Chapter

Non-Indigenous Marine Fish in Syria: Past, Present and Impact on Ecosystem, and Human Health

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Abstract

Biological invasions have posed a major threat to global and regional biodiversity. The Mediterranean, one of the world's main biodiversity hotspots, has long suffered from multiple and recurrent invasions. Due to the geographical location of Syria on the eastern Mediterranean coast, this chapter includes a historical and recent study over the past hundred years of the biodiversity reality of fish fauna in Syrian marine waters (as a representative part of the Levantine Basin). It also includes the evolution non-native fish species number that migrated to this area, both from the Red Sea (through the Suez Canal) and from its original habitats in both Indian and Pacific Ocean, or from the Atlantic Ocean through the Strait of Gibraltar. Then, its spread extended to Syrian territorial waters due to the impact of climate change, which led to environmental changes in the characteristics of the marine waters. An explanation will also be given of the impact of non-indigenous species on native species such as competition for food, ecological niches, and predation, as well as the positive and negative effects on the economy and human health. The consumption of some invasive species, like buffer fish rich in tetrodotoxin, may lead to severe intoxication, sometimes to death.

Keywords: alien species, Lessepsian migration, Mediterranean Sea, tropicalization, marine ecosystems, range extension, Syria

1. Introduction

The habitats of the world's seas and oceans are under siege by invasive alien species, leading to adverse and irreversible consequences for native biodiversity, ecosystem services, the economy, and human health. However, there are some positive aspects resulting from the migration of certain species of high economic value (such as certain types of fish, mollusks, and crustaceans), provided that there is no intense environmental and food competition with local species. Climate change, the increase in the number, tonnage and speed of merchant ships, the widening and deepening of artificial channels, the pollution, and the increase in various human activities contribute to the success of the introduction and establishment of these species. The competition on habitats is a major threat to the structure and functioning of critical marine communities, destroys the exploitable areas, or reduces the productivity of marine environments. In this context, long-term monitoring studies have become necessary to assess the magnitude of these factors and prepare effective management plans to deal with these challenging issues [1]. The Mediterranean, one of the main biodiversity hotspots in the world, has always suffered from multiple and recurrent invasions. The first alien species recorded in the Mediterranean were a pair of fouling serpulid polychaetes, *Hydroids dianthus* Morch, 1863, and *H. diramphus* (Verrill, 1873), collected from the ports of Izmir and Naples in 1865 and 1870, respectively [2, 3]. As the Suez Canal was inaugurated in 1869, we can say that the arrival of these two species in the Mediterranean is due to cargo or transport ships. The next two species were Red Sea mollusks, *Pinctada radiata* (Leach, 1814) and *Cerithium scaridum* Philippi, 1848, collected at Alexandria and Port Said in 1874 and 1883, respectively [4, 5], announcing the Eritrean invasion of the Mediterranean Sea. The influx of alien species has continued since, and evolves with time, human activities, climate change and resulting changes in the physicochemical characteristics of Mediterranean water.

The impacts of alien species have not been undertaken in a serious and deepened way until the beginning of the twenty-first century. The preponderance of species arriving in the Mediterranean *via* the Red Sea (called Eritrean) in the south-east of the Mediterranean, which was called integral Syria (**Figure 1**), or natural Syria [6].

The invasions have been perceived until the beginning of the twenty-first century as singular and widely in the world that bioinvasions constitute one of the most important elements of global changes, with often harmful effects on biodiversity, the economy, and human health.

Many atlases and articles (fish, crustacean and mollusks) summarize existing knowledge of the scale and impact of alien species in the Mediterranean [7, 8]. Research publications, surveys, and conference abstracts indicate that the alien species recorded in the Mediterranean Sea till 2020 more than 188 species of fish are thus

Figure 1.
Map of the coast of greater Syria in 1914, this coast that grovel surveyed marine life during 1929–1931.

broken down: 25 introduced by shipping, mariculture and aquarium releases, or by other human activities; 106 species crossed the Suez Canal; 57 Atlantic species whose arrival in the Mediterranean Sea is attributed to unassisted migration through the Strait of Gibraltar [9]. Through our current reference study, we estimate the number of fish species that entered the Mediterranean until the end of 2022 at about 214 species, of which about 120 species entered through the Suez Canal, 65 species of Atlantic species, and 29 species introduced by shipping, aquaculture, or other human activities. We will focus in this chapter on the group of exotic fish invading the territorial waters of (current) Syria, which constitute the extreme east of the Mediterranean coast and a hot spot to receive species introduced into the Mediterranean Sea *via* the Suez Canal. This is attributed to the great Atlantic current from west toward the east (Coriolis Force), bringing with it the larvae, eggs, and adults preferably toward the east and north in front of the east coast, before gradually scattering in the eastern basin, and then throughout the Mediterranean (**Figure 2**).

Figure 2 clarifies that the eastern coast of the Mediterranean, with the Syrian coast in the middle, is primarily subject to the arrival of migratory species from the Red Sea (Lessepsian), due to the main marine current heading from east to west and then to the north in a counterclockwise direction, in addition to the environmental characteristics (temperature and salinity), closer to the characteristics of the waters of the Red Sea than the rest of the Mediterranean.

Syrian sea water occupies about 4000 km^2 of the Levantine Basin in the eastern part of the Mediterranean, where the Syrian coast extends 183 km from the Turkish border in the north to the Lebanese border in the south (**Figure 3**). The Syrian marine waters as part of the Levantine Basin and the easternmost part of the Mediterranean Sea are characterized by high salinities and high temperature. In the Mediterranean, salinity exhibits an east ward increase, from approximately 37.5‰ in the west to 39.5‰ in the east; temperature increases from west to east, ranging from 15 to 26°C [11]. Gruvel [6] was the first specialist to report on the marine ichthyofauna of the Eastern

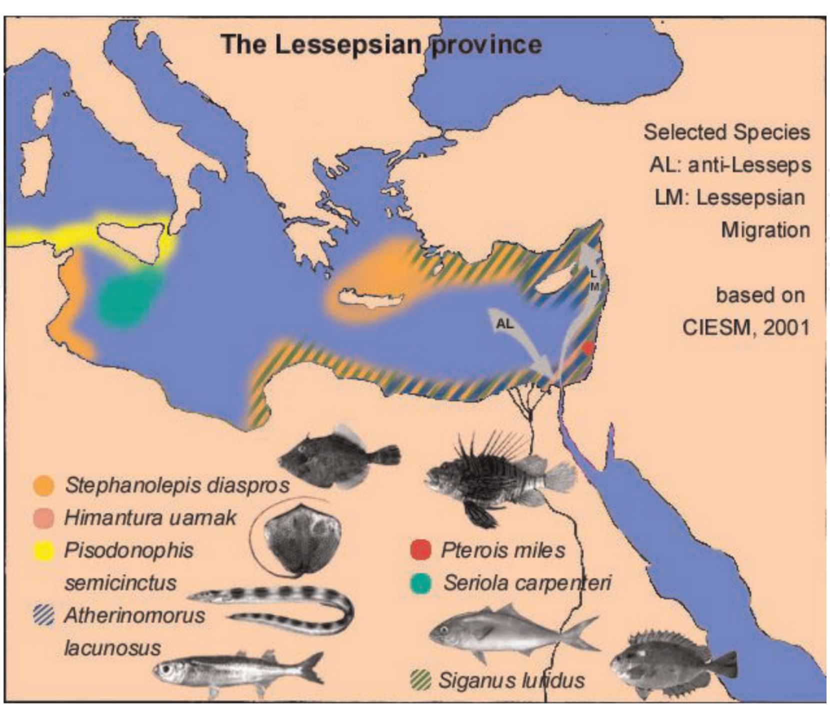

Figure 2.
Species migration from the Red Sea to eastern coast of the Mediterranean.

Figure 3.
The exclusive economic zone (EEZ) and shelf area (to 200 m depth) of Syria [10].

Mediterranean Sea. Forty years later, a local study was carried out on the marine ichthyofauna from the Syrian coast [12]. During the last three decades, several studies have been carried out sporadically, and all recorded species have been documented with voucher specimens, photographs, and scientific publications [13–17].

2. Definitions and working methods

An alien species is defined as an organism present outside its known or consensual range [18]. Alien species were grouped into four main categories, namely established, casual, questionable, and cryptogenic, the definition of these terms can be found in Ref. [19]. Clearly and concisely, the established species are the exotic species with self-maintaining populations; casual species are the species which were reported only once in the region; questionable species are the species which were reported without sufficient information and their taxonomic status is uncertain; cryptogenic species are the species with no definite evidence of their native or introduced status according to Carlton [20]. Other important definitions to know are as follows:

Invasive species are the established exotic that have overcome biotic and abiotic barriers in the region and are able to expand their distributional ranges through the production of fertile offspring, with noticeable impact on the prevailing ecosystem.

The Lessepsian migration refers to the migration through the Suez Canal (planned by Ferdinand de Lesseps), generally, from the Red Sea to the Mediterranean, and rarely in an opposite way, favored by two distinct man-made events: the creation of a waterway between the Indo-Pacific and the Mediterranean basins and the control of the Nile fresh-water outflow.

Range expansion refers to species that have recently arrived in a given area by natural dispersal from a neighboring area in which they are native, without the intentional or unintentional intervention of human.

The increase in shipping and the opening of the Suez Canal predates modern studies of Mediterranean marine taxa, saving mollusks and fish, by at least half a century. Since the beginning of the twentieth century, extensive biological studies have been carried out in the Mediterranean, allowing a reasonable measure of confidence in the separation of alien from native biota in the best-known taxa. Since the probability of encountering a stray animal at sea is less and less important, most recorded alien species are considered "established" species that have self-sustaining populations of some duration. It is recognized that some alien species may not maintain their populations over time, and therefore, a single record dating back decades may be considered an ephemeral entry. The distinction between "established" and "ephemeral" extraterritorials can vary in space and time and is sometimes difficult to discern and largely circumscribed by our unfamiliarity with the marine environment. This study is geographically restricted to the Levantine Basin—in general—and specifically the Syrian marine waters. The list of species was taken from several sources. Primary sources include research articles, fish fauna inventories, fisheries management studies and reports, author-supervised, and unpublished M.Sc. and Ph.D. theses conducted over the past 30 years. The dataset includes the native range of the extraterritorial, and its means of introduction, whether through the Suez Canal, ships (drilling hull transport, fouling, crevicultural or clinging species, and ballast), marine cultivation (intentional or not), and other commercial introductions (ornamental, bait, edible species).

The results presented in this chapter depend mainly on the results of field research conducted by the author and his team during the past three decades, represented by the results of master's and doctoral researches and the author's research whose results have been published in scientific journals. In addition, the data for this chapter included a review of the results of work published by other researchers in the area. The work included following up the landing of fish in fishing ports, studying the quantitative and qualitative composition of the catch, as well as following up with local fishermen to inform the author of any unfamiliar fish species so that the author or a member of his team could bring the fish sample to the laboratory for study and classification, and then the results in a scientific journal are published. Each reference will be mentioned next to each new result in succession in the results and discussion section.

3. Results and discussion

3.1 List of species and composition of fish fauna

A total of 106 species of exotic fish have been identified in Syrian marine waters until end of August 2023. While the number in 1931 was only seven species [6], in 1976 it rose to 11 species [12], while in 2005 it reached 54 species [15], and since that date the acceleration in recording the presence of exotic species has now reached 106 species out of 343 species (**Tables 1** and **2**). The total number of fish species in Syrian marine waters, that is, about 30% of the total fish fauna in this region, and this large increase in the number of alien species are attributed to the following:

1. climate changes and the subsequent changes in the environmental characteristics of water and the food chain,

Category	Species	Families	Orders	Alien
Chondrichthyes	50	25	10	5
Actinopterygii	292	98	26	101
Class:Hyperoartia	1	1	1	—
Total	343	124	37	106

Table 1.
Number of recorded fish species and lamprey from Syrian Marin water, and number of alien species.

2. the increase in human activities represented by fishing and transportation,

3. the second Suez Canal was built, which increased the migration of more tropical species from the Red Sea to the Mediterranean (**Figure 3**), and

4. increased monitoring and scientific research in the field of biodiversity and ecosystems.

3.2 Coexistence with local species

Alien species composition differs between ecoregions in the Mediterranean; studies have shown that these differences are greater for species introduced by Lessepsian and for aquaculture species. The spatial pattern of biodiversity of native and exotic species is different: The overall richness of native species decreases from northwestern to southeastern regions, while the opposite trend is observed for exotic species [19].

The impact of the exotic migration was enormous on the ecosystem of the Levant Basin, within which the Syrian marine waters lie. The fact that many species have proven successful in the new environment indicates that the nutritional requirements of many migratory species reflect the non-selective nature of their feeding habits. This adaptation is of great importance to any immigrant in its new environment. It is self-evident that successful colonization can only be established when the overlap between the environmental conditions in the source and target regions is within the colonizer's tolerance (**Figure 4**). Since these environments are not identical, the colonizing population will respond to new selective pressures by moving away from the parent population, thus becoming more adapted to their new habitat. The successful establishment of the large number of exotic species raises the question of complex interactions with native species. However, this high number is determined mainly by the ability of the migrants to occupy a niche in the new ecosystem, maintain itself by successful breeding when environmental and hydrological conditions are suitable for reproduction and growth of larvae to maturity, and then replenish and develop their stocks in the new environment.

3.3 Impact of alien species on marine ecosystems

The impact of alien species, known as biological contamination, is something that must be considered in environmental impact assessments [81]. Human-mediated introduction of marine species to a region outside their natural range of distribution is widely considered to be the major threat to indigenous species diversity and community structures. This can cause habitat modifications, changes in ecosystem functioning, introduction of new diseases and parasites, and genetic modifications, such as

Family	Species	Origin	Status	First record	Ref.
Apogonidae	*Apogon atradorsatus*	South-east pacific	sin	Alshawy et al., 2019a	[21]
	Apogonichthyoides pharaonic (mis id Apogon taeniatus)	Red sea Indo-Pacific	est	Sbaihi and Saad, 1992	[22]
	Cheilodipterus novemstriatus	Indian	est	Ali et al., 2018	[23]
	Epigonus constanciae	Western Mediterranean	N	Sbaihi, 1994 (as *Epigonus telescopus* (synonyme))	[13]
	Jaydia smithi	Red sea	sin	Alshawy et al., 2017	[24]
	Jaydia queketti	Western Indian Ocean	sin	Al shawy et al., 2019b	[25]
	Ostorhinchus fasciatus	Indo-West Pacific	sin	Al Shawy et al., 2019c	[26]
Argentidae	*Aregentina sphyraena*	Western Mediterranean		Saad and Sbaihi, 1995	[27]
	Glassanodon leioglossus	Western Mediterranean		Saad and Sbaihi, 1995	[27]
Atherinidae	*Atherinomorus forskalii (=Atherinomorus lacumosus)*	Red sea Indo-Pacific	est	Saad et al., 2002	[28]
	Atherinomorus lacunosus	Indo-Pacific	sin	Othman et al., 2022	[29]
	Atherinomorus pinguis (=Pranesus pinguis)	Red sea		Saad et al., 2002	[28]
Belonidae	*Ablennes hians*	Worldwide distribution	sin	Al Shawy et al., 2019d	[30]
	Tylosurus crocodilus (=Tylosrus corma)	Red sea Indian	est	Saad et al., 2002	[28]
Blenniidae	*Petroscirtes ancylodon*	Red sea Indian	est	Saad, 2002	[31]
Bramidae	*Brama brama*	Western Mediterranean	N	Saad and Sbaihi, 1995	[27]
Bregmacerotidae	*Bregmaceros nectabanus*	Atlantic and Indian Ocean and tropical western Pacific	sin	Othman & Galiya, 2019	[32]
Callionymidae	*Callionymus filamentosus*	Red sea Indo-Pacific	est	Saad and Sbaihi, 1992	[33]
Caproidae	*Capros aper*	Western Mediterranean	N	Saad and Sbaihi, 1995	[27]
Carangidae	*Aleps djedaba*	Red sea Indo-Pacific	est	Saad, 2002	[31]
Carangidae	*Naucrates ductor*	Eastern Atlantic and Indian Ocean	est	Ali-Basha et al., 2021	[34]
Chaetodontidae	*Chaetodon larvatus*	Indian	sin	Ali et al., 2017a	[35]
	Heniochus intermedius	Indo-West Pacific Ocean	sin	Saad et al., 2022a	[36]
Champsodontidae	*Champsodon nudivittis*	Indo-Pacific	est	Ali et al., 2017b	[37]

Family	Species	Origin	Status	First record	Ref.
Clupeidae	*Dussumieria elopsoides*	Red sea Indo-Pacific	est	Saad, 2002	[31]
	Etrumeus sadina (=Eutrimeus teres)	Red sea Indian	est	Saad, 2002	[31]
	Herklotsichthys punctatus	Red sea Indo-Pacific	est	Saad, 2005	[15]
Cynoglossidae	*Cynoglossus sinusarabici*	Red sea Indo-Pacific	est	Saad and Sbaihi, 1992	[33]
Dussumieriidae	*Dussumieria elopsoides*	Red sea Indo-Pacific	est	Saad, 2002	[31]
	Etrumeus sadina (=Eutrimeus teres)	Red sea Indo-Pacific	est	Saad, 2002	[31]
Epigonidae	*Epigonus denticulatus*	Western Mediterranean		Ibrahim et al., 2023	[38]
Exocoetidae	*Parexocoetus mento*	Red sea Indo-Pacific	est	Saad et al., 2002	[28]
Fistulariidae	*Fistularia commersonii*	Red sea Indo-Pacific	est	Saad, 2002	[31]
	Fistularia petimba	Atlantic and Indo-Pacific	sin	Hussein et al., 2019	[39]
Gadidae	*Micromesistius poutassou*	Western Mediterranean	N	Saad and Sbaihi, 1995	[27]
	Phycis phycis	Western Mediterranean	N	Saad and Sbaihi, 1995	[27]
	Gadiculus argenteus	Western Mediterranean	N	Saad and Sbaihi, 1995	[27]
Gobiidae	*Oxyurichthys petersi*	Red sea	est	Saad and Sbaihi, 1992	[33]
	Silhouetta aegyptia	Red sea Indian	est	Sbaihi and Saad, 1995	[27]
Gobiesocidae	*Lepadogaster lepadogaster*	Western Mediterranean	N	Saad and Sbaihi, 1995	[27]
	Lepadogaster candolli	Western Mediterranean		Saad and Sbaihi, 1995	[27]
Haemulidae	*Pomadasys stridens*	Indian	est	Saad, 2005	[15]
Hemiramphidae	*Hemiramphis far*	Red sea Indo-Pacific	est	Gruvel, 1931	[6]
	Hyporamphus affinis	Red sea Indo-Pacific	est	Saad, 1996	[39]
Heterenchelydae	*Panturichthys flowleri*	Western Mediterranean		Sbaihi, 1994	[13]
Holocentridae	*Sargocenrum rubrum*	Red sea Indo-Pacific	est	Anon, 1976	[12]
Labridae	*Pteragogus trispilus*	Indian	est	Soliman et al., 2014	[40]
	Symphodus bailloni	Eastern Atlantic	sin	Khrema et al., 2022	[41]

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Family	Species	Origin	Status	First record	Ref.
Leiognathidae	*Equulites klunzingeri* *(= Leiognathus kluningeri)*	Red sea Indo Pacific	est	Sbaihi and Saad, 1995	[27]
	Equulites popei	Indo-West Pacific	sin	Ibrahim et al., 2020	[42]
	Leiognathus berbis	Indo-Pacific	est	Alshawy et al., 2016	[43]
Lophotidae	*Lophotus lacepede*	Western Mediterranean		Ali et al., 2021	[44]
Lutjanidae	*Lutjanus fulviflamma*	Indo-Pacific:	sin	Saad et al., 2022	[45]
Monacanthidae	*Stephanolepis diaspros*	Red sea Indian	est	Gruvel, 1929	[6]
Mugilidae	*Liza carenata*	Red sea Indian	est	Saad, 1995	[46]
Mullidae	*Parupeneus forsskali*	Indian	est	Ali et al., 2016b	[47]
	Parupeneus rubescens	Indo-West Pacific		Sabour and Masri, 2022	[48]
	Upeneus moluccensis	Red sea Indo-Pacific	est	Gruvel, 1931	[6]
	Upeneus pori	Red sea	est	Sbaihi and Saad, 1995	[27]
Nemipteridae	*Nemipterus randalli*	Indian	est	Ali et al., 2013	[49]
Ophichthidae	*Ophisurus serpens*	Atlantic and Indo-Pacific	sin	Al Shawy et al., 2019d	[50]
Ophidiidae	*Dalophis imberbis*	Eastern Atlantic	rex	Capape et al., 2021	[51]
	Ophidion rochei	Mediterranean and Black Sea	rex	Othman et al., 2020	[52]
	Ophidion rochei	Mediterranean and Black Sea	rex	Othman et al., 2020	[52]
Ostraciidae	*Tetrosomus gibbosus*	Red sea Indo-Pacific	est	Saad, 2002	[31]
Pempheridae	*Pempheris rhomboidea* *Pempheris vanicolensis*	Red sea Indo-Pacific	est	Sbaihi and Saad, 1992 as P. vanicolensis	[22]
Platycephalidae	*Platycephalus indicus*	Red sea Indo-Pacific	est	Saad et al., 2002	[28]
Plotosidae	*Plotosus lineatus*	Indo-Pacific	est	Ali et al., 2015	[53]
Pomacanthidae	*Pomacanthus imperator*	Indo-Pacific	sin	Saad et al., 2018	[54]
	Pomacanthus maculosus	Red sea Western Indian Ocean		Capapé et al., 2023	[55]
Pomacentridae	*Abudefduf vaigiensis*	Indo-Pacific	sin	Saad et al., 2020a	[56]
Priacanthidae	*Priacanthus hamrur*	Indo-Pacific		Capape et al., 2022	[57]
	Priacanthus sagittarius	Indo-West Pacific	sin	Al Shawy et al., 2019e	[58]
Scaridae	*Scarus ghobban*	Indo-Pacific	est	Saad et al., 2018	[59]
Scombridae	*Scomberomorus commerson*	Red sea Indo-Pacific	est	Anon, 1976	[12]
	Scomber indicus	Indo-Pacific	sin	Othman et al., 2023	[60]

Family	Species	Origin	Status	First record	Ref.
Scorpaenidae	*Pterois miles*	Indian	est	Ali et al., 2016	[61]
	Pterois volitans	Indo-Pacific		Fandi et al., 2022	[62]
Serranidae	*Epinephelus areolatus*	Indo-Pacific	2 records	Al Mabruk et al., 2021	[63]
	Epinephelus caninus	Eastern Atlantic	est	Saad et al., 2020b	[64]
	Epinephelus fasciatus	Red sea	sin	Foulquie & Dupuy de la Grandrive, 2003	[65]
Siganidae	*Siganus javus*	Indo-Pacific	sin	Ibrahim et al., 2010	[66]
	Siganus luridus	Red sea Indian	est	Gruvel, 1931	[6]
	Siganus revulatus	Red sea	est	Gruvel, 1931	[6]
Soleidae	*Pegusa lascaris (=Solea lascaris)*	Western Mediterranean	N	Sbaihi, 1994	[13]
Sparidae	*Acanthopagrus bifasciatus*	Western Indian Ocean	sin	Saad et al., 2022b	[67]
	Crenidens crenidens	Red sea Indo-Pacific	est	Saad et al., 2002	[28]
	Pagellus bellottii	western Mediterranean	N	Sbaihi and Saad, 1992	[68]
	Pagellus bogaraveo	Eastern Atlantic and west Mediterranean	sin	Saad et al., 2020	[69]
	Pagrus major	Northwest Pacific	sin	Saad et al., 2022	[70]
	Rhabdosargus haffara	Red Sea	est	Saad, 2005	[15]
	Rhabdosargus sarba	Indo-West Pacific	sin	Hamwi and Ali-Basha, 2021	[71]
Sphyraenidae	*Sphyraena chrysotaenia*	Red sea Indo-Pacific	est	Saad, 2002	[31]
	Sphyraena flavicauda	Red sea Indo-Pacific	est	Saad et al., 2002	[28]
Synanceiidae	*Synanceia verrucosa*	Indo-Pacific	sin	Ibrahim et al., 2019	[72]
Syndontidae	*Saurida lessepsianus Saurida undosquamis*	Red sea Indo-Pacific	est	Anon, 1976 as S. undosquamis	[12]
Tetraodontidae	*Lagocephalus guentheri (=Lagocephalus spadiceus)*	Red sea	est	Anon, 1976 as L. spadiceus	[12]
	Lagocephalus lagocephalus	Circumglobal		Alshawy et al., 2019c	[73]
	Lagocephalus sceleratus	Indo-Pacific	est	Khalaf et al., 2014	[74]
	Lagocephalus suezensis	Red sea	est	Saad et al., 2002	[28]
	Torquigener flavimaculosus	Indian	est	Sabour et al., 2014	[75]
Theraponidae	*Pelates quadrilineatus*	Red sea Indo-Pacific	est	Saad, 2005	[15]
	Terapon puta	Red sea Indo-Pacific	est	Saad, 2005	[15]

Family	Species	Origin	Status	First record	Ref.
Elasmobranchii:					
Dasyatidae	*Himantura uarnak*	Indo-Pacific	est	Ali et al., 2010	[76]
	Himantura leoparda	Indo-West Pacific	sin	Saad et al., 2021a	[77]
Rajidae	*Leucoraja circularis*	Eastern Atlantic	sin	Alkusairy and Saad, 2018	[78]
	Leucoraja fullonica	Eastern Atlantic	sin	Saad and Alkusairy, 2019	[79]
Torpedinidae	*Torpedo sinuspersici*	Indo-Pacific	cas	Saad et al., 2004	[14]
Jawless fishes (Class: Hyperoartia)					
Petromyzonidae	*Petromyzon marinus*	Northwestern Atlantic	sin	Saad et al., 2021b	[80]

Table 2.
Non endogenous fish in Syrian marine water, category, native range, and first records. Species in alphabetic order within each class and family. (Est = established, sin = single record, case = casual, rex = rang extending).

Figure 4.
Red Sea goatfish Parupeneus forsskali *that was recorded for the first time in the Syrian coast in 2015 [47]; it was able, within only 5 years, to become abundant in the catch with gill nets instead of the rest of the species of the mulledi family, and this is one of the examples of the competition of invasive species with indigenous species.*

hybridization with the native taxa [82], rabbitfishes (siganidae) have by now overgrazed a significant part of the eastern Mediterranean coast (including Syrian coast), degrading rich habitats of brown algal forests into bare rock, and such impacts, including completion with native herbivores, are likely to be exacerbated by climate change. In several instances, exotic species will outcompete native species, such as *Fistularia commersonii* and *Pterois miles*, and prey on various fish and invertebrates—some of commercial importance with impacts on both local population and fisheries. Our field study showed that *F. commersonii* is carnivorous and feed on many small fish species, such as *Sardinella* spp., *Sprarus spratus*, *Alosa fallax*, *Boops bops*. About 12–30 individual preys were found in the stomach of every specimen (**Figure 5**). The high fecundity rate, and its rapidly expanding population feeding on fish and some invertebrates, makes a decline of the biomass and causing damage and loss to fisheries yield [83, 84]. On the other hand, the results of a survey study during the years 2013–2014

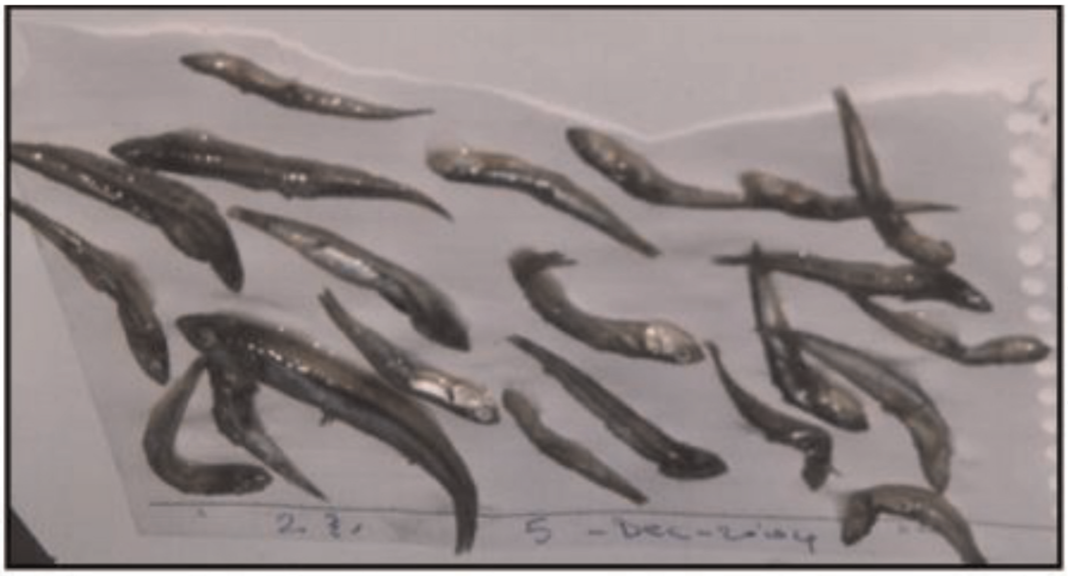

Figure 5.
The content of the digestive tube of one individual of the fish F. commersonii, *showing 22 individuals of prey belonging to several endemic species of small pelagic fish (and a greater number of these prey were found in other samples in several cases), indicating the danger of this exotic species to native fish fauna, biodiversity, and local fish stocks.*

showed that exotic fish (most of them are Lessepsian) constitute more than 27% of the weight catch by artisanal fishing (means gill net and trammel net) and more than 50 of trawl net in Syria [83, 84]. Comprehensive evaluation of the overall consequences of alien introductions must integrate the impact of climate change, which clearly reduces the suitability of the eastern Mediterranean waters (including Syrian waters) to several native fish species. This is already observed in this area, where no indigenous species of tropical origin are replacing the ecological functions of temperate native biota that are compromised by overfishing.

3.4 Impact of non-indigenous species on the public health

Fish invasions in many cases impact human health, and one of the best documented examples is provided the buffer fish *Lagocephalus scelertaus*, which has caused severe damages since its relative recent apparent in Syrian marine waters. The consumption of this invasive species, rich in tetrodotoxin, may lead to severe intoxication, sometimes to death. By examining hospital records in both Lattakia and Tartous during the past 10 years, it is clear that this fish has caused many cases of poisoning and several cases of death for consumers in Syria [85–87].

The marketing of this species is currently banned in Syria and in other Mediterranean countries. To inform local populations about the risks associated with this invasion, Syrian authorities and many non-governmental associations (NGO) have launched awareness campaigns (**Figures 6**–**8**), which have succeeded in reducing the risk of inadvertent consumption by obtaining information on the occurrence and abundance of this "unwanted guest." Other dangerous species include *Pterois miles*, *Plotosus lineautus*, *Synannceia verrucosa*, and two rabbitfishes (*Siganus luridus* and *Siganus rivulatus*) all possessing venomous spines and capable of causing severe injuries [88]. The impact of invasive fishes is not all negative, however. Often food provision is a clear benefit of invasions. That is the case of rabbitfishes, goatfishes (*Upeneus moluccensis, Upeneus pori*, *Parupeneus forsskali*), and other edible species such

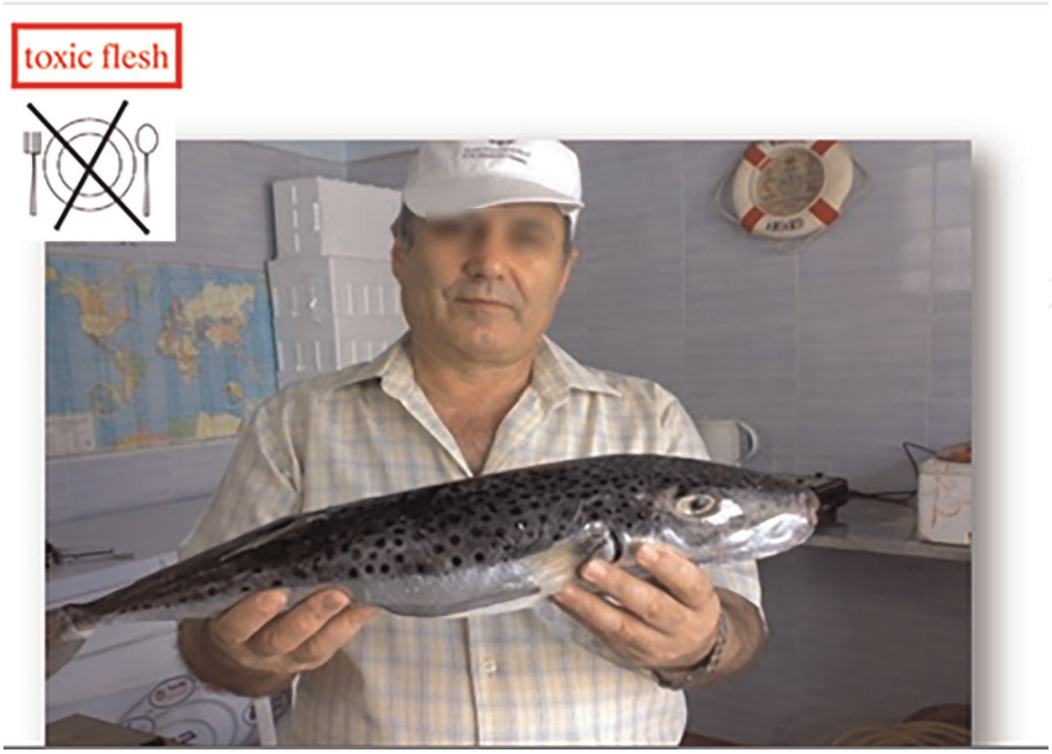

Figure 6.
*Example of campaign signaling the toxicity of the silver-cheeked toadfish (*Lagocephalus sceleratus*) in Syria (by Syrian society for aquatic environment protection (NGO) and general commission of fisheries and aquatic resources). The text illustrates how to distinguish from native pufferfishes. The poster illustrates the risk associated with the consumption of this toxic species.*

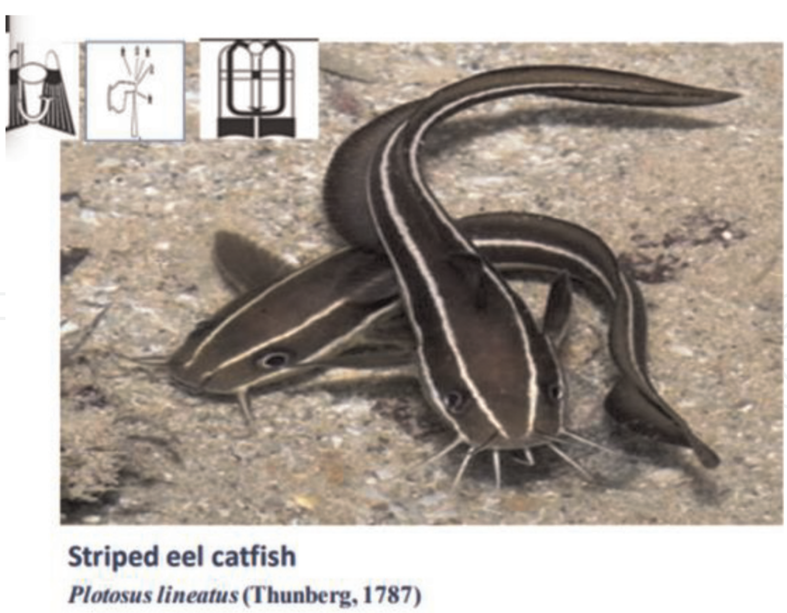

Figure 7.
*Example of campaign signaling the poisoning through prickling of strpeed eel catfish (*Plotosus lineatus*, (by Syrian society for aquatic environment protection (NGO)).*

as *Nemipterus randelli, Saurida lessepsianus*, and *Scomberomorus commerson*, which have over years developed abundant populations in the Leventine basin, to the point of becoming a target for local fisheries [10, 83].

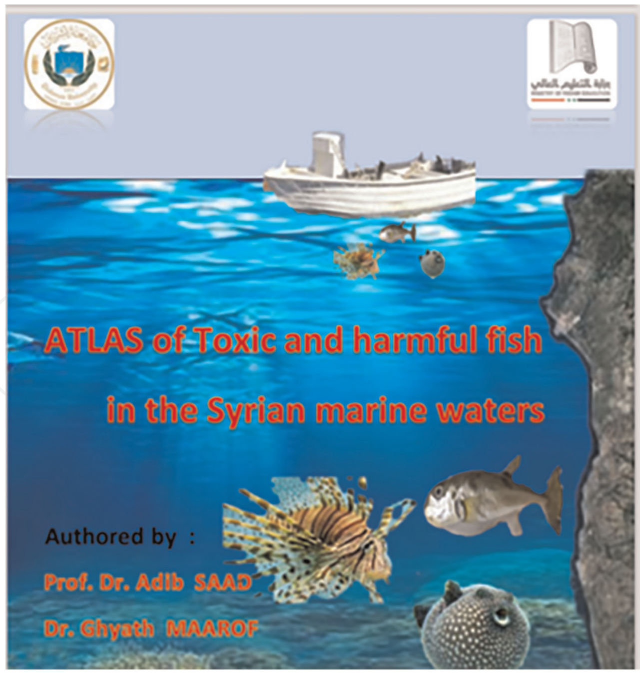

Figure 8.
The cover of the Atlas of toxic and harmful fish that threaten human health and community safety, which was published by Tishreen university and the Syrian Society for the Protection of the aquatic environment, addressed to the local population in Arabic [88].

A scientific explanation was provided for each hazard or damage, including toxins contained in certain species. The research also included illustrations of each fish species, explaining the harmful parts of the body, explaining the level of damage and danger caused by each fish species, as well as an explanation of how to prevent damage and the means of treating each type of damage: /9/ poisonous species in their flesh (i.e., poisoning of humans by eating their meat), /3/poisonous species of blood), and /13/ harmful and poisonous fish species through prickling or stinging poisonous thorns, and/ 4/ types of harmful cartilaginous fish through poisonous stinging with thorns on their body, especially the tail. In addition, / 4 / species of electric fishes that live in Syrian waters were documented (**Figure 8**) [88].

4. Conclusion

The present work elucidates that the marine waters of Syria, as a part of the Levantine basin, are under heavy invasion by alien species, mostly coming from the Red Sea and Indo-Pacific areas. Scientific and public interest in the species introductions and their impacts have resulted in the productions of new papers and synthesis on them and made great contributions to our understanding of the dimensions of this phenomenon. Therefore, this up-to-date inventory of the alien species on the coasts of Syria, apart from its scientific merits, can fulfill the needs of the regulatory requirements and environmental management options for decision makers. Unfortunately, strict precautions and regulations to limit the spread of invasive species have not been implemented in Syria.

It is necessary to consider the classification of non-indigenous and modern species, because these species, which differ in terms of entry pathways, also differ from each other in the ecological, social, and economic effects that they cause in the new environment (predatory fish and competition in the ecological habitat), as well as their impact on the community health of the population, locals, fishermen, and consumers (poisonous and stinging fish). These differences have been demonstrated by ecological and biological studies and practical solutions in the literature. In addition, these differences will directly affect the precautions taken in the sustainable management of the ecosystem and will therefore affect the success of these precautions.

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Conflict of interest

The authors declare no conflict of interest.

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