GenBank accession numbers of each sequence are given on the nodes, and collection localities are taken from the GenBank. The Iskenderun samples are from Turan et al., (2016), and and the others are taken from GenBank submissions of various studies.

The pattern of phylogenetic tree based on GenBank deposited sequences of pufferfish species from the all over the world seas suggest that there might be a sampling error of *L. guentheri* and *L. spadiceus* in some studies due to the high morphological similarity of this species (Figure 9).

Therefore, more detailed studies using different mtDNA genes are needed to elucidate whether they are exactly the same or different species. If we include them as the same species with the current knowledge in this checklist, we might be faced to include them as different species again in the future. Consequently, we remaind *L. spadiceus* and *L. guentheri* in the present checklist as different species (Figure 9) for the time being.

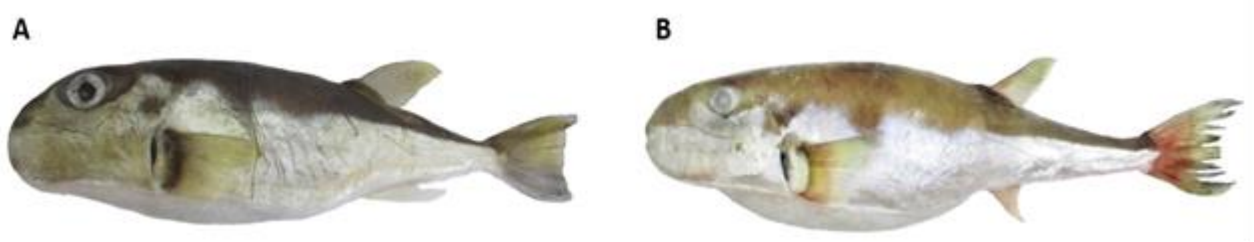

Figure 9. *Lagocephalus spadiceus* (A) and *Lagocephalus guentheri* (B) from the Iskenderun Bay, Türkiye.

One of the species whose existence is not valid in the Black Sea is the silver-cheeked toadfish (*Lagocephalus sceleratus*). Based on a local newspaper report, Bilecenoglu and Öztürk (2018) reported that the silver-cheeked toadfish *Lagocephalus sceleratus* caught from the Türkeli Sinop coast (Middle Black Sea) in December 2017 was on a fisherman's stall, expanding the distribution of this species to the Black Sea. In personal communication with the head of the Sinop fishery cooperative (Ferit Yıldız) and the fishermen by both the Ministry of Agriculture and Forestry officers and us, the fish that appeared in the newspapers as a pufferfish *Lagocephalus sceleratus* was actually an Atlantic stargazer, *Uranoscopus scaber*. The head of the cooperative talked to the fisherman and reported that the picture given in the newspaper as pufferfish was not taken from the stalls of the Sinop fisherman's, no further record of this species has not been given on the Black Sea coast. Therefore, the record of *L. sceleratus* in the Black Sea is not included in this checklist.

According to Çınar et al., (2021), soldier bream *Argyrops filamentosus*, which was reported for the first time from the Mediterranean by Gürlek et al., (2016b), is one of the species claimed to have been misidentified by Çınar et al., (2021) that *Pagrus caeruleostictus* was incorrectly identified as *A. filamentosus*. Soldier bream *A. filamentosus* recorded in the Mediterranean generally shows morphological similarity to the Lectotype specimen reported by Iwatsuki and Heemstra (2018). It is obvious that *A. filamentosus* differs from *Pagrus caeruleostictus* by morphological characters such as head length, body depth, longest dorsal spin, number of dorsal fin rays, number of gill spines, and lateral line (Chen et al.,, 2015). Recently, Ghanem et al., (2021) mentioned three *A. filamentosus* were observation in the Mediterranean coast while scuba diving at 20 m depth within the Specially Protected Areas of Zembra Island (Eastern Tunisia). Later, they reported in March 2020, that a single specimen of *A. filamentosus* was captured in the same area by local fishermen using gillnets at 60 m depth on sandy bottom. The existence of the species in the Mediterranean was once again confirmed by Ghanem et al., (2021).

Çınar et al., (2021) claimed the Mediterranean specimen of *Trachurus declivis* to be *Trachurus trachurus* based on the similarity of the dorsal accessory lateral line of *Trachurus trachurus*.

However, the structure of the curved part of the lateral line of *Trachurus declivis* differs from *T. trachurus*. Stephenson and Robertson (1977) stated that the onset of lateral line slope in *Trachurus declivis* is approximately in the fifth ray of the second dorsal fin and occurs along with the five dorsal fin ray distance. The Mediterranean specimen of *Trachurus declivis* reported by Gürlek et al., (2016c) seems to conform to the lateral line shape and structure specified by Stephenson and Robertson (1977). The controversy can be solved with genetic analysis of the reported *T. declivis* individuals. For this reason, it would be more accurate to state that this species does not exist in the Mediterranean Sea for the time being.

In conclusion, the number of alien species recorded in the Aegean and Marmara Sea is noticeably greater than the previous checklist (Turan et al., 2018) which indicate ongoing north towards migration of alien species. Although there has been a decrease in the number of alien species entering the Turkish seas in the last decade, the previously incoming and settled alien species are heading to the north towards the Aegean and Marmara Seas. Today alien fish species are more abundant in the Aegean and Marmara Seas. Climate change is compounding the problem of alien invasion, 99 alien species are now present in Turkish marine waters, spreading north every year and affecting resident species. Moreover, overfishing reduces native species diversity (Turan, 2021) and also accelerates the settlement of invasive alien species (Boudouresque et al.,, 2017), therefore ending overfishing and reducing other negative ecosystem effects of fishing would make fish stocks and marine ecosystems more resilient to climate change (Sumaila and Tai, 2020) and thus prevent spreading the alien invasion. Besides, the harmful and stingy characteristics of these alien species are another issue affecting the local fishery (economy) and public health since they usually prefer shallow coastal waters (Ünal et al.,, 2015; Uysal and Turan, 2020). A monitoring plan that compares current with historical species richness is mandatory in Turkish marine waters because this knowledge may help us to protect native species and control the spread of new alien species.

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Conflict of Interest

The authors declare that they have no competing interests.

Author Contributions

C.T., D.E., M.G., and S.A.D. performed all the experiments and drafted the main manuscript text. Authors reviewed and approved the final version of the manuscript.

Ethical Approval Statements

Local Ethics Committee Approval was not obtained because experimental animals were not used in this study.

Data Availability Statement

The data used in the present study are available upon request from the corresponding author.

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