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Research Article

Alien marine fishes in Cyprus: update and new records

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Abstract

The Mediterranean Sea, due to its connection to the Red Sea via the Suez Canal, its heavy maritime traffic, and the effects of climate change is a hotspot of invasion by alien species. A survey carried out around Cyprus during September 2014 documented the occurrence of 25 alien fishes. Seven Lessepsian migrants (*Hippocampus fuscus* Rüppell, 1838, *Nemipterus randalli* Russell, 1986, *Ostorhinchus fasciatus* (Shaw, 1790), *Parupeneus forsskali* (Fourmanoir & Guézé, 1976), *Pomadasys stridens* (Forsskål, 1775), *Sphyraena obtusata* Cuvier, 1829 and *Spratelloides delicatulus* (Bennett, 1832)) were recorded for the first time, increasing to 35 the number of alien fishes recorded around the island. Four of these first records can be considered as 'established', whereas the 2013 first record of *Pterois volitans/miles* is confirmed by new findings placing the species as newly 'established' in Cyprus. All the recorded alien fishes of Cyprus are Lessepsian migrants, 80% of which can be considered established and four of them are invasive. The rapid increase of alien fish species over time in Cyprus supports the accelerating tropicalisation process observed elsewhere in the Mediterranean over the last decades. Furthermore, the new finding of the tropical Atlantic immigrant *Enchelycore anatina* (Lowe, 1839) is documented.

Key words: Mediterranean Sea, first record, alien species, Lessepsian migration, Atlantic species, range extension, tropicalisation

Introduction

The Mediterranean Sea is currently a hotspot for marine bio-invasions (Edelist et al. 2013; Katsanevakis et al. 2014a; Nunes et al. 2014). About one thousand alien species have been recorded in the Mediterranean waters with an accelerating rate of discovery (Zenetos et al. 2012). The opening of the Suez Canal in 1869, which created a corridor between two distinct biogeographical provinces, allowed the so-called 'Lessepsian migration' of Indo-Pacific species into the Mediterranean (Por 1978). Other anthropogenic vectors such as shipping or aquaculture contribute significantly to the introduction of alien species in both the Mediterranean (Katsanevakis et al. 2014a) and European seas (Nunes et al. 2014).

As of 2000, 664 marine fish species were listed in the Mediterranean (Quignard and Tomasini 2000). Numerous additional species have been recorded in the last 15 years, bringing the number of Mediterranean marine fishes to about 750 currently, of which nearly one fifth are exotics (Golani et al. 2013). Recently Zenetos et al. (2012) revised their list of alien species for the Mediterranean and retained only 126 fishes, removing species of tropical Atlantic origin because their presence could represent a natural range expansion through the Straits of Gibraltar rather than human-mediated introduction. The ongoing warming trend, or tropicalisation (sensu Bianchi and Morri 2003), seems to be allowing successful establishment by some of these migrant species. The list of excluded alien species also included cryptic species that were probably present in the Mediterranean but overlooked in the past, and sharks with vagrant behaviour. Generally, the richness of Mediterranean fishes decreases from the West to the East (Quignard and Tomasini 2000). In contrast, there is a clear east to west gradient for Lessepsian species richness (Coll et al. 2010), with the highest number of records coming from the Israeli-Lebanese coast and eastern Turkey (Golani 1998; Golani 2010;

Azzurro et al. 2013). In the eastern (Levantine) basin, exotic fishes represent about 18% of the Mediterranean fish diversity (EastMed 2010; Golani 2010; Golani et al. 2013, 2006; Harmelin-Vivien et al. 2005), with most of them being Lessepsian migrants with an Indo-Pacific origin. Ten additional alien fishes were recorded in 2011–2012 and the number of documented occurrences is rapidly increasing (Golani 2010; Zenetos et al. 2012). However, we should also consider that increasing scientific efforts have likely augmented the rate at which exotic species are being discovered. According to Belmaker et al. (2009), Lessepsian fishes would have been introduced at a rate of 0.71 species/yr.

In the last twenty years, an increasing number of Lessepsian species seem to have extended their distributions from the eastern to the western Mediterranean (Galil and Zenetos 2002). Many exotic fishes are now well-established in the Mediterranean Sea, and at least 31 species can be considered as very abundant or dominant in their new environment (Azzurro et al. 2014), 11 of which may be invasive with significant ecological impacts (Katsanevakis et al. 2014b). Furthermore, with the recent completion of the Suez Canal expansion project, increasing rates of introduction are expected for the near future (Galil et al. 2014).

The first alien marine fish to be recorded in Cyprus was *Siganus rivulatus* Forsskål & Niebuhr, 1775 in 1928 (Norman 1929). In 1967, the first survey of the alien marine fishes of Cyprus was launched through a joint research program (Biota of the Red Sea and eastern Mediterranean). This project investigated the spread of Lessepsian migrants in the Levantine basin including Egypt, Israel, Cyprus, and Rhodes (Steinitz 1970). Significant findings of exotic fishes in Cyprus were recorded by Demetropoulos and Neocleous (1969). Despite very intensive surveys in Cyprus, conducted by the Joint Research Project of the Hebrew University of Jerusalem and the Smithsonian Institution, no additional Lessepsian species were discovered (Por et al. 1972). Afterwards, the number of recorded alien fishes in Cyprus increased significantly (Katsanevakis et al. 2009) but many of the species that colonized the Eastern Mediterranean are still unrecorded from this island. This relatively low number of alien species was tentatively attributed to the low water temperatures around the island and to the relatively large distance from the continental shores, which is the main route for advancing Lessepsian migrants (Por 1978). The low number of reports of Lessepsian species from Cyprus was also interpreted as being primarily due to a lack of sampling efforts in a wide range of habitats. It was suggested that well-designed surveys to detect and describe the distributions of non-native species in the marine ecosystem of Cyprus would surely uncover many more species from all marine groups (Chartosia and Menicou 2012). First records of non-indigenous marine fishes for Cyprus were much more numerous beginning in the 1990's (Katsanevakis et al. 2009). In Cyprus, Lessepsian fish species represent up to 10% of the biomass of annual artisanal landings over the last few years (Department of Fisheries and Marine Research - DFMR 2006, unpublished data in Michailidis 2010).

The field expedition *Cyprus-2014* was dedicated to improve the 'Identification and Classification of Chondrichthyans and Actinopterygians from the North-eastern Atlantic and the Mediterranean' (ICCANAM). This handbook project, with available (provisional) online versions, is focused on establishing an inventory of marine fishes in European and adjacent waters, based on collection of specimens, DNA barcoding, and standardized photographs (Iglésias 2014). Specimens newly vouchered during *Cyprus-2014* will be presented in the updated versions 11 of the online handbook. The aim of the present study was to provide an updated list of alien marine fishes in Cyprus based on a part of the collections and records collected during the most-recent expedition.

Materials and methods

The field expedition *Cyprus-2014* took place from 06 to 27 September 2014 along the coasts of Cyprus Island, in the eastern Mediterranean Sea. Special sampling efforts were dedicated to detecting and collecting exotic species. Specimens were collected by authors close to the shoreline by: snorkelling with hand nets 10 to 40 cm width, commercial spearguns, mini-spearguns using arrows 2 mm in diameter; hand lines; and by angling from the shore. Some collections, photographs, and observations, were also made by SCUBA diving. Fieldwork was carried out in the Republic of Cyprus, mostly in the district of Famagusta and occasionally in the districts of Larnaca and Paphos (Figure 1, Table 1). Other specimens from coastal fisheries were provided by fishermen from the ports of Agia Triada, Pernera, and Limassol, or collected in the fish markets of Paralimni, Deryneia, Limassol, Nikosia, and Paphos. Fishmongers were asked about the capture locality of specimens to avoid inclusion of fishes caught out of Cyprus waters.

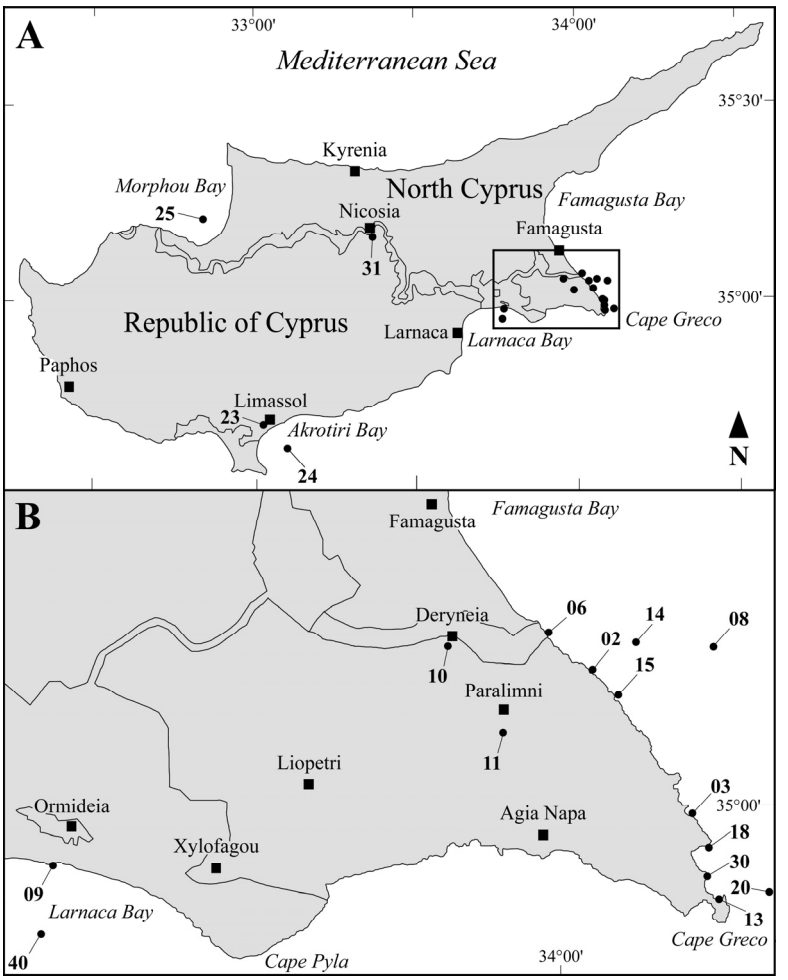

Figure 1. Map of the sampling stations (*black circles and numbers*) of the Lessepsian and tropical Atlantic fishes recorded as voucher specimens during the mission *Cyprus-2014*. **A**, The island of Cyprus; **B**, detail of the most sampled area (square in Fig. A).

Table 1. Sampling stations of the Lessepsian and tropical Atlantic fishes recorded from the island of Cyprus during the expedition *Cyprus-2014*.

Station No.	Locality	Latitude N	Longitude E
02	Agia Triada	35.051390	34.022777
03	Green Bay	34.996957	34.069442
06	Buffer area, North of Agia Triada	35.066668	34.002790
08	Off Pernera	35.058369	34.079728
09	Ormideia	34.979189	33.772507
10	Fishmarket *Maryos*, Deryneia	35.062509	33.958876
11	Fishmarket *Blue Island*, Paralimni	35.030833	33.981951
13	Cap Greco	34.963910	34.082788
14	Off Agia Triada	35.058486	34.041833
15	Pernera	35.039721	34.036945
18	Cyclope Cave	34.985557	34.078056
20	Off Cap Greco	34.966666	34.100000
23	Fishmarket *PanFish*, Limassol	34.679850	33.035694
24	Off Limassol	34.670013	33.043615
25	Morphou Bay	34.680289	33.052789
30	Agio Anargyroi	34.975014	34.076946
31	Fishmarket *Latsi*, Nikosia	35.168356	33.370299
40	Off Ormideia	34.950000	33.760000

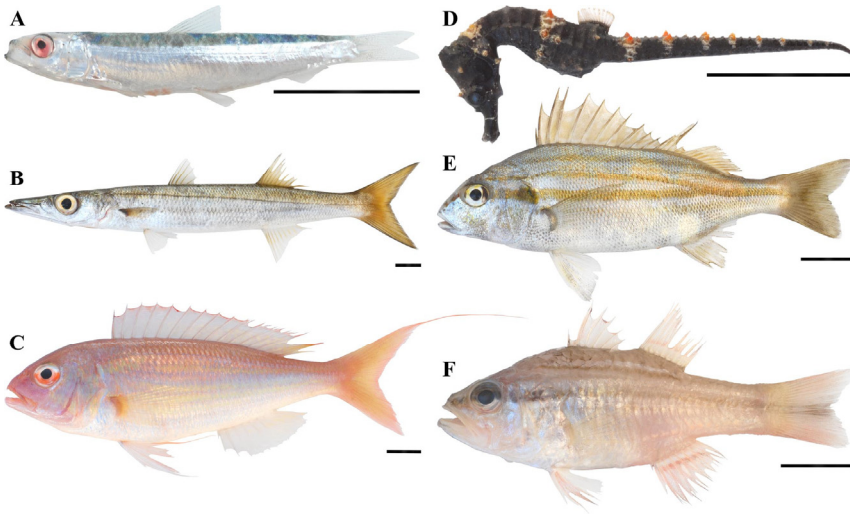

Figure 2. First records of alien marine fishes for Cyprus. **A**, *Spratelloides delicatulus*, MNHN 2014-2905, 56 mm TL, 20 Sep. 2014, Agia Triada, 0.5 m depth; **B**, *Sphyraena obtusata*, MNHN 2014-2853, 313 mm TL, 13 Sep. 2014, fish market Maryos at Deryneia; **C**, *Nemipterus randalli*, MNHN 2014-2912, 259 mm TL, 22 Sep. 2014, fish market Latsi at Nikosia; **D**, *Hippocampus fuscus*, MNHN 2014-2876, 56 mm high, 16 Sep. 2014, Cyclope Cave, 15 m depth; **E**, *Pomadasys stridens*, MNHN 2014-2878, 149 mm TL, 20 Sep. 2014, off Cape Greco, 20 m depth; **F**, *Ostorhinchus fasciatus*, MNHN 2014-2896, 107.5 mm TL, 20 Sep. 2014, from Morphou Bay. Scale bars = 20 mm.

Fresh specimens were photographed in a standard manner, and then tissue samples were taken and recorded under collection numbers (BPS) for future genetic analyses. Voucher specimens were fixed in 4% formalin for a month, then preserved in 80% ethanol, and registered in the ichthyologic collection of the Muséum national d'Histoire naturelle of Paris (MNHN-IC). Diagnostic characters observed on specimens were reported only for species that represent first records for Cyprus. Abbreviations: TL = total length; FL = fork length; SL = standard length (lengths in mm); D = dorsal fin; A = anal fin; P = pectoral fin; V = pelvic fin; LL = number of scales on lateral line; GR = number of gill rakers on first arch; stn = station.

Specimens were identified to species level according to the taxonomical characters provided by Golani et al. (2013). The scientific names used follow Golani et al. (2013) with updates according to Eschmeyer and Fricke (2015) and taking into account recent taxonomical revisions for Lessepsian fishes: Azzurro et al. (2015), Doiuchi and Nakabo (2005), Golani et al. (2014), Matsuura et al. (2011), Randall (2013), Randall et al. (2014), and Russell et al. (2015). Establishment success was updated from Katsanevakis et al. (2009). The listed species were classified into the following categories used by Zenetos et al. (2005; 2012): established, casual, questionable, and invasive. Species with at least three records in Cyprus spread over time and space were classified as established (Golani et al. 2013). Casual species are those having been recorded no more than twice in both scientific and grey literature and are presumed to be non-established in Cyprus. Questionable species are those with insufficient information; this category includes new entries not verified by experts or species with unresolved taxonomic status. Invasive species were defined as established alien species that have overcome biotic and abiotic barriers and are able to reproduce outside of their area of initial introduction with noticeable ecological or economic impact.

Results

We documented the occurrence of 25 Lessepsian fish species plus one Atlantic immigrant, representing 19 families (see also Supplementary Table S1).

A. Lessepsian fishes

CLUPEIDAE

Etrumeus golanii DiBattista, Randall & Bowen, 2012

Material: MNHN 2014-2877 (Figure 3A), tissue BPS-2974, 237/212/200 mm TL/FL/SL, off Pernera, stn 08, 17 Sep. 2014, fishing boat "Maria", net, 120 m depth. The species was occasionally observed in coastal fisheries catches.

Spratelloides delicatulus (Bennett, 1832)

Materials: MNHN 2014-2905 (Figure 2A), tissue BPS-3001, 56/51/47 mm TL/FL/SL, Agia Triada, stn 02, 20 Sep. 2014, hand net doing snorkelling

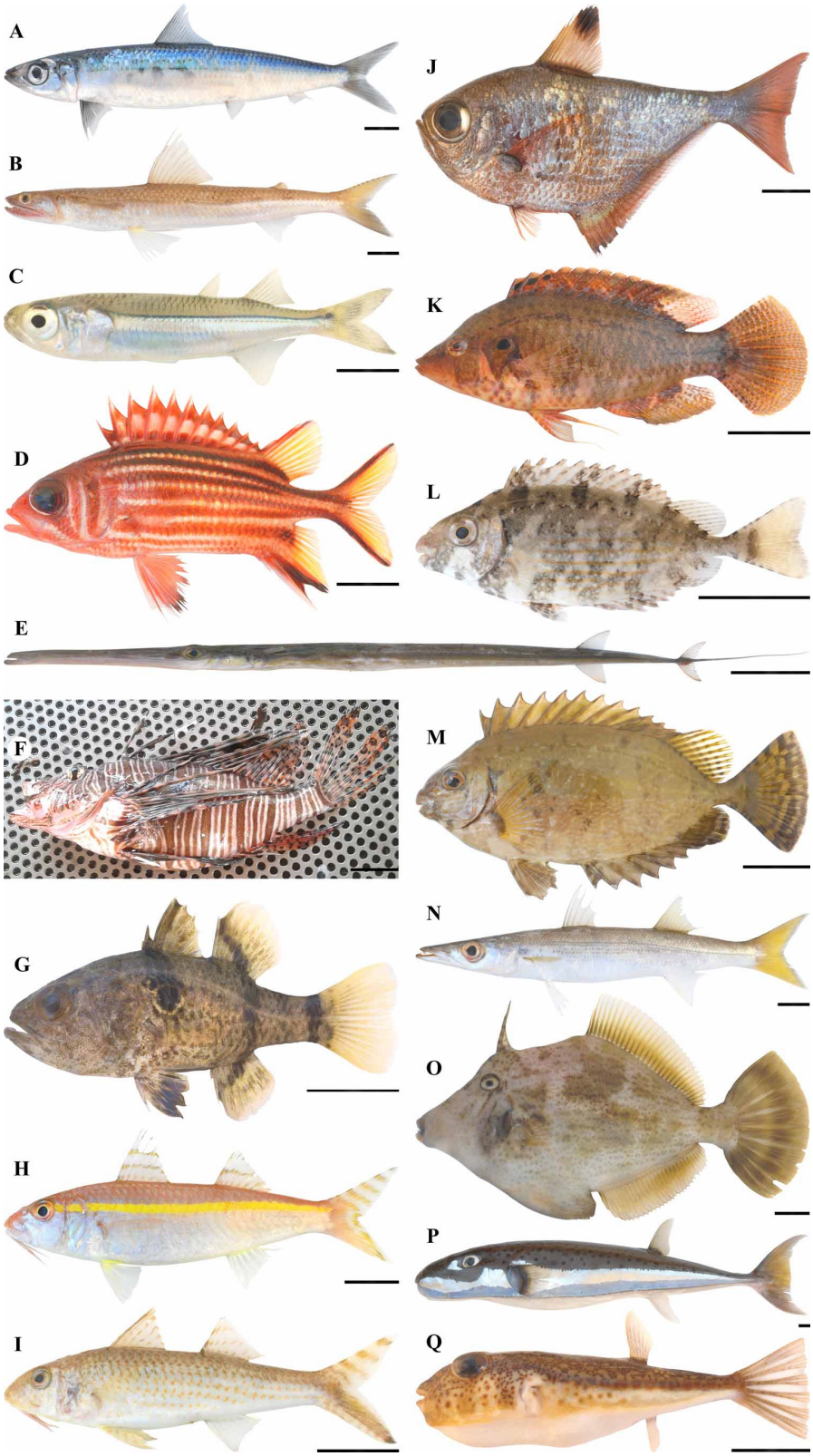

Figure 3. Additional records of alien marine fishes for Cyprus: **A**, *Etrumeus golanii*, MNHN 2014-2877, 237 mm TL, 17 Sep. 2014, off Pernera, 120 m depth; **B**, *Saurida lessepsianus*, MNHN 2014-2889, 256 mm TL, fishmarket PanFish at Limassol; **C**, *Atherinomorus forskalii*, MNHN 2014-2833, 122 mm TL, 122 mm TL, 10 Sep. 2014, Port of Agia Triada, 0.5 m depth; **D**, *Sargocentron rubrum*, MNHN 2014-2831, 127 mm TL, 09 Sep. 2014, Green Bay, 4 m depth; **E**, *Fistularia commersonii*, MNHN 2014-2920, 1001 mm TL, 22 Sep. 2014, Agia Triada, 1.5 m depth. **F**, *Pterois miles*, unpreserved, ~170 mm TL, 22 May 2014, off Ormidia, 10 m depth (photograph: A. Stavrinou); **G**, *Apogonichthyoides pharaonis*, MNHN 2014-2828, 83 mm TL, 08 Sep. 2014, Agia Triada, 1 m depth; **H**, *Upeneus moluccensis*, MNHN 2014-2900, 142 mm TL, 20 Sep. 2014, Morphou Bay; **I**, *Upeneus pori*, MNHN 2014-2870, 95 mm TL, Sep. 2014, Pernera, 1 m depth; **J**, *Pempheris rhomboidea*, MNHN 2014-2861, 156 mm TL, 14 Sept. 2014, Cape Greco, 1 m depth; **K**, *Pteragogus trispilus*, MNHN 2014-2824, 93 mm TL, 08 Sep. 2014, Agia Triada, 2 m depth; **L**, *Siganus rivulatus*, MNHN 2014-2921, 70 mm TL, 22 Sep. 2014, Agia Triada, 3 m depth; **M**, *Siganus luridus*, MNHN 2014-2845, 133 mm TL, 12 Sep. 2014, Omideia, 1 m depth; **N**, *Sphyraena pinguis*, MNHN 2014-2926, 236 mm TL, 26 Sep. 2014, Morphou Bay; **O**, *Stephanolepis diaspros*, MNHN 2014-2867, 239 mm TL, 15 Sep. 2014, Pernera, 6 m depth; **P**, *Lagocephalus sceleratus*, MNHN 2014-2875, 575 mm TL, 16 Sep. 2014, off Pernera; **Q**, *Torquigener flavimaculosus*, MNHN 2014-2827, 99 mm TL, 08 Sep. 2014, Agia Triada, 2 m depth. Scale bars = 100 mm for E and 20 mm for all others.

at night, 0.5 m depth; MNHN 2014-2906, tissue BPS-3002, 54/50/46 mm TL/FL/SL, stn 02; MNHN 2014-2907, 15 specimens, 43-52 mm TL, stn 02. Diagnostic characters observed on MNHN 2014-2905 (and MNHN 2014-2906 when different): D: 13; A: 11 (10); P: 12; V: 8; belly smooth without series of scutes; dorsal fin origin before midpoint; W-shaped scute at the base of the pelvic fin; relatively large scales easily detached with continuous vertical striae across them. The species, which forms shoals consisting of thousands of individuals, was regularly observed during the day near the surface in coastal waters, and commonly at night in compact shoals along the beach in 0–2 m depth. This species is presently a first record for Cyprus, where the observations made during *Cyprus-2014* allow it to be considered as established.

SYNODONTIDAE

Saurida lessepsianus (Russell, Golani & Tikochinski, 2015)

Materials: MNHN 2014-2888, tissue BPS-2986, 260/237/220 mm TL/FL/SL, Fishmarket PanFish, Limassol, stn 23, 19 Sep. 2014; MNHN 2014-2889 (Figure 3B), tissue BPS-2987, 256/232/215 mm TL/FL/SL, stn 23. The species was regularly observed in coastal fisheries catches and in fish markets.

ATHERINIDAE

Atherinomorus forskalii (Rüppell, 1838)

Materials: MNHN 2014-2833 (Figure 3C), tissue BPS-2930, 122/110/99 mm TL/FL/SL and a second specimen, 118/108/97, Agia Triada, stn 02, 10 Sep. 2014, angling, 0.5 m depth; MNHN 2014-2840, tissue BPS-2937, 94/87/77 mm TL/FL/SL, stn 02, 11 Sep. 2014, hand net at night, surface; MNHN 2014-2841, tissue BPS-2938, 41/39/35 mm TL/FL/SL and six other specimens, 37–60 mm TL, stn 02, 11 Sep. 2014. The species was observed commonly, forming shoals or as isolated individuals, in surface waters of bays and ports.

HOLOCENTRIDAE

Sargocentron rubrum (Forsskål, 1775)

Materials: MNHN 2014-2830, tissue BPS-2927, 117/103/95 mm TL/FL/SL, Green Bay, stn 03, 09 Sep. 2014, hand line doing snorkelling, 1.5 m depth; MNHN 2014-2831 (Figure 3D), tissue BPS-2928, 127/113/104 mm TL/FL/SL, stn 03, 09 Sep. 2014; MNHN 2014-2919, tissue BPS-3013, 42.5/39/35 mm TL/FL/SL, Agia Triada, stn 02, 22 Sep. 2014, hand line at night doing snorkelling, 1.5 m depth. The species, mostly forming small groups of < 10 individuals, was observed commonly in small caves in coastal waters.

FISTULARIDAE

Fistularia commersonii (Rüppell, 1835)

Materials: MNHN 2014-2849, tissue BPS-2946, 383/297/290 mm TL/FL/SL, Ormideia, stn 09, 12 Sep. 2014, spearfishing, 3 m depth; MNHN 2014-2920 (Figure 3E), tissue BPS-3014, 1001/851/833 mm TL/FL/SL, Agia Triada, stn 02, 22 Sep. 2014, hand at night doing snorkelling, 1.5 m depth. The species was observed commonly in coastal waters and in coastal fishery landings.

SYNGNATHIDAE

Hippocampus fuscus Rüppell, 1838

Material: MNHN 2014-2876 (Figure 2D), tissue BPS-2973, 56 mm high, female, Cyclope Cave, stn 18, 16 Sep. 2014, by hand, 15 m depth. Diagnostic characters observed on MNHN 2014-2876: trunk rings (until anus): 11; tail rings: 36; D: 17; A: 4. Snout length 2.5 times in head length. Coronet elevated with wedge-like ridges. DNA barcodes distinguish the present specimen from the other Mediterranean species (unpubl. data). The single individual was observed on sandy ground. This observation represented a first record for Cyprus.

SCORPAENIDAE

Pterois miles (Bennett, 1803) (properly *Pterois volitans/miles* species complex)

Two individuals of this venomous species were caught in the professional coastal fishery and were identified on the basis of photographs taken with smartphones. The first individual (Figure 3F), about 170 mm TL, was photographed by the fishery observer Andri Stavrinou (DFMR) and coming from off Ormideia, stn 40, on 22 May 2014, net, 10 m depth. The second individual was photographed by a fishmonger from Morfou fish market (Limassol) in 2014. The specimens were easily identified by the colour pattern and fin shape typical of this species complex. It can now be considered as established in Cyprus.

APOGONIDAE

Apogonichthyoides pharaonis (Bellotti, 1874)

Materials: MNHN 2014-2828 (Figure 3G), tissue BPS-2925, 83/82/68 mm TL/FL/SL, Agia Triada, stn 02, 08 Sep. 2014, hand net doing snorkelling, 1 m depth; MNHN 2014-2829, tissue BPS-2926,

97/96/80 mm TL/FL/SL, stn 02, 08 Sep. 2014; MNHN 2014-2902, tissue BPS-2998, 52/51/41 mm TL/FL/SL, stn 02, 20 Sep. 2014, hand net at night doing snorkelling, 1 m depth. The species was commonly observed in very shallow waters (0.5–2 m depth) of bays, under boulders during the day and active near the bottom at night.

Ostorhinchus fasciatus (Shaw, 1790)

Material: MNHN 2014-2896 (Figure 2F), tissue BPS-2992, 107.5/101/84 mm TL/FL/SL, fish market Morfou, coming from Morphou Bay, stn 25, 20 Sep. 2014. Diagnostic characters observed on specimen MNHN 2014-2896: D1: VII; D2: I+9; A: II+8; P: 15; V: I+5; LL: 27. Preoperculum edge serrated. Two dark longitudinal stripes, the upper one from the nape to the upper base of caudal fin, the lower stripe from the tip of the snout, through the eye, to the end of the middle caudal fin rays. This individual represented the first record for Cyprus.

NEMIPTERIDAE

Nemipterus randalli Russell, 1986

Materials: MNHN 2014-2897, tissue BPS-2993, 177/125/111 mm TL/FL/SL, fish market Morfou at Limassol, coming from Morphou bay, stn 25, 20 Sep. 2014; MNHN 2014-2898, tissue BPS-2994, 168/127/112 mm TL/FL/SL, stn 25, 20 Sep. 2014; MNHN 2014-2912 (Figure 2C), tissue BPS-3006, 259/178/160 mm TL/FL/SL, Fish market Latsi, Nikosia, stn 31, 22 Sep. 2014. Diagnostic characters observed on MNHN 2014-2897 (and MNHN 2014-2898 and MNHN 2014-2912, when different): D: X+9; A: III+7; P: 16 (17); V: I+5; LL: 48 (47). Many specimens were observed in the fish markets of Limassol and Nikosia and part of them were fished in Morphou Bay. While this study represented a first record for Cyprus, the species clearly has become established.

CARANGIDAE

Alepes djedaba (Forsskål, 1775)

While snorkelling, a group of about five individuals was observed swimming at Agio Anargyroi, stn 30, 25 Sep. 2014, 2 m depth with bottom about 5 m depth. Diagnostic characters observed were general body shape, colours, and scutes on flanks.

HAEMULIDAE

Pomadasys stridens (Forsskål, 1775)

Material: MNHN 2014-2878 (Figure 2E), tissue BPS-2975, 149/139/123 mm TL/FL/SL, off Cap Greco, stn 20, 17 Sep. 2014, net, Cape Greco 20 m depth. Diagnostic characters observed on MNHN 2014-2878: D: XII+13; A: III+9; P: 17; V: I+5; LL: 59; GR: 24. A single individual was collected and the species identity was unknown by the fisherman-fishmonger providing the specimen. The specimen was a first record for Cyprus.

MULLIDAE

Parupeneus forsskali (Fourmanoir & Guézé, 1976)

A single individual was photographed with a smartphone by a fishmonger (photograph not recovered). According to the fisherman, the specimen, about 15 cm in length, was caught with a net off Agia Triada, stn 14 in the beginning of September 2014, 15 m depth. The retained diagnostic characters were the presence of barbels, a pointed snout, a marked blotch on the upper caudal peduncle, and dark stripes on the lateral sides. The specimen was a first record for Cyprus.

Upeneus moluccensis (Bleeker, 1855)

Materials: MNHN 2014-2892, tissue BPS-2990, 147/129/116 mm TL/FL/SL, fish market Morfou at Limassol, coming from Morphou Bay, stn 25, 19 Sep. 2014; MNHN 2014-2900 (Figure 3H), tissue BPS-2996, 142/126/114 mm TL/FL/SL, stn 25, 20 Sep. 2014. Many specimens were observed in the fish markets of Limassol and Nikosia and part of them were fished in Morphou Bay.

Upeneus pori Ben-Tuvia & Golani, 1989

Materials: MNHN 2014-2838, tissue BPS-2935, 72/62/58 mm TL/FL/SL, Buffer area, North of Agia Triada, stn 06, 11 Sep. 2014, spearfishing, 3 m depth; MNHN 2014-2844, tissue BPS-2941, 155/136/123 mm TL/FL/SL, Ormideia, stn 09, 12 Sep. 2014, spearfishing, 3 m depth; MNHN 2014-2870, tissue BPS-2967 (Figure 3I), 95/82/75 mm TL/FL/SL, Pernera, stn 15, 15 Sep. 2014, spearfishing, 1 m depth. The species was commonly observed in very shallow waters (0.5–4 m depth) over clean, fine-sand, substrates.

PEMPHERIDAE

Pempheris rhomboidea Kossmann & Räuber, 1877

Materials: MNHN 2014-2860, tissue BPS-2957, 144/132/112 mm TL/FL/SL, Cap Greco, stn 13, 14 Sep. 2014, spearfishing, 1 m depth and MNHN 2014-2861 (Figure 3J), tissue BPS-2958, 156/142/123 mm TL/FL/SL, stn 13, 14 Sep. 2014, spearfishing, 1 m depth. This species was commonly

observed during the day in caves in 1–10 m depth in groups up to several tens of individuals.

LABRIDAE

Pteragogus trispilus Randall, 2013

Materials: MNHN 2014-2823, tissue BPS-2920, 92/73 mm TL/SL, Agia Triada, stn 02, 08 Sep. 2014, hand line while snorkelling, 1 m depth; MNHN 2014-2824 (Figure 3K), tissue BPS-2921, 93/73 mm TL/SL, stn 02, 08 Sep. 2014, 2 m depth; MNHN 2014-2825, tissue BPS-2922, 86/66 mm TL/SL, stn 02, 08 Sep. 2014, 2 m depth. The species was very commonly observed near rocky boulders in shallow waters of sheltered bays 1–4 m depth and observed in waters up to about 10 m depth near sea grass (*Posidonia)* meadows.

SIGANIDAE

Siganus rivulatus Forsskål & Niebuhr, 1775

Materials: MNHN 2014-2835, tissue BPS-2932, 50/48/42 mm TL/FL/SL, Agia Triada, stn 02, 10 Sep. 2014, angling, 0.3 m depth; MNHN 2014-2854, tissue BPS-2951, 246/226/203 mm TL/FL/SL, Fish market Blue Island, Paralimni, stn 11, 13 Sep. 2014, net; MNHN 2014-2921 (Figure 3L), tissue BPS-3015, 70/61.5/57 mm TL/FL/SL, stn 02, 22 Sep. 2014, hand net at night doing snorkelling, 3 m depth. The species was numerous and commonly observed at many coastal locations in coastal waters with great abundances.

Siganus luridus Rüppell, 1828

Materials: MNHN 2014-2836, tissue BPS-2933, 64/52 mm TL/SL, Buffer area, North of Agia Triada, stn 06, 11 Sep. 2014, spearfishing, 1 m depth; MNHN 2014-2845 (Figure 3M), tissue BPS-2942, 133/108 mm TL/SL, Ormideia, stn 09, 12 Sep. 2014, spearfishing, 1 m depth. The species was numerous and commonly observed at many coastal locations.

SPHYRAENIDAE

Sphyraena obtusata Cuvier, 1829

Materials: MNHN 2014-2853 (Figure 2B), tissue BPS-2950, 313/283/262 mm TL/FL/SL, Fish market Maryos, Deryneia, stn 10, 13 Sep. 2014. Diagnostic characters observed on MNHN 2014-2853: D1: V; D2: I+9; A: II+9; P: 13; V: I+5; LL: 90; GR: 2. Individuals were commonly observed in coastal fishery catches and in fish markets. This study represented the first record for Cyprus and it clearly has become established. It is presumed the species was confused with others *Sphyraena* in the past.

Sphyraena pinguis Günther, 1874

Materials: MNHN 2014-2926 (Figure 3N), tissue BPS-3020, 236/211/200 mm TL/FL/SL, fish market Morfou at Limassol, coming from Morphou Bay, stn 25, 26 Sep. 2014. A single individual was observed.

MONACANTHIDAE

Stephanolepis diaspros Fraser-Brunner, 1940

Materials: MNHN 2014-2867 (Figure 3O), tissue BPS-2964, 239/190 mm TL/SL, Pernera, stn 15, 15 Sep. 2014, spearfishing, 6 m depth; MNHN 2014-2874, tissue BPS-2971, 143/115 mm TL/SL, off Pernera, stn 08, 16 Sep. 2014, net, 25 m depth; MNHN 2014-2891, tissue BPS-2989, 115/90 mm TL/SL, off Limassol, stn 24, 19 Sep. 2014, net. Two individuals were observed underwater and some individuals were occasionally observed in coastal fishery catches and in fish markets.

TETRAODONTIDAE

Lagocephalus sceleratus (Gmelin, 1788)

Materials: MNHN 2014-2842, tissue BPS-2939, 259/242/220 mm TL/FL/SL, off Pernera, stn 08, 12 Sep. 2014, net, 70 m depth; MNHN 2014-2875 (Figure 3P), tissue BPS-2972, 575/532/485 mm TL/FL/SL, stn 08, 16 Sep. 2014, hand line. This invasive species was widespread and commonly observed in the landings of coastal fishermen where it often represented the most important catch biomass. Indeed, despite it not being a commercial species, since 2010 the pufferfish is periodically landed in the coastal fishery because the National Authorities of Cyprus take mitigation actions to control the population, focusing on its physical removal with a compensation of € 1 to € 3 per individual provided to local fisherman by the DFMR (Rousou et al. 2014).

Torquigener flavimaculosus Hardy & Randall, 1983

Materials: MNHN 2014-2826, tissue BPS-2923, 86/84/68 mm TL/FL/SL, Agia Triada, stn 02, 08 Sep. 2014, hand line while snorkelling, 2 m depth; MNHN 2014-2827 (Figure 3Q), tissue BPS-2924, 99/97/80 mm TL/FL/SL, stn 02, 08 Sep. 2014, 4 m depth. The species widely distributed around the island in 1–4 m depth of sheltered bays, typically on near sandy substrates, and occasionally in deeper waters.

Figure 4. New record for Cyprus of the tropical Atlantic *Enchelycore anatina*, about 1 m TL, 21 Sep. 2014, Agio Anargyroi, 7.5 m depth.

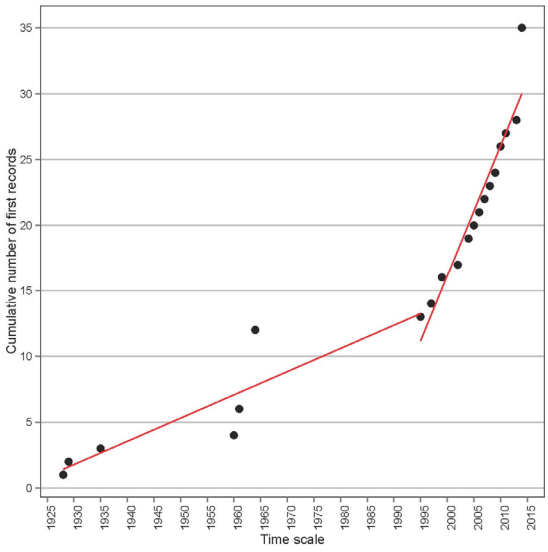

Figure 5. Cumulative number of first records of alien marine fishes for Cyprus. Black dots represent the reported year of first sighting (*i.e.*: the year of the record is not necessarily the year of publication). The linear regression equations (red lines) are: $y = 0.1763x + 0.7187$ ($R^2 = 0.7887$) pre-1995, and $y = 0.9915x - 59.237$ ($R^2 = 0.9173$) post-1995. The last point (outlier) represents the seven additional first records of alien fishes from the current study.

B. Tropical Atlantic immigrants

MURAENIDAE

Enchelycore anatina (Lowe, 1839)

A single individual was observed at Cyclope Cave, stn 18, on 16 Sep. 2014, at 5 m depth in a rocky hole. Two others individuals (Figure 4) were observed together at Agio Anargyroi, stn 30, on 25 Sep. 2014, at 7.5 m depth in holes on a vertical wall of coralline seaweeds. A small individual from the Cape Greco area is also visible in a submarine video on the Internet (Scuba Tech Diving Center, Cyprus, 2013). These observations, and additional observations by locals, support the hypothesis idea that *E. anatina* is now established in Cyprus.

C. Update of alien fishes in Cyprus

Taking into account: 1) the finding of seven alien fishes new to Cyprus; 2) the ten alien fishes reported for Cyprus but not observed during our survey; and 3) the status revision of previously recorded species presented in Table 2, at least 35 alien fish species now inhabit the waters of the island, 28 of which can be considered as established. The rate at which new alien marine fishes are recorded in Cyprus showed a significant increase (Figure 5). Twelve exotic species were recorded for the first time in Cyprus from 1928 to 1994 (a 66 year time span) whereas 23 aliens species were recorded for first time in Cyprus from 1995 to 2014 (a 20 year time span).

Discussion

The Cyprus survey identified seven new Lessepsian fishes (*Hippocampus* fuscus, *Nemipterus randalli*, *Ostorhinchus fasciatus*, *Parupeneus forsskali*, *Pomadasys stridens*, *Sphyraena obtusata* and *Spratelloides delicatulus*), increasing to 35 the number of alien fish species dwelling in the waters of the island. The study also serves as an update for the establishment success of alien fishes already recorded in the island. Finally, these new data improve knowledge on the establishment of a tropical Atlantic species, the recently recorded *Enchelycore anatina*.

A. Update of alien fishes in Cyprus

Excluded species or records

In the updated list of alien fishes for Cyprus (Katsanevakis et al. 2009), *Himantura uarnak* (Forsskål, 1775) is listed as 'questionable', based on Last and Stevens (1994). In a general comment on world distribution, the authors mention the species in the eastern Mediterranean. The world map presenting the distribution for the species includes Cyprus but it is imprecise at the regional scale. Some records of that species exist in the

Table 2. Updated checklist of the alien and tropical Atlantic marine fishes for Cyprus. Species are presented in reverse chronological order of records for Cyprus. In the case where the date of collection of a first record remains unknown, the date of publication was used instead accompanied with the symbol '<'. (* = observed during the expedition *Cyprus-2014*; Medit. = Mediterranean, E = East, W = West).

Species		1st record for Cyprus	Origin	Introduction pathway	Status in Cyprus	Reference of 1st record for Cyprus
Alien species						
Hippocampus fuscus Rüppell, 1838	*	2014	Red Sea, Indian	Suez	Casual	Present study
Nemipterus randalli Russell, 1986	*	2014	Red Sea, W Indian	Suez	Established	Present study
Ostorhinchus fasciatus (Shaw, 1790)	*	2014	Indo-Pacific	Suez	Casual	Present study
Parupeneus forsskali (Fourmanoir & Guézé, 1976)	*	2014	Red Sea	Suez	Casual	Present study
Pomadasys stridens (Forsskål, 1775)	*	2014	Red Sea, W Indian	Suez	Casual	Present study
Sphyraena obtusata Cuvier, 1829	*	2014	Indo-Pacific	Suez	Established	Present study
Spratelloides delicatulus (Bennett, 1832)	*	2014	Indo-Pacific	Suez	Established	Present study
Pterois miles (Bennett, 1803)	*	2013	Indo-Pacific	Suez	Established	Evripidou 2013 in Bariche et al. 2013
Acanthurus coeruleus Bloch & Schneider, 1810		2011	W Atlantic	Questionable	Casual	Langeneck et al. 2012
Scarus ghobban Forsskål, 1775		2010	Indo-Pacific	Suez	Casual	Ioannou et al. 2010
Torquigener flavimaculosus Hardy & Randall, 1983	*	2010	Red Sea, W Indian	Suez	Established	Michailidis 2010
Sillago suezensis Golani, Fricke & Tikochinski, 2014		2009	Indo-Pacific	Suez	Casual	Katsanevakis et al. 2009
Scomberomorus commerson (Lacepède, 1800)		2008	Indo-Pacific	Suez	Established	Katsanevakis et al. 2009
Lagocephalus suezensis Clark & Gohar, 1953		2007	Red Sea	Suez	Established	Katsanevakis et al. 2009
Lagocephalus guentheri Miranda Ribeiro, 1915		2006	Indo-Pacific	Suez	Established	Katsanevakis et al. 2009
Dussumieria elopsoides Bleeker, 1849		2005	Indo-Pacific	Suez	Established	Gitarakos et al. 2007
Lagocephalus sceleratus (Gmelin, 1789)	*	2004	Indo-Pacific	Suez	Invasive	DFMR 2006
Upeneus pori Ben-Tuvia & Golani, 1989	*	2004	Indo-Pacific	Suez	Established	Tzomos et al. 2007
Parexocoetus mento (Valenciennes, 1846)		<2002	Indo-Pacific	Suez	Established	Golani et al. 2002
Etrumeus golanii DiBatistta, Randall & Bowen, 2012	*	1999	Indo-Pacific	Suez	Established	Golani 2000
Fistularia commersonii (Rüppell, 1835)	*	1999	Indo-Pacific	Suez	Invasive	Wirtz and Debelius 2003
Pteragogus trispilus Randall, 2013	*	1997	Indo-Pacific	Suez	Established	Kaya et al. 2000
Pempheris rhomboidea Kossmann & Räuber, 1877	*	1995	Indo-Pacific	Suez	Established	Torcu et al. 2001
Alepes djedaba (Forsskål, 1775)	*	1964	Indo-Pacific	Suez	Established	Demetropoulos and Neocleous 1969
Apogonichthyoides pharaonis (Bellotti, 1874)	*	1964	Indo-Pacific	Suez	Established	Demetropoulos and Neocleous 1969
Hemiramphus far (Forsskål, 1775)		1964	Indo-Pacific	Suez	Established	Demetropoulos and Neocleous 1969
Siganus luridus (Rüppell, 1829)	*	1964	Indo-Pacific	Suez	Invasive	Demetropoulos and Neocleous 1969
Sphyraena pinguis Günther, 1874	*	1964	Indo-Pacific	Suez	Established	Demetropoulos and Neocleous 1969
Upeneus moluccensis (Bleeker, 1855)	*	1964	Indo-Pacific	Suez	Established	Demetropoulos and Neocleous 1969
Equulites klunzingeri (Steindachner, 1898)		1961	Red Sea	Suez	Established	Fodera 1961
Sargocentron rubrum (Forsskål, 1775)	*	1961	Indo-Pacific	Suez	Established	Fodera 1961
Saurida lessepsianus Russell, Golani & Tikochinski, 2015	*	1960	Indo-Pacific	Suez	Established	Ben Tuvia 1962
Stephanolepis diaspros Fraser-Brunner, 1940	*	1935	Indo-Pacific	Suez	Established	Hornell 1935
Atherinomorus forskalii (Rüppell, 1838)	*	1929	Indo-Pacific	Suez	Established	Norman 1929
Siganus rivulatus Forsskål & Nieburh, 1775	*	1928	Indo-Pacific	Suez	Invasive	Norman 1929
Tropical Atlantic species						
Enchelycore anatina (Lowe, 1839)	*	2008	E Atlantic	Gibraltar	Established	Katsanevakis et al. 2009

eastern Mediterranean (Golani et al. 2013) but there is to confirm that Last and Stevens (1994) actually observed this species in Cyprus. As a consequence the reference of Last and Stevens (1994) is not retained as first record of *H. uarnak* for Cyprus. Debelius (1997, p. 20) presents an underwater photograph of a specimen of *H. uarnak* with the footnote "Cyprus". According to Debelius (pers. com.) the locality "Cyprus" as a footnote was incorrect and the photograph was taken off northern Beirut in Lebanon in early 1977. Consequently there is currently no valid record of *H. uarnak* for Cyprus. In a similar manner, in the updated list of alien fishes for Cyprus (Katsanevakis et al. 2009), *Herklotsichthys punctatus* and *Dussumieria elopsoides* are recorded as 'casual' and 'established' respectively based on Whitehead (1985). In a general comment on world distribution the author mentions the species in the eastern Mediterranean but does not mention actual records from Cyprus. These species appear to be established all around Cyprus but the present reference (Whitehead 1985) could not be considered as a first record. *D. elopsoides* is recorded in Cyprus by Gitarakos et al. (2007), and thus is considered as the first record for the species in Cyprus, whilst *H. punctatus* is excluded from the list of alien fishes for Cyprus. Photographs taken in 2012 in Cyprus of specimens identified as *Hippocampus fuscus* are available on the Internet (Association Peau-Bleu 2015). Diagnostic characters distinguishing these specimens from other Mediterranean congeners, *H. guttulatus* Cuvier, 1829 or *H. hippocampus* (Linnaeus, 1758), could not be observed on the photographs; therefore, the records are not retained.

Establishment success

The review of establishment success of alien fishes in Cyprus (based on Zenetos et al. 2006, 2012), reveals 28 species are considered as established or invasive (80%) and seven are considered to be casual (20%). Four aliens are newly considered as 'established' in Cyprus, with the firstly recorded *Nemipterus randalli*, *Sphyraena obtusata*, *Spratelloides delicatulus*, still considered locally common in the eastern Mediterranean (Golani et al. 2013), and the newly recorded *Pterois volitans/miles* previously considered to be casual (Bariche et al. 2013a). Four of the new aliens recorded species (*Hippocampus fuscus*, *Ostorhinchus fasciatus*, *Parupeneus forsskali*, and *Pomadasys stridens*) are known from single specimens in Cyprus and consequently are considered as 'casual'. *Hippocampus fuscus*, was first recorded in the Mediterranean in 2001 in Israel (Golani and Fine 2002) and later recorded in Turkey (Gökoğlu et al. 2004). *Ostorhinchus fasciatus* was first recorded in the Mediterranean in 2008 in Israel (Goren et al. 2009) then extended its distribution to Turkey (Gökoğlu et al. 2012). *Parupeneus forsskali* was recorded first in the Mediterranean in 2012 in Lebanon and Israel where it is known by a single collected specimen and some unsubstantiated records (Bariche et al. 2013b). *Pomadasys stridens* was first recorded in the Mediterranean in the Gulf of Genoa in Italy (Torchio 1969) but it appears to be established only in the eastern Mediterranean.

Among the 35 alien marine fishes of Cyprus, 34 are Lessepsian migrants. Only one unexpected species (*Acanthurus coeruleus* Bloch & Schneider, 1810) has a western tropical Atlantic origin. Its introduction pathway remains unknown (Langeneck et al. 2012). All species recorded before 2009 have currently an established or invasive status suggesting that when an alien species migrates to Cyprus it successfully naturalizes. Consequently it could be predicted that the same establishment success will occur for other species with a casual status recorded since 2009.

Immigration rate

In marine waters of Cyprus, the number of new exotic fish species recorded per year, was 0.41 from 1928 (year of the first record of an alien fish in Cyprus) to 2014. The rate of first recording was 0.18 per year pre-1995, and then grew to 1.15 per year post-1995 - an apparent 6.3 fold increase between the two periods (Figure 5). This acceleration process of introduction is well documented in the Mediterranean Sea (Galil et al. 2002; Zenetos et al. 2012) and it appears after a sharp increase in water temperatures detected in the 1990s in the eastern Mediterranean (Raitsos et al. 2010; Macias et al. 2013). Nevertheless this apparent increasing introduction rate of exotic fishes in Cyprus can be also an artefact reflecting the increased sampling effort (Belmaker et al. 2009). The two hypotheses are not mutually exclusive.

Invasive species

The four invasive fishes present in Cyprus (*Fistularia commersonii*, *Siganus luridus*, *Siganus rivulatus*, and *Lagocephalus sceleratus*) are

considered to have a high-impact in the Mediterranean Sea (Katsanevakis et al. 2014b). The first three are landed by coastal fisheries, where they are of some commercial interest (Chartosia and Menicou 2012). *L. sceleratus*, having arrived only ten years before in Cyprus, has a significant negative impact on the artisanal fishery since it often damages both the fishing gear and the catch of the fishermen; moreover, it represents a potential risk to humans because it contains tetrodotoxins, which are toxic to humans (Michailidis 2010; Nader et al. 2012; Rousou et al. 2014). The average time that was needed by alien fishes to reach the waters of Cyprus after entering the Mediterranean was 25.2 years (range 0 to 76 years). For the four invasive species present in Cyprus, the average time was only 6.5 years (range 0 to 24 years) consistent with invasive species having a high dispersal rate in their new environment, at least for the particular case of Cyprus. The venomous *Pterois volitans/miles* species complex has recently been recorded in the Mediterranean, and Cyprus need to be particularly monitored in light of the rapid invasion of this species complex in western Atlantic tropical waters (Albins and Hixon 2013). Surprisingly, oceanographic models indicate that invasion of the Mediterranean by *P. volitans/miles* was unlikely to occur (Johnston and Purkis 2014). However, the morphological peculiarities (e.g. the elongated fin rays) of this species complex are so distinctive from other Mediterranean fishes that it unlikely to be misidentified, and its venomous nature could represent an adaptative advantage in this new environment (Azzurro et al. 2014).

B. First and additional records of tropical Atlantic species

The tropical Atlantic *Enchelycore anatina* has been excluded from the previous inventories of aliens for the Mediterranean because its presence can be explained by a natural expansion of their tropical Atlantic range through the Straits of Gibraltar rather than as human mediated introduction (Zenetos et al. 2012). *E. anatina* was first recorded from Cyprus in 2008 and considered as 'casual' (Katsanevakis et al. 2009). According to the present observations the species can now be considered established in Cyprus.

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The following supplementary material is available for this article:

Table S1. Checklist of recorded Lessepsian and tropical Atlantic marine fishes preserved as vouchers or observed during the expedition *Cyprus-2014*.

This material is available as part of online article from:
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