



- REVIEW ARTICLE -

A Checklist of the Non-indigenous Fishes in Turkish Marine Waters

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Abstract

A checklist of non-indigenous marine fishes including bony, cartilaginous and jawless distributed along the Turkish Marine Waters was for the first time generated in the present study. The number of records of non-indigenous fish species found in Turkish marine waters were 101 of which 89 bony, 11 cartilaginous and 1 jawless. In terms of occurrence of non-indigenous fish species in the surrounding Turkish marine waters, the Mediterranean coast has the highest diversity (92 species), followed by the Aegean Sea (50 species), the Marmara Sea (11 species) and the Black Sea (2 species). The Indo-Pacific origin of the non-indigenous fish species is represented with 73 species while the Atlantic origin of the non-indigenous species is represented with 22 species. Only first occurrence of a species in the Mediterranean, Aegean, Marmara and Black Sea Coasts of Turkey is given with its literature in the list.

Keywords: Checklist, non-indigenous fishes, Turkish Marine Waters

Article history:

Received 14 August 2018, Accepted 08 October 2018, Available online 10 October 2018

Introduction

Fishes are the most primitive members of the subphylum Craniata, constituting more than half of the living vertebrate species. There is a relatively rich biota in the Mediterranean Sea although it covers less than 1% of the global ocean surface. Among the entire faunal assemblages, fishes are one of the most intensely studied groups, with nearly 650 species recorded throughout the Mediterranean basin (Quignard & Tomasini, 2000; Coll et al., 2010). Recent extensive faunal

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assessments have revealed a lower number of fish species distributed along the Turkish coasts (Fricke et al., 2007) that seems to be more related to the scarcity of taxonomical studies, rather than the oligotrophic nature of the eastern Mediterranean basin.

The biodiversity in the East Mediterranean has been considerably altered since the opening of the Suez Canal in 1869. The completion of the High Aswan Dam in 1965-67 has retained important changes in the Levantine basin which favored the settlement and spread of lessepsian/Erythrean fish and invertebrates in the Mediterranean basin (Halim et al., 1995; Halim, 2004) that appears to be in accelerating process (Turan et al. 2016). Tortonese (1964) estimated the Indo-Pacific immigrant fish species to be about 30 for a Mediterranean total of about 550. Ben-Tuvia (1985) listed 41 species. In the Atlas of Exotic fish species in the Mediterranean, Golani et al. (2002) reported 59 exotic fish species for an estimated total of 650 in the Mediterranean, which is almost 10% of the population. The check list of Zenetos et al. (2010) comprises 92 non-indigenous species of the Indo-Pacific origin in the Mediterranean.

Checklists are important survey tools for the study of the fish communities, providing the essential data sets for fishery management actions. Ongoing and preparation of non-indigenous species checklists and the development of relevant Web based databases have been challenging tasks over the latest decades (AliMed, AquaNIS, DAISIE, EASIN, ESENIAS, NOBANIS). One major drawback in these systems is the lack of long-term funding, which often results in a lack of updates which is, in turn, a prerequisite for delivering timely reliable information to environmental managers (Lucy et al., 2016). Nevertheless, the most serious problem in these databases is often the lack of expertise that species records in the existing data systems are often taken at face value without investigating their validity.

Turkey is surrounded by four large water masses, the Mediterranean Sea, Aegean Sea, Marmara Sea and Black Sea with different hydrographic regimes and ecological characters. It is very important to provide a list of non-indigenous species in these waters for ecologists and fishery managers for better understanding of population dynamics in these environment and conservation of native biodiversity and habitats.

The main objectives of this study is to provide for the first time a checklist of the as non-indigenous bony and cartilaginous fishes found in the Mediterranean, Aegean, Marmara and Black Sea coasts of Turkey.

Material and Methods

All the non-indigenous bony and cartilaginous fish species distributed along the Turkish coasts are presented in this paper. The geographical area concerned in this study includes the Turkish coasts of the Mediterranean Sea, Aegean Sea, Marmara Sea and Black Sea. East of the Dalaman creek (36°42'N–28°43'E) is considered as the Turkish coasts of Mediterranean Sea.

The check list comprises origin of the non-indigenous species such as the Indo-Pacific, Red Sea, Atlantic, Atlanto-Mediterranean. Only 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. Second and third occurrence of a species for each sea are not considered here. Only extension reports from one sea to another sea for a species such as from the Aegean Sea to the Marmara Sea, and ext. are given in the check list. The species which its existence has been misclassified with

sister species were not considered as non-indigenous species. Moreover, formerly realised species to be exist and different from its sister species in our waters were also not included as non-indigenous species in the check list.

The records of species that were only reported from the Aegean Sea coast of Turkey as first occurrence were indicated from Mugla coasts since this coast is an entrance or gate of the Aegean Sea for the Atlantic and Indo-Pacific migrants which was also used in the colour density map.

Turkish coasts have been divided into equivalent squares of 15 × 15 km, where all recorded fish (exclusively those associated with exact coordinates; unpublished data and gray literature are not included) was plotted using the QGIS software. The natural breaks method was used to indicate the areas with the highest number of species.

Results

Up to date, non-indigenous marine fish in Turkish marine waters comprises 101 species of which Actinopterygii classes is represented with 89 species, and Elasmobranchii is represented with 11 species and Hyperoartia is represented with 1 species (Table 1). In terms of occurrence of non-indigenous fish species in the surrounding Turkish marine waters, the Mediterranean part has the highest diversity (92 species), followed by the Aegean Sea (50 species), the Marmara Sea (11 species) and the Black Sea (2 species) (Table 1).

The Indo-Pacific origin of the non-indigenous fish species is represented with 73 species, while the Atlantic origin of the non-indigenous species is represented with 22 species. However, there has been no acknowledge of the origin of the non-indigenous species for 6 fish species (Table 1). Exclusively, the Elasmobranch species show worldwide distribution, and therefore, the origin is not given for the most of these species, especially for sharks.

On the other hand, there are species which were occurred or recorded only from one sea in Turkish marine waters that 44 species were recorded only from the Mediterranean coast of Turkey and 7 species were recorded only from the Aegean Sea.

Table 1. Checklist of the non-indigenous bony and cartilaginous fishes for Turkish marine waters (A: Atlantic; ATM, Atlanto-Mediterranean IP: Indo-Pacific, R: Red Sea). Grey colour in each cell represent first report and occurrence in each Sea and its reported Reference is given in the cell.

Family/Species	Mediterranean	Aegean	Marmara	Black Sea	Source
Jawless Fishes					
Petromyzontidae					
<i>Petromyzon marinus</i> Linnaeus, 1758	Çevik et al. (2010)	Tessalou-Legaki et al. (2012)			A

Elasmobranch					
Alopiidae					
<i>Alopias superciliosus</i> Lowe, 1841	Kabasakal (2011)	Mater (2005)	Kabasakal & Karhan (2007)		
Triakidae					
<i>Mustelus punctulatus</i> Risso, 1827	Whitehead et al. (1984–1986)	Whitehead et al. (1984–1986)			A
Carcharhinidae					
<i>Carcharhinus altimus</i> (Springer, 1950)	Başusta & Erdem 2000				
<i>Carcharhinus brevipinna</i> (Müller & Henle, 1839)	Whitehead et al. (1984–1986)	Whitehead et al. (1984–1986)			
<i>Carcharhinus limbatus</i> (Müller & Henle, 1839)	Whitehead et al. (1984–1986)				
Centrophoridae					
<i>Centrophorus granulosus</i> (Bloch & Schneider, 1801)	Whitehead et al. (1984–1986)	Whitehead et al. (1984–1986)	Benli et al. (1993)		
<i>Centrophorus uyato</i> (Rafnesque, 1810)			Meriç (1995)		
Squatinae					
<i>Squatina aculeata</i> Cuvier, 1829	Başusta (2002)	Filiz et al. (2005)			A
Dasyatidae					

<i>Himantura leoparda</i> (Manjaji-Matsumoto & Last, 2008)	Yucel et al. (2017)				IP
<i>Dasyatis marmorata</i> (Steindachner, 1892)	Erguden et al. (2014)				A
Mobulidae					
<i>Mobula japonica</i> (Müller & Henle, 1841)	Sakalli et al. (2016)				IP
Bony Fishes					
Notacanthidae					
<i>Notacanthus bonaparte</i> Risso, 1840	Başusta et al. (2002a);	Bilecenoğlu et al. 2014			A
Muraenidae					
<i>Enchelycore anatina</i> (Lowe, 1838)	Yokes et al. (2002)	Okuş et al. (2004)			A
Synphobranchidae					
<i>Dysomma brevirostre</i> (Facciola, 1887)	Bilecenoğlu et al. 2014	Aydın et al. (2009)			A
Ophichthidae					
<i>Apterichtus caecus</i> (Linnaeus, 1758)	Fricke et al. (2007)				A
<i>Pisodonophis semicinctus</i> (Richardson, 1848)	Yağlıoğlu & Ayas (2016)	Bilecenoğlu et al. (2009)			A
Plotosidae					
<i>Plotosus lineatus</i> (Thunberg, 1787)	Doğdu et al. (2016)				IP

Nettastomatidae					
<i>Nettastoma melanurum</i> Rafinesque, 1810	Başusta et al. (2002b);	Bilecenoglu et al. 2014			A
<i>Facciolella oxyrhyncha</i> (Bellotti, 1883)	Golani et al. (2006)	Leblebici et al. (2010)			A
Clupeidae					
<i>Etrumeus golanii</i> DiBattista, Randall & Bowen, 2012	Başusta et al. (1997)	Okuş et al. (2004)			IP
<i>Herklotsichthys punctatus</i> (Rüppell, 1837)	Whitehead et al. (1984-1986)				IP
Dussumeriidae					
<i>Dussumieria elopsoides</i> Bleeker, 1849	Ben-Tuvia (1953)				IP
Engraulidae					
<i>Stolephorus insularis</i> Hardenberg, 1933	Dalyan et al. (2014)				IP
<i>Encrasicholina punctifer</i> Fowler, 1938	Çiftçi et al. (2017)				IP
Chanidae					
<i>Chanos chanos</i> (Forsskål, 1775)	Özvarol & Gökoğlu (2012)				IP
Synodontidae					
<i>Saurida lessepsianus</i> Russell, Golani & Tikochinski, 2015	Ben-Tuvia (1966)	Ben-Tuvia (1973)			IP
Bregmacerotidae					

<i>Bregmaceros atlanticus</i> Goode & Bean, 1886	Yılmaz et al. (2004)				IP
Moridae					
<i>Lepidion lepidion</i> Risso, 1810		Bilecenoğlu et al. 2014			A
Gobiesocidae					
<i>Apletodon incognitus</i> Hofrichter & Patzner, 1997	Bilecenoğlu and Kaya (2006a)	Bilecenoğlu et al. 2014			A
Atherinidae					
<i>Atherinomorus forskalii</i> (Rüppell, 1838)	Kosswig (1950)	Geldiay (1969)			IP
Hemiramphidae					
<i>Hemiramphus far</i> (Forsskål, 1775)	Kosswig (1950)	Kosswig (1950)			IP
Exocoetidae					
<i>Parexocoetus mento</i> (Valenciennes, 1847)	Ben-Tuvia (1966)	Ben-Tuvia (1966)			IP
Holocentridae					
<i>Sargocentron rubrum</i> (Forsskål, 1775)	Kosswig (1950)	Kosswig (1950)	Artüz & Golani 2018		IP
Fistulariidae					
<i>Fistularia commersonii</i> Rüppell, 1838	Bilecenoğlu et al. (2002)	Bilecenoğlu et al. (2002)			IP
<i>Fistularia petimba</i> Lacepède, 1803	Ünlüoğlu et al. (2017)				IP

Syngnathidae					
<i>Hippocampus fuscus</i> Rüppell, 1838	Gokoglu et al. (2004)				IP
<i>Syngnathus rostellatus</i> Nilsson, 1855	Gokoglu et al. (2004)				A
Scorpaenidae					
<i>Pterois volitans</i> (Linnaeus, 1758)	Gurlek et al. (2016a)				IP
<i>Pterois miles</i> (Bennett, 1828)	Turan et al. (2014a)	Turan & Öztürk (2015)			IP
Synanceiidae					
<i>Synanceia verrucosa</i> Bloch & Schneider, 1801	Bilecenoğlu (2012)				IP
Serranidae					
<i>Epinephelus coioides</i> (Hamilton, 1822)	Gökoğlu et al., (2015)				IP
<i>Cephalopholis taeniops</i> (Valenciennes, 1828)		Engin et al. (2016)			A
Terapontidae					
<i>Pelates quadrilineatus</i> (Bloch, 1790)	Mater & Kaya (1987)				IP
Apogonidae					
<i>Apogonichthyoides pharaonis</i> (Bellotti, 1874)	Mater & Kaya, (1987)	Okuş et al. (2004)			IP
<i>Jaydia smithi</i> Kotthaus, 1970	Goren et al. (2009)				IP

<i>Jaydia queketti</i> (Gilchrist, 1903)	Eryılmaz & Dalyan (2006)	Filiz et al. (2012)			IP
<i>Cheilodipterus novemstriatus</i> (Rüppell, 1838)	Turan et al. (2015)				IP
<i>Ostorhinchus fasciatus</i> (White, 1790)	Turan et al. (2010)	Bilecenoğlu et al. (2013)			IP
Priacanthidae					
<i>Priacanthus hamrur</i> (Forsskål, 1775)	Ergüden et al. (2018)				IP
<i>Priacanthus prolixus</i> Starnes, 1988	Gürlek et al. (2017)				IP
<i>Priacanthus sagittarius</i> Starnes, 1988	Gökoğlu & Teker (2018)				IP
Sillaginidae					
<i>Sillago suezensis</i> Golani, Fricke & Tikochinski, 2013	Gücü et al. (1994)	Bilecenoğlu (2004)			IP
Rachycentridae					
<i>Rachycentron canadum</i> (Linnaeus, 1766)		Akyol & Ünal (2013)			IP
Carangidae					
<i>Alepes djedaba</i> (Forsskål, 1775)	Akyüz (1957)	Geldiay (1969)	Artüz & Kubanç (2014)	Turan et al. (2017)	IP
<i>Decapterus russelli</i> (Rüppell, 1830)	Sakınan & Örek (2011)				IP
<i>Seriola fasciata</i> (Bloch, 1793)	Kapiris et al. (2014)				A

<i>Trachurus indicus</i> Nekrasov, 1966	Dalyan & Eryilmaz (2009)				IP
<i>Trachurus declivis</i> (Jenyns, 1841)	Gurlek et al. (2016b)				IP
Leiognathidae					
<i>Equulites elongatus</i> (Günther, 1874)	Irmak et al. (2015)				IP
<i>Equulites klunzingeri</i> (Steindachner, 1898)	Erazi (1943)	Ben-Tuvia 1966			IP
Haemulidae					
<i>Pomadasys incisus</i> (Bowdich, 1825)	Whitehead et al. (1984–1986)	Whitehead et al. (1984–1986)			A
<i>Pomadasys stridens</i> (Forsskål, 1775)	Bilecenoğlu et al. (2009)	Akyol&Ünal (2016)			IP
Sparidae					
<i>Argyrops filamentosus</i> (Valenciennes, 1830)	Gürlek et al. (2016c)				IP
Lethrinidae					
<i>Monotaxis grandoculis</i> (Forsskål, 1775)	Bilecenoğlu (2007)				IP
Nemipteridae					
<i>Nemipterus randalli</i> Russell, 1986	Bilecenoğlu (2008)	Gulsahin and Kara (2013)			IP
Mullidae					

<i>Parupeneus forsskali</i> (Fourmanoir & Guézé, 1976)	Çinar et al. (2006)				IP
<i>Upeneus moluccensis</i> (Bleeker, 1855)	Kosswig (1950)	Kosswig (1956)			IP
<i>Upeneus pori</i> Ben-Tuvia & Golani, 1989	Kosswig (1950)	Akyol et al. (2006)			IP
Pempheridae					
<i>Pempheris rhomboidea</i> Kossmann & Räuber, 1877		Akyol et al. (2017)			IP
<i>Pempheris mangula</i> Cuvier, 1829	Bilecenoglu et al. (2002)				IP
Chaetodontidae					
<i>Heniochus intermedius</i> Steindachner, 1893	Gokoglu et al. (2003)				IP
Pomacentridae					
<i>Abudefduf saxatilis</i> (Linnaeus, 1758)		Bilecenoğlu (2016)			A
Mugilidae					
<i>Liza carinata</i> (Valenciennes, 1836)	Kosswig (1956)				IP
<i>Planiliza haematocheila</i> (Temminck & Schlegel, 1845)		Kaya et al. (1998)	Ünsal (1992)	Ünsal (1992)	IP
Labridae					
<i>Pteragogus trispilus</i> Randall, 1981	Taşkavak et al. (2000)	Bilecenoğlu et al. (2002)			IP
Scaridae					

<i>Scarus ghobban</i> Forsskål, 1775	Turan et al. (2014b)				IP
Champsodontidae					
<i>Champsodon capensis</i> Regan, 1908	Dalyan et al. (2012)	Mytilineou et al. (2016)			IP
<i>Champsodon nudivittis</i> (Ogilby, 1895)	Çiçek & Bilecenoğlu (2009)	Filiz et al. (2014)			A
<i>Champsodon vorax</i> Günther, 1867	Gökoglu & Özvarol (2013)	Yapici et al. (2016)			IP
Blenniidae					
<i>Parablennius thysanius</i> (Jordan & Seale, 1907)	Özbek et al. (2013)				IP
<i>Petroscirtes ancylodon</i> Rüppell, 1835	Taşkavak et al. (2000)	Okus et al. (2006)			IP
Callionymidae					
<i>Callionymus filamentosus</i> Valenciennes, 1837	Gücü et al. (1994)	Bilecenoğlu et al. 2014			IP
<i>Diplogrammus randalli</i> Fricke, 1983		Seyhan et al. (2017)			IP
<i>Synchiropus sechellensis</i> Regan, 1908	Gökoğlu et al. (2014)				IP
Gobiidae					
<i>Oxyurichthys petersii</i> (Klunzinger, 1871)	Bilecenoğlu et al. (2002)				IP
<i>Vanderhorstia mertensi</i> Klausewitz, 1974	Bilecenoğlu et al. (2008)	Çinar et al. (2011)			IP

<i>Trypauchen vagina</i> (Bloch & Schneider, 1801)	Akamca et al. (2011)				IP
<i>Corcyrogobius liechtensteini</i> (Kolombatović, 1891)		Bilecenoğlu (2016)			A
Ephippidae					
<i>Platax teira</i> (Forsskål, 1775)	Bilecenoğlu & Kaya (2006b)				IP
Siganidae					
<i>Siganus luridus</i> (Rüppell, 1829)	Ben-Tuvia (1973)	Ben-Tuvia (1973)			IP
<i>Siganus rivulatus</i> Forsskål & Niebuhr, 1775	Kosswig (1950)	Tortonese (1947)	Artüz & Koç (2012)		IP
Sphyaenidae					
<i>Sphyaena chrysotaenia</i> Klunzinger, 1884	Akyüz (1957)	Geldiay (1969)			IP
<i>Sphyaena viridensis</i> Cuvier, 1829	Mater & Bilecenoğlu (1999)	Bizsel & Cihangir (1996)			A
Scombridae					
<i>Scomberomorus commerson</i> (Lacepède, 1800)	Fischer et al. (1987)	Buhan et al. (1997)			IP
Cynoglossidae					
<i>Cynoglossus sinusarabici</i> (Chabanaud, 1931)	Akyüz (1957)	Bilecenoğlu et al. (2014)			IP
Monacanthidae					

<i>Stephanolepis diaspros</i> Fraser-Brunner, 1940	Kosswig (1950)	Kosswig (1950)	Bilecenoğlu et al. (2013)		IP
Ostraciidae					
<i>Ostracion cubicus</i> Linnaeus, 1758	Gerovasileiou et al. (2017)				IP
Tetraodontidae					
<i>Lagocephalus sceleratus</i> (Gmelin, 1789)	Bilecenoğlu et al. (2006)	Akyol et al. (2005)	Artüz & Kubanç (2015)		IP
<i>Lagocephalus spadiceus</i> (Richardson, 1845)	Kosswig (1950)	Ben-Tuvia (1966)	Tuncer et al., (2008)		IP
<i>Lagocephalus suezensis</i> Clark & Gohar, 1953	Avsar & Cicek, (1999)	Bilecenoglu et al. (2002)			IP
<i>Lagocephalus guentheri</i> Miranda Ribeiro, 1915	Erguden et al. (2017)	Akyol & Aydın (2016)	Tuncer et al. (2008)		IP
<i>Sphoeroides pachygaster</i> (Müller and Troschel, 1848)	Mater & Bilecenoğlu (1999)	Eryılmaz et al. (2003)			A
<i>Torquigener flavimaculosus</i> Hardy & Randall, 1983	Bilecenoglu, (2003)	Bilecenoğlu et al. (2014)			IP
<i>Tylerius spinosissimus</i> (Regan, 1908)	Turan and Yağlıoğlu (2011)				IP

When historical increases (in decades) of the distribution of first occurrence of non-indigenous fish species in Turkish Marine waters were analysed with colour density map, there is gradual clear increase of non-indigenous species along the Turkish marine waters (Figure 1). Especially, the Iskenderun Bay is a hot spot region for the occurrence and receiving the non-indigenous fish species in Turkish marine waters. The second hot spot region seems to be Muğla coast, but this is mostly due to the records of species that were only reported from the Aegean Sea coast of Turkey as first occurrence without location which was indicated from Muğla coasts since this coast is entrance or gate of the Aegean Sea for the Atlantic and Indo-Pacific migrants.

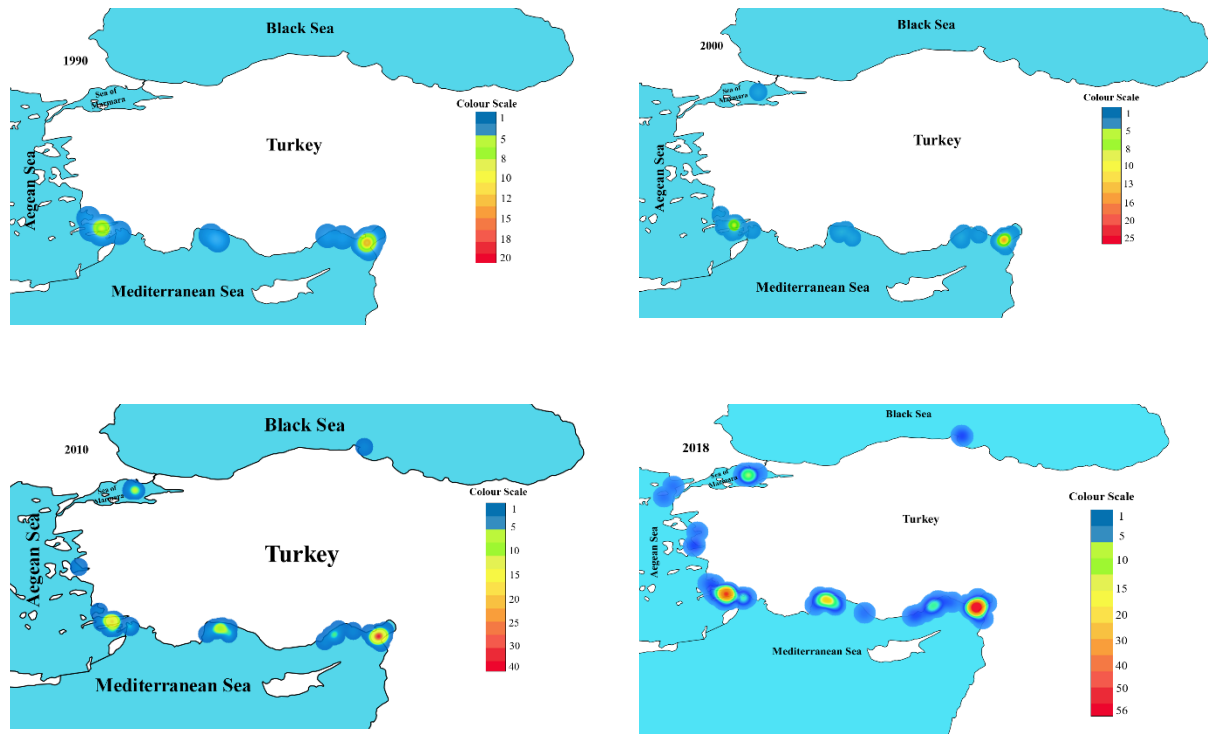


Figure 1. Colour density map showing historical increase (in decades) of the distribution of first occurrence of non-indigenous fish species in Turkish Marine waters, including bony, Elasmobranch and jawless species, along Turkish coasts. Colour scale gives the number of species.

The distribution of first occurrence of total non-indigenous bony and Elasmobranch fish species in Turkish marine waters are giving similar pattern (Figure 2). For both bony and Elasmobranch non-indigenous species, the Iskenderun Bay seems to be hot spot region. Interestingly, there are more species recorded in the Marmara Sea than that the Aegean Sea which may indicate migration pathway in the Aegean sea may be occurring in the Greek coastal waters.

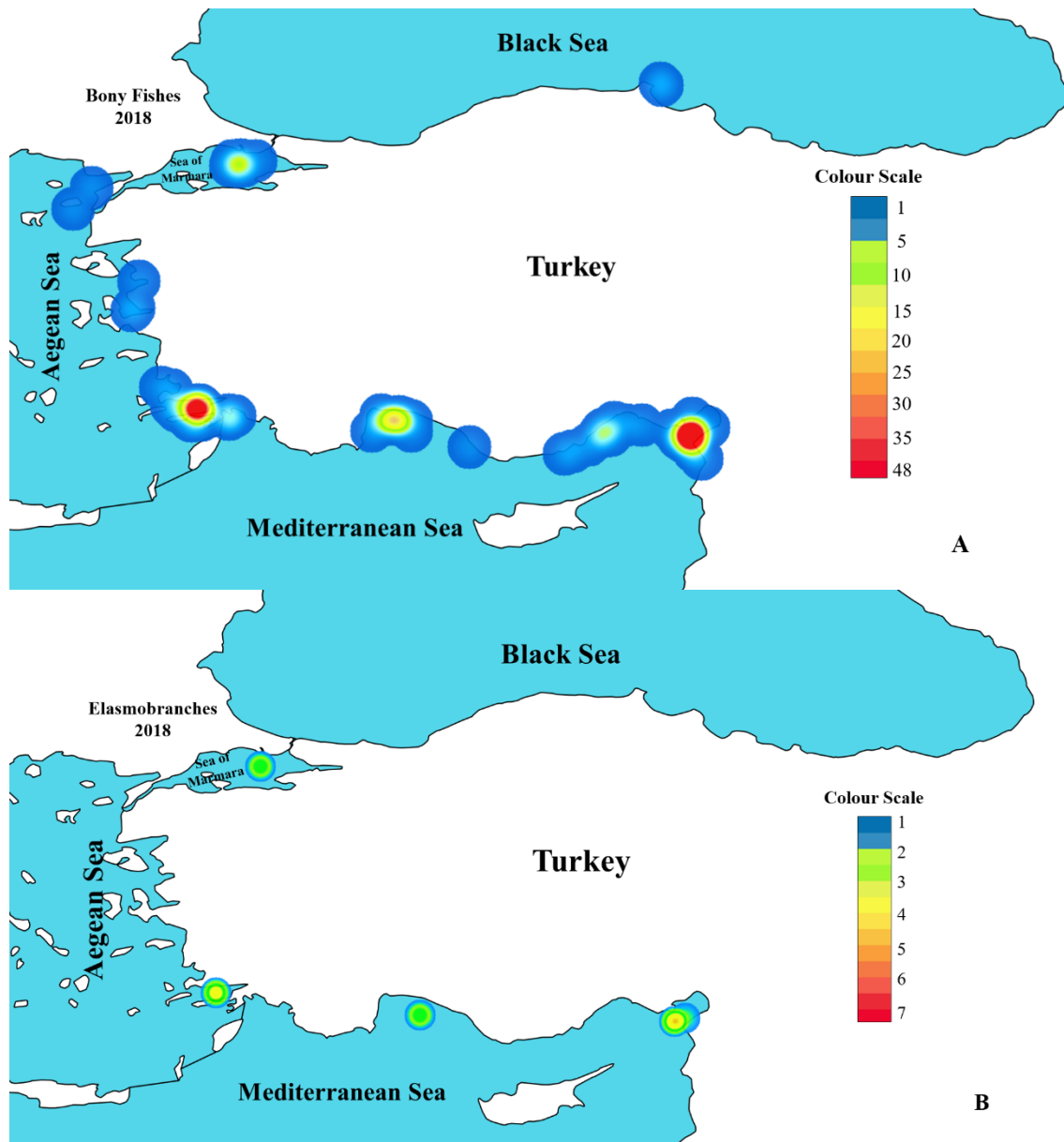


Figure 2. Colour density map showing the distribution of first occurrence of total non-indigenous bony (A) and Elasmobranch (B) fish species along Turkish coasts in September 2018.

When the time-series data of cumulative increase in non-indigenous fish diversity in Turkish Marine waters was analysed, there is high increase of number of non-indigenous fish species occurring in the Turkish marine waters (Figure 3). Interestingly, low number of entrance/occurrence of non-indigenous species between 1960-1980 years was observed in Turkish marine waters.

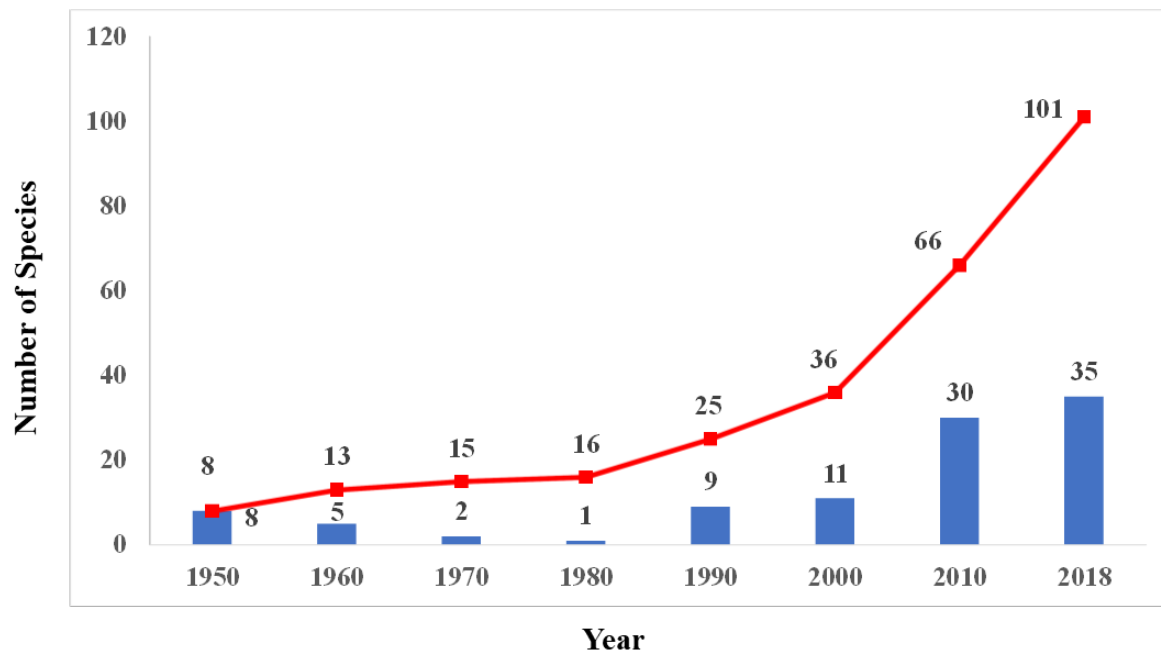


Figure 3. Time-series data of cumulative increase in non-indigenous fish diversity in Turkish Marine waters (solid line indicates cumulative increase in non-indigenous fish diversity; bars indicate the total number of non-indigenous species recorded in Turkish Marine Waters).

Discussion

The spread of non-native species into Turkish marine waters and their impacts on the host environment is of much concern to ecologists and fishery managers. Invasive non-indigenous species have adverse effects and threaten native biological diversity and the ecological stability of invaded ecosystems which are resulting economic and ecological consequences.

There is an increase in the number of non-indigenous species in Turkish marine waters (Figure 3). Climate change and overfishing in addition to enlargement of the Suez Canal are two major threats to biodiversity in the Mediterranean Sea (Dukes, 2003; Turan et al. 2016; Galil et al. 2017). Of course, there are other additional factors such as destruction of habitats and the introduction of harmful pollutants. The Iskenderun Bay is a hot spot region for non-indigenous of both bony and Elasmobranchs species which may be used as a pilot region for observation, monitoring and warning studies or activities for the non-indigenous species.

The factors contributing to the increase the non-indigenous species are quite evident. The impact of the non-indigenous species in Turkish marine waters should be constantly monitored, and strategies and dynamic management plans should be developed. The ecosystem based management concerning non-indigenous species should also be placed in the fishery management policies. The given check list has also of crucial importance in prioritizing the marine protected areas scheduled to be established.

Acknowledge

Thanks to the General Directorate of Agricultural Research and Policies department of Republic of Turkey Ministry of Agriculture and Forestry (TAGEM 16/AR-GE/21) for financial support.

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